Prepared for
K plus S Salt Australia Pty Ltd
ABN: 55 607 033 447

AECOM

Marine Fauna Impact Assessment

Ashburton Salt Project

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Client: K plus S Salt Australia Pty Ltd

ABN: 55 607 033 447

Prepared by

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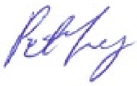
3	03-Nov-2022	Issue for Use	Peter Young Team Lead - Marine and Coastal Science	

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1.0 Introduction

1.1 Project Overview

K plus S Salt Australia Pty Ltd (K+S) is proposing to develop a green field solar salt project on the Western Australia coast approximately 40 km south-west of Onslow; adjacent to Tubridgi Point. The Project, named the Ashburton Salt Project, will include the construction of solar salt concentration and crystallisation ponds and associated infrastructure. A development envelope has been proposed including:

- a seawater intake (comprising an intake sump, pipelines, pumps and channel)
- concentration and crystallisation ponds
- salt wash plant
- stockpiles and conveyors
- bitterns discharge infrastructure (including a dilution pond, pipeline and diffuser)
- jetty and product loading infrastructure
- access road, internal site roads and haul roads (for construction materials and, during operations, for site maintenance and product transfer)
- borrow pits for extraction of clay and other construction materials
- drainage diversions
- dredging and onshore placement of dredged material
- buildings such as offices, storage and workshops
- sewage treatment
- water monitoring bores
- small desalination plant
- service corridors
- electricity and natural gas distribution
- equipment parking and laydown areas
- fuel storage and a refuelling station
- helipad.

The proposed Project layout is shown in Figure 1.

Seawater will be pumped from Urala Creek South via a channel into a series of eight evaporation (salt concentration) ponds. As seawater passes through the pond system, water is evaporated via solar energy, thereby producing a progressively denser brine with an increasing concentration of dissolved salts. Saturated brines are transferred to the crystalliser ponds, where water is evaporated by solar energy until salt crystals (predominantly sodium chloride) are precipitated. Under normal operational conditions, it is anticipated that 250-300 mm of harvestable salt will accumulate in the crystalliser ponds over a 12 month period.

At optimum times, the crystallisers ponds will be drained, dried and harvested. After washing and stockpiling the salt is delivered to the jetty via conveyor for loading onto a purpose-built shallow draft, self-propelled transhipment vessel (‘transhipment vessel’), which will carry the salt to a larger oceangoing vessel moored in deeper water offshore.

The Project components related to the marine fauna impact assessment are discussed in more detail below.

1.1.1 Seawater intake

The location of the seawater intake in Urala Creek South is shown in Figure 1 with a cross section presented in Figure 3. The annual intake is estimated to be 250 GL. The peak intake is required in October to December when evaporation rates are highest with an estimated monthly intake during the peak months of 29 GL per month. This includes all seawater required for the evaporation ponds, wash plant and bitterns dilution water (approximately one part bitterns is expected to be diluted with one part seawater). It comprises:

- A rock armoured pump inlet well screened to reduce the risk of entrapment of floating debris and large fauna, with the following design parameters:
    - The inlet well screen will be oriented, and the intake velocity managed, so as to reduce the risk of fauna impingement (i.e. 'trapping' against the screens) by maintaining a water flow velocity at the screens of less than 0.15 m/s, in line with USEPA recommendations for protection of 96% of motile species concluded from fish swim speeds (USEPA, 2014).
    - The inlet well will be positioned in the optimal location to minimise environmental impacts such as erosion and scour.
- Several seawater intake pipes will be located within the inlet well, with screens across the downward facing pipe openings.

The seawater extraction process will be driven via a pump station situated on the creek bank which will transport seawater into a connecting intake channel leading the first evaporation pond.

1.1.2 Bitterns discharge

After the salt has built up to a nominal depth in crystalliser ponds, it is then drained and the salt collected using mechanical harvesters. The leftover wastewater brine (known as bitterns) from the salt farming process contains residual naturally occurring elements from the seawater.

Discharge of bitterns to the marine environment results in the need for careful consideration of how appropriate dilution and mixing can be achieved on discharge. The approach proposed for the Ashburton Salt Project involves:

- Pre-dilution with seawater (at a rate of approximately one to one) in a bitterns dilution pond.
- Pumping of the diluted bitterns via a pipeline to the jetty for disposal offshore. The pipeline overland route will follow the conveyor route and will extend offshore along the export jetty (Figure 2).
- Discharge via a pipeline extending 400 m from the coast.
- Discharge through a specially designed diffuser beneath the jetty to optimise mixing with seawater.
- The diluted bitterns will be pumped via a pipeline to the jetty for disposal offshore. The pipeline overland route will follow the conveyor route and will extend offshore the along the export jetty (Figure 2).

A multi-port diffuser will be installed at the end of the bitterns pipeline, co-located with the jetty, to ensure mixing of discharged bitterns with seawater is optimised. Several concepts were tested for the diffuser design. The Cormix nearfield model was used to model the various configurations of a diffuser located beneath the seaward 400 m portion of the jetty. A diffuser located mid-water with the bittern jets oriented towards the sea surface increased the trajectory of the sinking plume towards the seabed. This provided a modelled dilution of approximately 100 times the discharge concentration at the seabed. The diffuser design concept therefore proposed is a 400 m long diffuser with approximately 25 mm diameter ports (nozzle), each discharging bitterns at 6 m/s. Considering redundancies necessary for such a system approximately 350 ports will be required.

The hydrodynamic model was used determine the near field and far field impact of the bittern discharge from such a diffuser. Changing the jetty alignment was also modelled to ascertain the best alignment to optimise the bitterns mixing (by locating the jetty in the deepest water possible). The current alignment of the jetty and design of the diffuser was optimised after serval iterations to achieve the best practicable bitterns dilution (Water Technology 2021a).

1.1.3 Dredging

Dredging of a berthing pocket at the end of the jetty (on the northern side) is required to allow the transhipment vessel adequate water depth to remain within the berthing pocket without tidal restriction. The berthing pocket is required to be of sufficient depth, length and width to allow the loaded transhipment vessel adequate under keel clearance enable unhindered navigation out of the berthing pocket.

The planned dimensions of the berth pocket are 200 m x 35 m x 6 m of water depth (at low tide) – this requires dredging of approximately 2.5 m of seabed. Total dredge volume is estimated to be 17,000 m^3 and may be dredged by either a backhoe dredge or a cutter suction dredge. The dredging program will take approximately two weeks to complete. The location of the dredged berthing pocket is provided in Figure 2**.**

Dredge spoil disposal will occur on land near the jetty at the location shown in Figure 2. The spoil will be pumped onshore to a bunded area to allow dewatering and, if necessary, treatment of acid sulfate sediment within the spoil. Where possible the dewatered solid material will be used for site construction material. Dewatered water will be clarified, allowing particles to settle on the bottom, before being piped back to the ocean, near the jetty. The disposal of dredge tailwater to the ocean has been included within the dredging sediment dispersion modelling conducted by Water Technology (2021a).

1.1.4 Jetty and vessel movements

A 700 m trestle jetty will be constructed to facilitate the loading of salt onto a purpose-built shallow draft, self-propelled transhipment vessel ('transhipment vessel') that travels at an approximate speed of 10-12 knots, with a maximum draft of 6 m, when fully loaded. Construction of the jetty will comprise installation of tubular piles that will be driven in using a hydraulic impact hammer, this method will also be used to install the required dolphins and restraint structure (see Figure 4). The first 180 m of the trestle jetty will be constructed on the mud flat reef which is exposed at low tide. The remaining 530 m will be in shallow water at low tide. The piles will be driven in one at a time and it is assumed minimal dressing of the piles will be required.

The transhipment vessel will transport the salt to ocean going vessels that will be anchored approximately 14 nautical miles (nm) offshore (see Figure 1).

A total transhipment vessel cycle time of 13.21 hours has been calculated by the project of which a total of 4.25 hours will be spent travelling to and from the marine jetty to the offshore loading locations. The remainder of the time will be spent loading and unloading. It is estimated that nine cycles (approximately 4.8 days) are required to load the ocean-going vessel.

The number of ocean-going vessel and transhipment vessel movements expected will depend on international demand for the salt product, which is difficult to predict with certainty. However, the following estimates are provided to indicate the scale of potential vessel movements:

- Based on a maximum project production level of 4.7 million tonnes per annum (MTPA), ocean going vessel capacity of 70,000 t and 8,000 t transhipment vessel parcel loads:
  - 67 ocean going vessels proceeding to anchor points per year.
  - 587 transhipment vessel movements per year.
- Based on a slightly lower project production level of 4.5 MTPA, ocean going vessel capacity of 150,000 t and 12,000 t transhipment vessel parcel loads:
  - 30 ocean going vessels proceeding to anchor points per year.
  - 375 transhipment vessel movements per year.

1.1.5 Ocean going vessel anchorage

Ocean going vessels will be loaded whilst anchored at the Transhipment Area approximately 14 nm offshore (see Figure 1).

Within the transhipment area, suitable anchorage areas will be designated in sandy areas to ensure sufficient anchor holding capacity. These areas will be identified through a combination of bathymetric and side scan sonar survey. Once target locations have been selected, video footage of the seabed will be taken at each location to confirm substrate is sand, with sparse to nil benthic habitat present. Final site selection will be done in consultation with Pilbara Ports Authority (PPA). Selection of transhipment points and management of transhipment operations will be covered within the Vessel Management Plan (VMP). K+S is confident of achieving no loss of benthic communities and habitats in the anchorage area.

1.2 Regional Overview

1.2.1 North-west Marine Region

The Project sits within the North West Marine Region of Western Australia. The North West Marine Region extends from the Western Australia–Northern Territory border to Kalbarri, south of Shark Bay. The region covers approximately 1.07 million km^2 of sub-tropical and tropical waters of the Indian Ocean and Timor Sea. The marine environment of the region is characterised by shallow-water tropical marine ecosystems, a large area of continental shelf (including the narrowest part of continental shelf on Australia’s coastal margin) and continental slope, with two areas of abyssal plain with depths to 6,000 m (Director of National Parks 2018).

The region is subject to extreme tidal regimes and a high incidence of cyclones. It is influenced by a complex system of ocean currents that change seasonally and between years, generally resulting in surface waters that are warm, nutrient-poor and of low salinity. The southern part of the region transitions between tropical and temperate waters.

The region supports internationally important breeding and feeding grounds for a number of threatened and migratory marine species, including humpback whales, which mate and give birth in the waters off the Kimberley coast (Commonwealth of Australia 2012). Significant turtle rookeries are found on coastal beaches and offshore islands in and adjacent to the region (Commonwealth of Australia 2012).

1.2.2 Exmouth Gulf and Ningaloo Marine Park

The proposed Project is located in the southern reaches of the North-west Marine Region, northeast of Exmouth Gulf and Ningaloo Marine Park (Figure 1).

Exmouth Gulf is one of the largest embayments (about 3,000 km^2) on the Western Australian coast. Exmouth Gulf is enclosed by the Cape Range Peninsula to the west and the Yannarie Coastal Plain to the east and marks the start of the shallow Pilbara waters region. At its deepest, the Gulf is 21 m in depth and the relatively narrow entrance between Point Murat and the Murion Islands is approximately 19 m. The shallow waters of Exmouth Gulf provide a stark contrast to the waters of Ningaloo Reef which, outside the reef line, are exposed to the open ocean and rapidly drop off into the waters approximately 1,000 m deep. The Gulf is strongly influenced by the Leeuwin Current being in the region where it forms and starts to head south down the coast.

The annual rainfall in the region, as recorded at Learmonth Airport, is highly variable with an annual average of 250 mm where peak rainfall occurs from January to March and between May and June (Bureau of Meteorology 2021). The heaviest rainfall is generally associated with tropical cyclones and can cause extensive flooding in the area. Evaporation is high with annual average rainfall significant exceeded be the mean annual evaporation of around 3140 mm (Bureau of Meteorology 2021).

Exmouth Gulf and the surrounding waters encompass diverse habitats, including seagrass meadows, mangroves, coral reefs, sandy beaches, and island habitats. The diversity of habitats supports a high biodiversity of marine fauna, where critically important behaviours such as breeding, foraging, resting or migration take place. The key ecological values of Exmouth Gulf are under increasing pressure from commercial and recreational fishing, mining, tourism, climate change and development. In 2020 the then Minister for Environment made a request to the EPA to provide strategic advice on the potential cumulative impacts of current and proposed activities and developments on the local environmental, social, and cultural values of Exmouth Gulf. In 2021 the Premier announced plans to increase protections within the Gulf in response to the EPA's Cumulative Impacts Report. A new marine park is proposed at the southern and eastern edges of Exmouth Gulf; however, the exact location of the expansion has not been formalised at this stage.

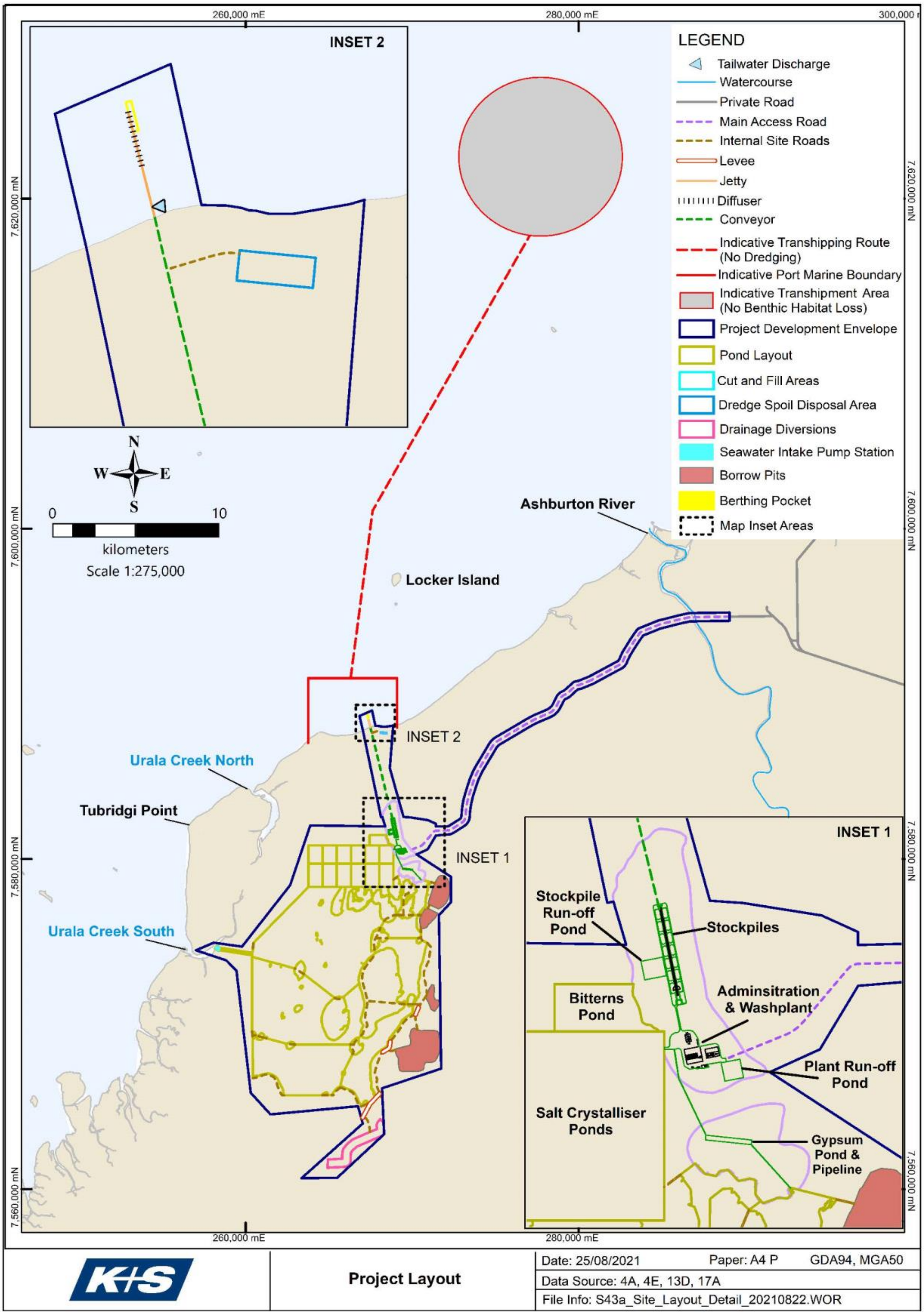


Figure 1 Project layout

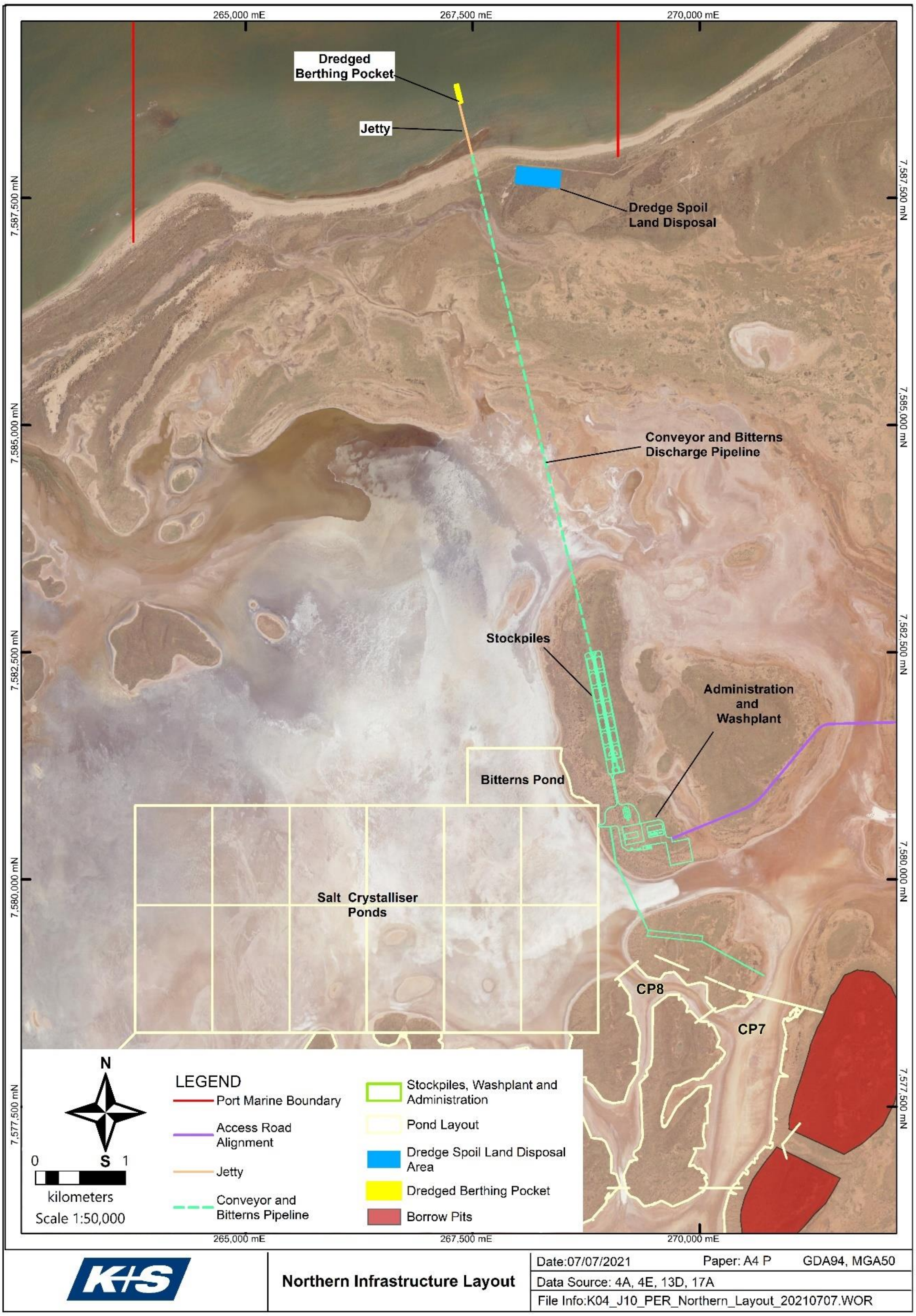


Figure 2 Northern infrastructure layout

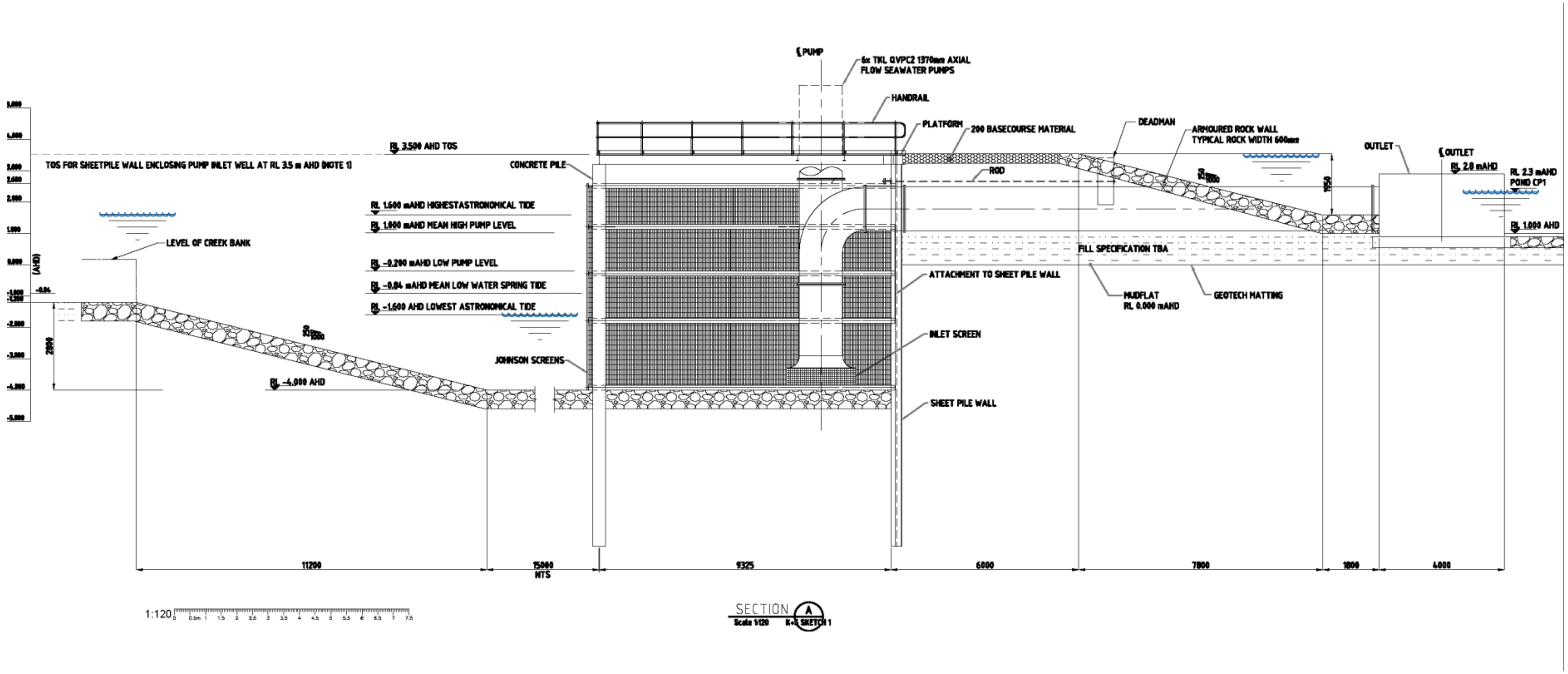


Figure 3 Seawater intake cross-section

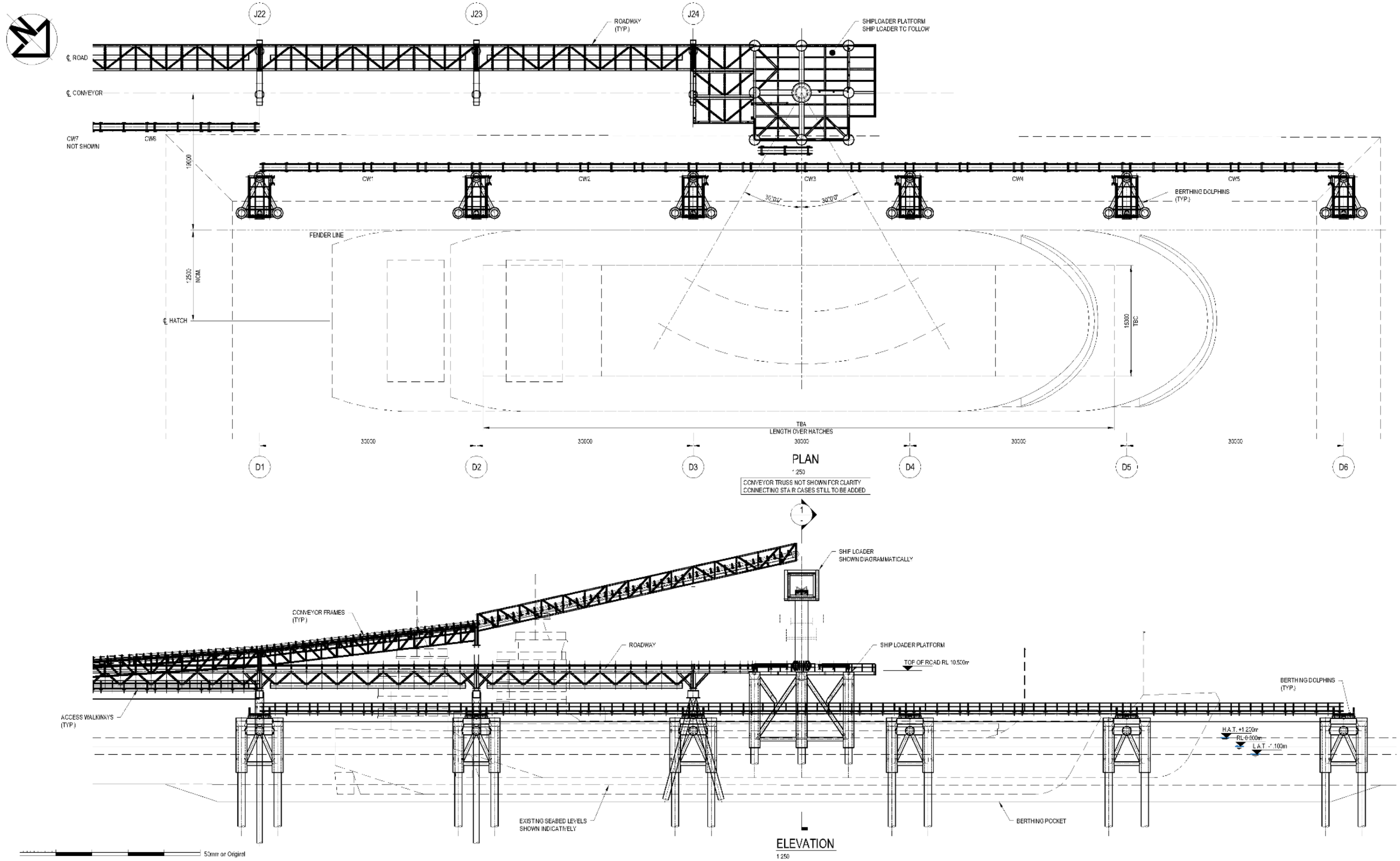


Figure 4 **Barge loading schematic (preliminary design)**

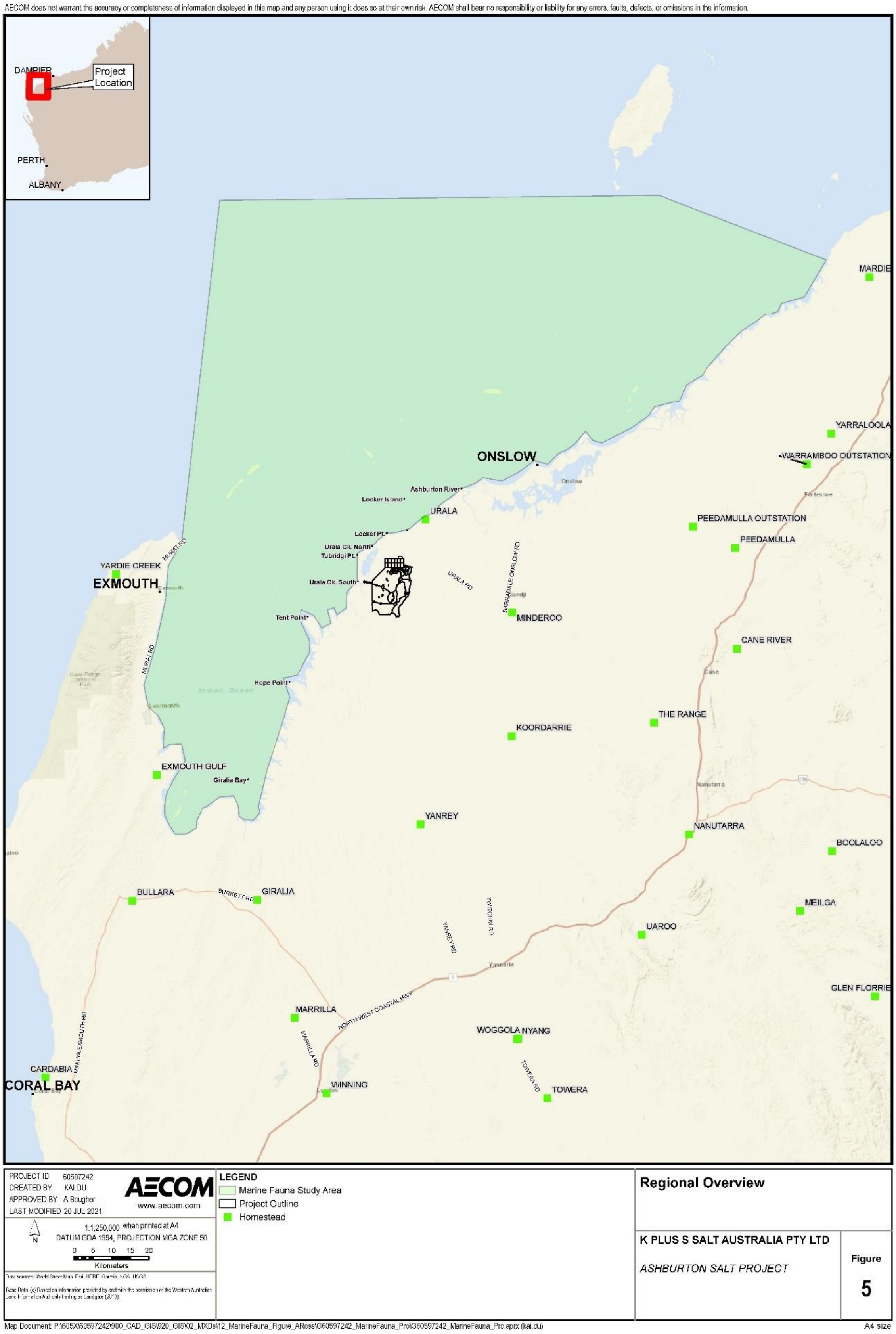


Figure 5 Project regional overview

2.0 Scope and Objectives

This document provides an assessment of the marine fauna relevant to the Project area using a combination of desktop and field investigations. The specific objective of this document is to address the Environmental Scoping Document (ESD) requirements outlined in Table 1, the sections where each of the ESD requirements have been addressed are detailed in the table.

Table 1 ESD requirements

ESD Requirement No.	ESD Required Work	Section Addressed
43	Undertake desktop review of previous marine fauna surveys conducted in the area focusing on conservation significant species (as well as ecological 'keystone' species and species important to commercial and recreational fishers), and produce a gap analysis of further marine fauna survey work required for this Project. The gap analysis will consider the age and techniques of previous surveys and whether the distribution and abundance of listed threatened species has changed over time. Consideration will be given to: a. the different usage types and behaviours (e.g. foraging, calving, nursing, resting, roosting, nesting, migrating, or passing between other habitat areas), their spatial extents and locations, and the habitat characteristics that support, or facilitate these patterns of use (e.g. the availability of a particular food source, or natural darkness); b. timeframes and seasonality of fauna use, identifying periods of high and low vulnerability to impacts; c. fauna abundances, (presented where possible in the context of local populations or management units, including the percentages of flyway populations using migratory bird 'sites' as outlined in Significant impact guidelines for 36 migratory shorebird species (EPBC Act Policy Statement Ashburton Salt Project: Environmental Scoping Document) (Department of the Environment, Water, Heritage and the Arts 2009); and d. the conservation significance at local and regional scales, of the marine fauna, and their associated habitats including access routes to and between significant habitats in Exmouth Gulf and the adjacent Pilbara nearshore bioregion.	Section 4.1 a. Appendices A and B b. Section 0 c. Section 6.0 d. Section 6.1 e. Migratory Shorebird Assessment (Biota 2021)
44	Undertake appropriate marine fauna surveys to fill gaps identified above.	Section 5.0 and Appendices
45	Particular focus should be on identifying elements of the proposal that may affect conservation significant marine fauna (as well as ecological 'keystone' species and species important to commercial and recreational fishers) and demonstrating how the mitigation hierarchy has been considered and applied in generating predictions of the severity, extent and duration of both direct and indirect impacts associated with planned construction and operational activities, as well as plausible unplanned scenarios (e.g. oil spills).	Applied throughout Section 7.0
46	Describe and quantify the flow-on effects of altered nutrient inputs into the Gulf in relation to productivity of the ecosystem (including prawns and fish).	Section 7.9

ESD Requirement No.	ESD Required Work	Section Addressed
47	Undertake an analysis of: a. The potential impacts on marine fauna from shipping and boating activities and identify appropriate mitigation/management measures. b. The potential impacts on marine fauna from dredging activities and identify appropriate mitigation/management measures.	a. Section 7.8 b. Section 7.4
48	Undertake site and noise source specific modelling of underwater noise (including vessel operations and piling) and potential impacts on marine fauna. Modelling will take into account concurrent emission sources, as well as cumulative effects from existing emission sources, and consider the area of impact with consideration of conservation significant fauna (as well as ecological 'keystone' species and species important to commercial and recreational fishers) with known noise sensitivity (e.g. humpback whales).	Section 7.4 and Appendix F
49	Undertake a light study (including current baseline and predicted) to characterise the potential changes to the light environment and the implications this may have on threatened turtles.	Section 5.2.3 and Section 7.6
50	Identify sources of noise and light (e.g. dock lights, jetty construction etc. and ensure appropriate mitigation/management/offset measures are in put in place.	Sections 7.5.6 and 7.6.3
51	Prepare a comprehensive management plan for shipping and Project related boat traffic to avoid, minimise and manage marine fauna collisions and noise/light related impacts.	Section 7.8.3
52	Evaluate the risk of entrainment/entrapment (particularly of prawn larvae) and potential impacts on recruitment and populations. Prepare a comprehensive design and management plan for the seawater intake(s) to minimise fauna entrapment.	Section 7.7
53	Undertake a Vessel Ballast Water/Hull and Construction Equipment and Materials Pest Risk Assessment and develop an appropriate Monitoring and Management Plan to avoid and minimise pest and/or disease introduction. The resulting pest management strategy will include vessel ballast water/hull and construction equipment and materials risk assessment and mitigation prior to entry of vessels into State waters in addition to introduced marine pest (IMP) monitoring and reporting, with the aim of: a. preventing the establishment and proliferation of IMPs; b. control (and eradication) any IMP that has established and proliferated; and c. minimising transfer of any established IMPs further within Western Australia.	Section 7.11
54	Identify any significant marine fauna (as well as ecological 'keystone' species and species important to commercial and recreational fishers) likely to be found in the area of influence of the proposal, including commercially important species and migratory species.	Section 6.1 and Appendices A and B
55	Identify any known temporal windows that represent critical periods for key environmental/life cycle events for marine fauna (e.g. Humpback Whale calving).	Section 6.5 and Appendices A and B

ESD Requirement No.	ESD Required Work	Section Addressed
56	Identify likelihood of EPBC conservation significant species (as well as ecological 'keystone' species and species important to commercial and recreational fishers) to occur within/near the proposed Project area, including: a. Information on the abundance, distribution, ecology and habitat preferences of the listed species b. Information on the conservation value of each habitat type (e.g. breeding, migration, feeding, resting, internesting etc.) from a local and regional perspective, including the percentage representation of each habitat type on site in relation to its local and regional extent c. If a population of a listed species is present on the site, its size and the importance of that population from a local and regional perspective d. An assessment of the risk of impact to any listed threatened species as a result of project activities e. For any impact identified, appropriate mitigation/management measures to reduce the level of impact f. Baseline information and mapping of local occurrences	a. Section 6.1 and Appendices A and B b. Section 6.4.5 c. Section 6.1 d. Throughout Section 7.0 e. Throughout Section 7.0 f. Section 5.0
57	Predict the residual impact/loss of marine fauna and larval life stages and assess the likely consequences in a local and regional context.	Section 7.7
58	Describe the proposed monitoring, management and mitigation measures to be implemented, including an assessment of their effectiveness, at the design and operations stages to demonstrate that all reasonable and practicable avoidance and mitigation measures will be taken to ensure residual impacts and risks are acceptable.	Throughout Section 7.0
59	Document comprehensive management and monitoring measures for construction, operations and closure, including defined trigger levels and adaptive management responses to ensure: a. residual impacts on conservation significant marine fauna (as well as ecological 'keystone' species and species important to commercial and recreational fishers) are not greater than predicted and achieve predicted outcomes/objectives; and b. an appropriate level of preparedness to respond to impacts on marine fauna (as well as ecological 'keystone' species and species important to commercial and recreational fishers) associated with unplanned events such as hydrocarbon, salt resource or bitterns spills.	Throughout Section 7.0
60	Summarise residual impacts, after considering avoidance and minimisation. Analyse these impacts to identify and detail any that are significant. If significant residual impacts remain propose appropriate offsets.	Section 8.0
61	Create an offsets position following application of the 'mitigation hierarchy' and analyse these impacts to identify and detail any that are significant.	Section 8.0
62	Demonstrate and document how the EPA's objective for this factor can be met.	Throughout Section 7.0 Section 8.0

ESD Requirement No.	ESD Required Work	Section Addressed
5.	Determine the likely toxicity of the bitterns to be discharged and use in combination with bitterns plume modelling to determine the potential impacts of the discharge on benthic communities and habitats. Specifically, undertake a marine biota ecotoxicology assessment of local marine indicator species for proposed marine discharges (bitterns, dredging sediment mobilisation). This assessment will: a. Identify appropriate local indicator species (including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages); b. Test the tolerance of indicator species to predicted bitterns discharge and turbidity (under usual operation and extreme events), with consideration given to fertilisation, embryo and larval development, growth, and chronic and acute toxicity. c. Establish trigger thresholds, below which discharge concentrations may be considered safe. d. Use the results of the biota ecotoxicology assessment to inform the marine hydrodynamic modelling and design process to determine the likely impact of the discharges modelled on marine biota sensitive receptors.	Section 7.2 BCH Report (AECOM 2021) Coastal Modelling (Water Technology 2021a)

3.0 Environmental Impact Assessment Process

The Project was referred to the Western Australian Environmental Protection Authority (EPA) under Section 38 of the *Environmental Protection Act 1986* (EP Act) in October 2016. The referral and supporting document (EnviroWorks 2016) identified marine fauna as a key environmental factor that may potentially be directly and indirectly impacted as a result of the Project.

In November 2016, the EPA determined that the Project required a detailed assessment to determine the extent of the Project's direct and indirect impacts, including long-term impacts, and how the environmental issues could be managed, and therefore the Project would require assessment via a Public Environmental Review (PER).

3.1 EPA Objective for Marine Fauna Environmental Factor

The EPA recognises the ecological importance of protected marine species with the EPA's objective "to protect marine fauna so that biological diversity and ecological integrity are maintained".

3.2 Definition of Marine Fauna

For the purposes of this impact assessment, and as defined in the EPA's Environmental Factor Guideline for Marine Fauna (2016), marine fauna are defined as; *animals that live in the ocean or rely on the ocean for all or part of their lives.* Marine organisms, also classified as animals, such as corals and sponges, that are anchored to the sea floor or hard substrate are considered under the Benthic Communities and Habitats (BCH) environmental factor (2016) and therefore addressed in the BCH impact assessment (AECOM 2021a).

3.3 Impact Assessment Methodology

In order to undertake an impact assessment, it is necessary to understand the likely effects of the Project components and the receptors that may be impacted by them. The literature review and gap analysis (Section 4.0) identifies the marine fauna receptors (and the relevant protection status) that have the potential to be impacted by the Project. Species that required targeted surveys or further investigation to be undertaken, to provide sufficient information to determine presence, were identified by the gap analysis. This initial process also comprised a likelihood of occurrence assessment (Section 4.1.2), to determine which of those species identified during the literature review are likely to occur locally, and may be impacted (directly or indirectly) during the construction and/or operational phase of the Project.

Those species identified as likely to occur in the project area are described in more detail in the existing environment section (Section 6.0); the nature of their occurrence (e.g. breeding, foraging), population abundances (where available). Any key ecological windows as well as critical habitat are also detailed in this section.

Project activities have the potential to impact multiple sensitive marine fauna receptors, and it is necessary to evaluate those receptors so that the significance of the potential and, ultimately, the residual impacts of the Project can be determined. This receptor-specific approach is adopted because, in impact assessment terms, an impact of similar magnitude affecting a more sensitive receptor is deemed to have a more significant impact than an impact on a less sensitive receptor. Thus, it becomes easier to identify where the potential impacts are likely to be the most significant and, therefore, to identify the appropriate actions needed to mitigate (based on the mitigation hierarchy of avoid, minimise and/or offset) those potentially significant impacts.

3.4 Predicted Outcome

The predicted outcome of potential impacting processes on marine fauna, as a result of the Project, is assessed from a consideration of the potential direct and indirect impacts identified against the EPA objective. This assessment determines if any impact is predicted to affect the biological diversity and/or ecological integrity of marine fauna populations and ecosystems after suggested mitigation measures have been implemented.

3.5 Relevant Policy and Guidance

The scope of the marine fauna impact assessment has been undertaken in accordance with:

- Environmental Factor Guideline: Marine Fauna (EPA 2016).
- Technical Guidance - Environmental Impact Assessment of Marine Dredging Proposals (EPA 2016a).
- Environmental Assessment Guideline 5 – Protecting Marine Turtles from Light Impacts (EPA 2010).
- National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (Department of Agriculture, Water and the Environment [DAWE] 2020a).
- Approved Conservation Advice for *Megaptera novaeangliae* (humpback whale) (Threatened Species Scientific Committee 2015).
- Approved Conservation Advice for *Pristis zijsron* (Green Sawfish) (Threatened Species Scientific Committee 2008).
- Marine Bioregional Plan for the North-West Marine Region (DSEWPaC 2012).
- Sawfish and River Sharks Multispecies Recovery Plan (DoE 2015).
- Threat Abatement Plan for the Impacts of Marine Debris on Vertebrate Marine Life (DEWHA 2009).
- A Directory of Important Wetlands in Australia (Australian Nature Conservation Agency 1993).
- Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017aa)
- Biofouling Biosecurity Policy (Department of Fisheries 2017a).
- Vessel Check: Biofouling Risk Assessment Tool (Department of Fisheries 2017b).
- Status reports of the fisheries and aquatic resources of Western Australia 2018/19: State of the Fisheries (Gaughan and Santro 2020).
- Status reports of the fisheries and aquatic resources of Western Australia 2019/20: State of the Fisheries (Gaughan and Santro 2021).
- Australian Ballast Water Management Requirements (Department of Agriculture and Water Resources 2020).
- WA Environmental Offsets Policy (Government of Western Australia 2011).
- WA Environmental Offsets Guidelines (Government of Western Australia 2014).
- Light Pollution Guidelines: National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds (DoEE, 2020).
- EPBC Act Policy Statement 2.1 - Interaction between offshore seismic exploration and whales: Industry guidelines (DEWHA, 2008).

4.0 Literature Review and Gap Analysis

The marine fauna baseline assessment is based on an extensive review of available literature and Project specific survey data that were available at the time of writing. A literature review has been undertaken, comprising not only a review of publicly available literature, but also liaison with technical specialists, including sawfish and prawn specialists from Murdoch University and Department of Primary Industries and Regional Development (DPIRD), to understand current and past research into potentially affected marine fauna species and identify knowledge gaps that exist.

4.1 Data Gap Analysis

4.1.1 Database search

An EPBC Act Protected Matters Search was used to identify species listed under the EPBC Act that may occur within or pass through the Project area (Appendix A). In addition, a search under the Western Australian *Biodiversity Conservation Act 2016* (BC Act) and the International Union for Conservation of Nature (IUCN) Red List of Threatened Species was undertaken. The results of the search informed the assessment of potential direct and indirect impacts of the planned Project.

Due to the highly mobile and transitory nature of most marine fauna the literature review and gap analysis considered all marine fauna that may occur within an area that encompassed Exmouth Gulf to just south of Barrow Island (see Figure 5), to identify those species that have the potential to occur within or in close proximity to the Project area.

Results of these searches are presented in Section 6.0.

4.1.2 Likelihood of occurrence

An assessment was undertaken of the 'likelihood of occurrence' for threatened species identified through the database search and desktop review. The Department of Water and Environmental Regulation (DWER) and Department of Biodiversity, Conservation and Attractions (DBCA) do not have prescriptive likelihood of occurrence guidelines within their policies but rather clarify the scale of assessment required to determine the level of impact. The following criteria have been developed to classify the likelihood of occurrence for threatened species:

- Unlikely to occur – the local area is outside the known distribution for the species, or no suitable habitat is present, and the species has not been recorded in close proximity to the Project or locally.
- May occur – the local area is within the known distribution of the species, marginal habitat may be present, and/or the species has been recorded in close proximity to the Project area.
- Likely to occur – the local area is within the known distribution for the species, suitable habitat is present, and the species has been recorded in close proximity to the Project area.

The results of the likelihood assessment have been presented in Appendix B and summarised in Section 6.1. Those identified as 'may' or 'likely' to occur have been assessed further in Section 6.1.

4.1.3 Gap analysis

The literature review and gap analysis identified a number of focus areas for the marine fauna study that required further investigation to enable adequate assessment of potential impacts. These focus areas comprised those marine species:

- which are known, or are considered likely, to occur within and or in close proximity to the Project (locally) and have the potential to be either directly or indirectly impacted by the Project; and
- for which there are important gaps in knowledge regarding their abundance and distribution.

The results of the gap analysis are summarised in Table 2.

Table 2 Gap analysis – key species of focus and surveys undertaken

Summary of Baseline Gap Analysis	Gaps Identified	How the Gaps Have Been Addressed
Sawfish		
• The closest known research into sawfish distribution and abundance was undertaken in the Ashburton River, as well as surrounding creeks, as part of the Chevron Wheatstone Project. • A review of Exmouth Gulf Prawn Resource Status Report revealed that 15 sawfish were caught in commercial fishing activities during 2017 (Kangas et al. 2019), indicating that sawfish are present in the vicinity of the Project area.	• There is no information on the use of the nearshore area surrounding the Project area by sawfish. • It is believed that both Urala Creek North and South contain suitable habitat for sawfish; however, the importance of this habitat is unknown (i.e. pupping ground and/or nursery area). • Benthic habitat mapping to determine Project specific habitat associations has not yet been undertaken. • Project specific potential effects of sound, light, vessel movement, seawater intake and water quality changes are not yet well understood.	• The use of the creeks and nearshore environment by sawfish species and the importance of these creeks as pupping/nursery areas for juvenile sawfish was investigated in February 2019 (Morgan et al. 2020). • Benthic habitat survey was undertaken in February 2019 to identify areas of habitat to assist in minimising potential Project related impacts (Geo Oceans 2019). • Water quality and ecotoxicity studies were undertaken to minimise the potential for impacts from changes in water quality due to bitterns discharge, sedimentation and nutrient flows from the catchment. • Modelling of the seawater intake was undertaken including potential impacts to assist in quantifying the potential impact on important sawfish habitat (Water Technology 2021a). • Underwater sound modelling was undertaken to determine the potential zones of impact of pile driving and other Project generated sound sources, and to determine suitable observation and management zones (e.g. for application of soft start procedures) (Talis, 2021). • Light modelling was undertaken to understand the potential impacts of artificial light spill on ontogenetic changes in behaviour (e.g. predator-prey relationships) (Pendoley Environmental 2020).
Whales, dolphins and dugong		
• The abundance, distribution and habitat associations of cetaceans and dugongs known to occur in Exmouth Gulf region are well understood. • It can be assumed that species that have been recorded, or are known to occur, in Exmouth Gulf region have the potential to pass through the Project area. • Habitat associations are well known and detailed habitat mapping can assist in determining the use of the Project area by certain species, such as dugong distribution being closely related to seagrass distribution. • Mitigation measures associated with Project related activities (such as piling and vessel activities) are well understood and therefore can be applied to the Project.	• Benthic habitat mapping to determine Project specific habitat associations has not yet been undertaken. • Project specific potential effects of sound, light, vessel movement and water quality changes are not yet well understood.	• Benthic habitat survey was undertaken in February 2019 to determine areas of important habitat and to assist in implementing management measures to minimise the potential for impact to important habitat associations (Geo Oceans 2019 and AECOM 2021a). • Water quality and ecotoxicity assessments were undertaken to minimise the potential for impacts from changes in water quality due to bitterns discharge, sedimentation and nutrient flows from the catchment (Water Technology 2021a). • Underwater sound modelling was undertaken to determine the potential zones of impact of pile driving and other Project generated sound sources, and to determine suitable observation and management zones (e.g. for application of soft start procedures) (Talis 2021). • Light modelling was undertaken to understand the potential impacts of artificial light spill on ontogenetic changes in behaviour (e.g. predator-prey relationships) (Pendoley Environmental 2020).
Marine turtles		
• Previous surveys have recorded low density nesting of flatback and green turtles on Urala Beach in front of Urala Homestead. • Aerial surveys have recorded a number of turtles around the mouth of Urala Creek North, indicating that this area may be important foraging habitat; however, the importance of the creeks to juvenile turtles is not well understood.	• No dedicated nesting track census survey has been undertaken between Urala Creek North and South. • Use of Urala Creek South by foraging juveniles is unknown. • Benthic habitat mapping to determine Project specific habitat associations has not yet been undertaken. • Project specific potential effects of sound, light, vessel movement and water quality changes are not yet well understood.	• A turtle nesting survey of the Project area and surrounding beaches was undertaken by AECOM Turtle Biologists in December 2018 and 2019. Opportunistic observations were made of the use of Urala Creek South for foraging juveniles. Together, these enable a reduction in the risk of potential impacts to key habitats, and the evaluation and mitigation of the risk of entrapment in the seawater intake. • Benthic habitat survey was undertaken in February 2019 to determine areas of important habitat and to assist in implementing management measures to minimise the potential for impact to important habitat associations (Geo Oceans 2019 and AECOM 2021a). • Water quality and ecotoxicity assessments were undertaken to minimise the potential for impacts from changes in water quality due to bitterns discharge, sedimentation and nutrient flows from the catchment (Water Technology 2021a). • Underwater sound modelling was undertaken to determine the potential zones of impact of pile driving and other Project generated sound sources, and to determine suitable observation and management zones (e.g. for application of soft start procedures) (Talis 2021). • Light spill modelling was undertaken to determine the impacts of lighting on beaches and nearshore areas surrounding the proposed jetty location (Pendoley Environmental 2020)
Prawns		
• All waters adjoining the Project development footprint are included in Exmouth Gulf Prawn Managed Fishery (EGPMF) footprint. • The primary species associated with the EGPMF are brown tiger prawns (*Penaeus esculentus*), western king prawns (*P. latisulcatus*) and blue endeavour prawns (*Metapenaeus endeavouri*). • It is understood that the primary area for prawn recruitment is towards the southern end of Exmouth Gulf in the area south of Tent Point and away from Urala Creek South (M Kangas *pers. comm*. 2018).	• Little is known about juvenile prawn abundance and distribution within the tidal creeks of the eastern Exmouth Gulf (including Urala Creek South, where the seawater intake will be located). • Benthic habitat mapping to determine Project specific habitat associations has not yet been undertaken. • Project specific potential effects of sound, light, vessel movement, pests, entrainment and water quality changes are not yet well understood.	• The abundances of post-larval and juvenile prawns in Urala Creek North, in Urala Creek South, within the predicted nursery area at the mouth of Urala Creek South, and in the vicinity of the proposed bitterns discharge location was investigated in 2019 (Murdoch University 2020). • Benthic habitat survey was undertaken in February 2019 of nearshore environments (including intertidal creeks) to identify areas of potential juvenile habitat to assist in minimising potential impact to key nursery habitat (Geo Oceans 2019 and AECOM 2021a). • Water quality and ecotoxicity assessments were undertaken to minimise the potential for impacts from changes in water quality due to bitterns discharge, sedimentation and nutrient flows from the catchment (Water Technology 2021a). • Light modelling was undertaken to determine if light spill may affect creeks where juvenile prawns are present (Pendoley Environmental 2020). • Independently to the PER process, a modelling exercise is being undertaken with K+S, Water Technology, Murdoch University, DPIRD and Kailis to model potential proportional loss of prawns from the EGPMF as a result of the Project. The results of this prawn modelling exercise are intended to be provided to DPIRD as the managers of the fishery.

5.0 Field Surveys and Modelling

5.1 Baseline Studies

Targeted marine fauna studies were undertaken following the outcomes of the gap analysis and to help inform the marine fauna impact assessment. Marine fauna studies completed as part of the Project are outlined in Table 3.

Table 3 Overview of marine fauna surveys undertaken

Target Species	Survey	Date(s) Undertaken	Comment	Reference
Turtles	Snapshot track survey 2018 & 2019 Benchmark light data collection	• 6 & 7 December 2018 • 20 December 2019 • 22 to 25 May 2019.	Collected data on the mainland beaches as well as Locker Island to establish if there is suitable nesting habitat in proximity to the project. Light data were also collected to provide ambient light conditions to inform the light modelling. Nesting surveys were undertaken by AECOM turtle biologists and are documented in this report and Light Monitoring/Modelling was conducted by Pendoley Environmental personnel.	Nesting Survey – this report. Light monitoring - Pendoley Environmental 2020 (Appendix C)
Sawfish	Sawfish survey of Urala Creek North and South	• 3 to 6 February 2019	Targeted surveys were undertaken to establish the presence of sawfish in both Urala Creek North and South. Surveys were undertaken by Murdoch University.	Morgan et al. 2020 (Appendix D)
Prawns	Prawn larvae surveys	• 4 to 7 January 2019 • 4 & 5 February 2019 • 28 & 29 October 2019 • 27 & 28 November 2019 • 16 & 17 December 2019	Surveys were undertaken to target optimal timing for potential post-larval and juvenile prawns to be present in the survey area. Surveys targeted new moon phases. Surveys were undertaken by Murdoch University and AECOM personnel.	Murdoch University 2020 (Appendix E)
All marine fauna	• Habitat survey • Incidental observations • Underwater noise modelling	• 3 to 6 February 2019 • All other field surveys	Surveys included: • Habitat towed video survey -completed by Geo Oceans. • Habitat mapping by AECOM. • Water quality sampling surveys, completed by AECOM, UWA and Terrafirma Offshore. • Underwater noise modelling completed by Talis	Geo Oceans 2019 BCH Mapping and Report – AECOM (2021a) Talis (2021) (Appendix F)

A summary of the survey areas investigated is illustrated in Figure 6 and fauna observed opportunistically and during surveys are shown in Figure 7.

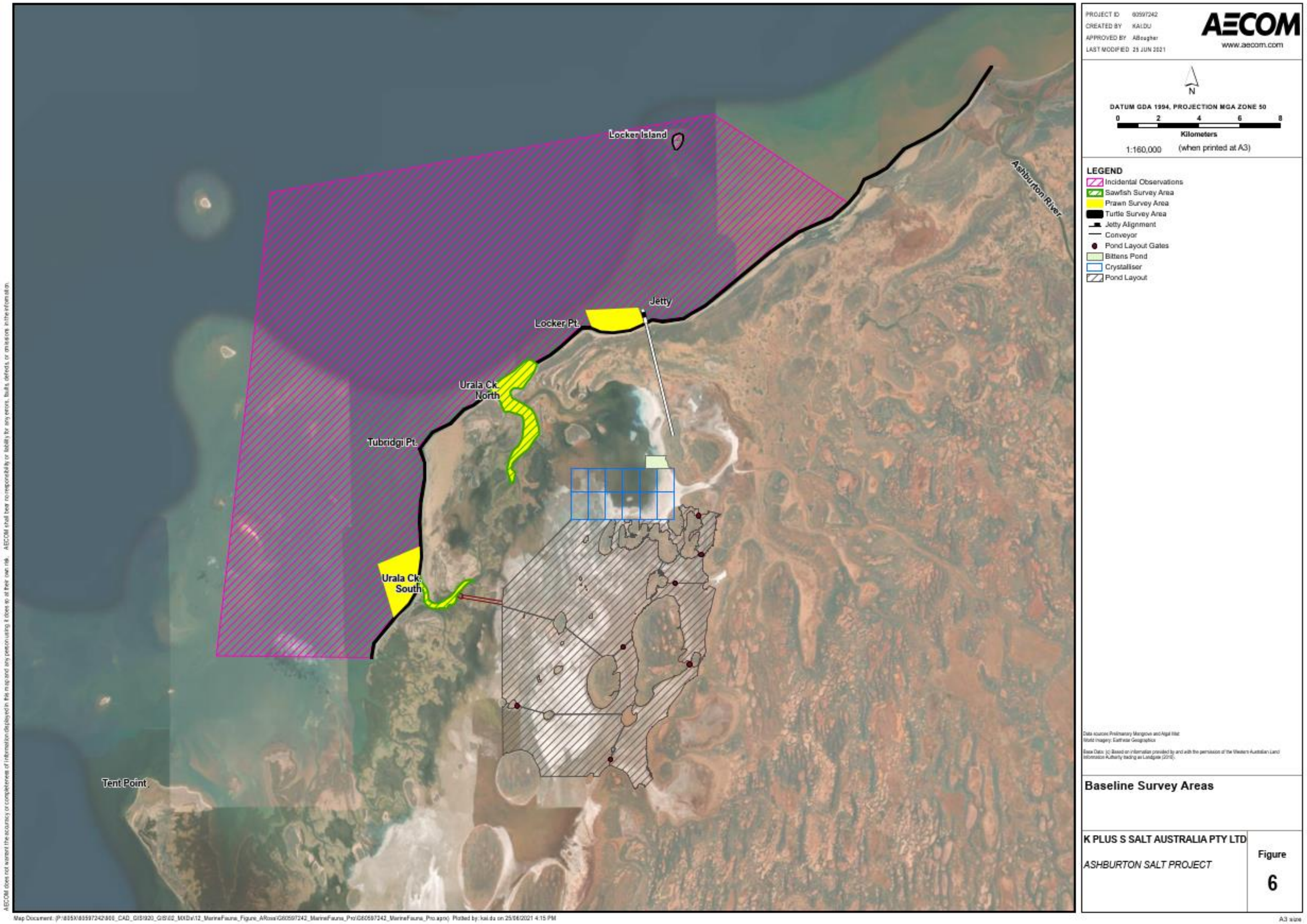


Figure 6 Marine fauna baseline survey areas

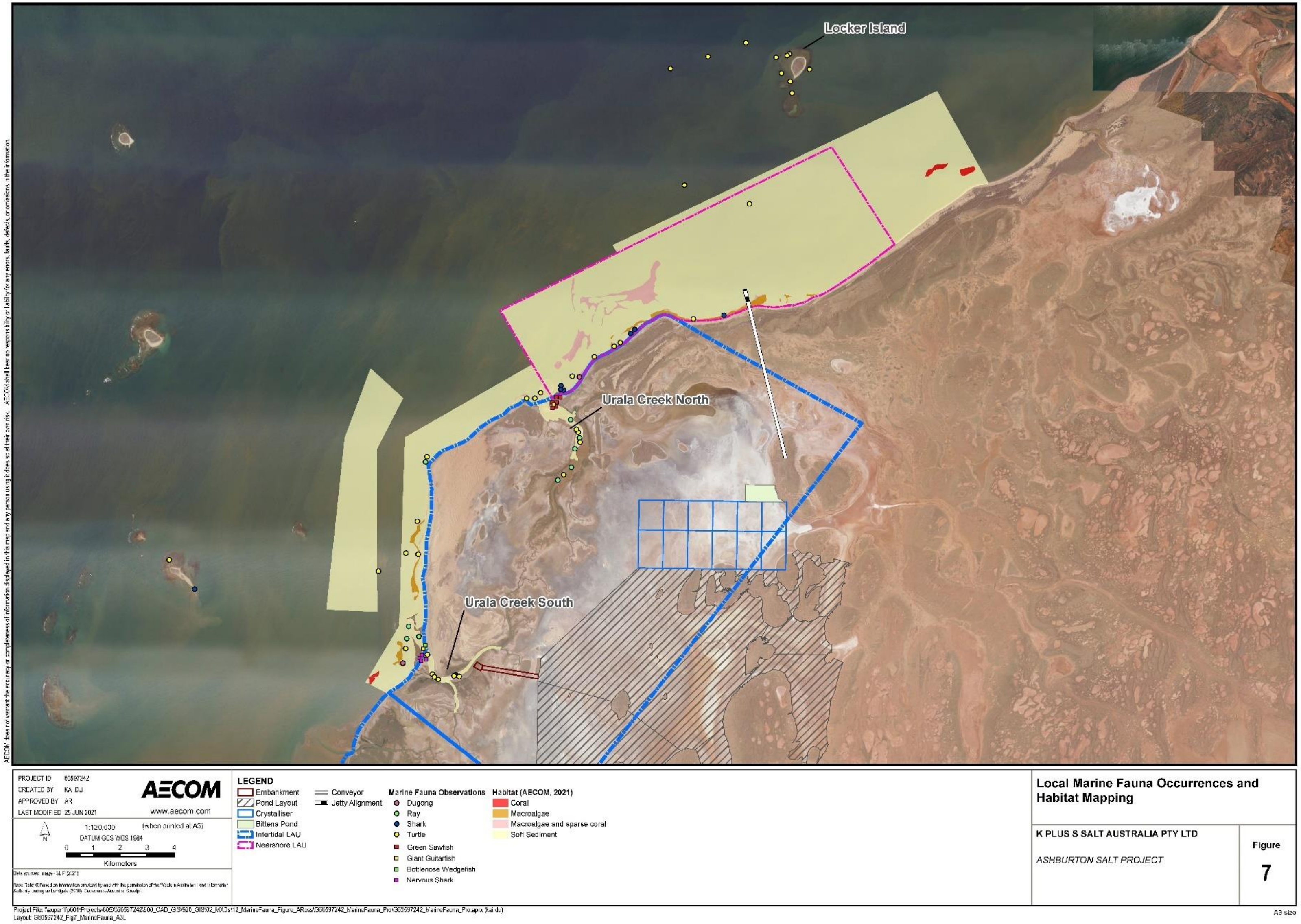


Figure 7 Local marine fauna occurrences and habitats

5.1.1 Benchmark light data collection (Pendoley Environmental 2020)

Pendoley Environmental (2020) undertook a benchmark light survey from several locations to calibrate the light modelling required to assess the potential changes to the light environment from the Project. Four survey locations were selected for benchmark light data collection, three situated on the mainland and the one on the south side of Locker Island (Figure 8). Light data were collected for three monitoring nights between 22–25 May 2019 using a Sky42™ light monitoring camera to acquire low-light images of the entire night sky – Appendix C.

All suitable images were processed into isophote maps using specialised software to determine "whole-of-sky" (WOS) and "horizon" sky brightness levels. WOS is the mean value of sky glow in the entire image, and horizon is the mean value of sky glow within the 60°–90° outer band.

Sky brightness was quantified in units of visual magnitudes/arcsec^2 (V mag), a standard unit used in astronomical measurements and emerging as a standard for sky glow monitoring globally. V mag quantifies light intensity on an inverted logarithmic scale (i.e. higher values represent lower intensity light, while lower values represent higher intensity light). The image with the median value of sky brightness for each site on a clear night was selected for complete analysis.

Modelling of predicted light from the Project was undertaken using the imagery captured as part of the benchmark light survey as a base that represented existing lighting conditions (as of May 2019) (see Section 5.2.3) – Appendix C.

Figure 8 Light Monitoring Locations

5.1.2 Benthic habitat survey (Geo Oceans 2019)

A detailed analysis of previous data and maps was undertaken by Geo Oceans (2019) to validate the available Locker Point data and maps in the survey area. Prior to the survey, Geo Oceans defined the planned towed camera transect locations in Arc GIS software; these formed the basis for the survey. Additional transects were added in response to on-site habitat assessment.

The benthic habitat survey was undertaken in February 2019. A total of 73 towed camera transects were completed, covering 5.9 km of seafloor (benthic) habitat.

The towed camera system consisted of topside electronic technology and survey software and in-water towed camera equipment. The topside technology allowed the on-site (real-time) assessment of data and the assimilation and recording of data sets (i.e. video, still images, GPS and on-site habitat assessment).

Further benthic habitat investigations were subsequently undertaken by AECOM, including targeted sonar data acquisition and satellite imagery interpretation. The benthic habitat mapping methodology and outputs subsequently compiled by AECOM, are presented in the Ashburton Salt Project Assessment of Benthic Communities and Habitats Report (AECOM 2021a) and resulting mapping is shown in Figure 7. The significant habitats used by marine fauna are discussed in Section 6.0.

5.1.3 Sawfish survey (Morgan et al. 2020)

Morgan et al. (2020) undertook targeted sawfish surveys in Urala Creek North and Urala Creek South in February 2019. Nets were set in the afternoon and removed in the evening; noting that dusk/night fishing occurred on only one occasion in each creek – Appendix D.

Sampling consisted of setting up to two 60 m lengths of 152 mm (stretched mesh) monofilament gill nets. Nets were most often set perpendicular to the bank, fishing from the shallows (0–0.1 m) to deeper water (down to 2 m), and were used to survey a variety of habitats in both creeks, including shallow sand flats, deeper channels, tidal flats close to mangroves, and mangrove lined side creeks. Nets were set for between 1.5 and 5 hours and were monitored constantly and checked when activity was observed in the net, or at a minimum of once per hour.

In addition to gillnet surveys, visual surveys from the shoreline and from the boat were conducted in each creek to provide additional information on the species diversity and densities present. Walking surveys were conducted by researchers either walking along the shoreline or along straight transect lines in shallow areas at different times of the day, recording any elasmobranchs or other notable taxa seen. Small juveniles of species tended to aggregate in certain areas near the shoreline, and for these aggregations the number of individuals was counted and the area occupied by the aggregation approximated. Surveys from the boat were conducted by driving the 3.75 m tender slowly along straight transect lines throughout the mouth and shallow areas of both creeks and noting any elasmobranchs observed. While these visual surveys are less precise than net surveys in quantifying the densities of species present, visual surveys can cover a greater area than stationary gillnets.

5.1.4 Marine turtle nesting survey

Two snapshot marine turtle nesting surveys were undertaken by an experienced AECOM turtle biologist in December 2018 and December 2019, to target the peak nesting period of flatback turtles, which the desktop review revealed were the most likely species nesting in the area. The survey area comprised mainland beaches from Ashburton River to the mouth of Urala Creek South and where possible nearshore islands, such as Locker Island were surveyed (see Figure 6).

The surveys in December 2018 were completed over two days and targeted both mainland and nearshore islands. The December 2019 survey was undertaken over a single day and concentrated on surveying the mainland beaches.

Surveys were undertaken from dawn until midday and completed using an R44 Helicopter (due to the remote nature of the site). The helicopter was flown at slow speeds at a height of approximately 100 m to allow any recent turtle activity to be identified. All turtle activity was recorded on an electronic tablet with the location of the activity recorded on a handheld GPS. Photographs were also taken.

All turtle activity identified was recorded and the turtle activity classified as per the following:

- **False crawl** – turtle emerged from the water and crawled to the nesting zone however returned to the water without carrying out any nesting activities (such as nesting or body pitting).
- **U-turn** – turtle emerged from the water but turned around and re-entered the water prior to reaching the nesting zone.
- **Body pit** – turtle emerged from the water and crawled to the nesting zone and commenced nesting activity, however only dug a body pit before returning to the water.
- **Nest** – turtle presumed to have successfully nested due to visual identification of nest.

Where possible, the species of turtle was identified from the track. It was also recorded whether the turtle activity occurred before, during or after high tide.

Habitat data were also collected along the length of the mainland survey area.

5.1.5 Prawn post-larval and juvenile survey (Murdoch University 2020)

Field work was conducted in January, February, October, November and December 2019 to sample post-larval and juvenile prawns in Urala Creek North, Urala Creek South, the prawn nursery area adjacent to the mouth of Urala Creek South, and in the vicinity of the bitterns discharge area – Appendix E.

Two sampling methods were used:

- A plankton net to capture post-larval prawns in the upper half of the water column (0.1 m^2 opening, 0.35 m diameter, 177 µm mesh).
- A benthic trawl to capture juvenile and adult prawns from the seabed (0.75 m x 0.45 m mouth, 2.4 m long body of 26 mm diamond mesh, 1.2 m cod end of 6 mm octagonal mesh).

All plankton and prawns were identified to species where possible under a dissecting microscope. Data from the surveys have been provided for consideration as part of a prawn modelling exercise being undertaken independently to the PER process, by K+S, Water Technology, Murdoch University, DPIRD and Kailis. The aim of this exercise is to model potential proportional loss of prawns from Exmouth Gulf Prawn Managed Fishery (EGPMF) and Onslow Prawn Managed Fishery (OPMF) as a result of the Project. The results of this prawn modelling exercise are intended to be provided to DPIRD as the managers of the fishery.

5.1.6 Migratory shorebird assessment (Biota 2021)

Biota (2021) undertook a five-phase assessment of the migratory shorebird assemblage and usage of the development envelope for the proposed project. The surveys were carried out in November and December 2018; and March, April and late May (2019) in accordance with EPBC Act Policy Statement 3.21: Industry Guidelines for Avoiding, Assessing and Mitigating impacts on EPBC Act listed Migratory Shorebird Species (Commonwealth of Australia 2017b).

The study area was located within Exmouth Gulf and Onslow shorebird areas defined by BirdLife Australia's Shorebirds 2020 program. For the purposes of applying the criteria for important shorebird habitat, the shorebird habitat within the study area was separated into two discrete shorebird areas:

- Western shorebird area in the west, encompassing the majority of shorebird habitat in the study area; and
- Ashburton River shorebird area in the east.

For the purposes of counting, the study area was further divided into six smaller shorebird count areas, five within the Western shorebird area and one covering the Ashburton River shorebird survey area. These areas were defined following the first phase of field survey based on expected shorebird usage (e.g. low tide foraging or high-tide roosting), counting methodology employed, and ability to complete a count of the area within the optimal part of the tidal cycle. A combination of ground counts and aerial counts were used to cover the extent of available shorebird habitat within the study area. Some count data from the study area were also available from BirdLife Australia's Shorebirds 2020 count program (BirdLife Australia 2020).

5.2 Modelling

Several modelling studies have been undertaken to guide the identification of potentially suitable mitigation measures and the development of robust management plans. Modelling studies undertaken to inform the marine fauna impact assessment are detailed below.

5.2.1 Sediment dispersion and deposition modelling (Water Technology 2021a)

Project activities, particularly dredging programmes, have the potential to suspend sediments into the water column; these will subsequently deposit onto the seabed and a portion will be prone to resuspension.

Modelling to estimate predicted plume suspended sediment concentrations, dispersion and persistence, as well as areas of sediment deposition from dredging and tailwater disposal, was conducted to inform detailed impact assessments at habitat and species levels.

5.2.2 Underwater sound modelling (Talis 2021)

Underwater sound modelling was required to assess the potential for impacts of sound-generating Project activities particularly dredging and pile driving on marine fauna – Appendix F.

This modelling took into consideration ambient sound levels, concurrent emission sources, as well as cumulative effects from existing emission sources, and considered the area of impact in relation to sensitive environmental receptors (i.e. marine mammals and marine turtles). The objective of the modelling was to inform the development of appropriate mitigation and management measures for marine fauna, for application during the construction and operational phases of the Project (e.g. observation and exclusion zones around piling and dredging activities).

5.2.3 Light spill modelling (Pendoley Environmental 2020)

The potential risk of lighting to threatened fauna in the area will depend on the dispersal and intensity of light emitted from the infrastructure, and also on the importance of the area to light sensitive marine fauna species.

A line-of-sight (LOS) assessment was completed to identify the potential visibility of artificial light associated with the Project site at sensitive locations (i.e. turtle nesting beaches). The analysis was undertaken using 3D Analyst in ESRI ArcGIS and involved analysing areas of land that are visible from the Project site – Appendix C.

To consider the inverse proportional relationship between light intensity and distance, and to present a potential lighting scenario associated with the Project, an artificial light model was developed. The model considered the location of light sources, total lumens, type of artificial lights, and height of light placement used as part of the proposed development. In addition, the model considered the height of the receptor, i.e. marine turtle hatchlings and adults.

Of the four locations surveyed in the benchmark light survey, two were selected to be used in the artificial light modelling (Locker Island and LM3) (see Section 5.1.1, Figure 8). These locations were selected due to their close proximity to the Project location and marine turtle nesting habitat. For the Project, the jetty and conveyor lighting may be completely switched off when no vessel loading is taking place. This therefore formed the basis for the two scenarios assessed in light modelling:

- Scenario 1: 'Worst case' with all jetty and conveyor lights switched on at all times.
- Scenario 2: 'Best case' with all jetty and conveyor lights switched off when not in use (other lighting remains on).

5.2.4 Marine discharge and seawater intake modelling (Water Technology 2021a)

A hydrodynamic model was developed to represent the existing movement of marine waters within the receiving marine environment (under both extreme and normal weather conditions). The hydrodynamic model was used to assess the potential impacts from the proposed discharge of bitterns (taking into account the results of the bitterns ecotoxicology assessment) and the proposed intake of seawater. These included the potential impacts on hydrology and water quality of the system.

5.2.5 Nutrient assessment modelling (Water Technology 2021b)

Comprehensive modelling of hydrology and nutrient flows in the Project area was undertaken to investigate, document, illustrate and map the existing surface water flow regime and nutrient pathways that support important environmental values of the system. Understanding any potential changes in nutrient flows into the Project catchment and Exmouth Gulf as a result of the Project is important for assessing potential nutrient flow related impacts to marine ecosystem productivity (especially nutrient related productivity of the prawn nursery).

5.2.6 Prawn modelling

Independently to the PER process, a modelling exercise is being undertaken with K+S, Water Technology, Murdoch University, DPIRD and Kailis to model potential proportional loss of prawns from the EGPMF and OPMF as a result of the Project. The results of this prawn modelling exercise are intended to be provided to DPIRD as the managers of the fishery.

5.3 Data Assumptions and Limitations

The reports are deemed fit for purpose to undertake the impact assessment and specific technical assumptions and limitations are listed in each specific report, which are included separately within the PER.

6.0 Existing Environment

6.1 Important Habitat

A detailed description of the subtidal and intertidal habitats recorded within proximity to the Project is provided in the BCH report (AECOM 2021a).

A number of marine fauna species can associate with certain habitats and therefore the presence of certain habitats in an area can infer presence of certain species where survey data may be lacking. A summary of important habitat associations applicable to significant marine fauna identified as likely to occur in the area is provided in Table 4.

Table 4 Significant marine fauna habitat associations

Habitat Type	Marine Fauna
Mangroves	Juvenile green turtles are known to forage on mangroves and were recorded in both Urala Creek North and Urala Creek South (see Figure 7).
Soft sediment (including potential seagrass habitat, tidal creeks and shallow intertidal zones)	Dugongs and turtles are known to forage on seagrass beds and these species were recorded opportunistically (Figure 7). Sawfish and other elasmobranchs are known to forage in inshore marine waters, river mouths, embankments and along sandy and muddy beaches. A number of elasmobranch species were recorded in Urala Creek North and in the nearshore shallow intertidal zone (Figure 7). Both Urala Creek North and Urala Creek South are believed to be nursery areas for species of elasmobranchs.
Sandy beaches	The beach from Urala Creek North to Ashburton River is low quality nesting habitat. Turtles nest at low density in sandy beaches locally, with higher density nesting on local islands.
Offshore waters	Offshore waters including Exmouth Gulf and North-east to Barrow Island are habitat for marine mammals such as migrating and calving humpback whales and Australian humpback dolphins. Offshore waters are also used as transit zones for dugongs, turtles and elasmobranchs.

In accordance with the EPBC Act Significant Impact Guidelines 1.1 – Matters of National Environmental Significance, an action is deemed to have a significant impact if there is a real chance or possibility that it will adversely affect habitat critical to the survival of a species.

6.2 Biologically Important Areas

Biologically Important Areas (BIAs) are spatially defined zones where aggregations of individuals of a species are known to display biologically important behaviours such as foraging, breeding, resting or migration (DAWE 2021c). They are important components of Species' Recovery Plans. A search of the Conservation Values Atlas identified BIAs within proximity to the Project area, which are presented in Table 5 and Figures 9-14.

Table 5 Biologically Important Areas that Spatially Overlap with the Project Area.

Species	Type	Marine Component
Humpback Whale	Migration and Resting	Nearshore, navigation route and Offshore
Pygmy blue whale	Distribution	Nearshore, navigation route and Offshore
Whale Shark	Foraging	Offshore, Southwestern boundary of the BIA
Flatback Turtle	Nesting and internesting*	Nearshore, navigation route and Offshore
Hawksbill Turtle	Internesting*	Navigation route and Offshore
Green Turtle	Internesting*	Nearshore, navigation route and Offshore
Loggerhead Turtle	Internesting*	Nearshore, navigation route and Offshore
Dugong	Breeding, nursing and foraging	Nearshore
Wedge-tailed shearwater	Breeding and foraging	Nearshore and Offshore

* Includes internesting buffer

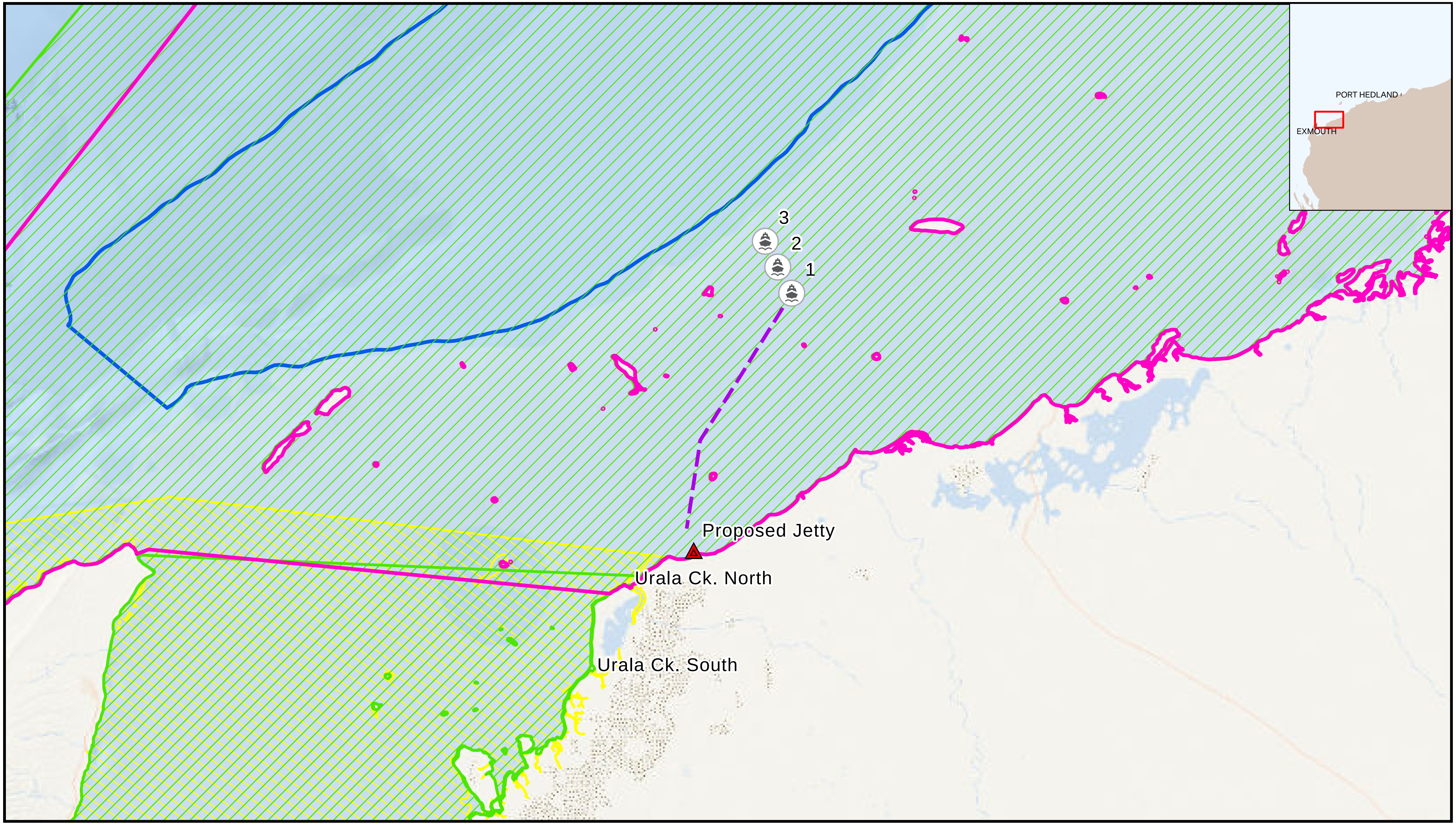
6.3 Critical Habitat for Marine Turtles

The Recovery Plan for Marine Turtles in Australia 2017-2027 (Commonwealth of Australia 2017) identifies habitat critical to the survival of various sea turtle species. These have been identified by consensus of an expert panel of marine turtle biologists. These critical habitats are not listed on the Register of Critical Habitat under the EPBC Act; however, they are relevant for the Project.

Relevant Critical Habitat Areas for listed species can be found in Figures 11-14 and Table 6.

Table 6 Critical Habitat Areas that Spatially Overlap the Project Area

Species	Activity	Marine Component
Flatback Turtle	Nesting	Nearshore and Offshore
Green Turtle	Nesting	Nearshore and Offshore
Hawksbill Turtle	Nesting	Nearshore and Offshore
Loggerhead Turtle	Nesting	Nearshore (Urala Creek South) and Offshore



PROJECT ID 60692046
CREATED BY SMITHS9
APPROVED BY INITIALS
LAST MODIFIED 03 NOV 2022

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0 4.1 8.2 12.3
Kilometers

Data sources:
Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, GeosciencesAustralia, Esri, DeLorme, NaturalVue

LEGEND
- Proposed Anchorage
- Proposed Jetty
- Proposed Transhipping Route

BIA Whales, Sharks and Dugong
- Humpback Whale
- Pygmy Blue Whale
- Whale Shark
- Dugong

Biologically Important Areas Whales, Sharks and Dugong

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ASHBURTON SALT PROJECT

Figure
9

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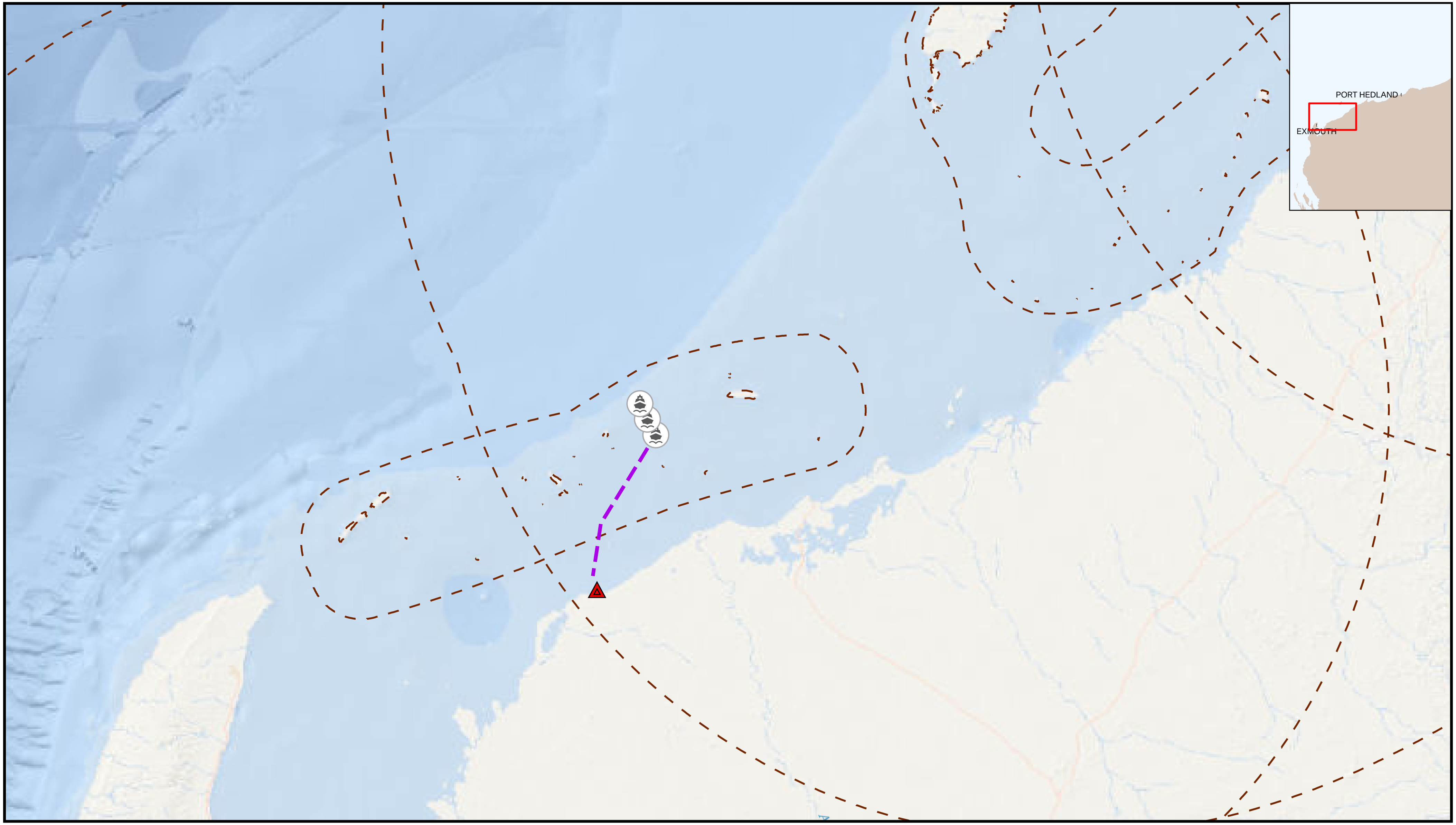

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APPROVED BY	INITIALS
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Data sources:
Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, GeosciencesAustralia, Esri, GEBCO, DeLorme, NaturalVue

LEGEND
- Proposed Anchorage
- Proposed Jetty
- Proposed Transhipping Channel
- BIA Wedge-tailed Shearwater
- Wedge-tailed Shearwater (Breeding)

Biologically Important Areas Wedge-tailed Shearwater

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ASHBURTON SALT PROJECT

Figure 10

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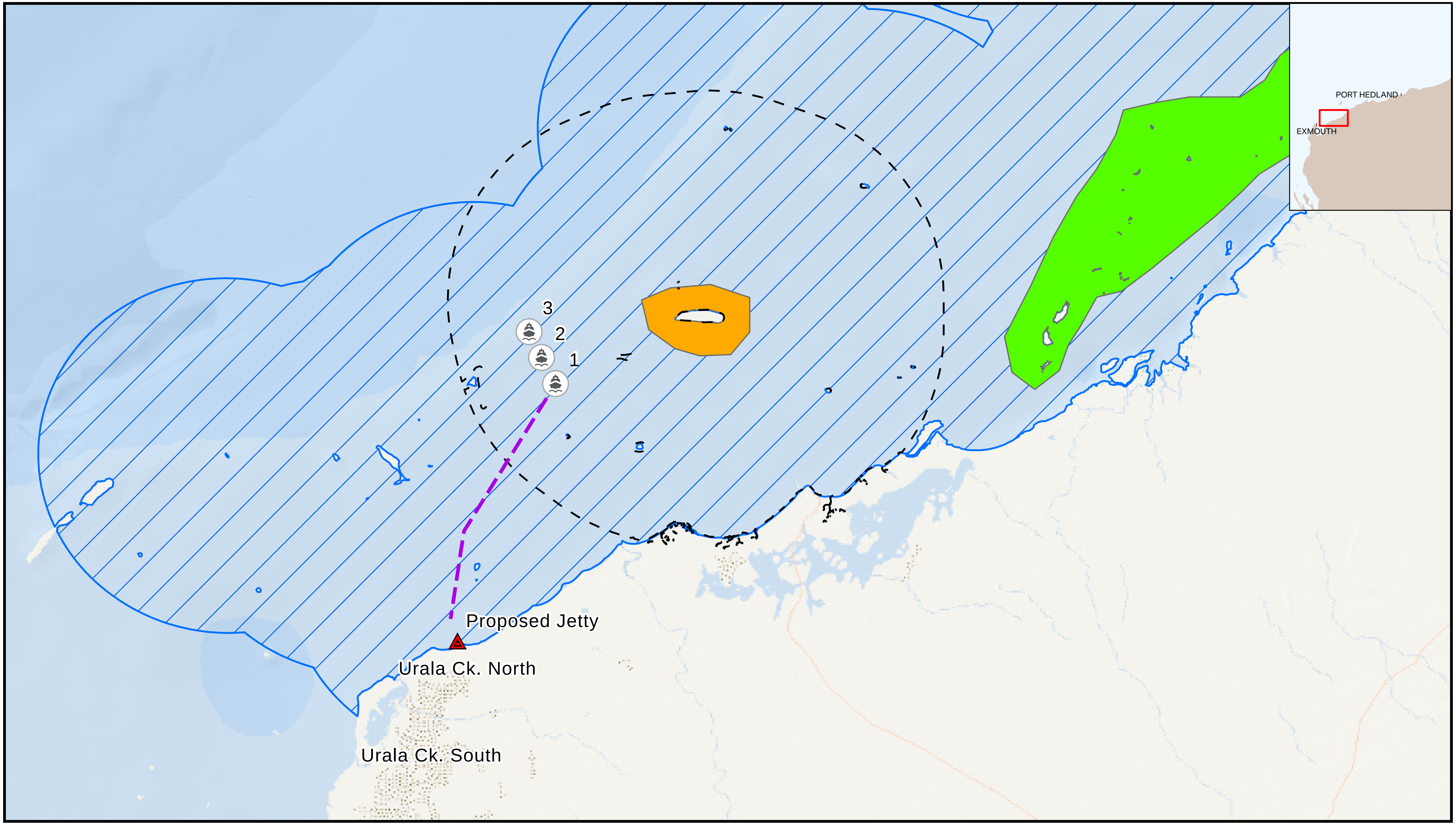

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LEGEND
BIA Hawksbill Turtle
Foraging
Nesting
Internesting Buffer
Critical Habitat
Proposed Transhipping Route
Proposed Anchorage
Proposed Jetty

Biologically Important Areas Hawksbill Turtle

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
11

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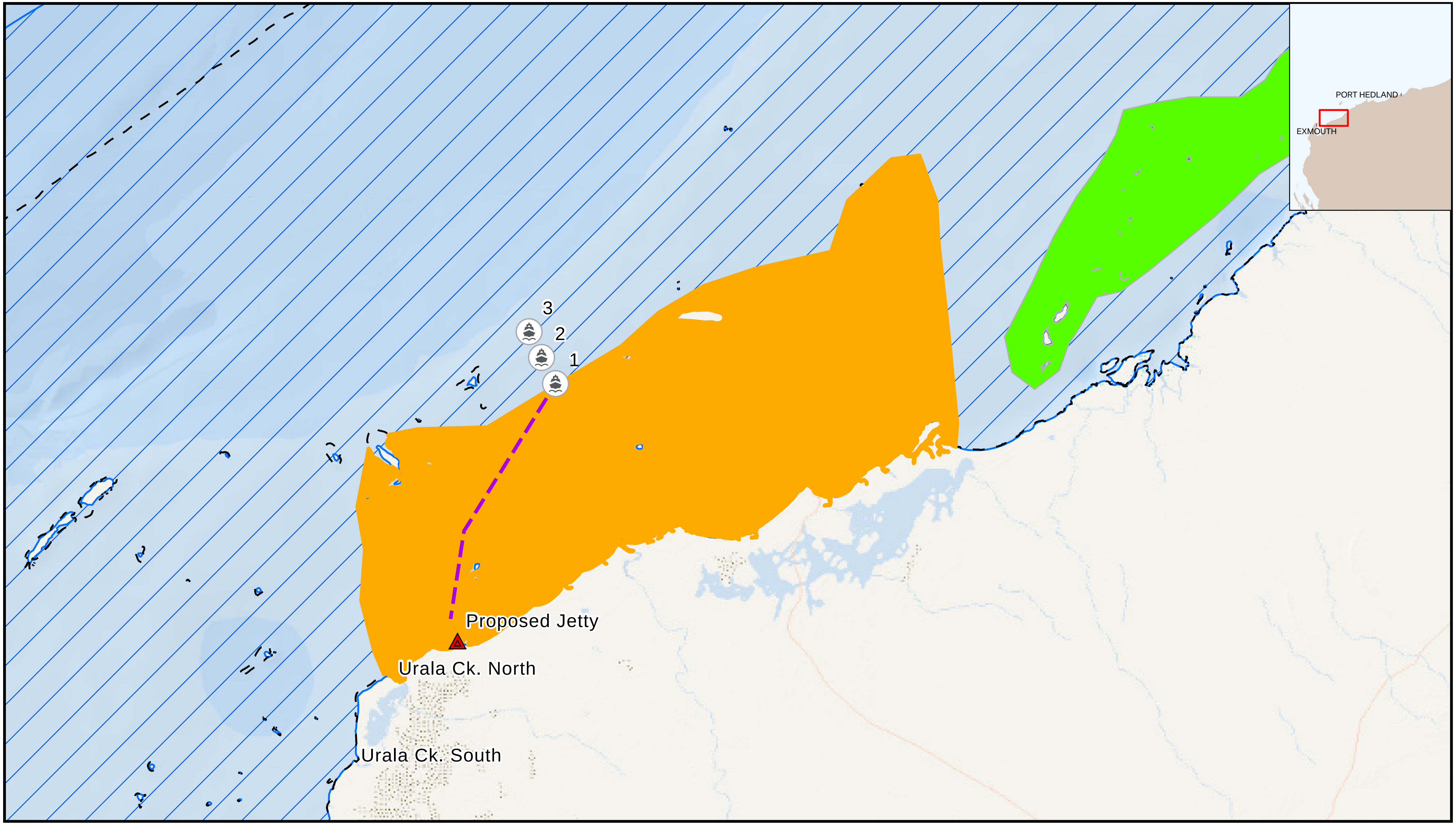

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Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, GeosciencesAustralia, Esri, DeLorme, NaturalVue

LEGEND

- Proposed Anchorage
- Proposed Jetty
- Proposed Transhipping Route

BIA Flatback Turtle

- Foraging
- Nesting
- Internesting Buffer
- Critical Habitat

Biologically Important Areas Flatback Turtle

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ASHBURTON SALT PROJECT

Figure

12

Project: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\14_MarineFauna_ABrowncliff\60597242_14_MarineFauna.aprx (SmithS9), Layout: G60597242_1401_Fig12_Flatback Turtle_v2, Last exported: 3/11/2022 12:02 PM

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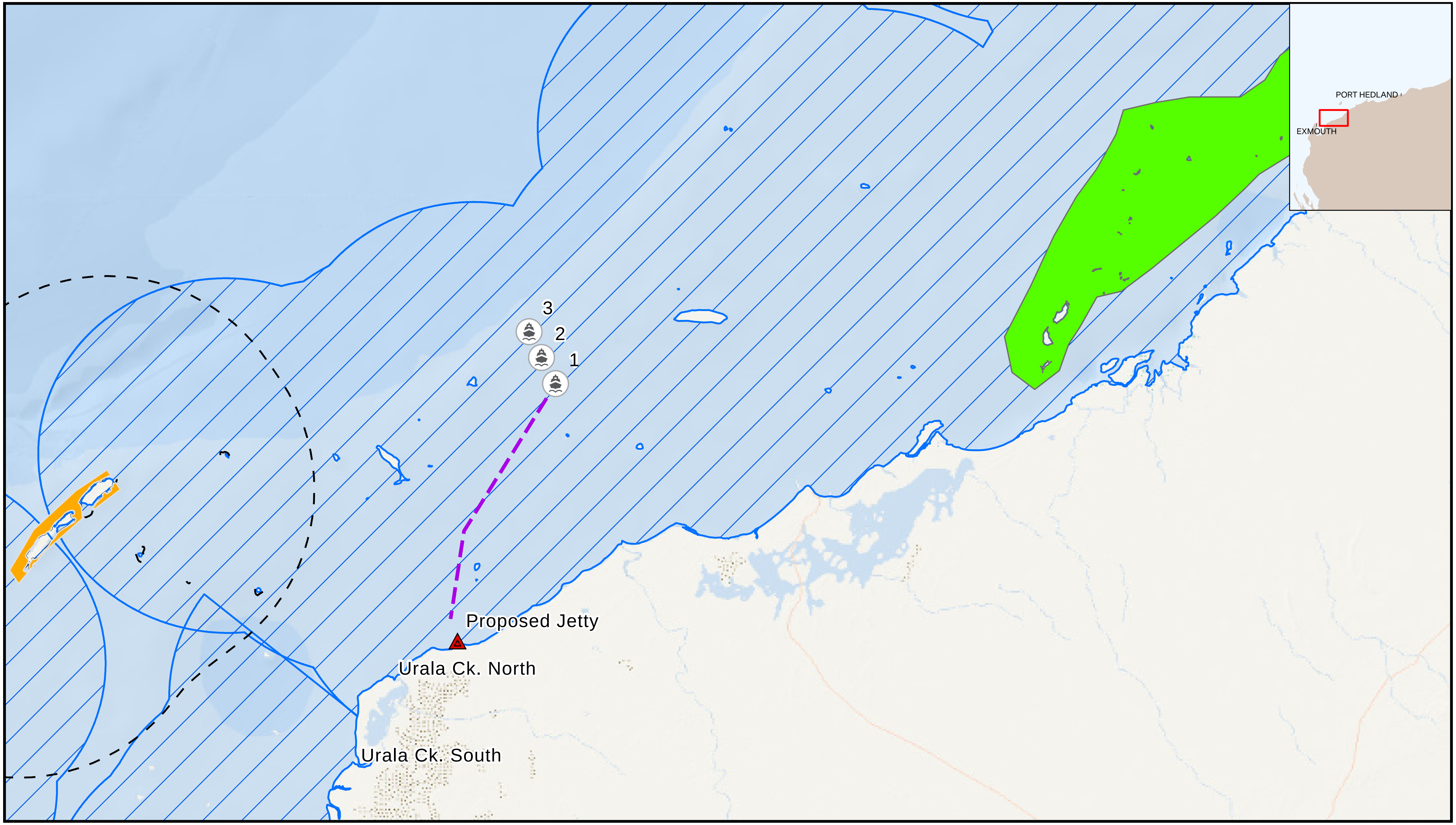

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Data sources:
Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, GeosciencesAustralia, Esri, DeLorme, NaturalVue

LEGEND

Proposed Anchorage
Proposed Jetty
Proposed Transhipping Route

BIA Green Turtle
Foraging
Nesting
Internesting Buffer
Critical Habitat

Biologically Important Areas
Green Turtle

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ASHBURTON SALT PROJECT

Figure
13

Project: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\14_MarineFauna_ABrowncliff\60597242_14_MarineFauna.aprx (SmithS9), Layout: G60597242_1401_Fig13_Green Turtle_v2, Last exported: 3/11/2022 12:03 PM

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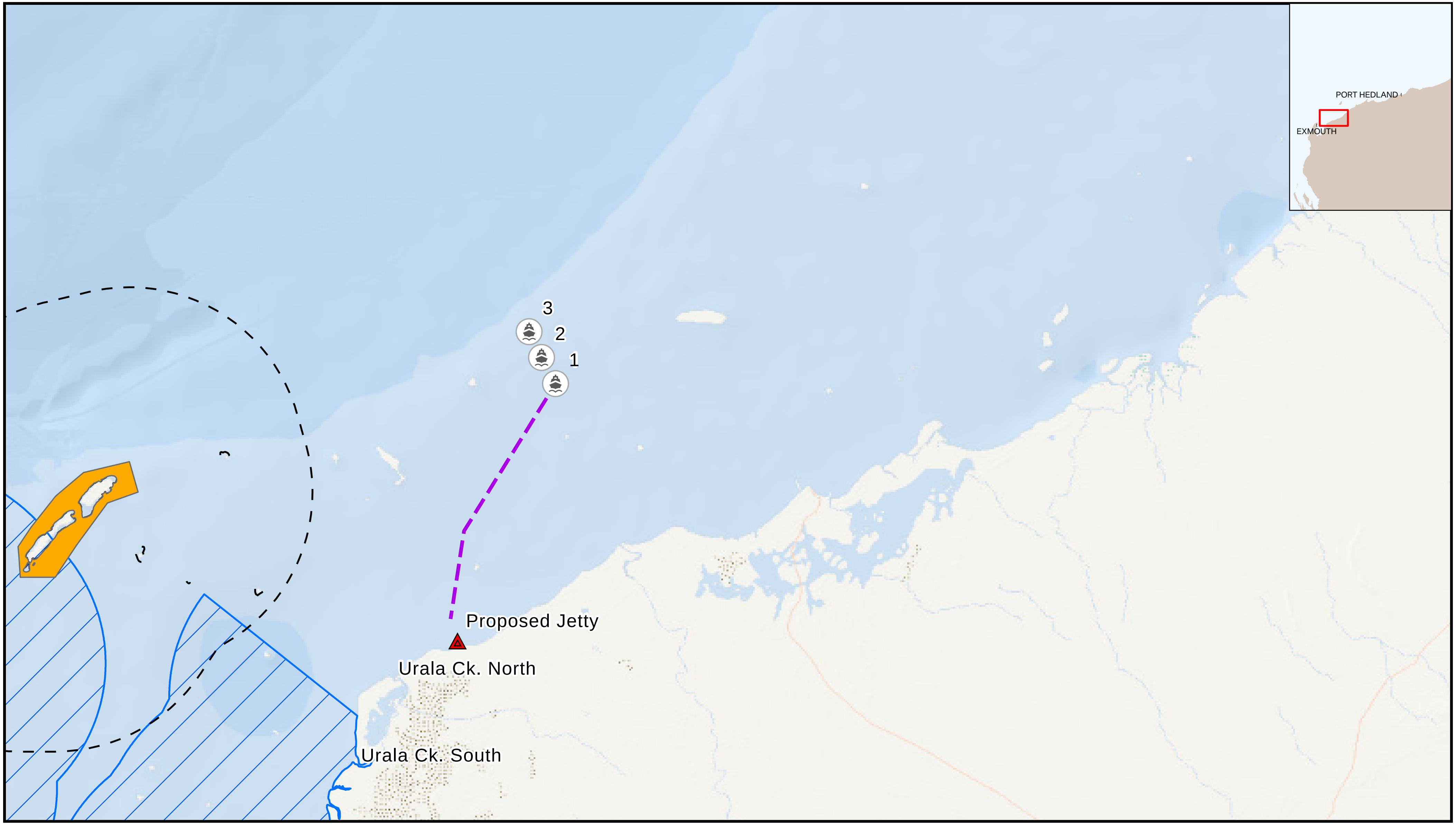

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Kilometers

Data sources:
Esri, HERE, Garmin, Foursquare, FAO, METI/NASA, USGS, GeosciencesAustralia, Esri, DeLorme, NaturalVue

LEGEND
- Proposed Anchorage
- Proposed Jetty
- Proposed Transhipping Route

BIA Loggerhead
- Nesting
- Internesting Buffer
- Critical Habitat

Biologically Important Areas
Loggerhead Turtle

K PLUS S SALT AUSTRALIA PTY LTD

ASHBURTON SALT PROJECT

Figure
14

Project: \\na.aecomnet.com\LFS\APAC\Perth-AUPER1\Legacy\Projects\605X\60597242\900_CAD_GIS\920_GIS\02_MXDs\14_MarineFauna_ABrowncliff\60597242_14_MarineFauna.aprx (SmithS9), Layout: G60597242_1401_Fig14_Loggerhead_v2, Last exported: 3/11/2022 12:03 PM

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6.4 Significant Marine Fauna Species

The impact assessment focuses on ‘key receptors’ defined as species of conservation or ecological significance that are likely to occur in the area potentially influenced by the Project.

The desktop assessment identified a number of significant marine fauna species, listed under either the EPBC Act, BC Act or on the IUCN Red List. These species have been identified as either likely to occur (or their habitat is known to occur) or potentially occurring (or their habitat potentially occurring) within the marine region locally.

Table 7 provides a summary of the desktop ecological investigation and a breakdown of species that are ‘likely’ to occur, ‘may’ occur and are ‘unlikely’ to occur locally.

Table 7 Summary of desktop ecological investigation

	Total Number of Species	Number of Species by Group
Species ‘likely to occur’ locally	35	**Avifauna** – 21 species **Mammals** – 4 species **Reptiles** – 5 species **Fish** – 5 species
Species or species habitat that ‘may occur’ locally	23	**Avifauna** – 9 species **Mammals** – 4 species **Reptiles** – 2 species **Fish** – 8 species
Species not identified but deemed ‘not likely’ to occur locally	11	**Avifauna** – 7 species **Mammals** – 4 species **Reptiles** – 0 species **Fish** – 0 species

Table 8 provides an overview of the species identified during the desktop review, their applicable threatened status (under both the EPBC Act and BC Act, as well as the relevant IUCN Red List listing) and their likelihood of occurrence in the vicinity of the Project area. During marine fauna field surveys, undertaken in 2018 to inform the impact assessment, an additional three elasmobranch species (listed on the IUCN Red List) were recorded. During the Biota (2021) field survey, additional migratory shorebirds were observed. These additional species have also been included within Table 8.

Table 8 Summary of protected species and their likelihood of occurrence locally

Common Name	Scientific Name	Threatened Status			Likelihood of Occurrence
		EPBC Act	BC Act	IUCN Status	
Elasmobranchs - Sharks, fish and rays					
Whale shark	*Rhincodon typus*	V, MM	OS	E	May occur
White shark	*Carcharodon carcharias*	V, MM	V	V	May occur
Grey nurse shark (west coast population)	*Carcharias taurus*	V	V	V	Likely to occur
Green sawfish	*Pristis zijsron*	V, MM	V	CE	Likely to occur
Dwarf sawfish	*Pristis clavata*	V	P1	E	May occur
Narrow sawfish	*Anoxypristis cuspidata*	MM	-	E	May occur
Shortfin mako	*Isurus oxyrinchus*	MM	-	V	May occur
Longfin mako	*Isurus paucus*	MM	-	E	May occur
Reef manta ray	*Manta alfredi*	MM	-	V	May occur
Giant manta ray	*Manta birostris*	MM	-	V	May occur
Giant Guitarfish	*Glaucostegus typus*	-	-	CE	Likely to occur
Nervous Shark	*Carcharhinus cautus*	-	-	LC	Likely to occur
Bottlenose Wedgefish	*Rhynchobatus australiae*	-	-	CE	Likely to occur
Marine mammals					
Sei whale	*Balaenoptera borealis*	V, MM	E	E	May occur
Fin whale	*Balaenoptera physalus*	V, MM	E	V	May occur
Humpback whale	*Megaptera novaeangliae*	MM	CD	LC	Likely to occur
Blue whale	*Balaenoptera musculus*	E, MM	E	E	May occur
Southern right whale	*Eubalaena australis*	E, MM	V	LC	May occur
Antarctic minke whale	*Balaenoptera bonaerensis*	MM		NT	Unlikely to occur
Bryde's whale	*Balaenoptera edeni*	MM		LC	Unlikely to occur
Sperm whale	*Physeter macrocephalus*	MM	V	E	Unlikely to occur
Killer whale	*Orcinus orca*	MM	-	DD	Unlikely to occur
Spotted bottlenose dolphin	*Tursiops aduncus*	MM	-	NT	Likely to occur
Australian humpback dolphin	*Sousa sahulensis*	MM	P4	V	Likely to occur
Dugong	*Dugong dugon*	MM	OS	V	Likely to occur
Marine reptiles					
Hawksbill turtle	*Eretmochelys imbricata*	V, MM	V	CR	Likely to occur
Flatback turtle	*Natator depressus*	V, MM	V	DD	Likely to occur

Common Name	Scientific Name	Threatened Status			Likelihood of Occurrence
		EPBC Act	BC Act	IUCN Status	
Green turtle	*Chelonia mydas*	V, MM	V	E	Likely to occur
Loggerhead turtle	*Caretta caretta*	E, MM	E	CR	Likely to occur
Leatherback turtle	*Dermochelys coriacea*	E, MM	V	CR	May occur
Short-nosed sea-snake	*Aipysurus apraefrontalis*	CE	CR	CR	May occur
Leaf-scaled sea snake	*Aipysurus foliosquama*	CE	CR	DD	Likely to occur
Birds					
Curlew sandpiper	*Calidris ferruginea*	CE, MM	S5	NT	Likely to occur
Bar-tailed godwit (menzbieri)	*Limosa lapponica menzbieri*	CE, MM	S1 (CR), S3 (V), S5	NT	Likely to occur
Eastern curlew	*Numenius madagascariensis*	CE, MM	S1 (CR), S5	EN	Likely to occur
Great knot*	*Calidris canutus*	CE, MM	S1 (CR), S5 (MI)	NT	Likely to occur
Red knot	*Calidris canutus*	E, MM	S2 (EN), S5 (MI)	NT	Likely to occur
Lesser sand plover*	*Charadrius mongolus*	E, MM	S2 (EN), S5 (MI)	LC	Likely to occur
Greater sand plover*	*Charadrius leschenaultii*	V, MM	S3 (VU), S5 (MI)	LC	Likely to occur
Whimbrel*	*Numenius phaeopus*	MM	S5 (MI)	LC	Likely to occur
Pacific golden plover*	*Pluvialis fulva*	MM	S5 (MI)	LC	Likely to occur
Grey plover*	*Pluvialis squatarola*	MM	S5 (MI)	LC	Likely to occur
Ruddy turnstone*	*Arenaria interpres*	MM	S5 (MI)	LC	Likely to occur
Sanderling*	*Calidris alba*	MM	S5 (MI)	LC	Likely to occur
Red-necked stint*	*Calidris ruficollis*	MM	S5 (MI)	NT	Likely to occur
Southern giant petrel	*Macronectes giganteus*	E, MM	S5	LC	Unlikely to occur
Australian painted snipe	*Rostratula australis*	E, MM	S5	EN	Unlikely to occur
Bar-tailed godwit (baueri)	*Limosa lapponica baueri*	V, MM		NT	May occur
Campbell albatross	*Thalassarche impavida*	V, MM	S3 (V), S5	V	Unlikely to occur
Common noddy	*Anous stolidus*	MM	S5	LC	Unlikely to occur
Fork-tailed swift	*Apus pacificus*	MM	S5	LC	May occur
Streaked shearwater	*Calonectris leucomelas*	MM	S5	NT	May occur
Lesser frigatebird	*Fregata ariel*	MM	S5	LC	May occur
Flesh-footed shearwater	*Puffinus carneipes*	MM	S5	NT	Unlikely to occur
Wedge-tailed shearwater	*Puffinus pacificus*	MM	S5	LC	May occur
Bridled tern	*Sterna anaethetus*	MM	S5	LC	May occur

Common Name	Scientific Name	Threatened Status			Likelihood of Occurrence
		EPBC Act	BC Act	IUCN Status	
Caspian tern	*Sterna caspia*	MM	S5	LC	Likely to occur
Roseate tern	*Sterna dougallii*	MM	S5	LC	May occur
Common sandpiper	*Actitis hypoleucos*	MM	S5	LC	Likely to occur
Sharp-tailed sandpiper	*Calidris acuminata*	MM	S5	LC	Likely to occur
Pectoral sandpiper	*Calidris melanotos*	MM	S5	LC	May occur
Terek sandpiper*	*Xenus cinereus*	MM	S5 (MI)	LC	Likely to occur
Broad-billed sandpiper*	*Limicola falcinellus*	MM	S5 (MI)	LC	Likely to occur
Grey-tailed tattler*	*Tringa brevipes*	MM	P4, S5 (MI)	NT	Likely to occur
Oriental plover	*Charadrius veredus*	MM	S5 (MI)	LC	May occur
Oriental pratincole	*Glareola maldivarum*	MM	S5 (MI)	LC	Unlikely to occur
Osprey	*Pandion haliaetus*	MM	S5 (MI)	LC	Unlikely to occur
Crested tern	*Thalasseus bergii*	MM	S5 (MI)	LC	Likely to occur
Common greenshank	*Tringa nebularia*	MM	S5 (MI)	LC	Likely to occur

Key: * - Species identified during field surveys, CE / CR – Critically Endangered, E – Endangered, V/VU – Vulnerable, MI – Migratory, MM – Migratory Marine, CD – Conservation Dependent, P4 – Priority 4, OS – Other specially protected fauna, LC – Least Concern, DD – Data Deficient, NT – Near Threatened

Key receptors were selected from the inventory of marine fauna whose distributions occur in the vicinity of the Project area and have been assessed against the 'likelihood of occurrence' based on the availability of suitable habitat locally, records in the vicinity, and distributional data where available. Key species are discussed further in in the following sections.

6.4.1 Elasmobranchs

The desktop review and corresponding field surveys identified a total of 13 elasmobranchs that have the potential to occur locally. Of these, only four species are considered likely to occur, and six may occur near the Project area. Key species are discussed in further detail in the following sub-sections.

6.4.1.1 Green sawfish – *Pristis zijsron*

The green sawfish is listed as Critically Endangered on the IUCN Red List and as Vulnerable under both Commonwealth and State legislation. Green sawfish are most common in shallow coastal and estuarine areas but can occur in depths down to 70 m (IUCN 2020). The species inhabits inshore marine waters, estuaries, river mouths, embankments and along sandy and muddy beaches (Threatened Species Scientific Committee [TSSC] 2008).

The Green sawfish is primarily under threat from fishing, as the large, toothed rostrum is easily entangled in nets and other fishing gear (IUCN 2020). Other threats to green sawfish include habitat loss (particularly loss of intertidal areas, and coastal development), pollution, loss of genetic diversity and climate change (IUCN 2020). *The Sawfish and River Sharks Multispecies Recovery Plan* has been adopted to manage this species (Department of the Environment (2015d).

The green sawfish was recorded in Urala Creek North during targeted sawfish surveys conducted in 2018 (Figure 7). Ashburton River mouth, located approximately 30 km north of Urala Creek North, has been identified as an important nursery area for green sawfish (Morgan et al. 2015, 2017). It is likely that sawfish are pupped just outside the river mouth and use the Ashburton River as a nursery for their first several months (Morgan 2020). When the river floods following storms in summer, acoustic tracking has shown that the young-of-year sawfish leave the river, and while some return after flooding has subsided, others do not (Morgan et al. 2017).

It is hypothesised that these sawfish begin to use other nearby tidal creeks along the coastline when the freshwater pulse pushes them out of the Ashburton. As the second and third major creeks found south of the Ashburton, it is likely that Urala Creek North and South are important secondary nurseries for sawfish, which was confirmed in the present work by the sighting of at least three individuals ranging in size from approximately 1.2 to 1.4 m in Urala Creek North. These individuals are likely less than one year old, based on age-growth curves estimated by Peverell (2008). It's likely the nearshore habitat between Ashburton River and Urala Creek North and South is an important migratory corridor for juvenile sawfish.

6.4.1.2 Dwarf sawfish - *Pristis clavata*

The dwarf sawfish is listed as Migratory and Vulnerable under the EPBC Act and Endangered under the IUCN Red List. The dwarf sawfish usually inhabits shallow (2–3 m) coastal waters and estuarine habitats. A study in north-western Western Australia found that estuarine habitats are used as nursery areas by dwarf sawfish, with immature juveniles remaining in these areas up until three years of age (Thorburn et al. 2007). This species is known to occur in northern Australia, from Cairns to 80 Mile Beach in Western Australia (Morgan *et al* 2011).

As the closest confirmed occurrence of this species is located over 600 km away, and targeted surveying of sawfish in Urala Creek North and South in 2018 did not record any dwarf sawfish, this indicates that the Project area is not within the home range of this species (Morgan *et al* 2011).

6.4.1.3 Giant guitarfish – *Glaucostegus typus*

The giant guitarfish is listed as Critically Endangered on the IUCN Red List and typically occurs from close inshore (including the intertidal zone and estuarine reaches of rivers) to depths of at least 100 m on the continental shelf of northern Australia (Last et al. 2016, cited on IUCN 2020). Although juveniles and adults are known to co-occur within inshore coastal habitats, embayments and coral reef atolls, neonates and juveniles are more common within shallow areas, including the intertidal zone (IUCN 2020). Globally, Giant guitarfishes are subject to fishing pressures including gillnet, trawl, hook, line, and trap fishing, however, these pressures are relatively low within Australian waters (IUCN 2020).

This species was recorded in both Urala Creek North and Urala Creek South during targeted sawfish surveys (Figure 7), conducted in 2018 and ranged in size from neonates to juveniles, with aggregations of neonate giant guitarfish (~400-500 mm total length) observed in both creeks (Morgan et al. 2020). The high number of neonates and juveniles recorded in both creeks suggest that these habitats may be pupping locations and nursery areas for this species (Morgan et al. 2020).

6.4.1.4 Bottlenose wedgefish – *Rhynchobatus australiae*

Bottlenose wedgefish are listed as Critically Endangered on the IUCN Red List and occur across the northern part of Australia. *Rhynchobatus* spp. are caught throughout their range as target and bycatch in demersal trawl, net, and long-lining fisheries for their fins and flesh (Giles *et al* 2016). The bottlenose wedgefish inhabits shallow soft substrate inshore areas, to depths of at least 60 m across the continental shelf. A single male, measuring 1420 mm (total length), was recorded in Urala Creek South during the targeted sawfish surveys conducted in 2018 (Figure 7), indicating that Urala Creek South supports suitable habitat for this species.

6.4.1.5 Nervous shark – *Carcharhinus cautus*

The nervous shark occurs on continental and insular shelves in shallow tropical and subtropical waters to depths of 20 m (IUCN 2020). In Australia the distribution of this species extends from Moreton Bay in Queensland to Shark Bay in Western Australia. The species prefers inshore sandy habitats, estuaries and mangrove fringed coastlines (IUCN 2020). Aggregations of neonate nervous sharks (~400 mm total length) were observed in both Urala Creek North and South during the targeted sawfish surveys (Figure 7) conducted in 2018. An aggregation of 23 nervous sharks was observed in an area of approximately 1000 m^2 and a total of 16 nervous sharks were caught in gillnets (ranging in size from 718-1180 mm total length). The high number of neonates and juveniles recorded in both creeks suggest that these creek habitats may be pupping locations and nursery areas for this species (Morgan et al. 2020).

6.4.1.6 Whale Shark - *Rhincodon typus*

Whale sharks are listed as Migratory and Vulnerable under the EPBC Act, and are Other Protected Fauna under the BC Act and Endangered under the IUCN Red List. Whale sharks inhabit oceanic and coastal waters of 124 countries worldwide (Fowler 2000), however, a population of approximately 300-500 individuals aggregate seasonally (March–June) to feed in coastal waters off Ningaloo Reef, Western Australia (Wilson et al 2006, Bradshaw *et al* 2008).

Whale sharks are migratory and under threat from a range of anthropogenic impacts, such as commercial and illegal fishing, disturbance to important habitat and tourism (Wilson *et al* 2006). While residing at Ningaloo Reef, Whale sharks spend approximately 40% of their time in the upper 15 m of the water column and routinely move between the sea surface and deep water, down to 1000 m (Wilson et al. 2006). There is no adopted recovery plan for the species, however Whale sharks are included in the *Marine Bioregional Plan* for North-west and East Marine Regions.

The Project area is not within the declared foraging BIA for this species; however, the transhipping channel and offshore anchorage site are within proximity to the BIA (Figure 9). Aerial surveys of Exmouth Gulf conducted by Irvine and Kent (2019) revealed 153 individual shark sightings however, these were not recorded to species level. It is unlikely near shore construction or operation activities of the Project will impact whale sharks, however vessel movements between the jetty and offshore anchorage site have the potential to occasionally interact with this species.

6.4.1.7 Grey Nurse Shark – *Carcharias taurus (*west coast population)

Within Australia there are two genetically distinct populations of grey nurse sharks; the East Coast population is considered Critically Endangered with less than 1000 individuals, whereas the West Coast population can be found in waters off the Southwest WA cost, North West Shelf and Timor Sea (Hoschke and Whisson, 2016). West Coast grey nurse sharks are listed as Vulnerable under the EPBC Act and can be found to depths of 230 m. Aggregation sites are critically important in the lifecycle of *C. taurus*, primarily for mating and pupping. There are several important aggregation sites in West Australian waters including Rottenest Island and the Navy Pier in Exmouth Gulf (Hoschke and Whisson, 2016).

Grey nurse sharks are under primarily threat from commercial fishing, recreational fishing and Eco Tourism; as a result the *Recovery Plan for the Grey Nurse Shark 2014* (Commonwealth of Australia 2014) has been implemented with the aim of increasing population numbers. It is unlikely that nearshore construction activities for the Project will impact this species, however vessel movements within the transhipment route and anchorage site may interact with individuals.

6.4.2 Marine mammals

The desktop review and baseline surveys identified 12 marine mammal species with the potential to occur locally. Of these, only three species are considered likely to occur near Project area, these are discussed in the following sub-sections.

6.4.2.1 Humpback whale – *Megaptera novaeangliae*

Humpback whales are listed as Migratory under the EPBC Act and Conservation Dependent under the BC Act. Current threats to humpback whales include climate change, noise interference, habitat degradation, marine debris, and vessel strike (IUCN 2020). Humpback whales are protected by a number of measures, including sanctuaries and a moratorium on commercial whaling. In Australia, there are no current recovery plans in place for this species, however humpback whales have been identified as a conservation value in three Marine Bioregional Plans. The Project area is located within the BIA for this species (Figure 9).

The largest population worldwide (Breeding Stock D) breeds along the coast of Western Australia (Branch 2011; Salgado Kent et al. 2012; IWC 2014; Irvine and Salgado Kent 2019), with a number of locations along this coastline identified as critical habitat and essential for the survival of humpback whales (Irvine and Salgado Kent 2019).

These areas are known to support significant seasonal aggregations of humpback whales, during key life processes (such as migrating, calving and resting). Exmouth Gulf is located within the humpback whale migration (north and south) BIA and has been identified as one of four important resting areas along the Western Australian coast during the southern migration (DAWE 2020), utilised between July and November each year, with peak numbers in September and October (Irvine and Salgado Kent 2019). Exmouth Gulf is considered critical habitat for the survival of humpback whales as mothers and their calves utilise the sheltered waters for resting and nursing, allowing calves to grow and build sufficient energy reserves for the long southwards migration to their Antarctic feeding grounds (Irvine and Salgado Kent 2019).

Aerial surveys conducted by Irvine and Salgado Kent in 2018 recorded the number of humpback whales using Exmouth Gulf as a resting area, with nine surveys conducted between August and November 2018. The aerial survey area included the Project area and therefore results from this survey provided an indication of the likelihood of occurrence of humpback whales near the Project area.

Aerial surveys conducted by Jenner et. al. (2010) recorded the number of Humpback whales using the waters from the mouth of Exmouth Gulf to Barrow Island with 26 aerial transect surveys conducted between May 2009 and April 2010. Peak numbers were recorded in September and October. The aerial survey area included the Project indicative transhipment route and therefore results from this survey provided an indication of the likelihood of occurrence of humpback whales in the transhipment areas.

Figure 15 provides the distribution of humpback whales recorded during these 2018 and 2010 aerial surveys. The 2018 surveys show more concentration of whales and calves on the western and southern portions of Exmouth Gulf with very few sightings in the shallow waters immediately off the eastern coast of Exmouth Gulf or the project area for a distance of approximately 5–10 km. The 2010 surveys show a high density whales and calves to the northeast of Exmouth Gulf (offshore from Onslow to Barrow Island) as expected given this area is part of the known migration route of Western Australian Humpback Whales Jenner et. al. (2010).

6.4.2.2 Australian humpback dolphin (*Sousa sahulensis*)

Australian humpback dolphins are widely distributed along the northern Australian coastline from approximately the Queensland/New South Wales border to Western Shark Bay, found mainly in coastal waters and often sighted within waters 5 km from the coast (Parra and Cagnazzi 2016). Australian humpback dolphins are listed as Migratory under the EPBC Act and Vulnerable in the IUCN Red List. The humpback dolphin is primarily under threat due to habitat loss from coastal developments, however there are no adopted recovery plans for this species (IUCN 2020).

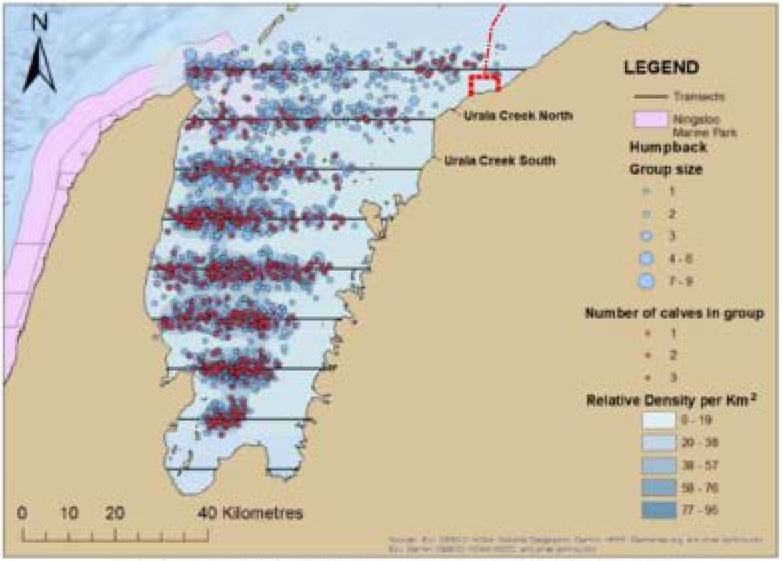
Across Australia, humpback dolphins have been observed feeding in a wide range of inshore-estuarine coastal habitats including rivers and creeks, exposed banks, shallow flats, rock and coral reefs as well as over submerged reefs in waters at least up to 40 m deep (Parra and Cagnazzi 2016). This species has been recorded throughout Exmouth Gulf and has been sighted in coastal waters close to the Project area, therefore due to the highly mobile nature of this species it is likely that individuals may occasionally pass adjacent to the Project area.

The aerial surveys described above for humpback whales also recorded dolphins (although not to species level) as depicted in Figure 15 below. These surveys indicate a wide distribution of dolphins in the region (Irvine and Salgado Kent, 2018) (Jenner et. al., 2010).

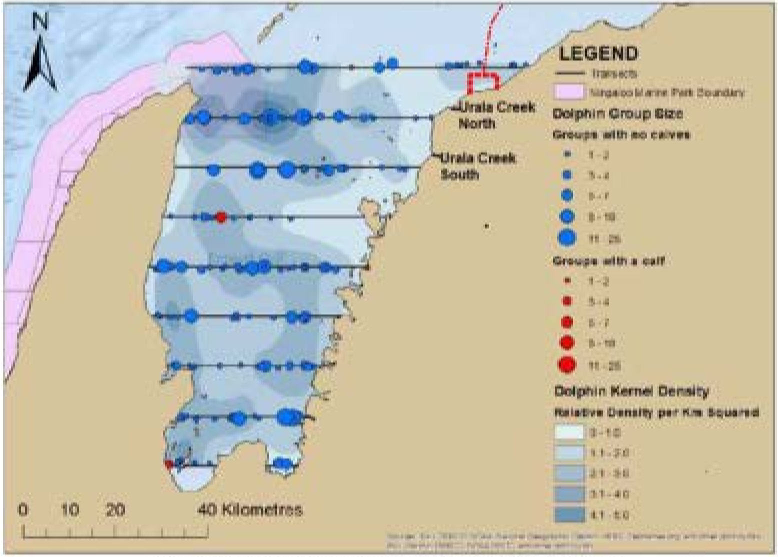
6.4.2.3 Pigmy Blue Whale (*Balaenoptera musculus brevicauda*)

Pygmy blue whales are listed as Endangered and Migratory under the EPBC Act and Endangered under both the BC Act and IUCN Red List. These whales are under threat from climate change, underwater noise, and vessel disturbances. Pygmy blue whales are generally restricted to the Southern Hemisphere including the Indian Ocean. Double et al. (2014) satellite tagged 11 pygmy blue whales over a two-year period and found that they travelled northward from the Perth Canyon towards Indonesia from March to June. The Project area is located within blue whale BIA (Figure 9), however, research suggests that this species primarily favours deeper waters and is unlikely to occur within the shallow habitat of the Project area (Thums et al 2022).

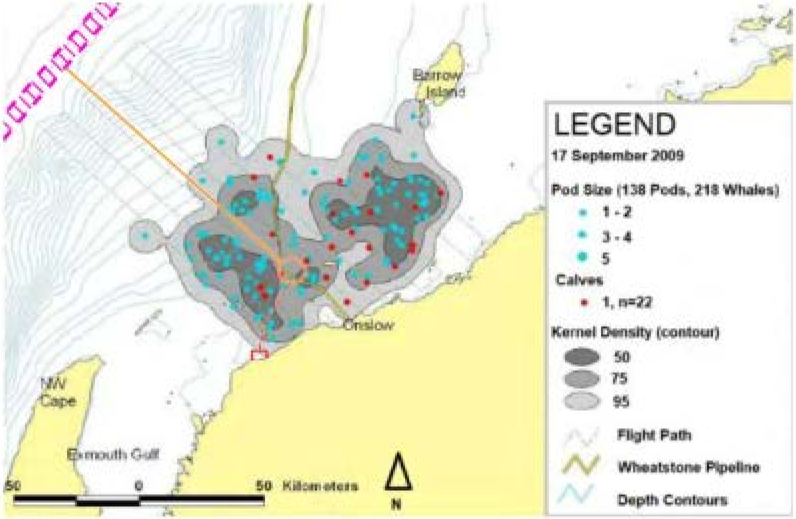
Figure 15 Distribution of humpback whales and dolphins (all species) during aerial surveys in 2018 and 2010 (Source: Irvine and Salgado Kent 2019, Jenner et. Al. 2010)



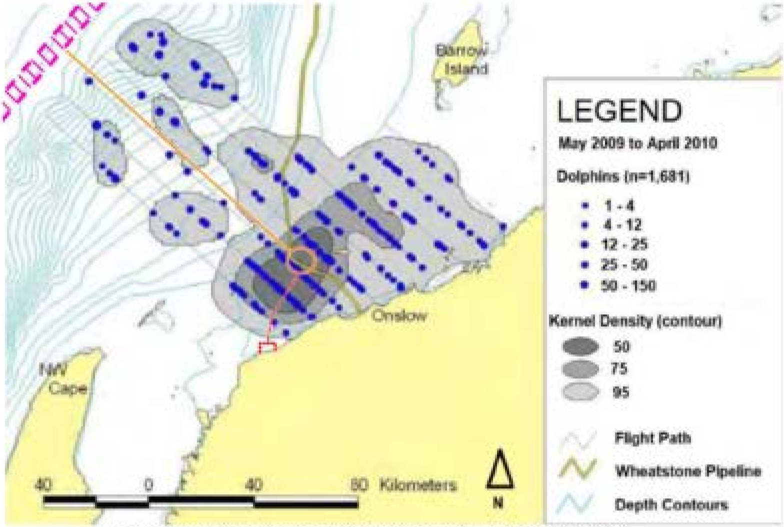
Humpback Whales Exmouth Gulf August – November 2019



Dolphins Exmouth Gulf August to November 2019



Humpback Whales Northeast of Exmouth Gulf 17 September 2009



Dolphins Northeast of Exmouth May 2009 to April 2010

6.4.2.4 Dugong – *Dugong dugon*

Dugongs are listed as Migratory under the EPBC Act, other specially protected fauna under the BC Act and as Vulnerable on the IUCN Red List. Dugongs are under threat from several anthropogenic factors including coastal development, pollution, entanglement, and vessel strike (Woinarski et al. 2014). This species inhabit coastal and island waters from Shark Bay in Western Australia across north Australia to Moreton Bay in Queensland and individuals spend most of their time in the neritic zone, especially near tidal and subtidal seagrass meadows (DAWE 2021b). There are currently no recovery plans for this species, however dugongs are considered a priority for conservation and therefore included in the Marine Bioregional Plan for the North-west and North Marine Regions. The Project area is located within critical habitat for this species (Figure 9).

Dugongs are seagrass community specialists, and the range of the dugong is broadly coincident with the distribution of seagrasses in the tropical and sub-tropical waters in their Australian range (DAWE 2021b). Exmouth Gulf is recognised as a specific area that supports dugong populations.

Dugongs were observed in close proximity to the Project area, during field surveys undertaken as part of the Project, with sightings of dugongs recorded foraging in the nearshore area to the south-west of Urala Creek South (Figure 7).

Figure 16 provides the distribution of dugongs recorded during 2018 and 2010 aerial surveys. These surveys show significant concentration of dugong (including calves) in the nearshore area approximately 5 km south west of the mouth of Urala Creek South (Irvine and Salgado Kent 2018) and nearshore along the coastline from the top of Exmouth Gulf for a distance of approximately 80 km.

6.4.3 Marine reptiles

The desktop review and baseline surveys identified seven reptile species (five marine turtle species, and two sea snake species) that have the potential to occur locally. Four marine reptile species are considered likely to occur, and three may occur near the Project area (Table 8), these species are discussed in the following sub-sections.

6.4.3.1 Sea Snakes

6.4.3.1.1 Short nosed sea snake - *Aipysurus apraefrontali*

The Short nose sea snake is listed as Critically Endangered under the EPBC Act, the BC Act and IUCN Red List due to their apparent disappearance from their known habitat of Ashmore Reef and Hibernia Reef (Lukoschek et al., 2010). However, recent surveys and distribution modelling conducted by D'Anastasi *et al* (2016) have identified previously unknown breeding populations in Exmouth Gulf and Ningaloo Reef.

The Short nosed sea snake is a true sea snake, giving birth to live young and spending their whole lifecycle at sea. This species resides in shallow coral reefs to depths of 10 m and will often rest during the day under coral overhangs in water depths of 1-2 m (Minton and Heatwole (1975). The Short nosed sea snake is under threat from anthropogenic activities such as commercial fishing, climate change, increased boat traffic and pollution. A recovery plan is not in place for this species as research is ongoing to determine management strategies.

Little is known about the abundance or dynamics of Exmouth Gulf population; however suitable habitat can be found in proximity to the Project area. Therefore, this species is considered as potentially occurring in the Project area.

6.4.3.1.2 Leaf-scaled sea snake - *Aipysurus foliosquama*

The Leaf-scaled sea snake is listed as Critically Endangered under the EPBC Act and the BC Act, however, is Data Deficient on the IUCN Red List. Threats to this species include incidental catch from commercial fish and prawn trawling, increasing vessel traffic and climate change.

The Leaf-scaled sea snake is a true sea snake, the species is known to inhabit coral reefs and lagoons to depths of 10 m, with their whole lifecycle occurring at sea. Like the Short nosed sea snake, the Leaf-scaled sea snake was once thought to be endemic and abundant at Ashmore Reef and Hibernia Reef, however the population experienced drastic declines since 1998 (Udyawer *et al* 2020).

Recent research conducted by D'Anastasi *et al* (2016) have identified a previously unknown breeding population as far south as Shark Bay, suggesting the species restricted geographic range is no longer valid. New distribution modelling by Udyawer *et al* (2020) has suggested this species may be present in locations close to sea grass meadows and coral reefs, similar to those found along the Ningaloo coast and Exmouth Gulf.

More research is required to understand the distribution and population dynamics of this species, however suitable habitat can be found in proximity to the Project area. There are currently no recovery plans for this species, though they are listed in the *Marine Bioregional Plan for the North-west Marine Region (*Commonwealth of Australia, 2012).

6.4.3.2 Marine Turtles

Figure 16 provides the distribution of turtles (although not to species level) recorded during 2018 and 2010 aerial surveys. These surveys show turtles are widespread in the region, along the eastern Exmouth Gulf and to the northeast of the Gulf in the vicinity of transhipment operations (Irvine and Salgado Kent, 2018) (Jenner et. al., 2010).

Figure 17 shows the 2018 and 2019 turtle nesting survey results which indicate that:

- The beaches from Urala Creek South to Ashburton River (including the proposed Jetty location) support low density nesting for flatback turtles (no green turtle nesting was recorded) and are considered 'low quality nesting habitat'.
- Locker Island supports a higher density of nesting for both flatback and green turtle. Locker Island has a density of nesting similar to that recorded on other Pilbara Islands.

The Project area is within the internesting buffer for Flatback and Hawksbill turtles in Figure 11 and Figure 12.

6.4.3.2.1 Hawksbill turtle – Eretmochelys imbricata

Hawksbill turtles are listed as Vulnerable and Migratory under the EPBC Act, Vulnerable under the BC Act and Critically Endangered on the IUCN Red List. In Australia the main threats to Hawksbill turtles include disturbances to critical habitat, by-catch, nest predation, entanglement, and marine pollution. Subsequently, the species is included in the *Recovery Plan for Marine Turtle in Australia* (Commonwealth of Australia 2017a).

Hawksbill turtles nest in Western Australia with key nesting and internesting areas (areas where turtles inhabit between successive clutch lays) comprising (DAWE 2021d):

- Dampier Archipelago
- Ningaloo and Jurabi Coasts
- Thevenard, Barrow, Lowendal and Montebello Islands

From Tubridgi Point north to the Dampier Archipelago is designated as critical nesting habitat for the species (DAWE 2020b, (Figure 11) however, no hawksbill nesting was recorded during snapshot surveys undertaken in 2018 and 2019 and the coastal beach in close proximity to the Project footprint appears to only support low density nesting of flatback turtles.
Hawksbill turtles are omnivorous, eating a variety of animals and plants including sponges, hydroids, cephalopods, gastropods, cnidarians, seagrass and algae (DAWE 2020). Reefs west of Cape Preston and south to Onslow are recognised as important feeding grounds for the species (Pendoley 2005, cited in DAWE 2020b).

The species may pass through local waters; however, it is believed that this would be transitory in nature.

6.4.3.2.2 Flatback turtle – *Natator depressus*

The flatback turtle is listed as Vulnerable and Migratory under the EPBC Act, Vulnerable under the BC Act and as Data Deficient on the IUCN Red List. Flatback turtles face a number of threats within Australia, including light pollution, by-catch, marine debris, vessel strike, and climate change. Due to this, the species is included in the *Recovery Plan for Marine Turtle in Australia* (Commonwealth of Australia 2017a).

Flatback turtles are endemic to the northern Australian continental shelf and no nesting is known to occur outside of Australia. Approximately one third of the known total breeding for the species occurs in Western Australia, which supports two genetic stocks: the Pilbara Stock characterised by summer nesting and the Southwest Kimberley stock which breeds year-round with a winter peak (Limpus 2008a).

No breeding sites for this species are known on the eastern side of Exmouth Gulf, however Exmouth Gulf is within the internesting BIA for the species and the northern half of Exmouth Gulf (including the Project area) is contained within the area declared as critical habitat for the species (DAWE 2021c,e, Figure 12).

The coastal area north of the Project site, from Urala Creek North, is included within the nesting BIA for the species; however, snapshot turtle surveys conducted in 2018 and 2019 indicated that the mainland coastal area between Urala Creek North and Ashburton River supported low density nesting, with three flatback turtle nests recorded on the beach adjacent to Urala Station during both the 2018 and 2019 surveys. The closest nest to the proposed jetty location was 3.5 km to the north-east of the jetty (Figure 17).

One false crawl was recorded in both 2018 and 2019 surveys approximately 1.8 km and 3.2 km (respectively) north-east of the proposed jetty location. No turtle activity was recorded or evident in the immediate vicinity of proposed jetty.

The nesting habitat recorded on the mainland beach, in proximity to the jetty and conveyor location, typically comprised a shallow limestone rock platform in the nearshore area and exposed areas of rock platform with large broken slabs evident in the intertidal area, these broken slabs may present an obstacle to nesting turtles and deter those turtles emerging at low tide. A small sand escarpment <0.5 m was present along the high tide line and the area of beach between the high tide line and the vegetation line was flat, approximately 25 m wide and comprised predominantly medium coarse sand with shell and rock fragments, vehicle tracks were present (as seen in Plate 1). The incipient dune was relatively flat and comprised sparse vegetation hummocks. There was no significant dune present behind the vegetation line. This habitat assessment classified the nesting habitat as low quality turtle nesting habitat.

Flatback turtle nesting was recorded on Locker Island during the snapshot survey conducted in 2018, and the density of nesting activity recorded was consistent with other offshore islands in the Pilbara, such as Ashburton Island. The Project area (including transhipment channel and offshore anchorage site) is within the internesting buffer for this species from October to March (Commonwealth of Australia 2017a, Figure 12).

Plate 1 Nesting habitat recorded in the Project area

6.4.3.2.3 Green turtle – *Chelonia mydas*

Green turtles are listed as Vulnerable and Migratory under the EPBC Act, vulnerable under the BC Act and Endangered on the IUCN Red List. In Australia, the main current threats to Green Turtles are coastal development, by-catch, predation on nests, boat strikes, marine debris and climate change. As a result, the species is included in the *Recovery Plan for Marine Turtle in Australia* (Commonwealth of Australia 2017a).

Green turtles, nest, forage and migrate across tropical northern Australia and Western Australia supports one of the largest green turtle populations remaining in the world. Important nesting areas in Western Australia include:

- Dampier Archipelago
- Lacepede Islands
- Ningaloo and Jurabi Coasts
- Serrurier Island
- Thevenard, Barrow, Lowendal and Montebello Island
- North West Cape
- Exmouth Gulf
- Muiron Islands

The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) identifies the nesting period for the North West Shelf stock as November to March, with peaks in January and February.

Exmouth Gulf, including the Project area, is included within the area declared as critical nesting habitat for green turtles (DAWE 2021c, Figure 13).however, no green turtle nesting was recorded on the mainland beaches between Urala Creek North and Ashburton River during the snapshot surveys undertaken in 2018 and 2019. Nesting was recorded on Locker Island in 2018.
Adult green turtles eat mainly seagrass and algae, although they will occasionally eat other items such as mangroves (Forbes 1994; Limpus and Limpus 2000; Pendoley and Fitzpatrick 1999). Juvenile turtles are known to be more carnivorous than adults (Brand-Gardner et al. 1999; Cogger 2000; Whiting 2000a). The mangrove creeks and vegetated shallows of the east side of Exmouth Gulf, and along the majority of nearshore mangrove habitat, are believed to be important nursery areas for this species (Irvine and Salgado Kent 2019), refer to Figure 16. Juvenile and sub-adult green turtles were recorded foraging in the nearshore coastal areas and juvenile, sub-adult and adult turtles were recorded in both Urala Creek North and South during field surveys conducted for the Project.

6.4.3.2.4 Loggerhead turtle – *Caretta*

The loggerhead turtle is listed as Endangered and Migratory under the EPBC Act, Endangered under the BC Act and Critically Endangered on the IUCN Red List. In Western Australia, nesting is known to occur from Shark Bay (including the mainland near Steep Point) to North West Cape with major nesting sites located at Dirk Hartog Island, Gnarloo Bay, Murion Island and the beaches of North West Cape (Baldwin et al. 2003; Hattingh et al. 2011, 2012c, 2013, 2014; Prince 1993, 1994b, as cited in DAWE 2021f). In Australian waters, Loggerhead turtles are threatened by coastal infrastructure, nest predation, by-catch and climate change. Due to this, the species is included in the *Recovery Plan for Marine Turtle in Australia* (Commonwealth of Australia 2017a).Loggerhead turtles are carnivorous, feeding primarily on benthic invertebrates; as juveniles they eat algae, pelagic crustaceans, molluscs, and anthropogenic debris (Plotkin 1996, as cited in DAWE 2021f).

No loggerhead turtles were recorded during field surveys conducted for the Project, however, as Urala Creek South is within the area declared as critical nesting habitat for this species (DAWE 2021c, Figure 14). *The Recovery Plan for Marine Turtles in Australia (*Commonwealth of Australia 2017a) identifies the nesting period for loggerhead turtles in Western Australia as November to May.

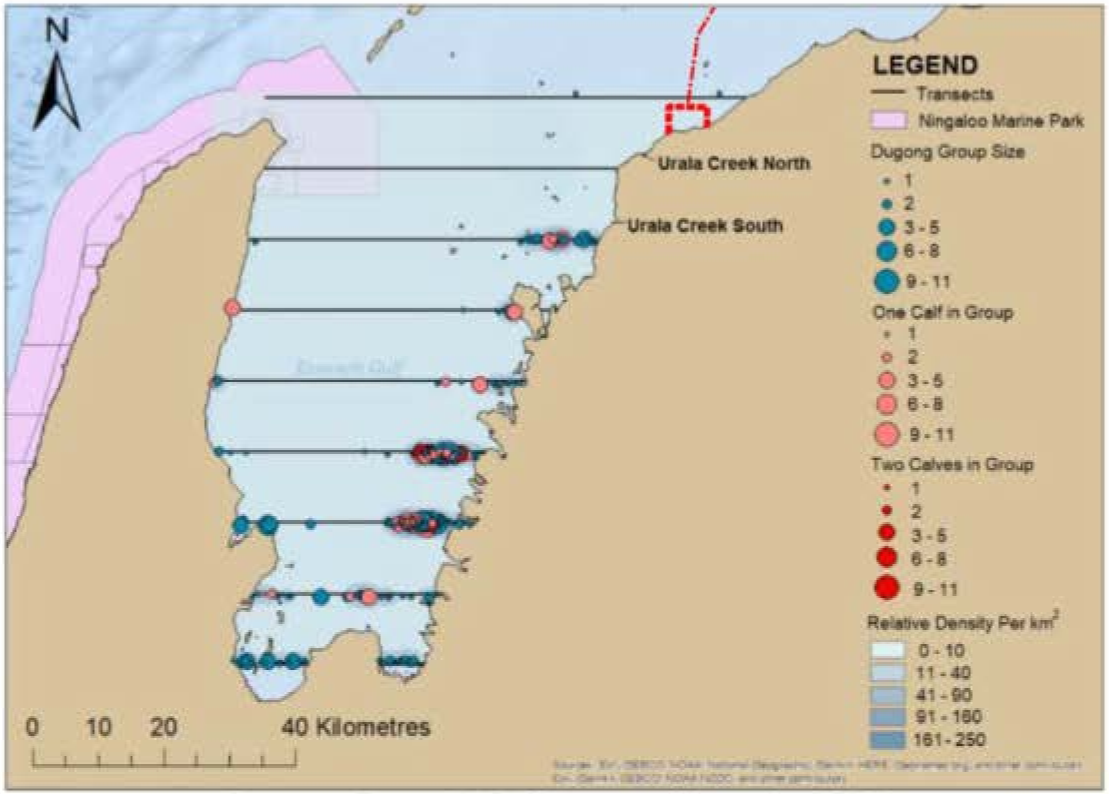
6.4.3.2.5 Leatherback turtle - *Dermochelys coriacea*

The Leatherback turtle is listed as Endangered and Migratory under the EPBC Act and Vulnerable under the BC Act and IUCN Red List of Threatened Species. The Leatherback is the largest of all marine turtle species, with adult females having a mean curved carapace length of 1.6 m (Limpus et al 1984). It is a pelagic feeder, found in tropical, subtropical and temperate waters throughout the world (Marquez 1990).

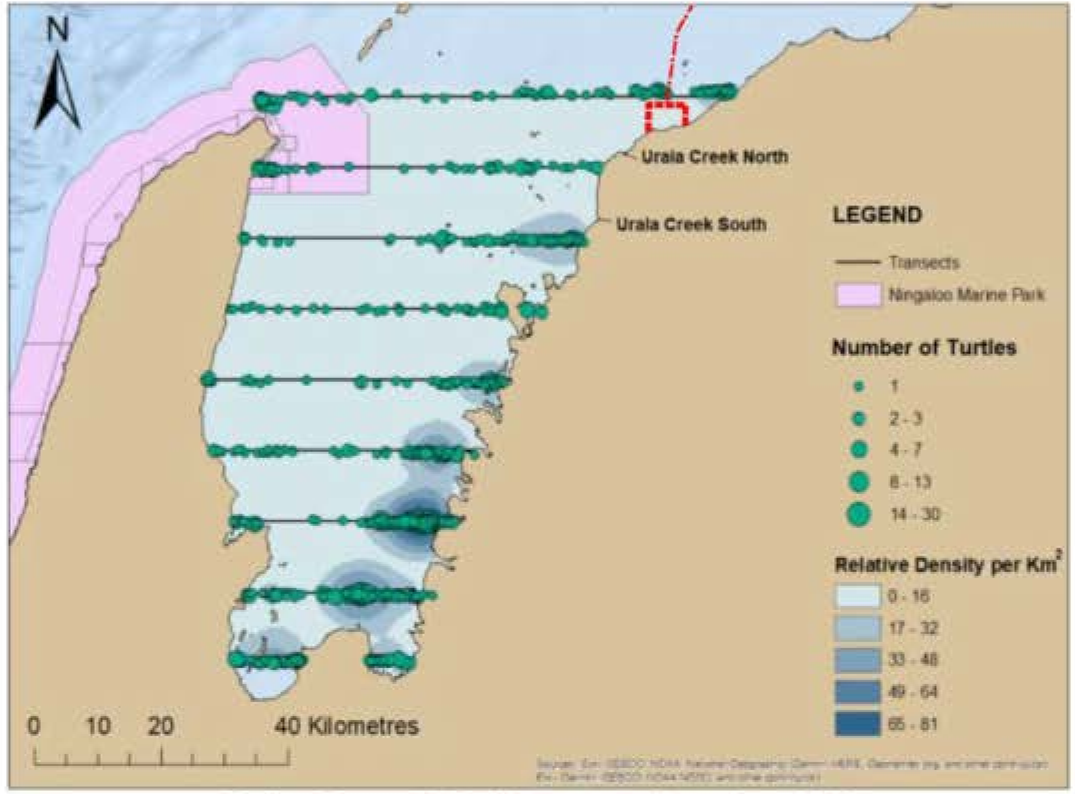
The Leatherback turtle has been found feeding in all coastal waters of Australia, however no major nesting has been recorded on Australian beaches (Haman et al 2006). Due to this, there are fewer anthropogenic impacts to Leatherback turtles in Australian waters, however by-catch, marine debris and vessel strike remain considerable threats. As a result, they are included in The *Recovery Plan for Marine Turtle in Australia* (Commonwealth of Australia 2017a).

Leatherback foraging habitat is known to occur locally, therefore the species may pass through the transhipping channel and offshore anchorage site; however, it is believed that this would be transitory in nature.

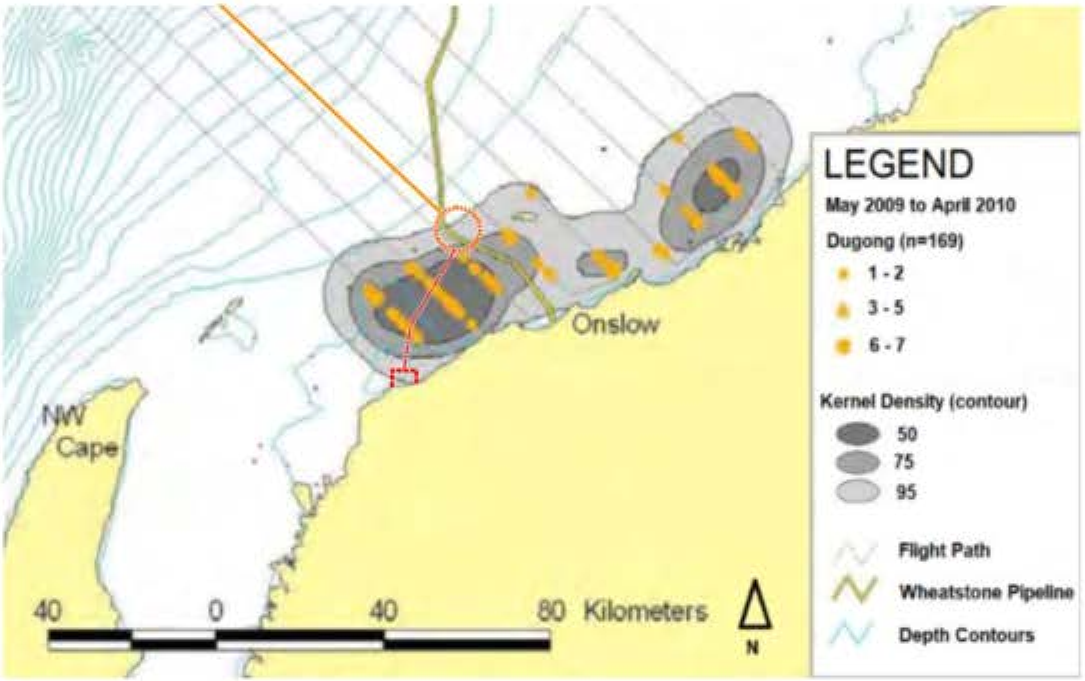
Figure 16 Distribution of Dugong and Turtles (all species) during aerial surveys in 2018 and 2019 (data source Irvine and Salgado Kent, 2018 and Jenner et. al., 2010)



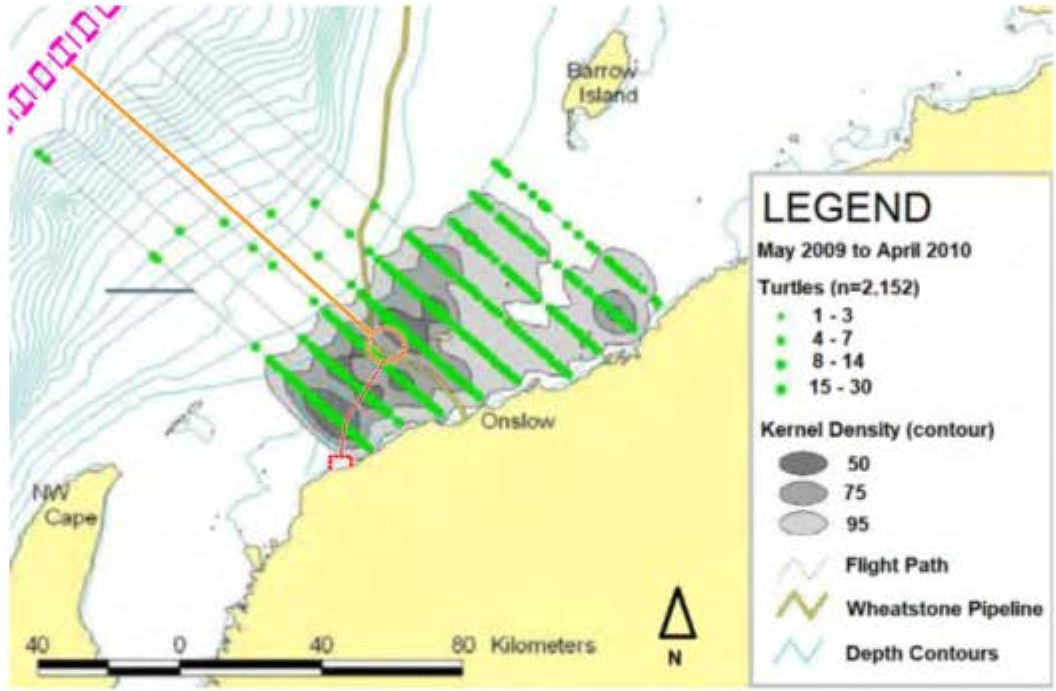
Dugongs Exmouth Gulf August – November 2019



Turtles Exmouth Gulf August to November 2019



Dugongs Northeast of Exmouth Gulf May 2009 to April 2010



Turtles Northeast of Exmouth Gulf May 2009 to April 2010

Figure 17 Marine turtle snapshot survey results

PROJECT ID	60597242
CREATED BY	KAI.DU
APPROVED BY	AR
LAST MODIFIED	25 JUN 2021

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DATUM GCS WGS 1984
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Kilometers

Data sources: Image - SLIP (2021)

Base Data: © Based on information provided by and with the permission of the Western Australian Land Information Authority trading as Landgate (2010); Geoscience Australia; Streetpro

LEGEND

- Bittens Pond
- Crystalliser
- Pond Layout
- Embankment
- Jetty Alignment
- Conveyor
- Dead

Turtle Observations 2019

- Nest
- Body Pit
- False Crawl
- Track
- U-Turn

Turtle Observations 2018

- Nest
- Body Pit
- False Crawl
- Track
- U-Turn

Snapshot Marine Turtle Results (2018,2019)

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ASHBURTON SALT PROJECT

Figure

17

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6.4.4 Other listed marine fauna species

In addition to providing for the protection of threatened and migratory species, the EPBC Act also provides for the listing of marine species for protection. The list of species protected under this section of the Act include all Australian sea snakes, dugongs, turtles, seahorse, seabirds and a large number of cetaceans. The listed marine species that were identified in the EPBC Protected Matters Search for this project have been discussed in the following sections.

6.4.4.1 Birds

The EPBC Protected Matters Search listed 37 species of bird that may occur in the Project area, of these six species were classified as threatened and 12 species classified as migratory. Bird species that are likely to occur in the Project area are addressed in Biota (2021) as well as Section 6.1.5 and Appendix A and B of this report.

6.4.4.2 Bony fish

Syngnathids, an order of ray-finned fishes comprising seahorses and pipefish are widespread throughout Western Australia, with approximately 32 species thought to inhabit shallow coastal waters. All syngnathids are listed marine species under the EPBC Act, however, are currently listed as threatened or migratory. There is limited information about the distribution of the individual species within the Pilbara region (Kuiter 2009), however of the 32 species it is thought that 22 syngnathid species occur in the North-west Marine Region (DSEWPaC 2012). No biologically important areas have been identified for seahorses or pipefish species in this region (DSEWPaC 2012).

Almost all syngnathids live in nearshore and inner shelf habitats, usually in shallow coastal waters, among seagrasses, mangroves, coral reefs, macroalgae-dominated reefs and sand or rubble habitats (DSEWPaC 2012). Syngnathids tend to use only certain parts of apparently suitable habitat. For example, they have been recorded occupying the edges of seagrass beds or macroalgae-dominated reefs and leaving large areas unoccupied (Scales 2010; Vincent 1996 as cited in DSEWPaC 2012). Physical habitat modification is of potential concern for Syngnathids, with species associated with associated with soft bottom substrates particularly vulnerable to habitat loss (DSEWPaC 2012).

The EPBC Protected Matters search listed 31 species of syngnathids (22 pipefish, five seahorse and four pipehorse species) that may occur locally to the Project area. No syngnathids were recorded during the field surveys, however if any of these species are present in the Project area, then it is considered likely that they would also be present in similar shallow benthic habitats, that are well represented across the broader region.

6.4.4.3 Sea snakes

All sea snakes in Australia are protected under the EPBC Act as listed marine species with ten of the 22 species of sea snakes known to occur in Western Australia recorded in Exmouth Gulf (Kangas et al. 2015). Sea snakes can be found throughout the Gulf but are most common in the shallow waters of the eastern shore (Storr et al. 2002; Morrison et al. 2003 as cited in Kangas et al. 2015). Most sea snake species within the Gulf are considered to be abundant or common, and populations are not known to be at vulnerable levels (Kangas et al. 2006 as cited in Kangas et al. 2015).

6.4.4.4 Whales and other cetaceans

The EPBC Protected Matters Search listed 29 whale and other cetacean species, of these five were listed as threatened and six were listed as Migratory. Marine mammals that are likely to occur in the Project area have been discussed in Section 6.1.2 and Appendix A and B of this report.

Due to the mobile nature of cetaceans, it is possible that listed species of dolphins and whales may pass through the local area, during either migrational movements or when foraging, however it is likely that these occurrences would be transitory in nature.

6.4.5 Migratory shorebirds

Across the five phases of the Biota (2021) survey, 27 species of shorebird were recorded locally, of which 21 are Migratory shorebirds and classified as such under State and Commonwealth legislation. These species are discussed in the following sub-sections.

6.4.5.1 Curlew sandpiper - *Calidris ferruginea*

The curlew sandpiper is listed as Critically Endangered and Migratory under the EPBC Act and the BC Act and Near Threatened on the IUCN Red List. In Western Australia, they are widespread around coastal and sub-coastal plains from Cape Arid to south-west Kimberley. They occur in large numbers, in thousands to tens of thousands, at Port Hedland Saltworks, Eighty-mile Beach, Roebuck Bay and Lake Macleod (DBCA 2018).

The curlew sandpiper is a common species found in Exmouth Gulf. They usually forage in water, near the shore or on bare wet mud at the edge of wetlands (DBCA 2018).

Curlew sandpipers were recorded on all five of the Biota (2021) surveys with a high count of 355 in March, though the remaining counts were significantly lower (<45). The high count in March may indicate that the study area is used as a migratory staging point for birds migrating north from further south (Biota 2021). It is also possible that this usage extends more broadly within the Gulf but was missed on previous surveys which were not conducted during northward migration (Biota 2021).

6.4.5.2 Bar-tailed godwit (menzbieri) - *Limosa lapponica menzbieri*

The bar-tailed godwit (menzbieri) is listed as Critically Endangered and Migratory under the EPBC Act and the BC Act and Near Threatened on the IUCN Red List. The bar-tailed godwit (both subspecies combined) has been recorded in the coastal areas of all Australian states. In Western Australia it is widespread around the coast, from Eyre to Derby. The species usually forages near the edge of water or in shallow water, mainly in tidal estuaries and harbours.

The bar-tailed godwit is a common species found in Exmouth Gulf but was proportionally under-represented in the study area during the recent Biota (2021) field surveys. All previous counts recorded over 1,000 bar-tailed godwits, compared to a high count of 137 for the study area during the Biota (2021) surveys.

6.4.5.3 Eastern curlew - *Numenius madagascariensis*

The eastern curlew is listed as Critically Endangered and Migratory under the EPBC Act and the BC Act and Endangered on the IUCN Red List. Non-breeding birds occur around coastal Australia, are more common in the north and have disappeared or become much rarer at many sites along the south coast (Garnet et al. 2011).

The eastern curlew is a common species found in Exmouth Gulf. However, it was proportionally under-represented in the study area during the recent Biota (2021) field surveys. This may partly reflect variation in populations using Exmouth Gulf between years, particularly given that 200 eastern curlews were counted within the study area in 2018 (BirdLife Australia 2020).

6.4.5.4 Great knot - *Calidris canutus*

The great knot is listed as Critically Endangered and Migratory under the EPBC Act and the BC Act and Near Threatened on the IUCN Red List. The great knot has been recorded around the entirety of the Australian coast, with a few scattered records inland. The species is common on the coasts of the Pilbara and Kimberley, from the Dampier Archipelago to the Northern Territory border. In Australia, great knots prefer sheltered coastal habitats with large intertidal mudflats or sandflats. This includes inlets, bays, harbours, estuaries and lagoons (DBCA 2018).

Great knots were recorded in all five of the Biota (2021) surveys with a high count of 126 in March, though the remaining counts were significantly lower (<45). The high count in March may indicate that the study area is used as a migratory staging point for birds migrating north from further south (Biota 2021).

6.4.5.5 Red knot - *Calidris canutus*

The red knot is listed as Endangered and Migratory under the EPBC Act and the BC Act and Near Threatened on the IUCN Red List. The red knot breeds in Siberia and spends the non-breeding season in Australia and New Zealand. Non-breeding season is spent on tidal mudflats or sandflats where they feed on intertidal invertebrates, especially shellfish (Garnet et al. 2011).

The red knot is commonly observed in Exmouth Gulf and was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of 89 red knots were recorded during the March 2018 survey.

6.4.5.6 Lesser sand plover - *Charadrius mongolus*

The lesser sand plover is listed as Endangered and Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. Within Australia, the lesser sand plover is widespread in coastal regions and has been recorded in all states. The lesser sand plover is gregarious and usually occurs in small to large flocks often with more than 100 individuals at favoured sites in northern Australia. This species often occurs with other shorebird species when feeding, especially the greater sand plover (Marchant and Higgins 1993). The species is mainly diurnal but may forage on moonlit nights (BirdLife International 2015).

The lesser sand plover was recorded during four of the five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of 100 lesser sand plovers were recorded during the April 2019 survey.

6.4.5.7 Greater sand plover - *Charadrius leschenaultii*

The greater sand plover is listed as Vulnerable and Migratory under the EPBC Act, vulnerable and migratory under the BC Act and Least Concern on the IUCN Red List. The greater sand plover distribution in Australia during the non-breeding season is widespread, although the most are found in northern Australia (Ward 2012). They are especially widespread between North West Cape and Roebuck Bay and occasionally recorded along the coast of southern Western Australia. The species is almost entirely coastal, inhabiting littoral and estuarine habitats (DBCA 2018).

The greater sand plover was recorded during four of the five Biota (2021) field surveys at Urala Creek. A maximum of 189 greater sand plovers were recorded during the March 2019 survey.

6.4.5.8 Whimbrel - *Numenius phaeopus*

The whimbrel is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. It is common and widespread from Carnarvon to the north-east Kimberley Division, Western Australia. The whimbrel is often found on the intertidal mudflats of sheltered coasts.

The whimbrel is commonly observed in Exmouth Gulf and. was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of 23 whimbrels were recorded during the March 2018 survey.

6.4.5.9 Pacific golden plover - *Pluvialis fulva*

The Pacific golden plover is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. Within Australia, the Pacific golden plover is widespread in coastal regions, though there are also a number of inland records. In Western Australia, the species is widespread along the Pilbara and Kimberley coasts. The number of Pacific golden plovers recorded in Australia can vary significantly between years (DAWE 2021).

The Pacific golden plover was recorded in low numbers during the Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of four Pacific golden plovers were recorded during the November 2018 survey.

6.4.5.10 Grey plover - *Pluvialis squatarola*

The grey plover is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. In Australia, the grey plover has been recorded in all states, where it is found along the coasts, and is especially abundant on the western and southern coastlines. Grey plovers usually forage on large areas of exposed mudflats and beaches of sheltered coastal shores such as inlets, estuaries and lagoons. They also occasionally feed in pasture and at the muddy margins of inland wetlands such as lakes, swamps and bores (Marchant and Higgins 1993).

The grey plover was recorded during four of the five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of 24 grey plovers were recorded during the March 2019 survey.

6.4.5.11 Ruddy turnstone - *Arenaria interpres*

The ruddy turnstone is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. The ruddy turnstone is widespread within Australia during its non-breeding period of the year (Bamford et al. 2008). Australian sites of international importance in Western Australia include Barrow Island, Ashmore Reef, Roebuck Bay and Eighty Mile Beach (Bamford et al. 2008). The ruddy turnstone is mainly found on coastal regions with exposed rock coastlines or coral reefs.

The ruddy turnstone is commonly observed in Exmouth Gulf and was recorded during all five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of 95 ruddy turnstones were recorded during the April 2019 survey.

6.4.5.12 Sanderling - *Calidris alba*

The sanderling is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. They occur on most of the coast of Western Australia. They are more often recorded on the south and south-west coasts, north to around southern Shark Bay, with more sparsely scattered records further north in the Pilbara region. In Australia, the species is almost always found on the coast, mostly on open sandy beaches.

The sanderling is commonly observed in Exmouth Gulf and was recorded during all five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of 51 sanderlings were recorded during the March 2019 survey.

6.4.5.13 Red-necked stint - *Calidris ruficollis*

The red-necked stint is listed as Migratory under the EPBC Act and the BC Act and Near Threatened on the IUCN Red List. It has been recorded in all coastal regions of Australia and found inland in all states when conditions are suitable. The red-necked stint mostly forages on bare wet mud on intertidal mudflats or sandflats, or in very shallow water; mostly in areas with a film of surface water and mostly close to the edge of water. During high tides they sometimes forage in non-tidal wetlands.

The red-necked stint is commonly observed in Exmouth Gulf and was recorded during all five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of approximately 680 red-necked stints were recorded during the December 2018 survey.

6.4.5.14 Caspian tern - *Sterna anaethetus*

The Caspian tern is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. Within Western Australia, they are widespread in coastal regions. Caspian terns tend to forage in open wetlands, including lakes and rivers. They often prefer sheltered shallow water near the margins but can also be found in open coastal waters. In coastal inlets they may prefer to forage in tidal channels, or over submerged mudbanks (Higgins and Davies 1996).

During the Biota (2021) field surveys, Caspian terns were recorded at Urala Creek North (up to six individuals), Urala Creek South (up to two individuals) and in surrounding habitats.

6.4.5.15 Common sandpiper - *Sterna dougallii*

The common sandpiper is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. Found along all coastlines of Australia and in many areas inland, the common sandpiper is widespread in small numbers. The species utilises a wide range of coastal wetlands and some inland wetlands, with varying levels of salinity, and is mostly found around muddy margins or rocky shores and rarely on mudflats. Generally, the species forages in shallow water and on bare soft mud at the edges of wetlands; often where obstacles project from substrate, e.g. rocks or mangrove roots. Birds sometimes venture into grassy areas adjoining wetlands (Higgins and Davies 1996).

During the Biota (2021) field surveys, common sandpipers were recorded at Urala Creek North, with a maximum of seven individuals sighted.

6.4.5.16 Sharp-tailed sandpiper - *Actitis hypoleucos*

The sharp-tailed sandpiper is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. The sharp-tailed sandpiper spends the non-breeding season in Australia. Most of the population migrates to Australia, mostly to the south-east and they are widespread in both inland and coastal locations, in both freshwater and saline habitats (Higgins and Davies 1996). Small numbers arrive in north-west Australia during mid-August, with large numbers in early September.

The sharp-tailed sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. During the Biota (2021) field surveys, four sharp-tailed sandpipers were recorded at Urala Creek South.

6.4.5.17 Terek sandpiper - *Xenus cinereus*

The Terek sandpiper is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. The species is widespread in the Pilbara region and Kimberley Division, from Dampier to Wyndham, with occasional records around Shark Bay. Approximately 23,000 spend the non-breeding season in Australia (Geering et al. 2007). The Terek sandpiper mostly forages in the open, on soft wet intertidal mudflats or in sheltered estuaries, embayments, harbours or lagoons (Marchant and Higgins 1993).

The Terek sandpiper was recorded during two Biota (2021) field surveys at both Urala Creek North and Urala Creek South, December 2018 and March 2019. A maximum of 26 Terek sandpiper were recorded during the March 2019 survey.

6.4.5.18 Broad-billed sandpiper - *Actitis hypoleucos*

The broad-billed sandpiper is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. In Western Australia, they mostly occur on the coasts of the Pilbara and Kimberley between Onslow and Broome (Higgins and Davies 1996). Very few adults arrive during August and early-September. By late October both adults and first-year birds have arrived.

The broad-billed sandpiper occurs in sheltered parts of the coast, favouring estuarine mudflats and is commonly observed in Exmouth Gulf. It was recorded during four of the five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of approximately 175 broad-billed sandpipers were recorded during the December 2018 survey.

6.4.5.19 Grey-tailed tattler - *Tringa brevipes*

The grey-tailed tattler is listed as Migratory under the EPBC Act, Priority 4 and Migratory under the BC Act and Near Threatened on the IUCN Red List. Within Australia, the grey-tailed tattler has a primarily northern coastal distribution and is found in most coastal regions (Higgins and Davies 1996). The Grey-tailed Tattler usually forages in shallow water, on hard intertidal substrates. It has also been recorded foraging on exposed intertidal mudflats, especially with mangroves and possibly seagrass nearby (Higgins and Davies 1996).

The grey-tailed tattler is commonly observed in Exmouth Gulf and was recorded during all five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of 228 grey-tailed tattlers were recorded during the March 2019 survey.

6.4.5.20 Crested tern - *Thalasseus bergii*

The crested tern is listed as Migratory under the EPBC Act and the BC Act and Least Concern on the IUCN Red List. It is the second largest of the terns found in Australia and one of the most commonly seen species. Crested terns form small to large flocks, often with other species, along coastal areas throughout Australia. They are seldom seen on inland waterways, preferring islands, beaches, lakes and inlets.

During the Biota (2021) field surveys, crested terns were recorded at Urala Creek North (5-10 individuals), Tubridgi Coast (6 individuals), Locker Island (~70 individuals), Fly Island (~80 individuals), Observation Island (~3 individuals) and the islet north of Brown Island (~50 individuals).

6.4.5.21 Common greenshank - *Tringa nebularia*

The common greenshank is listed as migratory under the EPBC Act and the BC Act and least concern on the IUCN Red List. Common greenshanks are found both on the coast and inland, in estuaries and mudflats, mangrove swamps and lagoons. They are common throughout Australia in the summer.

During the Biota (2021) field surveys, common greenshank were recorded during four of the five Biota (2021) field surveys at both Urala Creek North and Urala Creek South. A maximum of 93 grey-tailed tattlers were recorded during the March 2019 survey within Urala Creek North.

6.4.5.22 Wedge-tailed shearwater – *Ardenna pacifica*

The wedge-tailed shearwater is listed as Migratory under the EPBC Act and of Least Concern on the IUCN Red List. This species has been identified as a conservation value in the South-west, North-west and Temperate-east marine region plans. This species was not recorded during the Biota (2021) field survey; however, the project area supports BIAs for foraging and nesting for this species (Figure 10).

6.5 Ecological Windows and Seasonal Sensitivities of Protected Species

Periods of the year coinciding with key ecological sensitivities for EPBC Act listed Threatened and/or Migratory species potentially occurring locally, are presented in Table 9. These relate to breeding, foraging or migration of the indicated fauna. Species that were listed in the EPBC Act Protected Matters Search but do not have defined seasonal sensitivities in the region, or seasonal sensitivities are poorly defined, are not included in Table 9.

Table 9 Key environmental sensitivities and timings for marine fauna (indicative)

Species	January	February	March	April	May	June	July	August	September	October	November	December
Elasmobranchs - Sharks, fish and rays												
Green sawfish – presence[1]												
Giant guitarfish												
Bottlenose wedgefish												
Whale Shark												
Nervous Shark												
Marine mammals												
Humpback whale – northern migration (Jurien Bay to Montebello)[2]												
Humpback whale – southern migration (Montebello to Jurien Bay)[3]												
Spotted bottlenose dolphin – presence												
Australia humpback dolphin – presence												
Dugong – presence[4]												
Marine reptiles												
Hawksbill turtles – various nesting areas[5,6]												
Flatback turtle – various nesting areas[5,7]												

Species	January	February	March	April	May	June	July	August	September	October	November	December
Green turtle – various nesting areas[5]	Peak	Peak	Present								Present	Present
Loggerhead turtle – various nesting areas[5,8]	Peak	Present	Present								Present	Peak

Species likely to be present in the region.
Peak period: presence of animals reliable and predictable each year.
References for species seasonal sensitivities:

[1] Morgan et al. 2016
[2.] CALM 2005; Environment Australia 2002; Jenner et al. 2001a; McCauley and Jenner 2001
[3.] McCauley and Jenner 2001
[4.] DSEWPaC 2012b
[5] Commonwealth of Australia 2017; CALM 2005; DSEWPaC 2012b
[6.] DAWE 2012d
[7.] DAWE 2021e
[8.] DAWE 2021f

6.6 Introduced Marine Pests

6.6.1 Background

Introduced marine pests (IMP; also known as invasive marine species) are one of the most serious anthropogenic threats to global marine biodiversity (Johnson and Chapman 2007; Molnar et al. 2008; Katsanevakis et al. 2014; Crowe and Fri 2015). They cause a variety of adverse effects, including; affecting human health, competing with native species, damaging coastal areas and structures, restricting access to waterways, ports and marinas and spreading disease (DAWE 2020b). Fortunately, only a very small proportion of introduced species become marine pests.

Of particular interest with regard to the Ashburton Salt Project is the fact that relatively few introductions have been detected in tropical waters, and even fewer marine pest species (Coles and Eldredge 2002; Hewitt 2002; Huisman et al. 2008; Freestone et al. 2011). For example, California in the United States has recorded 307 introduced marine species, including 190 in San Francisco Bay (Foss 2008), and Port Philip Bay, Victoria has 99 species (Hewitt et al. 2004). A number of reasons have been proposed for the low numbers of introduced marine species and IMP in the tropics, including the greater diversity of tropical communities conferring an increased resistance to invasions through an increase in biotic interactions. Alternatively, it has been suggested that tropical waters have been less surveyed, resulting in fewer detections, or our lack of taxonomic knowledge of the biodiverse tropics may result in introduced species remaining undetected (Hewitt 2002). This was investigated by Wells (2018), who developed a database of 5,532 species recorded in the Pilbara. Only 17 species in the area are known to have been introduced and there is only one IMP species, the ascidian *Didemnum perlucidum* (Monniot 1983). A similar study was undertaken in Singapore, one of the largest ports in the world, with direct connections to over 600 ports in 120 countries. Seebens et al. (2013) concluded Singapore was at the greatest risk of IMP introduction in the world. However, of the 3650 species recorded in Singapore only 22 have been introduced and only two are possible IMP (Wells et al. 2019). A similar study in preparation records 4615 species in southern Florida; only 29 species are thought to have been introduced through shipping (Wells and Bieler 2020)

6.6.2 Australian IMP species lists

As our understanding of IMP issues has evolved, a number of IMP lists have been developed in Australia. The first nationwide compilation was prepared by the Consultative Committee on Introduced Marine Pest Emergencies in 1999 and included 20 species on the interim trigger list. The National Introduced Marine Pest Coordination Group (NIMPCG) introduced a broader list of 55 species in 2006.

The documents were updated in 2009 (NIMPCG 2009a,b) and included a detailed format for developing IMP monitoring programs to be used to form the basis of a nationwide monitoring of 15 high risk ports. An accompanying Excel spreadsheet (NIMPCG 2008) was to be used to determine the sampling frequency, sample methods and number of samples required at each location for each species.

The nationwide national IMP monitoring program was unwieldy and was never funded on a national basis. Some jurisdictions monitored ports identified in their region, but most did not. The 55 species on the NIMPCG (2009a,b) lists were in a wide variety of taxa. Many were small and required specialist expertise to identify; in some cases, the required identification expertise was not available in Australia. The NIMPCG (2009a,b) IMP species list and monitoring strategy has been abandoned (McDonald et al. 2020).

More recently, the national Marine Pest Sectoral Committee, which replaced NIMPCG, agreed 20 potential IMP species that present a risk to Australian waters. Eight of these species are established in some parts of Australia and 12 are not. There is a subset of nine species on the Australian Priority Marine Pest List; these species are nationally significant, able to be identified in the marine environment and able to be eradicated. The list includes three established and six exotic species (DAWE 2019).

In a related action, the Western Australian Department of Fisheries (DoF; now part of the Department of Primary Industry and Regional Development; DPIRD) introduced the Western Australian Prevention List for Introduced Marine Pests in 2012. The DoF list was composed of species that may be spread via biofouling or ballast water that are (1) present on national aquatic pest lists or (2) of concern to the protection of Western Australian aquatic resources. The most recent version of the list is dated November 2016 (DoF 2020).

In collaboration with Western Australian Port Authorities and port industry stakeholders, DPIRD developed a State-Wide Array Surveillance Program (SWASP) that uses standard settlement plates deployed in each location for six months before being retrieved. Biota collected from the arrays is processed using Next-Generation Sequencing (NGS) to identify the presence of IMP in each port. Eleven ports in Western Australia are monitored through this system, including three in the Pilbara (Port Hedland, Dampier and Cape Preston) (McDonald et al. 2020).

6.6.3 IMP in the Pilbara

As part of a major DoF IMP research program, a detailed compilation was made of IMP in Western Australia. A total of 60 introduced marine species were considered to be established; most (37) are temperate species that occur from Geraldton south; only six are tropical species that occur from Shark Bay north; 17 introduced species occur in both the southern and northern halves of Western Australia. Sixteen of the 23 introduced marine species occurring in tropical Western Australia were recorded in the Pilbara (Huisman et al. 2008).

All major developments in Western Australia are required by the EPA to undertake an IMP management program, approved by the national system or by DoF. Over the last 20 years, the Pilbara coastline has been the most intensively surveyed area for IMP in the world. DoF undertook surveys using the NIMPCG methodology between 2010 and 2015 in Dampier and Port Hedland. The initial monitoring methodology for the SWASP was developed in the Pilbara and is still used at three ports (McDonald et al. 2020). There have been a range of monitoring programs undertaken by individual companies in the last decade ranging from brief one-off investigations of the local area to extensive surveys of widely separated sites undertaken with Remotely Operated Vehicles (ROVs), settlement plates, epibenthic sleds, grabs and shoreline visual surveys at quarterly intervals for up to six years. The surveys initially targeted the 55 species on the NIMPCG list, but the expanded Western Australian Watch List was also used after it was first issued in 2012 (Wells 2018). Wells (2018) developed an extensive database of 5,532 shallow water marine species that have been recorded in the Pilbara. Only 17 of these are believed to have been introduced and only one, the ascidian *Didemnum perlucidum* (Monniot 1983), is listed as an IMP.

Didemnum perlucidum was first detected in the Fremantle marine area in 2010 (Smale and Childs 2011). Following this it was rapidly found throughout Western Australia from Esperance on the southeast coast, along the west coast, to the Kimberley in the northeast and in Darwin, Northern Territory. It is widespread in the Pilbara and has been reported from Exmouth Boat Harbour, Mangrove Passage near Onslow, Barrow Island and Dampier (Bridgwood et al. 2014).

To date *D. perlucidum* in the Pilbara has only been recorded on artificial surfaces, but in temperate Fremantle it also occurs on the seagrass *Halophila ovalis* (R. Brown) J.D. Hooker, 1858 in areas near artificial habitats (Simpson et al. 2016). The species is expected to colonise artificial structures constructed by the Ashburton Salt Project.

6.7 Commercial and Recreational Fisheries

The Project footprint intersects with a number of commercial fisheries boundaries. An overview of these and their potential relevance to the Project are detailed in Table 7. Where applicable recreational fishing activity has also been detailed.

The Project's seawater intake occurs within the Gascoyne Coast Bioregion (GCB) with the jetty and bitterns discharge situated on the boundary of the Gascoyne Coast Bioregion and the North Coast Bioregion (NCB).

The GCB represents a transition between the tropical waters of the North West Shelf of the NCB and the temperate waters of the West Coast Bioregion. The major fish stocks subject to commercial fishing are generally tropical in nature. The seawater intake falls within Exmouth Gulf meso-scale region, as defined by the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) spatial framework (V 4.0) (Gaughan and Santro 2020). Recreational fishing in GCB is predominantly for tropical species such as emperors, tropical snappers, groupers, mackerels, cods, trevallies and other game fish (Gaughan and Santro 2020). The two commercial fisheries whose boundaries intersect with the Project footprint comprise the EGPMF and the West Coast Deep Sea Crustacean Managed Fishery (Table 10).

The NCB includes waters of Pacific Ocean origin that enter through the Indonesian archipelago bringing warm, low salinity waters polewards via the Indonesian Throughflow and Holloway Currents which flow seasonally and interact with Indian Ocean waters (Gaughan and Santro 2020). The Integrated Marine and Coastal Regionalisation for Australia (IMCRA V 4.0) scheme divides this Bioregion into 10 meso-scale regions: Pilbara inshore, Pilbara offshore, North West Shelf, Eighty Mile Beach, Canning, King Sound, Oceanic Shoals and Kimberley (Gaughan and Santro 2020). The Project jetty and bittern discharge points fall just outside the southern boundary of NCB, however transhipment vessel and ocean-going vessel movements will fall within both the Pilbara inshore and Pilbara offshore meso-scale regions. Fish stocks in the North Coast Bioregion are entirely tropical, with most having an Indo-Pacific distribution extending eastward through Indonesia to the Indian subcontinent and Arabian Gulf regions (Gaughan and Santro 2020).

Recreational fishing in the NCB has a distinct seasonal peak in winter (Gaughan and Santro 2020) with the numerous creek systems, mangroves, rivers and beaches providing shore and small boat fishing for a variety of finfish species including barramundi, tropical emperors, mangrove jack, trevallies, sooty grunter, threadfin, cods and catfish, and invertebrate species including blue swimmer crabs, mud crabs and squid (Gaughan and Santro 2020).

There are six commercial fisheries whose boundaries intersect with the area in which Project vessels will operate, these are discussed in Table 10.

Table 10 Commercial fisheries relevant to the Project

Fishery	Overview	Relevance to the Project
Exmouth Gulf Prawn Managed Fishery (EGPMF)	The EGPMF uses low opening, otter prawn trawl systems within the sheltered waters of Exmouth Gulf to target western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), endeavour prawns (*Metapenaeus endeavouri*) and banana prawns (*Penaeus merguiensis*) (DoF 2015a,b).	The Project area is adjacent to the northern section of the EGPMF, with Urala Creek South (the proposed intake location) located within the dedicated nursery area for the EGPMF. Potential impacts to this fishery are discussed in Section 7.
West Coast Deep Sea Crustacean	The fishery targets crystal (snow) crabs (*Chaceon albus*), giant (king) crabs (*Pseudocarcinus gigas*) and champagne (spiny) crabs (*Hypothalassia acerba*) using baited pots operated in a longline formation in	The Project is located within waters that are permanently closed to this fishery; however, the ocean-going product export vessels would transit through the fishery zone. Due to the

Fishery	Overview	Relevance to the Project
Managed Fishery	the shelf edge waters (>150 m deep) of the West Coast and Gascoyne Bioregions (DoF 2015a,b) The boundaries of this fishery include all the waters lying north of latitude 34° 24' S (Cape Leeuwin) and west of the Northern Territory border on the seaward side of the 150m isobath, out to the extent of the Australian Fishing Zone (DoF 2015a,b).	extent of this fishery it is unlikely that vessel movements associated with the Project would impact this fishery.
WA Pearl Oyster Managed Fishery	This pearl oyster fishery is the only remaining significant wild-stock fishery for pearl oysters in the world. It is a quota based, dive fishery, operating in shallow coastal waters along the North West Shelf (DoF 2013). The fishery is separated into four zones, Zone 1 extends from North West Cape (including Exmouth Gulf) to longitude 119˚ 30'E (DoF 2013).	The Project area falls within Zone 1 of this fishery. Due to the extent of this fishery it is unlikely that the Project would impact this fishery.
WA Sea Cucumber Fishery (Formally Beche-de-mer Fishery)	The WA sea cucumber fishery is a hand-harvest fishery, with animals caught principally by diving and a smaller amount (<5%) by wading. The fishery is permitted to operate throughout WA coastal waters, with the exception of several permanently closed areas. Fishing to date has only occurred in the NCB.	Project area is within the fishery boundary. Due to the extent of this fishery it is unlikely that the Project would impact this fishery.
North Coast Crab Fishery	Blue swimmer crabs are targeted by the Pilbara Developing Crab Fishery within inshore waters around Nickol Bay using hourglass traps. Mud crabs are also targeted in the area between Broome and Cambridge Gulf (Guaghan and Santoro 2020).	The Project area falls outside of the area targeted for fishing (Nickol Bay) and therefore is unlikely to impact this fishery.
Mackerel Fishery	The fishery extends from the West Coast Bioregion to the WA/NT border, with most effort and catches recorded north of Geraldton, especially from the Kimberley and Pilbara coasts of the NCB (DoF 2013).	The Project area falls within Area 2 (Pilbara) for this fishery. Due to the extent of this fishery it is unlikely that the Project would impact this fishery.
North Coast Prawn Fishery including Onslow Prawn Managed Fishery (OPMF)	The north coast prawn fishery operates as four separate fisheries; Kimberley, Broome, Nickol Bay and Onslow. The Onslow Prawn Managed Fishery (OPMF) encompasses the WA coastal waters between the EGPMF and the Nickol Bay prawn fishery out to the 200 m depth isopleth (DoF 2013). The fishery is divided into three parts with associated 'size management fish grounds' (SMFGs).	The jetty and bitterns discharge point are located just outside the southern boundary of the OPMF. The offshore transhipment locations are located within Area 1. Potential impacts to this fishery are discussed in Section 7.

6.7.1 Exmouth Gulf Prawn Managed Fishery (EGPMF)

The Project area is adjacent to the northern section of the EGPMF, with Urala Creek South (the proposed intake location) located within the dedicated nursery area for the EGPMF; this area is closed to all trawling activities.

The EGPMF ranks with the Shark Bay fishery as one of the two most important prawn fisheries in Western Australia. Like all commercial fisheries, the EGPMF operates under a management plan, Exmouth Gulf Prawn Managed Fishery Harvest Strategy 2014–2019 (DoF 2014) and received Marine Stewardship Council (MSC) certification in October 2015 (Gaughan and Santro 2020). The fishery has a long-term catch rate varying between 721 and 1420 tonnes (t) per annum. The primary species are brown tiger prawns (*Penaeus esculentus*), western king prawns (*P. latisulcatus*) and blue endeavour prawns (*Metapenaeus endeavouri*).

In 2018, the last year for which reports are available, the fishery caught a total of 880 t, including 392 t of brown king prawns, 174 t of western king prawn and 313 t of blue endeavour prawns (Gaughan and Santro 2020). There are also a variety of minor bycatch species that include smaller prawns, blue swimmer crabs, squid, cuttlefish, bugs and octopus (Kangas et al. 2019).

Tiger prawns are generally associated with seagrass beds and western king prawns prefer sand substrates; therefore, it is generally considered that endeavour prawns are the species most likely to be recorded in the creeks. However, during the 2019 surveys juveniles of all three of the primary species, and also juvenile banana prawns (*Penaeus merguiensis*), were found within Urala Creek South. The latter species is occasionally caught in commercial quantities within Exmouth Gulf and tends to be most abundant following large rainfall events (N Loneragan *pers. comm*. 2018).

It is understood that prawn species spawn in deeper offshore waters and move closer to the inshore environment during the larval and post-larval stages. They enter estuarine areas towards the late post-larval stage and juvenile stage before returning to sandy bottom offshore environments when adults. Juvenile prawns exhibit diurnal behaviour, with most species becoming more active at night, when they are less visible to predators. Tidal conditions also impact behaviours, with juvenile prawns moving into the water column during a flood tide and sinking to the bottom on an ebb tide.

The EGPMF operates under a tight series of controls to maximise fishery returns, maintain breeding stocks and minimise environmental impact. The controls include the fishery being limited to 15 boats, with limits on vessel size, types and sizes of fishing gear, bycatch reduction devices and turtle exclusion devices, and seasonal and spatial closures, which may be seasonal, lunar or dependent on stock availability (DoF 2014).

Several aspects of Exmouth Gulf Prawn Managed Fishery Harvest Strategy 2014–2019 (DoF 2014) are directly relevant to the Project. All the waters adjoining the proposed Project site are included in the fishery. Foremost among these is a permanently closed nursery area along the eastern and southern areas of Exmouth Gulf (Figure 18) where extensive seagrass beds occur. The Project area is alongside the northern portion of the nursery closure with Urala Creek South (where the seawater intake is situated) located within the nursery area. Urala Creek North is located outside of the nursery area.

The EGPMF has a fixed seasonal closure from November to April. Trawling is monitored through the fishing season to ensure stock levels are protected and the fishery operates efficiently. Sections of the various areas are opened and closed to ensure these goals are met. There are also short-term closures, such as four nights during each full moon period.

Kangas et al. (2006) provides an overview of the life history of each of the prawn species. In all species males inseminate the females when the females are in the soft-shell stage, having just moulted. To spawn, females release the eggs near the bottom. The eggs then float to the surface and hatch. A complex set of moults, through various life stages, occurs over varying periods of up to several weeks during which the larvae progress to the settlement stage. The eastern shallows are the primary nursery area in Exmouth Gulf. Young prawns continue to develop and grow in the nursery area for several months before migrating into the sandy bottoms of the central gulf where the fishery is concentrated. There are differences in the breeding cycles of the four major species.

In 2018, a number of protected species interactions were recorded during the EGPMF fishing season, these comprise: turtles (n=20); sea snakes (n=1248), syngnathids (n=4) and sawfish (n=9).

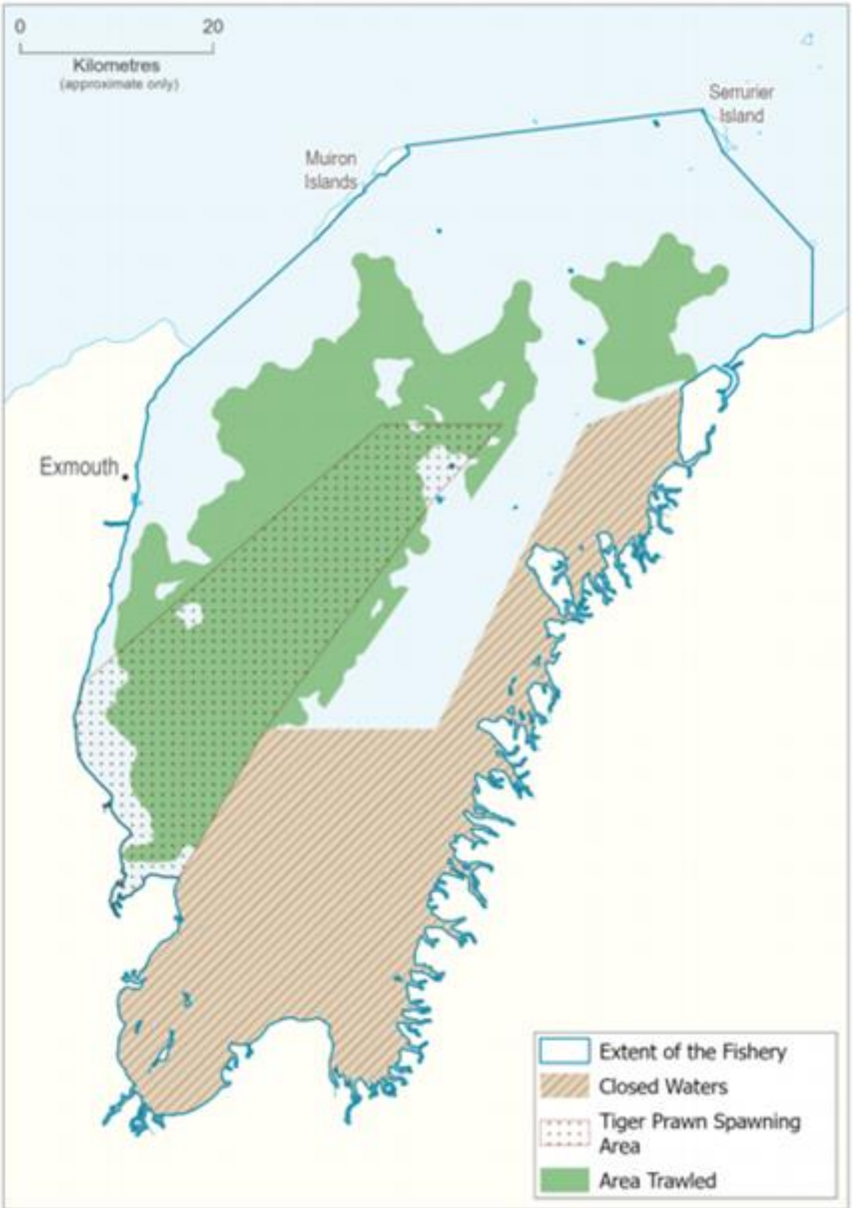

Figure 18 Exmouth Gulf Prawn Managed Fishery (Source: Guaghan and Santoro 2021)

6.7.2 Onslow Prawn Managed Fishery (OPMF)

The OPMF occurs to the immediate north of the project area, along the coast to Dampier and offshore approximately 150 km (Figure 19).

The OPMF targets western king prawns, brown tiger prawns and endeavour prawns (*Metapenaeus* spp.). Since 2012, very low effort has been expended in the OPMF as a result of disruption to fishing activities and area access due to resource developments in the region, with effort levels in the five years prior to 2012 being between 60 and 260 boat days (WAFIC 2018; FRDC 2018). The total landings in 2017 were negligible, only five days of fishing effort was undertaken (one boat) in 2017 (Kangas et al. 2019).

The total landings in 2019 were less than 50 t, below the target catch range. Twenty eight days of fishing effort (308 hours) was undertaken by one boat in 2019 (Gaughan & Santoro, 2021). Due to the general low trawl effort that has been undertaken in recent years, and the extent of the fishery, it is unlikely that the Project will have a detectable impact on this fishery.

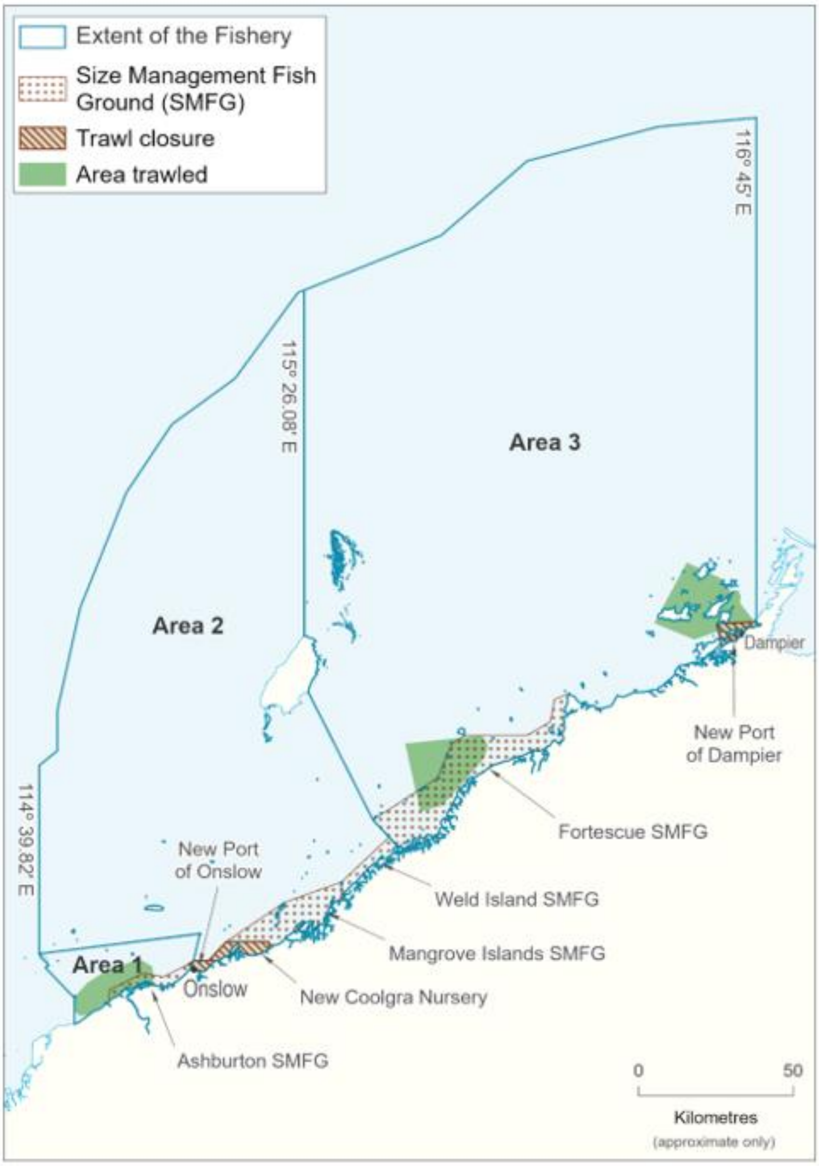

Figure 19 Onslow Gulf Prawn Managed Fishery (Source: Guaghan and Santoro 2021)

6.7.3 Western Australian Sea Cucumber Fishery

This fishery encompasses Western Australia's coastal waters (out to three nautical miles) and targets two species of sea cucumbers, sandfish (*Holothuria scabra*) and redfish (*Actinopyga echinites*), the latter being a more deepwater species. Sea cucumbers are widely distributed on soft sediments throughout shallow waters of the Indo-Pacific region. In tropical Western Australia, sandfish and redfish occur primarily within low energy environments behind fringing reefs or within protected bays (DPIRD 2018).

This fishery is primarily a "pulse" fishing operation, whereby extremely remote areas of the Kimberley where sea cucumbers occur in commercial densities are generally accessed two or three times a year for approximately two to three weeks per fishing trip (DPIRD 2018). Other areas are targeted less frequently. Redfish stocks have typically been fished in the Pilbara only for a period of two months every third year (DPIRD 2018).

Due to the extensive footprint of this fishery and the lack of suitable fringing reef habitat, it is unlikely that the Project would impact this fishery and therefore this fishery is not discussed further.

6.7.4 Western Australian Pearl Oyster Managed Fishery

The Western Australian Pearl Oyster Managed Fishery targets the silver-lipped pearl oyster (*Pinctada maxima*) and is a quota-based dive fishery (Hart et al. 2019). The fishery is currently managed under the *Pearling Act 1990* and uses output controls in the form of a total allowable catch divided up into individually transferable quotas. Fishing for *P. maxima* is one component of the pearling industry's activities, along with seeding and grow-out of pearl oysters to produce pearls. This fishery has been accredited for export under the EPBC Act for a period of ten years (reassessment in 2025) and was certified under the MSC certification process in 2017 (Hart et al. 2019).

The Project area falls within Zone1 of this fishery (Figure 20), however no fishing was conducted in this zone in 2017 and 2018, with only a small number (4,594) of culture shells taken in 2016 (Hart et al. 2019). The stock assessment undertaken in 2019 indicated that there is currently a low risk to pearl oysters in this zone as a result of low fishing levels.

Due to the low fishing effort in Zone 1 of this fishery area in recent years, and the small Project footprint relative to the size of the fishery, it is not anticipated that this fishery will be impacted as a result of the Project and therefore this fishery is not discussed further.

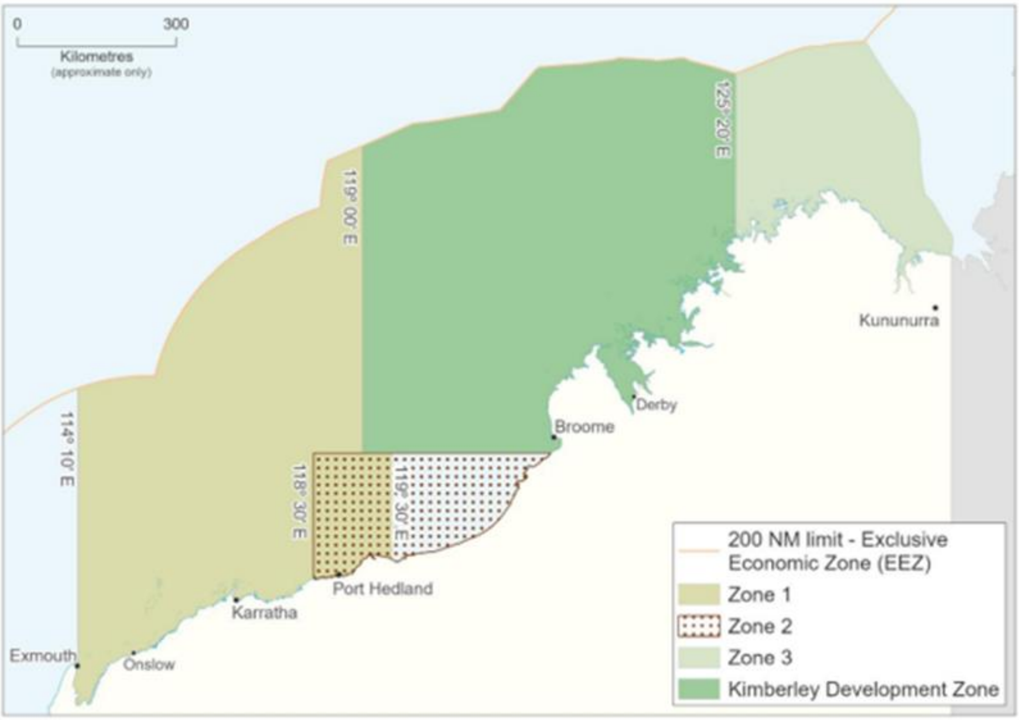

Figure 20 Western Australian Pearl Oyster Managed Fishery (Source: Guaghan and Santoro 2021)

6.7.5 Mackerel Managed Fishery

The Mackerel Managed Fishery (MMF) extends from the Western Australia and Northern Territory border to Augusta in Western Australia's south-west (Figure 21). The fishery is managed as three areas with the Project falling within Area 2 (Pilbara). This commercial fishery uses near-surface trolling gear from vessels in coastal areas around reefs, shoals and headlands, to target Spanish mackerel (*Scomberomorus commerson*). Jig fishing is also used to capture grey mackerel (*S. semifasciatus*), with other species from the genera *Scomberomorus, Grammatorcynus* and *Acanthocybium* also contributing to commercial catches (DoF 2013). Recreational fishers also target similar species with most effort occurring between Perth and Dampier.

There are currently 21 licences in Area 2, with three operating vessels (Lewis 2020).

Due to the extent of this fishery and the relatively small Project footprint, it is unlikely that the Project will impact this fishery and therefore this fishery is not discussed further.

Figure 21 Mackerel Managed Fishery (Source: Guaghan and Santoro 2021)

7.0 Impact Assessment

7.1 Assessment of Potential Impacts

The following potential direct and indirect impacts on significant marine fauna during construction and operations were identified and assessed:

- Habitat Loss.
- Bitterns Discharge.
- Dredging.
- Underwater sound.
- Anthropogenic light spill.
- Entrainment and entrapment due to the seawater intakes.
- Vessel collisions with marine fauna.
- Altered nutrient inputs in relation to productivity of marine ecosystems.
- Accidental release of hydrocarbons.
- Introduced marine pests (IMP)
- Cumulative impacts

A critical component of the impact assessment is identifying appropriate mitigation and management measures to minimise Project related impacts on marine fauna (including direct and indirect impacts) during construction and operation. Trigger levels and adaptive management responses have been identified where necessary. Areas are highlighted where mitigation and management measures to reduce the risk of residual impacts to marine fauna can be implemented during the design, construction and operational stages of the Project.

7.2 Assessment of Habitat Loss

A detailed assessment of habitat loss and mitigation measures has been included in the BCH assessment report (AECOM 2021a). The Project will result in the direct disturbance of approximately 76.75 ha of intertidal and 226.39 ha of nearshore BCH.. Direct removal of benthic habitats is required for construction of the jetty and berthing pocket, as well as the seawater intake and pumping station. Additional indirect loss of BCH is expected due to dredging plumes and ongoing bitterns discharge associated with the Project.

A summary of potential marine fauna habitat loss including proportional loss within Local Assessment Units (LAUs) and regionally within Exmouth Gulf is detailed in Table 9. This table represents the irreversible loss occurring from cumulative pressures associated with the Ashburton Salt Project. Based on the BCH assessment, it is considered likely that the disturbance of intertidal and nearshore habitat would have negligible potential to significantly impact upon any protected marine fauna populations that may inhabit the area.

Within the transhipment area (offshore), suitable anchorage areas will be designated in sandy areas to ensure sufficient anchor holding capacity. These areas will be identified through a combination of bathymetric and side scan sonar survey. Once target locations have been selected, video footage of the seabed will be taken at each location to confirm substrate is sand, with sparse to nil benthic habitat present. Final site selection will be done in consultation with Pilbara Ports Authority (PPA). Selection of transhipment points and management of transhipment operations will be covered within the VMP. K+S is confident of achieving no loss of benthic communities and habitats in the anchorage area.

Table 11 Predicted areas of habitat loss

Marine Fauna Habitat	Project Cumulative Loss (ha)	Proportion of Local Habitat (LAU)	Proportion of Sub-regional Habitat	Associated Protected Marine Fauna
Mangroves	4.28	0.2%	0.04	Mangrove loss identified within the BCH assessment. (AECOM 2021a). Important to juvenile green turtles.
Soft sediment (nearshore)	219.3	4.7%	<0.1%	Subtidal habitat loss identified within the BCH assessment. Potentially contains foraging habitat for turtles, dugong and sawfish (AECOM 2021a). Also prawn nursery habitat given its nearshore mix of soft sediment and reef.
Sandy beach	0.99	0.78%	0.10%	The area of loss comprises the area of beach where the jetty will be constructed (AECOM 2021a) and is considered low quality turtle nesting habitat.
Offshore waters	0	0	0%	Offshore waters are important to humpback whales and dolphins. Offshore waters are used as a transit done for turtles and dugongs.

7.2.1 Potential impacts of Habitat Loss

7.2.1.1 Mangrove habitat

Typical mangrove habitat has moderately high invertebrate fauna biodiversity and high primary productivity. A wide variety of invertebrates inhabit mangroves, dominated by molluscs, crustaceans, and polychaetes. Protected marine fauna such as green sawfish, humpback dolphin, and green turtles are known to utilise mangrove and intertidal habitats (e.g. Papastamatiou et al., 2015; Whitty et al., 2017; May et al., 2019, Parra and Jedensjö 2013).

Juvenile and sub-adult green turtles, as well green sawfish were recorded in both Urala Creek North and South during field surveys conducted for the Project. The presence of juvenile and sub-adult turtles within Urala Creek suggest the system is used as an important food source and nursery for the species. Similarly, Urala Creek North and South represent critical habitat for green sawfish as pupping/nursing environment. Some studies have suggested that there is a strong association between mangrove health and intactness, and the abundance of sawfish species (Dulvy et al 2016). Therefore, mangrove habitat within the Project area is of high conservation value.

The BCH assessments and associated modelling studies undertaken for this Project demonstrate a combined loss of 4.28 ha of mangrove habitat. All efforts have been made during Project design to maintain maximum mangrove biomass which would be of importance to marine fauna. While 4.28 ha will be lost, this represents less than 1% of this community and will not significantly impact the integrity of the habitat in terms of contributions to local and regional ecological function and connectivity.

7.2.1.2 Nearshore Habitat

Nearshore habitat that supports benthic communities such as seagrass, coral and macroalgae provide important feeding habitat for protected marine fauna. Seagrasses, along with macroalgae, are considered key food habitats for dugongs and green turtles, as well as providing critical nursery habitats for juvenile fish and many macroinvertebrates, including commercially valuable prawn species (Coles et al.1993). Prawn post-larvae settle into shallow seagrass areas which provide shelter and food sources such as epiphytic algae and detritus. Ecologically, macroalgae perform a similar role to seagrasses and they are important contributors to primary productivity. Following observations of minimal seagrass biomass in Exmouth Gulf, McCook (1995) suggested macroalgae are also an important secondary food source for dugongs. The removal of nearshore BCH would have the potential to affect the survival, fitness, distribution and feeding habitats of these key marine species.

The Project area is located within the critical habitat for flatback, hawksbill and green turtles (DoEE 2017a), as well as within the BIA for the pygmy blue whale, humpback whale and wedge-tailed shearwater. Additionally, the nearshore habitat within proximity to Urala Creek North and South is likely to be important foraging and migratory habitat for juvenile and sub-adult sawfish, giant guitar fish and green turtles. Disturbance to 226.39 ha of nearshore habitat is expected as a result of the combined effects of dredging, bitterns discharge, shading and shipping movements throughout the Project. All effort has been made during the planning phase of the Project to ensure minimal disturbance to nearshore BCH (as outlined in BCH report). Bare substrate has been targeted to ensure that high value nearshore habitat (such as high coral/seagrass cover) has been avoided where possible.

As a result, the total cumulative habitat loss for the Project is considered negligible when compared to the availability of similar habitat in the surrounding areas (less than 1% of available habitat), which will be easily accessible to highly mobile marine fauna species. Therefore, is it unlikely that habitat loss resulting from construction and operation of the Project will impact the biological diversity and ecological integrity of marine fauna populations and their habitats.

7.2.1.3 Sandy beach

Sandy beaches occur along the western and northern shorelines of Tubridgi Point and extended east along the coast from Urala Creek North, including the Locker Point area and the proposed location of the export jetty. The coastal area north of the Project site is included within the critical habitat for flatback, hawksbill and green turtles. However, snapshot turtle surveys conducted in 2018 and 2019 indicated that the mainland coastal area between Urala Creek North and Ashburton River supported low density nesting, with only three flatback turtle nests recorded.

The proposed disturbance of this beach is limited to a narrow section (less than 50 m) to install the trestle jetty structure, resulting in a disturbance 0.99 ha. The potential nesting habitat recorded within proximity to the jetty and conveyor location, typically comprised a shallow limestone rock platform in the nearshore area and exposed areas of rock platform with large broken slabs evident in the intertidal area. As a result, this environment is considered low quality potential nesting habitat.

Given the poor nesting quality of the impacted beach, the low recorded nesting and extensive availability of suitable nesting habitat within the region, the direct impacts of 0.99 ha sandy beach are not expected to be significant to local marine turtle populations.

7.2.2 Predicted outcome

Cumulative habitat loss resulting from the Project is not expected to result in significant impacts to protected marine fauna. Where possible, design and planning processes, along with mitigation measures outlined in the BCH assessment, have reduced potential for impacts to the benthic communities to as low as practicable.

7.3 Assessment of and Management of Bitterns Discharge

7.3.1 Description of source impact

Bitterns is a hypersaline solution of concentrated seawater, formed as a waste product of solar salt operations. Approximately 70% of the sodium chloride is removed through the salt production process and therefore the bitterns waste product is rich in magnesium sulphate. Bitterns solutions generally have a salinity of around 300 PSU and a density of 1,250 kg/m^3. They are markedly denser than local seawater, which in the area has natural range of 35.0 to 53.5 PSU and a corresponding range in density of 1,027 to 1,041 kg/m^3. Being denser than the receiving seawater (negatively buoyant), the bitterns discharge will behave in a similar manner to the wastewater discharge from a desalination plant. The bitterns are, however, significantly more saline and denser than the wastewater from a desalination plant which, typically, may have a salinity of around 70 PSU and a density of 1,050 kg/m^3.

The key impact that bitterns can have on biota within the receiving environment is physio-chemical stress due to the high salinity which has osmotic effects on the cells of living organisms. The salinity component of bitterns is classified as a physical chemical stressor.

Given no additives are introduced during the solar salt production process, the only toxicants that exist in the bitterns wastewater are naturally occurring elements of seawater (specifically metals) which have been concentrated by the solar evaporation process. Metal toxicity or metal poisoning is the toxic or poisonous effect of certain metals in certain forms and doses on living organisms. Metals can bioaccumulate in the marine environment, contributing to their potential toxicity.

The Ashburton Salt Project will produce bitterns, which is proposed to be discharged from a specially designed and optimised diffuser located along the outer end of the proposed export jetty.

7.3.1.1 Bitterns Ecotoxicology Assessment

A bitterns ecotoxicology assessment was undertaken by AECOM (2021b) to inform the bitterns discharge modelling for the project. This assessment is included as Appendix G**.** In summary the ecotoxicology assessment found that the only "toxicants" within the bitterns waste stream are naturally occurring metals within seawater. The solar salt evaporation process does not lead to chemical reactions that produce substances that do not commonly occur in seawater because it is essentially an evaporation and crystallisation process for removal of sodium chloride and no additives are used in the process. This process leaves behind only naturally occurring elements within the bitterns (predominantly magnesium sulphate). Once the metals within the bitterns plume are diluted such that they meet the 99% or 95% species protection level assigned in ANZG (2018), at the boundary of an appropriate Level of Environmental Protection "mixing zone" around the discharge point, they will present a very low risk of toxicity or bioaccumulation in the marine environment (AECOM, 2021b).

The distances from the bitterns discharge diffuser at which these dilutions are predicted to be met have been modelled by Water Technology (2021a). Further assessment was undertaken to compare the characteristics of bitterns likely to be produced by the Ashburton Salt Project with that of Onslow Salt. AECOM (2022) (included in Appendix G) found the bitterns from the two operations to be sufficiently comparable, such that the whole of effluent test (WET) assessment undertaken by O2 Marine (2019) provides a suitable set of species protection limits by which the impacts of the bitters may be assessed. These species protection limits were applied to modelling (Water Technology 2022) to determine zones for Low and Moderate Environmental Protection.

7.3.2 Assessment of potential impacts

To understand the potential extent of the mixing zone, Water Technology undertook bitterns dilution modelling (Water Technology 2021a). An assessment of potential zones of impact from the discharge of bitterns into the marine environment has been included in the BCH assessment report (AECOM 2021a).

The potential impact to BCH as a result of the bitterns discharge is localised to a small area that comprises a predominately soft-sediment habitat (with potential occasional seagrass cover) and is not anticipated to impinge upon the macroalgal and coral communities fringing the shoreline at the base of the jetty (AECOM 2021a).

Additionally, due to the highly mobile nature of marine fauna, it is considered unlikely that discharged bitterns will have the potential to significantly impact upon them; they will likely move away from any areas in which water quality is adverse, prior to any impacts occurring.

7.3.3 Mitigation measures

There are several aspects of Project design that inherently mitigate the risks of impacts to BCH from bitterns release:

- Prior to discharge, the bitterns flowing out of the crystalliser ponds will flow into a bitterns dilution pond. Seawater will be pumped into the bitterns dilution pond to dilute the bitterns to approximately a 1:1 ratio. The dilution pond will cover an area of approximately 70 ha and is designed to reduce the salinity of the bitterns before discharge to assist in achieving the required environmental quality criteria as well as improve the operational ability to manage the bitterns.
- Throughout the salt production process, no chemicals will be added at any stage of the process.
- The bitterns outfall point will be at the end of the jetty to take advantage of deeper water and greater tidal movement facilitate mixing upon discharge.

- Bitterns will be discharged through an upward facing diffuser which will force the bitterns to the surface, thereby facilitating enhanced mixing and diffusion with faster moving surface waters.
- The diffuser will be positioned such that the mixing zone is in an area of existing high disturbance such as the jetty berthing area and away from sensitive benthic habitats.

A Bitterns Discharge Environmental Monitoring and Management Plan (BDEMMP) will be developed and implemented to mitigate the risk of impacts from bitterns discharge on the receiving environment. The plan will be in line with EPA guidance (EPA 2016d) and will stipulate all aspects of monitoring including, but not limited to, delineation of a mixing zone, monitoring parameters and locations, monitoring frequencies and methods, management triggers, and management responses to trigger exceedances.

7.3.4 Predicted outcome

Adopting a conservative approach, it is assumed that the seabed habitat within the Low Environmental Protection Area (LEPA) will be unsuitable habitat for seagrasses, and any associated benthic communities (e.g. invertebrates), over the duration of bitterns discharge (due to salinity and temperature effects). As the bitterns discharge will continue for longer than five years, the LEPA is considered to represent an area of 'loss' of soft sediment (potential seagrass habitat). The predicted area of indirect loss of 'soft sediment' habitat within the LEPA is 219.3 ha (AECOM, 2021a). This habitat is unlikely to support seagrasses over the duration of Project operation and had been included in Section 7.2 as habitat loss.

Overall, given the very low proportion of 'soft sediment' habitat within the Nearshore LAU that is predicted to be affected of 219.3 ha or 4.7% of the area of this habitat within the Nearshore LAU (AECOM, 2021a), it is considered that there is no credible risk of the bitterns discharge having a significant regional impact to seagrasses, to other benthic communities that may be associated with them (e.g. invertebrates), or to ecosystem function (AECOM 2021a).

The risk to Marine Fauna from the bitterns discharge is also considered low given the low risk to BCH and the low risk of toxicity or bioaccumulation of metals (as described in Appendix G).

7.4 Assessment and Management of Dredging Activities

7.4.1 Description of sources of impacts

During the construction phase of the Project the dredging of the berth pocket has been assessed for direct and indirect potential impacts on marine fauna. These have been addressed in the following sections:

- Sediment dispersion and deposition – BCH report (AECOM 2021a) and below.
- Loss of feeding resources or refuge – BCH report (AECOM 2021a) and below.
- Underwater sound – Section 7.4.
- Vessel collision with protected marine species – Section 7.8.
- Accidental release of hydrocarbons – Section 7.9.

Dredging of a berth pocket at the end of the jetty is required to allow the loaded transhipment vessel adequate water depth to remain within the berth pocket without tidal restriction. The berth pocket is required to be of sufficient depth, length and width to allow a loaded vessel sufficient under keel clearance to be able to navigate out of the berth pocket. The dredged area will be approximately 200 m long by 35 m wide by 2.5 m deep (at low tide). Total dredge volume is estimated to be 17,000 m^3 and may be dredged by either a backhoe dredge or a cutter suction dredge. It is anticipated that maintenance dredging will also be required during the operational phase of the Project. The dredged material will be disposed of on land (Figure 1 and Figure 2).

Seabed disturbance through dredging can result in increased turbidity and creation of sediment plumes. Sediment plumes have the ability to extend the impact of dredging over larger areas than would otherwise remain unaffected physically.

7.4.2 Sediment dispersion and deposition modelling

Modelling by Water Technology (2021a) of turbid plume dispersion from dredging has been used to assess the potential for impacts upon benthic communities, which may be of importance to marine fauna. The outputs from this modelling are described in the BCH report (AECOM 2021a) and summarised below.

Within AECOM (2021), the Zone of Influence (ZoI) has been defined as the areas in which, at some time during the dredging works, benthic communities may experience (detectable) changes in sediment-related environmental quality outside the natural ranges that are normally expected. However, the intensity, duration and frequency of these changes are such that any damage to benthic habitats is likely to be reversible, and no mortality of benthic biota is expected to occur. The outer boundary of this zone was defined by Water Technology (2021a) to be where TSS was predicted to no longer exceed 2 mg/L.

If dredging was to take place in summer, the ZoI is predicted to extend some 4 km eastwards from the dredging footprint, not encroaching upon the nearshore, coastline or creek systems. If dredging was to take place in winter, the ZoI is predicted to extend some 3 km westwards from the dredging footprint, though not encroaching upon the macroalgae and coral habitats offshore from Locker Point or the creek systems. In combination with the ZoI associated with the tailwater discharge, though, the ZoI is predicted to extend across macroalgae and sparse coral habitats up to approximately 0.5 km either side of the base of the jetty.

7.4.3 Assessment of potential impacts

The modification of subtidal habitats within the footprint of the dredging works may have an indirect impact on marine fauna due to the change in habitat or the loss of feeding resources or refuge, with the potential for temporary or permanent displacement of species.

GHD, 2021 found that the surface material to be dredged is primarily comprised of unconsolidated clayey silt (approximately 0.4–0.7 m thick). Similarly, the Geo Oceans (2020) survey found unconsolidated sediment, consisting of predominantly sand and silt and supporting no epibenthic faunal communities, as the dominant habitat type within the survey area (96% of the area surveyed). This habitat is typical of the Pilbara region where a combination of unconsolidated sediment in shallow depths and high energy water movement impede the establishment of epibenthic faunal communities.

Dredging will generate plumes of turbid water containing elevated levels of suspended sediments and discharged tailwater will also contain some suspended sediments. Suspended sediments, and sedimentation, have the potential to significantly impact upon marine fauna through multiple pathways; these include the reduction of light levels by increased turbidity; the clogging of fauna feeding and respiratory structures by sediments; and the mobilisation of nutrients and/or contaminants in dredged sediments. These plumes of suspended sediments could impact upon marine fauna through a reduction in light penetration through the water column impairing visibility during foraging, and potentially leading to reduced growth or to mortality of light-dependent benthic habitats on which they feed on.

Potential impacts on marine fauna from the dredging activities have been summarised in Table 12.

Table 12 Potential impacts on marine fauna from dredging activities

Loss of Feeding Resources or Refuge	Sediment Dispersion and Deposition	Interaction with the Dredge
Elasmobranchs		
Sandy sediments have been previously shown to be important foraging grounds for several sawfish species (e.g. Papastamatiou et al. 2015; Whitty et al. 2017; May et al. 2019). However, it is considered that the area of direct habitat loss from	The ZoI is predicted to reach nearshore waters only if dredging and tailwater discharge occur in winter. The ZoI is not predicted to reach creek systems. Little is known about the sensory systems of green sawfish specifically, although preliminary work suggests they have lower numbers of	Elasmobranchs forage in shallow nearshore environments, that are often quite turbid and therefore have the potential to interact with the dredge head. However, this is deemed unlikely to occur as the noise generated by the dredge is likely to deter elasmobranchs away from the dredge head. Other dredging implementation measures,

Loss of Feeding Resources or Refuge	Sediment Dispersion and Deposition	Interaction with the Dredge
dredging will not have a measurable detrimental effect on sawfish, or other elasmobranchs, as similar habitat is widely distributed across the broader region.	electrosensory pores compared to freshwater and dwarf sawfish (Wueringer et al. 2011), which together with their relatively large eyes may indicate that they rely more on visual cues than other sawfish species, and therefore would fare better in less turbid water. However, the water in the Ashburton River mouth can be very turbid at times and it still supports the highest catch rates of green sawfish found in the world (Morgan et al., 2015), ranges from clear to relatively turbid. Therefore, sawfish present in nearshore waters potentially exposed to increased turbidity levels as a result of the Project will unlikely be affected as a result of the Project.	such as soft starts, will assist in deterring elasmobranchs.
Marine mammals		
Dugongs have been observed foraging on seagrass beds in the nearshore area to the south-west of Urala Creek South. As assessed within AECOM (2021), it is considered that there is no credible risk of 'loss' of seagrass habitat (outside of the berth pocket) due to dredging activities. It is therefore unlikely that dugongs will be impacted, as any loss in foraging habitat (if present) will be limited to the dredging footprint.	Marine mammals often inhabit turbid environments, and many utilise sophisticated sonar systems to sense the environment around them. Evidence that turbidity affects cetaceans or sirenians directly is not evident in the literature, and feeding methods employed by some baleen whales (e.g. grey whales), and by sirenians, create plumes of sediment, indicating that individuals must have some level of tolerance and are able to feed in turbid conditions. Natural events, such as sediment resuspension due to wind and waves, also increase turbidity. Given the naturally turbid conditions of the area and localised extent of the potential plume (ZoI of ~4 km), an impact on marine mammals in the area is unlikely.	Due to the highly mobile nature of marine mammals and with the implementation of pre-start (such as soft starts) and marine fauna observation procedures it is unlikely that marine mammals will interact with the dredge as they will likely be deterred by the noise generated by dredging operations.

Loss of Feeding Resources or Refuge	Sediment Dispersion and Deposition	Interaction with the Dredge
Marine reptiles		
As assessed within AECOM (2021) it is considered that there is no credible risk of 'loss' of seagrass habitat (outside of the berth pocket) due to dredging activities. It is therefore unlikely that marine turtles will be impacted, as any loss in foraging habitat (if present) will be limited to the dredging footprint.	Given the naturally turbid conditions of the area and localised extent of the potential plume (ZoI of ~4 km), an impact on marine reptiles in the area is unlikely.	Marine turtles are known to forage in shallow nearshore environments and therefore have the potential to interact with the dredge head. However, this is deemed unlikely to occur as the noise generated by the dredge is likely to deter marine turtles away from the dredge head..
Commercial species		
The removal of unconsolidated sandy substrates within the dredging footprint may potentially remove species directly. Western king prawns (*P. latisulcatus*) are the species most likely to be found within sandy substrates during larval and post-larval stages. However due to the size of the dredging footprint, a significant impact on the species population in the area is unlikely.	Prawns are benthic dwellers and generally have a high tolerance to turbidity in excess of 100 mg/L (Preston et al., 2005). Turbidity impacts on water quality during dredging operations will occur temporarily but are considered unlikely to significantly affect fisheries in the area. The fisheries in the area are based on mobile species that are periodically exposed to natural extreme turbidity events due to catchment run-off and resuspension due to wind and waves.	Mortality of small numbers of individual prawns may occur during the dredging program due to direct contact with the dredge, however these mortalities are likely to be insignificant in the context of regional prawn populations.

During the operational phase, whilst maintenance dredging will take place periodically, the dredging locations will be as initially undertaken in the construction phase, so no new or additional direct habitat loss will take place.

7.4.3.1 Sediment ecotoxicology assessment

A sediment geochemical assessment was undertaken by GHD (2021) to inform the dredging impact assessment. In summary sediment sampling did not detect any toxicants for which the 95% Upper Confidence Limit (UCL) concentrations exceeded the ANZG (2018) sediment Default Guideline Values (DGVs). In addition it is proposed that dredge spoil will be disposed of on land (not to the marine environment). Therefore, there is no indication that any further assessments of ecotoxicology or bioaccumulation are warranted for dredged sediment as it is considered of low ecotoxicology risk (AECOM 2021b).

7.4.4 Mitigation measures

There are several factors that inherently mitigate the risks of impacts to BCH and marine fauna from dredging and tailwater release:

- The area and volume of sediment to be dredged is limited (0.7 ha and 17,000 m^3).
- There is no requirement for disposal of dredged material at sea or to be used for coastal land reclamation.

- The dredging methodology (probably small cutter suction dredge) typically results in only very localised areas of elevated turbidity.
- Modelling predicts that plumes of elevated turbidity will not persist for more than a week following cessation of the dredging activity.

In addition to these factors, further mitigation measures will be included within a Dredging and Dredge Spoil Management Plan (DDSMP) developed prior to any dredging taking place. The DDSMP will identify:

- Monitoring to be undertaken for the duration of dredging and during ocean disposal of tailwater from the dewatering pond.
- Specific management measures to be implemented based on trigger levels and results of monitoring.

The management measures to be implemented through the DDSMP will be dependent on the dredging method to be employed and may include:

- Timing dredging to coincide with favourable tidal conditions.
- Reducing the cutter head speed (CSD) or bucket lift speed (if a BHD is used).
- Increasing pump speeds.
- Temporarily suspending dredging.
- Increasing tailwater residence time within the onshore dredged material dewatering pond. Turbidity levels within the pond will be monitored and tailwater will only be released when the level is below a defined trigger level. The latter will be determined on the basis of measured turbidity levels at nearshore reference locations established prior to the commencement of dredging.

To minimise the risk of marine fauna interaction with either the dredge and / or dredge head the following controls will be implemented as part of the DDSMP:

- Establishment of marine fauna safety zones (350 m observation and 170 m exclusion zone within the DDSMP. The dimensions of these zones are derived from underwater noise modelling, as described in Section 7.5.
- If applicable to the type of dredge that is engaged, turtle Exclusion Devices will be used. The type of exclusion device utilised will be similar to that used throughout Western Australia.
- From ten minutes prior to the commencement of any dredging activities, a dedicated Marine Fauna Observer (MFO) will monitor the safety zones to check for the presence of any protected marine species. If any protected species are observed within the observation zone, dredging activities will not commence until they are observed to have left the observation zone, or until ten minutes have elapsed since the last sighting, and no other protected species have entered the zone during this period.
- On each occasion that a dredge has been non-operational for a period exceeding 30 minutes, a visual assessment will be undertaken of the observation and exclusion zones by the MFO for a period of ten minutes. Dredging will not recommence until no protected marine species have been sighted within the observation zone for a period of ten minutes.
- Once dredging has commenced, the MFO will maintain ongoing visual scanning of the observation and exclusion zones for protected marine fauna and, every 30 minutes, will dedicate a period of five minutes for observation (from an elevated position) for protected marine fauna. Dredging activities will be temporarily suspended if an individual of a protected marine species encroaches within the pertinent exclusion zone. Dredging will not recommence until no protected marine species have been sighted within the observation zones for a period of ten minutes.
- Where possible, soft start procedures will be implemented to deter and bottom dwelling marine fauna away from the dredging activities.
- Dredging operations will be undertaken during daylight hours where practicable.

- Scheduling of dredging operations will take account of key ecological windows;
  - Sawfish pupping window (September – November).
  - Turtle mating, nesting and hatching window (October - February).
  - Southern migration of humpback whales (August-December)

Dredging will avoid the southern migration of Humpback Whales (August-December).It is anticipated that the development and implementation of the DDSMP, including the development of suitable trigger levels based on tolerance limits of sensitive marine habitats, and of management actions in the event of an exceedance of trigger levels, will effectively mitigate the risk of long-term impacts to the ecological function of the BCH in the Project area.

7.4.5 Predicted outcome

The proposed dredging is a relatively small dredging activity which is estimated to take two weeks to complete. It is considered that, as dredging will be planned to occur outside of key ecological windows, and with the mitigation measures detailed above and the implementation of a DDSMP, the Project is unlikely to have a significant impact on the biological diversity and/or ecological integrity of marine fauna populations in the region.

7.5 Assessment and Management of Underwater Sound

During the construction phase for the Project, the activities that generate underwater sound will include:

- vessel movements;
- dredging; and
- impact piling required for construction of the jetty.

The following sound generating activities are anticipated to occur during the operational phase of the Project:

- vessel movements:
- maintenance dredging; and
- jetty operations.

7.5.1 Background

7.5.1.1 Nature of underwater sound

Sound travels about four-and-a-half times faster in water than in air. The absorption of sound at frequencies where man-made sound generally has the most energy is much smaller in water than in air. As a result, sound is typically audible underwater over much greater distances than in air. Most sources of sound, including movement of large shipping vessels, generate acoustic energy over a broad range of frequencies.

Sound is usually characterised according to its continuous or impulsive character. Continuous sounds occur without pauses; examples include vessel sound, dredging and vibratory piling. Impulsive sounds are of short duration and can occur singularly, irregularly, or as part of a repeating pattern and includes sounds generated from impact piling. Impulsive signals typically sound like bangs and generally include a broad range of frequencies.

In shallow water, sound attenuates a lot faster than in the open ocean as the natural duct created between the surface and the seabed is very narrow, resulting in the acoustic pressure wave reflecting multiple times off the seabed and surface, with every reflection resulting in the pressure wave losing energy. Additionally, in very shallow water, low frequencies below a cut off frequency (determined by depth and the sound speed of the seabed) attenuate very quickly, thus not having any impact at distance from the source.

7.5.1.2 Ambient sound in the marine environment

The potential zone in which sound emissions from a source are detectable depends on the levels and types of ambient sound in the waters surrounding the sound source (McCauley et al. 1994). Underwater sound is generated by a variety of natural sources, including sounds associated with ocean surface waves generated by the wind acting on the sea surface, currents and rain, as well as human-made sources (Hildebrand 2005). Other natural sounds in the sea include echolocation and communication sounds generated by cetaceans and other marine life, and natural sources such as tectonic activity. Table 13 summarises some of the different types of natural sounds found in the marine environment (McCauley et al. 1994).

Table 13 Examples of natural sounds in the marine environment (Source: McCauley et al. 1994)

Sound source	Frequency range (kHz/Hz)	Sound Pressure Level (dB re 1 µPa^2)	Sound characteristics
Wind and waves	500 Hz –100 kHz	65 dB (Force 3*) 85 to 95 dB (Force 12*)	Greatest levels at higher wind speeds, sound is continuous on a scale of hours to days
Rain	Broad spectrum	0 dB (no rain) to 80 dB (heavy rainstorm)	Flat frequency spectra (white sound)
Earthquake events	5 – 15 Hz	200 to 240 dB (at 10 km from earthquake)	Short-term transitory events on a scale of minutes, sound levels may be high

*according to the Beaufort scale

The amplitude (or intensity) and frequency characteristics of the ambient sound environment are two factors that control how far away a given sound source can be detected (Morin et al. 2018). In general, sound is only detectable if it is within the audible hearing range of the receiver, and of a higher level than the ambient sound environment at similar frequencies.

7.5.1.3 Sound metrics

The intensity (or loudness) of sound is reported in decibels (dB). Decibels are a relative unit comparing the sound to a reference pressure. In underwater acoustics, the reference pressure is 1 microPascal (µPa), so the true unit of intensity for underwater sound is dB referenced to 1 µPa. In air, a reference pressure of 20 µPa is used. Thus, because they use different reference pressures, sound intensity given in dB in water is not the same as sound intensity given in dB in air. As decibels are a logarithmic scale, an apparent small increase, of 3 dB, is a doubling of the amplitude or intensity of the sound.

Sound Exposure Level (SEL) is a measure of the total sound energy, that takes into account both the received level and the duration of exposure. SEL is a useful metric since it allows sound exposures of different durations to be related to one another in terms of total acoustic energy. The units for SPL (regardless of the type) are dB re 1 µPa @ 1m and for SEL are dB re 1 µPa^2-s.

7.5.2 Potential Project generated noise source – vessel movements

Vessels generate broadband noise from a range of sources, principally their propellers, engines, gear boxes and shafts, auxiliary machinery, as well as flow noises from hulls and turbulence from wakes. Note that for the intended transhipment vessel, noise arising from shafts and gearboxes will be eliminated owing to the use of thrusters. Diesel engines produce more noise than gas turbines, but most persistent (generally the lower frequencies) noise is generated by the cavitation of propellers. Characteristic features of the principal sources and elements of vessel generated noise are as follow:

- **Propeller noise**: Originates from the propeller blade cavitation that forms gaseous voids, or ‘cavities’, whenever the pressure of the water accelerating over the face and any rough edges on each blade fall below a critical value. Intense broadband sound may be generated when the bubbles subsequently collapse. For any given propeller, cavitation noise is directly related to propeller speed of rotation, and hence vessel speed (the faster the propeller rotates, the more cavitation plus the larger the wake; in which further air bubble generation and collapse occur).

For vessels thrusters such as the transhipment vessel, cavitation noise can occur at both low and high speeds, with cavitation-free speeds often restricted to the 7-10 knot range. Propeller blades also generate distinct 'blade rate' tones that are proportional to the rotation rate of the propeller and the number of blades.

- **Flow noise**: While most collapsing bubble noise is generated by propeller cavitation; other bubble noises emanate from the passage of water over obstructions on the hull and within the wave wake produced by the vessel. Flow noise is sourced mainly from the external flow of water around the hull but also includes the noise of any fluids flowing through internal pipework systems that are acoustically coupled through the hull.

  External flow noise includes vibrations and rattles in the hull plating and fittings and other external structures, plus the noise of continuously breaking bow and stern waves and turbulence produced by protruding structures such as bilge keels and thruster bodies.

- **Machinery noise**: A range of mechanical vibrations are generated by the main motors and auxiliary machinery units and transmitted through the hull to the water, contributing to both broadband and narrowband noises.

A review of noise sources and acoustic characteristics from the types of vessels which will operate in the project area during its development, operational and maintenance stages is presented Figure 22 below.

Sound source levels and associated frequency characteristics of different vessel types, including trading ships, fishing vessels, selected specialist ships and small vessels, is summarised in Table 14 .

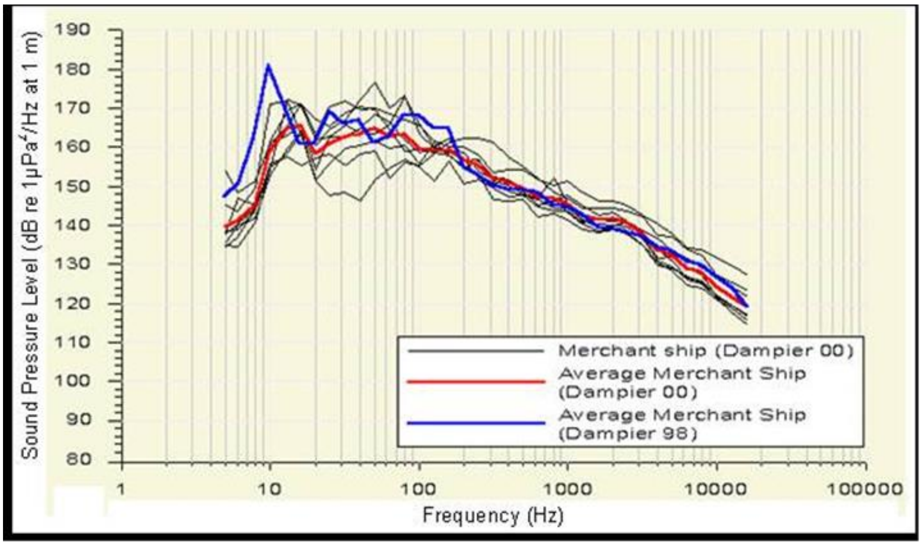

Figure 22 Merchant ship acoustic signatures measured off Dampier, WA (Hallett 2004)

Table 14 Comparison of sound levels from a range of vessel sources

Source	Peak Frequency or Band	Peak Source Level/s (re 1 µpa 1m)
Icebreaking ship (full power in ice)	10-1000 Hz	193 dB
Large tankers and bulk carrier blade and shaft rates* Container ship blade and shaft rates ** Large tanker and bulk carrier cavitation 64 m Rig supply tender* Tug towing barge cavitation noise*	10 30 Hz 7 33 Hz 1000–4000 Hz (*broadband*) 1000 5000 Hz	180-186 dB 181 dB Not sure 177 dB 145-171 dB

Source	Peak Frequency or Band	Peak Source Level/s (re 1 μpa 1m)
20 m Fishing vessel*	(*broadband*)	168 dB
25 m SWATH ferry with 2 x inboard diesels	315 Hz	166 dB
13 m catamaran with 2 x inboard diesels*	315/1600 Hz	159/160 dB
Bertram cabin cruiser with 2 inboard diesels*	400 Hz	156 dB
8 m RHIB with 2 x 250 hp outboards blade and shaft rates*	50-300 Hz	177-180 dB
8 m RHIB with 2 x outboards cavitation noise	1000 – 10 000 Hz	
4.5 m inflatable with 1 x 25 hp outboard*	2000-20 000 Hz	157-159 dB
Cutter-suction dredge (working)	100 Hz tonal	~180 dB
Clamshell dredge (working)	250 Hz pulses	150-162 dB
Pile driving operations	Low tonal pulses	170-180 dB
Seismic survey	0-1000 Hz	200-232 dB
Drilling	10-4000 Hz	154-170 dB
Supply vessel	1 500 Hz	182 dB

* recorded at 10-11 knots

** recorded at ~15 knots

Data sourced from Richardson et al. 1995; Dames & Moore 1996; Au & Green 2000, McCauley et al. 2002; University of Rhode Island 2022; DSTO data for the Port of Dampier.

Tugs

Tugs exhibit some distinct sound characteristics. Many tugs fitted with conventional propellers have these cowled, in the form of a nozzle, to improve protection and thrust. These types of configurations reduce the forward and lateral transmission of the sound waves from propeller cavitation and blade rate tonals but can also increase the directionality of sounds. Other harbour tugs employ Voith Schneider propellers, which operate on a different concept. The use of these types of propulsion systems results in less cavitation and lower noise as their rotors do not need to rotate as fast as a conventional propeller for any given level of thrust (ABS 2021).

Small Boats

Small vessels differ in their noise signatures from most other vessels. Underwater noise measurements of 22 m vessels of various designs which carried whale-watchers in Hervey Bay (Queensland) showed that vessel speed was the primary factor influencing the amount of radiated sound (McCauley et al. 1996). Small vessels produce significant directional noise patterns, with more noise radiating fore and aft than abeam. This has been attributed to the relative lack of hull noise shielding in the forward direction and only limited aft attenuation of propeller cavitation noise by the wake-induced bubble cloud. Several vessels had ‘singing’ propellers (producing strong audible tones that significantly add to the noise signature at particular RPM ranges). The other key factor influencing vessel noise is size of vessel. In another example, McCauley (1998) noted the difference in broadband noise from a 20 m fishing vessel (168 dB [re 1μPa at 1m]) and a 64 m offshore support vessel (177 dB [re 1μPa at 1m]), as recorded when both were underway at around 12 knots. The difference of 9 dB between the two vessels represents a tripling of sound energy.

Small craft fitted with large outboard motors can produce relatively intense sound levels, particularly when travelling at planing speed. Single or twin outboard installations are the most common type of propulsion for <7 m long power boats in Australian coastal waters, ie. inflatables, runabouts, small cabin cruisers, recreational fishing boats and rigid-hulled inflatable boats (RHIBs). The rapidly rotating and small propellers produce intense and more complex sound spectra than those of launches fitted with inboard diesels (eg. Gordon et al. 1992, Richardson et al. 1995, Au & Green 2000). Outboard motors produce broadband noise with many strong tonals and higher harmonics to 6 kHz or more, with peak source levels in the 150-180 dB (re 1 μPa at 1m) range (Table 13).

They also may be expected to produce cavitation noise with a peak frequency in 1 kHz to 6 kHz range, and to generate noise at frequencies of up to 20 kHz or possibly even higher

Transhipment vessel

The Transhipment vessel is a relatively small, slow speed, barge travelling predominantly in shallow water. During operations, it is estimated to spend only 4.25 hours out of every 13.21 hours underway, at a maximum speed of 9 knots. Given the current vessel traffic of Exmouth Gulf and Port of Ashburton, vessel traffic as a result of this Project is not expected to greatly increase the cumulative noise levels within the area. Therefore, noise from the transhipment vessel is not anticipated to pose a risk of thresholds being exceeded and has not been modelled.

7.5.3 Potential Project generated noise sources – dredging and piling

Underwater sound will be generated by activities during the construction phase and into the operational phase. A number of assumed construction-related activities that generate underwater sound have been identified. These include both impulsive sounds such as impact (or hammer) piling, as well as continuous sound sources from dredging.

The SELs adopted for modelling of sound generated by dredging and piling operations are shown in Table 15.

Table 15 SELs for proposed sound generating activities (Source: Talis 2021)

Activity/Equipment Description	SEL
Continuous sound sources	
Dredging	166 dB re 1µPa @ 1m
Impulsive sound sources	
Impact piling	193 dB re 1µPa2.s @ 1m

7.5.4 Underwater sound modelling

All underwater sound modelling results are for low tide (1.3 m below mean sea level [MSL]) and high tide (2.4 m above MSL). Additionally, all sources were positioned at the deepest point possible, and therefore the modelling predictions can be considered as conservative and worst case (Talis 2021). However, noise levels associated with vessel movements will be substantially lower than those arising from piling and dredging operations; hence, vessel noise has not been modelled, though the potential for noise from vessel movements to disturb marine fauna has been considered.

7.5.4.1 Predicted noise source – dredging

Dredging is a continuous noise source and is therefore considered as non-impulsive. It is expected that dredging will operate continuously for 12 or 24 hours a day. As there are no site bound species of interest within the area it has been assumed that the maximum exposure of the fauna considered in the study will be one hour. The Sound Power Level (SPL) source level was therefore converted to a 1-hour SEL by adding 36 dB. Table 16 provides the ranges at which Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) are predicted to be exceeded for each hearing group.

Figure 23 shows the dredge’s unweighted (i.e. no hearing curve applied and therefore worst case) instantaneous SEL predicted noise contours at high tide.

Table 16 Behavioural, TTS and PTS onset thresholds from non-impulsive noise (Source: Talis 2021)

Marine Fauna Hearing Group	Tide	TTS Exposure Range (metres)	PTS Exposure Range (metres)	Behavioural Response Distance (metres)
Sawfish	Low	~150	~90	~40
	High	~360	~170	~75
Whales (Low frequency)	Low	~180	<5	~800
	High	~260	<5	>3,600
Dugongs (Sirenians)	Low	<50	<5	NA
	High	<50	<5	NA
Dolphins (Medium frequency)	Low	<50	<5	~85
	High	<50	<5	~110
Marine turtles	Low	~150	~90	~40
	High	~360	~170	~75

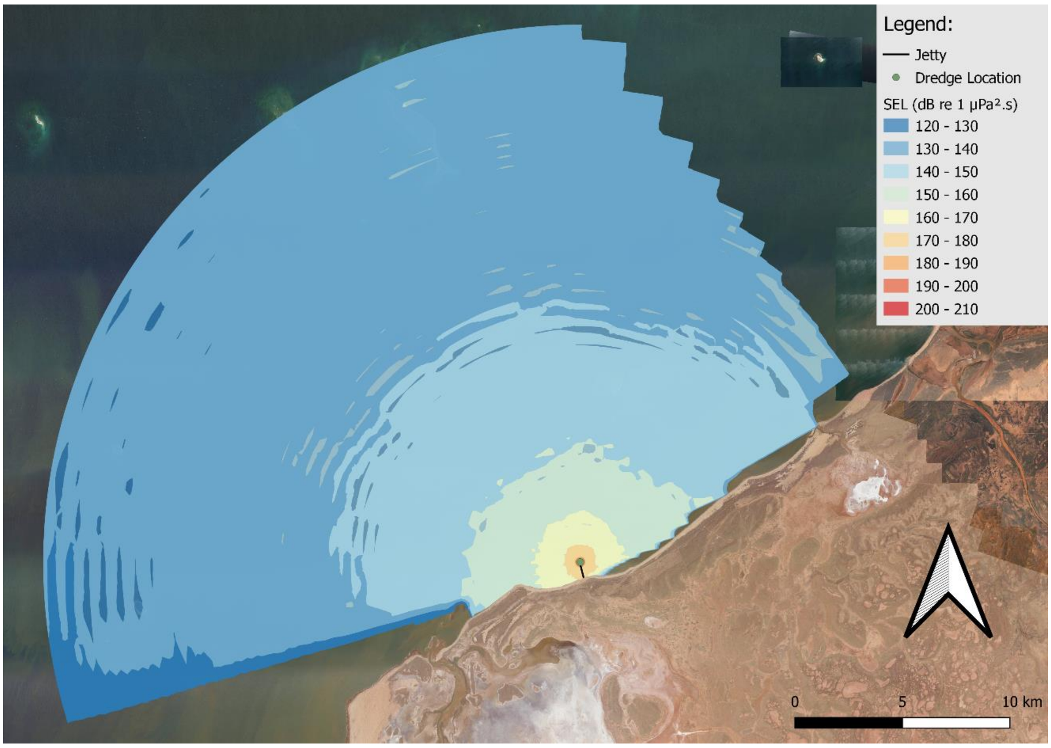

Figure 23 Noise contour – dredging operations – unweighted SEL (high tide) (Source: Talis 2021)

7.5.4.2 Predicted noise source – impact piling

Piling is an impulsive noise source involving multiple pile strikes. It has been estimated that the maximum exposure will occur when the hammer energy is at its maximum. The maximum hammer energy has been determined to be applied over a period of seven minutes, which equates to 200 hammer strikes. Exposure levels have therefore been determined using 200 strikes.

Table 17 provides the ranges at which TTS and PTS are predicted to be exceeded for each hearing group. The exposure ranges at which TTS thresholds are exceeded for high tide are 5 km for low frequency hearing groups and 1.2 km for turtles and sawfish. In comparison, low tide ranges are 2.7 km for low frequency hearing groups and 450 m for turtles and sawfish. This indicates that scheduling piling activities around low tides could potentially be used to reduce exposure ranges. Figure 24 shows the unweighted (i.e. no hearing curve applied and therefore worst case) instantaneous SEL predicted noise contours for piling at high tide.

Table 17 Behavioural, TTS and PTS onset thresholds from impulsive noise (Source: Talis 2021)

Marine Mammal Hearing Group	Tide	TTS Exposure Range (metres)	PTS Exposure Range (metres)	Behavioural Response Distance[a] (metres)
Sawfish	Low	~450	~250	~160
	High	~1,200	~550	~170
Whales (Low frequency)	Low	~2,700	~500	~4,400
	High	~5,000	~900	~10,250
Dugongs (Sirenians)	Low	<50	25	~250
	High	<50	25	~250
Dolphins (Medium frequency)	Low	<50	25	~250
	High	<50	25	~250
Marine turtles	Low	~450	~250	~160
	High	~1,200	~550	~170

[a] based on a single strike

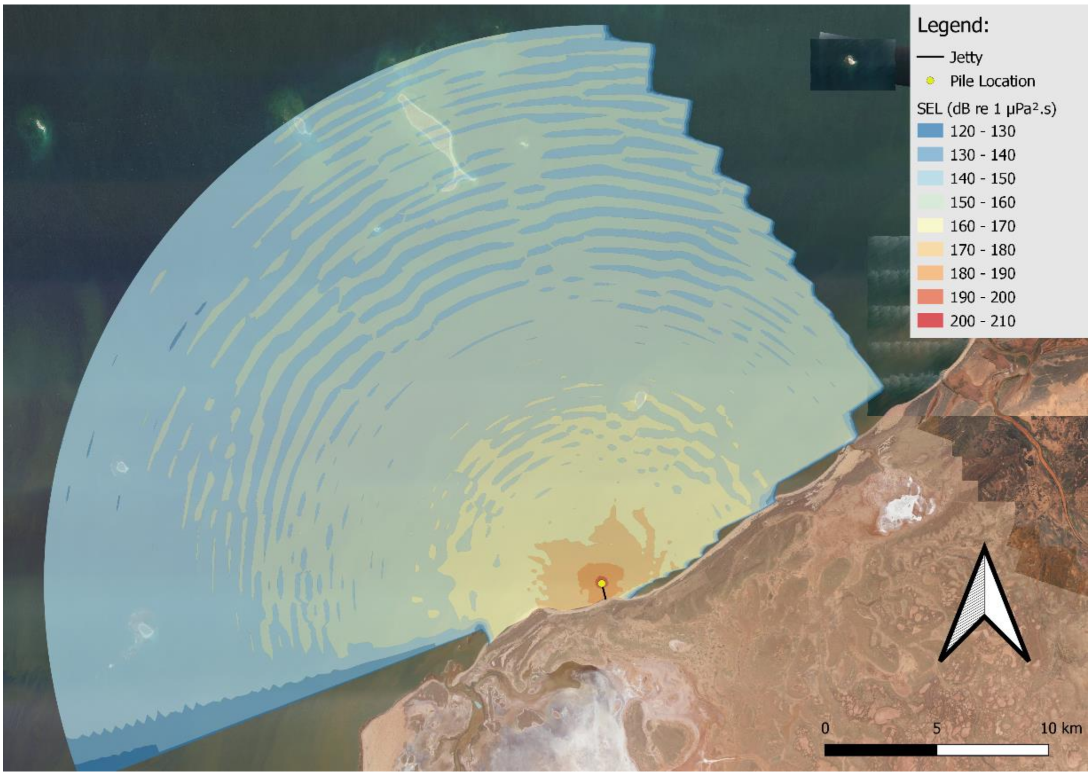

Figure 24 Noise contour – piling operations – unweighted SEL for a single strike (high tide) (Source: Talis 2021)

7.5.5 Assessment of potential impacts – sound thresholds

A range of potential effects on marine ecological receptors, from injury to minor behavioural responses, are commonly associated with anthropogenic underwater sound, depending on sound level, frequency and temporal characteristics relative to animal hearing sensitivities. The potential effects associated with underwater sound in marine mammals and other marine receptors are generally divided into the following categories:

- **Physical injury -** such as lung or gastrointestinal injury are rarely observed but have been reported in relation to blasting and military sonar (outside the scope of this Project).
- **Auditory impacts** – Underwater noise may result in injury to marine fauna (in the form of temporary or permanent threshold shift):
    - PTS is a permanent elevation in hearing threshold (i.e. an unrecoverable reduction in hearing sensitivity). PTS can occur from a variety of causes, but it is most often the result of very intense and/or repeated exposures to high or moderate-intensity sound; and
    - TTS is an elevation in hearing threshold (i.e. a non-permanent reduction in hearing sensitivity) most commonly resulting from sound exposure.
- **Masking** – anthropogenic underwater sound may partially or entirely reduce the audibility of ecologically significant signals such as those used for communication and prey detection and relates to behavioural responses.
- **Behavioural responses** – are highly variable and context-specific effects, ranging from increased alertness, altered vocal behaviour, interruption to feeding or social interaction, alteration of movement or diving behaviour, temporary or permanent habitat abandonment and, in severe cases, panic, flight or stranding, sometimes resulting in indirect injury or death. Minor or temporary behavioural responses are often simply evidence that an animal has heard a sound.

Researcher and regulatory agencies alike have long struggled with the complexities of establishing “thresholds” for different effects of noise on marine fauna. In an effort to quantify the noise criteria for marine fauna, Southall et al (2007) defined underwater noise in terms of “impulsive” or “non-impulsive” based on their characteristics at the source. Southall et al 2007 quantified SEL values based on discrete noise exposure, these same dual exposure metrics are used here. Table 18 presents the assessment criteria adopted for whales, dolphins, turtles, dugongs and sawfish for this study. A more detailed overview of the hearing bandwidths is provided in the following sections.

Table 18 Behavioural, TTS and PTS onset thresholds for non-impulsive and impulsive noise (Source: Talis 2021)

Marine Fauna Type	Marine Mammal Hearing Group	Hearing Bandwidth	Noise Type	SEL (Weighted) dB re 1µ Pa^2.s		Possible Behaviour Disturbance (dB re 1µ Pa^2 .s)
				TTS	PTS	
Sawfish [a]	Marine turtles	100 to 1000 Hz	Non-Impulsive	175	183	175[a]
			Impulsive	175	183	
Whales	Low frequency	7 Hz to 35 kHz	Non-Impulsive	179	199	140[c]
			Impulsive	168	183	
Dugongs[b]	Sirenians	100 to 1000 Hz	Non-Impulsive	186	206	140[c]
			Impulsive	175	190	
Dolphins[b]	Medium frequency	150 Hz to 160 kHz	Non-Impulsive	178	198	
			Impulsive	170	185	
Turtles [a]	Marine turtles	100 to 1000 Hz	Non-Impulsive	175	183	175[a]
			Impulsive	175	183	

Marine Fauna Type	Marine Mammal Hearing Group	Hearing Bandwidth	Noise Type	SEL (Weighted) dB re 1µ Pa^2.s		Possible Behaviour Disturbance (dB re 1µ Pa^2 .s)
				TTS	PTS	
Note: [a] McCauley et al. (2000a) and McCauley et al. (2000b) [b] NMFS (2018) [c] Dunlop et al (2017)						

The general scientific consensus in the literature is that the population-level consequences from extended, persistent sources of underwater noise are likely to be more significant than any acute behavioural or physiological effects (eg. see Dahl et al. 2015 and Ellison et al. 2012). This is particularly salient for long-term pile driving programs, which may extend through a number of seasonal or annual cycles of relevance to any particular species' life histories.

A key challenge in the development of threshold criteria is being able to distinguish a significant behavioural response from an insignificant, momentary alteration in behaviour. In extreme cases, behaviour responses can influence individuals of a species (such as stranding) or compound to population level, where habitats are essentially abandoned. However, in most cases behavioural response to noise will not have a significant effect on a population or even on individuals of a species. For example, it is unlikely that a startle response to a brief event will persist long enough to create a response which could be deemed substantial. In addition, even startle behaviour response to single pulses would be expected to dissipate rapidly and have limited long term effects on individuals, let alone populations.

Tougaard et al (2010) predicted linkages between adverse reactions upon individuals and how these may translate to population level (Figure 25). Factors such as activity at the time of exposure, habitation and sensitisation to the sound, similarities between anthropogenic and biologically relevant sounds, age, sex, reproductive status, and time of year, all have the potential to influence behavioural response to underwater sound (Southall et al 2007).

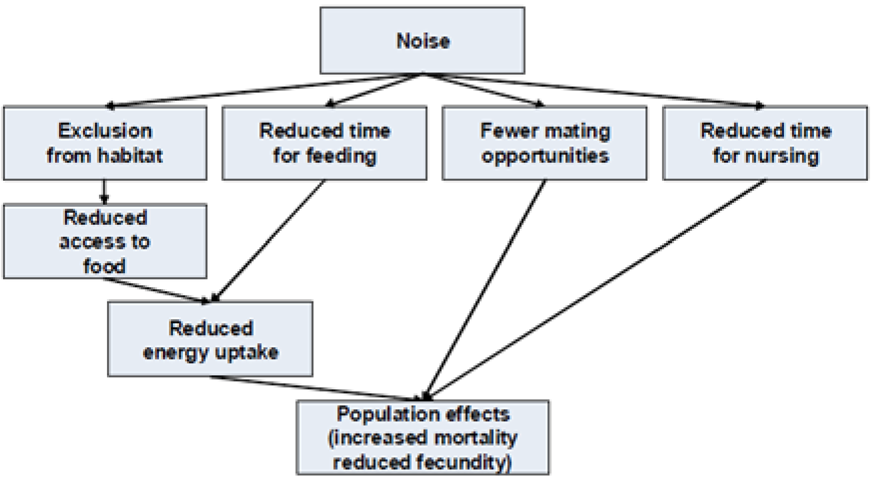

Figure 25 Conceptual model of behavioural reactions and subsequent population level effects (Tougaard et al 2010)

More recent efforts by Southall et al (2021) have attempted to quantify the potential impacts of underwater sound for free ranging marine mammals (Figure 26). This model proposes the severity of response within three progressive categories, ranging in severity from 0-9, for behaviours associated with critical survival functions (e.g., resting, feeding, reproduction). This approach allows for the evaluation of population level assessment where a score of 0-3 represents insignificant individual behavioural responses and a score of 7-9 represents large scale population disturbances.

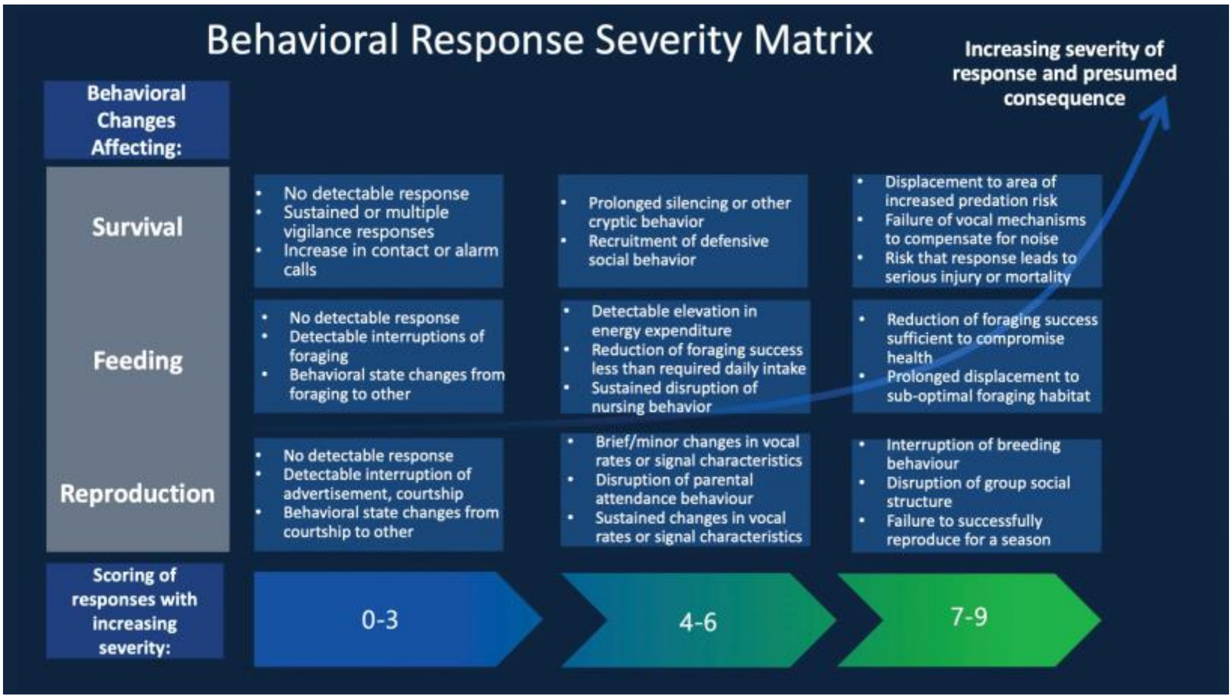

Figure 26 Behavioural response severity spectrum for marine mammals (Southall et al., 2021)

Having a population-based management approach allows for some impact on the individuals as long as the impact does not cause, or is not likely to cause, substantial impact to the species. This means that while injury to individuals should be minimised wherever possible, the level of behavioural impact tolerated from a particular activity should depend on the status of the relevant species (Tougaard et al. 2010). The consensus in the scientific community is that more research is required to fully understand the impacts of underwater sound on various marine fauna species. In the absence of an agreed behavioural threshold, Southall et al. (2007) suggests the onset of significant behavioural disturbance occurs at the lowest level of sound exposure that has a measurable transient impact on hearing, which is TTS.

The following sections review the known and theorised effects on protected marine fauna from likely noise sources associated with the Project. Impacts have been examined against measurable disturbances to TSS. The sources of noise examined below include dredging, pile driving and vessel movements.

7.5.5.1 Noise impacts on elasmobranchs and fish

Sound plays a major role in the lives of fish (Fay and Popper 2000), being important for communication, locating prey, and avoiding predators as well as for developing a general understanding of the surrounding environment. For example, research has shown the sound signatures of different habitats are important for the settlement of larvae and juvenile fish (Popper and Hastings 2009). Responses to underwater sound in fish include startle reactions, changes in swimming patterns and orientation, disrupted schooling patterns, altered horizontal or vertical distributions, disrupted feeding, displacement from preferred habitats, abandonment of spawning sites and diversion or delay of migration (Hawkins and Popper 2016; Hawkins et al. 2020).

The impact of sound on fish is, to a large extent, determined by the physiology of the species, particularly the presence or absence of a swim bladder and the potential for the swim bladder to improve the hearing sensitivity and range of hearing (Popper et al. 2014). These morphological features have been used to develop categories of fish depending on how they might be affected by sounds and these are used when assessing impacts.

A study of elasmobranch fish audiograms indicates that their hearing bandwidths range from 10 to 1000 Hz. As the very low frequencies have large wavelengths, it is expected that they will only exist as short duration evanescent waves in the water column of the study area. As a result, it has been assumed that frequencies below 100 Hz will attenuate very quickly. Sawfish will therefore have a similar hearing bandwidth to that of turtles (Talis 2021) and has been assessed as so.

7.5.5.1.1 Potential impacts from dredging activities - elasmobranchs and fish

The impact of underwater sound on fish ranges from behavioural responses to auditory and non-auditory tissue damage, as described above, and in extreme cases, mortality. For continuous sound, such as that produced from dredging activities during the construction phase, the risk of injury and mortality, even for high hearing sensitivity fish in very close proximity to the sound generating activity, is low (Popper et al. 2014).

The results of the sound modelling have been compared to the underwater sound thresholds for sawfish to show the estimated distance from the sound source at which the different impact categories may occur (Table 18). Geometric spreading calculations estimate an impact distance in sawfish of ~150 m for TTS and ~90 m for PTS during low tide and of ~360 m for TTS and ~170 m for PTS during high tide during dredging activities. At these distances, it is highly unlikely that sawfish will be exposed to damaging thresholds within their creek and nearshore habitats, given the dredging will occur approximately 700 m offshore. Dredging soft start procedures will allow elasmobranchs to move away from the noise source before such thresholds are reached.

There may be some observable behavioural responses in site-attached fish in the Project area during vessel movements and dredging, but these will be localised and short-term. The impacts of increased underwater noise on sawfish behaviour, stress, and movements has not been directly examined for any sawfish species, however, noise pollution has been identified as a potential concern for elasmobranch species in several past studies and assessments (e.g. GBRMPA 2012; Leeney and Poncelet 2013; Giglio et al. 2015). High noise levels have the potential to mask biologically important sounds including those associated with predator avoidance or prey capture (Jordan et al., 2013), or alter activity patterns and habitat use of elasmobranchs, particularly if noise occurs mainly during a specific time of day or specific location (Hammerschlag et al. 2017). However, as vessel sound is likely to be an often-repeated occurrence during the Project, site-attached fish are known to rapidly habituate to introduced sound (Popper et al. 2014) and most can temporarily reorient themselves within their habitats.

7.5.5.1.2 Potential impacts from piling activities – elasmobranchs and fish

Underwater sound resulting from impact piling has the potential to injure or disturb any fish in the vicinity of the works. The results of the sound modelling have been compared to the underwater sound thresholds for sawfish (Table 18). Modelling estimates an impact distance in sawfish of 450 m for TTS and 250 m for PTS during low tide and of 1,200 m for TTS and 550 m for PTS during high tide. At these distances it is possible that sawfish will be exposed to a reduction in hearing sensitivity within their nearshore habitats during impact piling which will occur from the shoreline and along the 700 m length of the jetty. Elasmobranchs within creek habitats are unlikely to be impacted. Piling soft start procedures will allow elasmobranchs to move away from the noise source before such thresholds are reached.

The American National Standards Institute (ANSI) guidance (Popper et al. 2014) provides no thresholds for behavioural disturbance in fish from multiple pulses due to a lack of, and contradictory, evidence on behavioural responses. Instead the thresholds indicate the likelihood of a behavioural response, and masking of ecologically important sounds, for fish, based on relative distance from the sound source. The National Marine Fisheries Service in the UK currently uses a criterion for behavioural response of 150 dB re 1 µPa, but it is not clear whether this is a peak or rms level. Also, as pointed out by Hastings (2008), no one is sure of the origin of this number, and it is not clear if it has any scientific validity.

7.5.5.1.3 Potential impacts from vessel activity- elasmobranchs

Only limited, at best, specific information is available on the responses of sawfish, or other fish to the noise associated with vessel movements. Fish have been recorded to avoid approaching vessels, usually by swimming down or laterally away from the vessel's track, with these effects noted to be transitory. The persistent presence of fish adjacent to operating marine and coastal infrastructure, such as wharves and offshore petroleum production platforms, indicates that at least some species are able to habituate to radiated underwater noise. Therefore, the associated underwater noise from operational vessels is not expected to significantly impact elasmobranchs.

7.5.5.2 Noise impacts on marine mammals

Marine mammals use sound for a number of social and biological activities, including echolocation and identification of prey as well as being highly important for communication with other individuals. This is particularly true for toothed whales (the Odontocetes) for whom it is the primary sensory modality due to their use of echolocation. Underwater sound has the potential to negatively impact marine mammals as it influences and masks this ability and, if loud enough, may cause direct or indirect physical harm through disorientation leading to strandings, though evidence of these significant impacts is limited to military sonar (Richardson et al. 1995). Permanent or temporary damage to hearing organs may also occur as a result of very high intensity sound or long periods of exposure to low or moderate sound levels.

Behavioural changes can involve increased alertness, modification of vocalisations, interruption or cessation of feeding or social interactions, alteration of movement or diving behaviour, and temporary or permanent habitat abandonment. Where behavioural impacts are minor or temporary, they are not likely to result in lasting consequences for exposed individuals and, thus, are unlikely to have population level effects. For the purposes of assessing the impact of underwater sound, the impacts of greatest concern are those that may negatively impact reproduction or survival.

As a group, cetaceans produce and receive sound over a wide range of frequencies from <10 Hz to 180 kHz. Species are classified into three different functional hearing groups – low, medium and high frequency - on the basis of their hearing range (Southall et al. 2007; NMFS 2018) although more recently these categories have been updated by Southall et al. (2019) to low, high and very high frequency. In the case of this Project, there is no difference in the categories for the species considered likely to be present and so it represents a change in group name only. Thus, the earlier more well-established names for the marine mammal hearing groups, as given by Southall et al. (2007) are adopted for this assessment to retain consistency with the most recent NOAA guidelines (NMFS, 2018).

There are several species of whale and dolphin that are considered likely to occur locally, as described in Appendix B and C. These species categorised by functional hearing group (Southall et al. 2007) are shown in Table 19.

Table 19 Potential cetacean species in the Project locally (Source: Southall et al. 2007)

Functional Hearing Group	Species	Estimated Auditory Bandwidth
Low frequency	**Baleen whales** Sei whale (*Balaenoptera borealis)* Fin whale (*Balaenoptera physalus)* Humpback whale (*Megaptera novaeangliae)* Blue whale (*Balaenoptera musculus)* Southern right whale (*Eubalaena australis)* Antarctic minke whale (*Balaenoptera bonaerensis)* Bryde's whale (*Balaenoptera edeni*)	7 Hz to 35 kHz
Medium frequency	**Toothed whales; beaked whales and dolphins** Sperm whale (*Physeter macrocephalus*) Killer whale (*Orcinus orca*) Spotted bottlenose dolphin (Arafura/Timor Sea populations) (*Tursiops aduncus*) Indo-Pacific humpback dolphin (*Sousa chinensis*)	150 Hz to 160 kHz
High frequency	**Toothed whales (high frequency specialists)** None reported	275 Hz to 160 kHz

No high frequency cetaceans have been identified as likely to be present in the Project area. Underwater sound thresholds for marine mammals, based on the most recent research and review, are only available for PTS and TTS impacts (NMFS 2018). These thresholds are shown in Table 18 for each of the cetaceans hearing groups.

7.5.5.2.1 Potential impacts from dredging activities - marine mammals

The results of the sound modelling have been compared to the underwater sound thresholds for low and medium frequency cetaceans to show the estimated distance from the sound source at which the different impact categories may occur (Table 18). Modelling estimates an impact distance in low frequency hearing (whales) of 180 m for TTS and <5 m for PTS during low and 260 m for TTS and <5 m for PTS during high tide, and no impact in medium frequency hearing groups (dolphins).

Throughout August-November, cow-calf humpback whale pairs rest and travel through the nearshore protected waters of Exmouth Gulf and surrounds. During this sensitive life phase, humpback whales are prone to predation and females expend much of their energy on lactation, which is the most energy demanding phase in their lifecycle (Bejder et al 2019). In order to reduce energy demands, adult females will devote a significant amount of time resting and nursing. An increase in underwater noise at this time could impact energy transfer and predator avoidance behaviours essential for successful migration of both mother and calf (Bejder et al. (2019). Severity assessments proposed by Southall et al (2021), suggest there is a correlation between prolonged sound exposure and increasing severity of behavioural response which could lead to population level consequences (such as displacement from foraging or resting grounds). Modelling for this Project suggests behavioural response to non-impulsive underwater sound could occur at a level of 140 dB, requiring an exclusion distance of over 3 km for humpback whales (at high tide).

Generally, there are no accepted behavioural thresholds for marine mammals. Previously, the US *Marine Mammal Protection Act* (MMPA) gave a 120 dB SPL_{rms} threshold for continuous sounds for behavioural responses, referred to as Level B Harassment. However, since the publication of the 2018 NMFS thresholds for PTS and TTS this threshold appears to have to been removed and it is widely recognised that there is significant variability in responses to underwater sound in marine mammals (Southall et al. 2007, Southall et al. 2021). For example, some studies have observed no behavioural response in some marine mammals at sound source levels of 170 dB SPL_{rms}.

In the absence of a behavioural threshold, Southall et al. (2007) suggests the onset of significant behavioural disturbance occurs at the lowest level of sound exposure that has a measurable transient impact on hearing, which is TTS. Thus, a significant behavioural response is only expected to occur for whales and dolphins very close to the sound source (<260 m). Permanent or temporary damage to hearing organs for marine mammals are unlikely due to the mobile nature of cetaceans and dolphins and their ability to avoid the area. Potential impacts will likely be limited to behavioural responses and are temporary in nature. These responses may include increased alertness, modification of vocalisations, interruption or cessation of feeding or social interactions and alteration of movement or diving behaviour. However, given that the Project area is located within critical nursery and resting habitat for Humpback whales, where practical, dredging operations will be undertaken outside key ecological windows to protect cow-calf pairs.

7.5.5.2.2 Potential impacts from piling activities – marine mammals

Pile driving activities can generate very high sound levels which are relatively broad band in frequency (20 Hz to >20 kHz) (Nedwell and Howell 2004) and can be detected by many groups of marine fauna, particularly marine mammals. The installation of driven piles in the marine environment without mitigation is likely to produce sound levels capable of causing substantial disturbance to marine mammals.

Sound levels from percussive piling have their highest energy at lower frequencies from about 20 Hz to 1 kHz, and whilst smaller cetaceans (approximately 3 to 4 m in length) are not known to be highly sensitive to sounds below 1 kHz, they can hear in some of this range (dolphin peak hearing range is reported to be 8 to 90 kHz). The reactions from marine mammals could range from brief interruption of normal activities to short or long-term displacement from noisy areas, and some acoustic masking of vocalisations in the lower frequencies could occur (David 2006).

There is no evidence in the literature to suggest physical injury is likely to occur as a result of impact piling but other injurious auditory impacts, such as PTS, TTS and behavioural responses, are possible.

The results of the sound modelling have been compared to the underwater sound thresholds for low and medium frequency hearing groups to show the estimated distance from the sound source at which the different impact categories may occur (Table 17). Geometric spreading calculations estimate a maximum impact distance in low frequency hearing (whales) of 2.7 km for TTS and 500 m for PTS during low tide, and 5 km for TTS and 900 m for PTS during high tide. Therefore, if unmitigated, exposure ranges to noise levels exceeding the TTS thresholds are predicted to extend over several kilometres with potential to result in behavioural responses. Modelling suggests behavioural impacts could occur in low frequency hearing cetaceans (whales) over a distance of 4.4 km (low tide), and over 10 km (high tide). Impact piling is therefore likely to cause widespread, behavioural reactions (avoidance) in the low frequency group over the range of the ensonified area, with some acoustic masking of vocalisations (David 2006).

The underwater noise mitigation measures proposed for the planned activities will each contribute to reducing the emitted or propagated underwater noise levels. However, none of the measures can be precisely quantified with regard to its contribution in reducing the noise. Therefore, where practicable, piling operations will be undertaken outside key ecological windows for protected marine species; e.g. humpback whale migrations (in particular the southern migration, August to November).

A maximum impact distance in medium frequency hearing groups (dolphins) has been calculated at <50 m for only PTS and up to 250 m for behavioural responses during low and high tide. Due to the likely low presence and mobile nature of dolphin species surrounding the piling activities, the potential impacts are considered likely to be limited to minor behavioural responses such as avoidance of the area, increased alertness, modification of vocalisations and/or interruption / cessation of feeding or social interactions.

7.5.5.2.3 Potential impacts from vessel activity – marine mammals

The responses of marine mammals to the nearby sound and approach of both large and small vessels varies considerably. Responses are influenced by factors such as size and speed of vessel, depth and other physical and habitat characteristics of the water body, activities engaged in at the time by the marine fauna of interest, and any element of habituation. Observed responses can be inconsistent and sometimes contradictory within the same groups. Some dolphin species, for example, exhibit a voluntary preference to closely approach moving vessels while others may display avoidance behaviours.

Short-term changes in surface behaviour of bottlenose dolphins in response to dolphin-watching vessels were reported in Koombana Bay, WA (Arcangeli & Crosti 2009). Dolphins were observed to be attracted to the vessel during 20% of cases and to have avoided it in 28% of cases. Time spent resting and feeding decreased in the presence of the tour vessels, whereas time spent travelling increased.

Sprogis *et al* 2020 found louder vessels approaching mother and calf humpback whales (within 100 m) resulted in increased respiration rates and reduced resting rates, suggesting that excessive vessel noise can affect the energy budgets of mother-calf pairs, resulting in decreased fitness of calves.

Excess noise may interfere with the ability of cetaceans to echolocate, communicate and navigate through masking. However, simultaneous acoustic measurements made by Lemon et al. (2006) determined that whistle rates did not change nor did the duration of echolocation click trains during boat approaches. Van Parijs and Corkeron (2001c) speculated that mother-calf pairs may be more vulnerable to noise disturbance since these groups exhibited an increased need to maintain vocal contact. Similarly, whistle rates of bottlenose dolphins increased in the presence of commercial dolphin-watch and dolphin swimming tours in Victoria (Scarpaci et al. 2000).

It should be noted that these studies are of varying intent and applicability to anticipated vessel activities in the Project area. The sound from vessels throughout the Project is not expected to significantly impact marine mammals. A study conducted by Bejder et al (2019) examined the ambient soundscape of Exmouth Gulf and determined the Gulf is primarily dominated by biological sounds from snapping shrimp and humpback whales, with minimal anthropogenic influences. Consequently, the minimal increase of vessel noise as a result of the Project is likely to be limited to temporary behavioural disturbance and/or masking of other biological sounds. Additionally, the transhipment vessel will not actively approach cetaceans, thus minimalizing the potential for interaction themes. As shipping and vessel noise is a continuous noise source of relatively low intensity, thresholds above which injury to marine mammal hearing could occur will not be exceeded. Bejder et al (2019) reported a reduction in vessel speed also reduces ship noise levels if the speeds are reduced to a level where cavitation is avoided; this is achievable as the transhipment vessel travels at a speed of 9 knots. Therefore, with mitigation measures outlined in section 7.5.6.3, it is unlikely that vessel noise resulting from the Project will have the potential to significantly impact upon cetaceans.

7.5.5.3 Noise impacts on sirenians

For dugongs a reliance on acoustic signalling is important because these animals commonly inhabit waters where subsurface visibility is limited to 1 to 10 m; dugongs are also active at night (Anderson and Birtles, 1978).

Dugong are known to vocalise, making complex sounds that vary in intensity, duration, frequency and amplitude modulations and number of harmonics (Anderson and Barclay 1995). The frequency of these sounds ranges from low frequency squeaks at 0.15 kHz to high frequency trills and chirp-squeaks at 18 kHz (Southall et al., 2019). Studies of dugong in Australia estimated the SSL of vocalisations to be up around 139 dB re 1 uPa @ 1m SPL_{rms} though the maximum recorded level was 152 dB re 1 uPa @ 1m. This research indicates that dugong call sound levels were considerably lower than those of other marine mammals (Parsons et al. 2013). The sound levels of dugong vocalisations in Exmouth Gulf are assumed to be similar.

The hearing capabilities of sirenians is poorly understood and there is no audiogram currently available for the dugong. There are, however, a few data from manatees, a sirenian of a different family but assumed to have a similar hearing to dugong. Audiograms produced for Florida manatee suggest they are capable of hearing between 0.4–46 kHz with peak sensitivity around 6 to 20 kHz (Gerstein et al. 1999). However, direct measurements by others have indicated that manatee hearing can extend from low frequencies to above 60 kHz (Southall et al. 2019).

7.5.5.3.1 Potential impacts from dredging activities - sirenians

The results of the sound modelling have been compared to the underwater sound thresholds for low frequency hearing group to show the estimated distance from the sound source at which the different impact categories may occur (Table 18). Modelling estimates an impact range in dugongs of <50 m for TTS and <5 m for PTS during dredging at low and high tide.

Behavioural responses may occur however if any dugong are present in the vicinity of dredging or vessels generating continuous sound. There are no quantitative thresholds available for behaviour to indicate potential impact zones, largely due to the difficulty in distinguishing a significant response from an insignificant, momentary alteration in behaviour (Southall et al. 2007). In addition, the responses of individual animals vary significantly depending on factors such as habituation, life cycle stage and habitat fidelity.

Southall et al. (2007) suggest the onset of significant behavioural disturbance occurs at the lowest level of sound exposure that has a measurable transient effect on hearing, which is TTS. On this basis a significant behavioural response is only expected to occur for individuals close to the source (<50 m).

Short-term behavioural responses to approaching vessels have been observed in both dugong and manatees. For example, responses in manatees included a change in orientation, depth and fluking behaviour, most often when boats were in close proximity (<10 m) (Rycyk et al. 2018) and in Australia dugong were observed to move away from a slow-moving vessel that was approximately 150 m away (Hodgson and Marsh 2006). Anecdotal evidence suggests sustained fast travel can only be maintained for a short period in dugongs, before there is a need to resurface and rest (Hodgson, 2004). Thus, although dugong are able to move away from vessel related sound sources, there is evidence to suggest that they are unable to flee from fast approaching vessels (Hodgson 2004).

The impact of continuous sound source activities on dugong may be adverse and direct, in that some discernible behavioural disturbance, such as swimming away or avoiding the area, may occur. However, whilst dugong exhibit short-term behavioural responses to dredging sound, such as interruptions to feeding and local movements, there is no evidence of dugong being displaced from key habitats due to underwater sound (DoEE 2017). Dugong persist in noisy environments, suggesting that they can habituate to chronic underwater shipping sound. Nevertheless, mitigation measures outlined in section 7.5.6 will be taken to reduce the potential for impacts on this species.

7.5.5.3.2 Potential impacts from piling activities - sirenians

There is no information regarding the impact of in-water impact piling on dugong or any other sirenian. The current impulsive sound thresholds for sirenians are derived from audiograms of sirenian hearing, measurements and observations of vocalisations and knowledge of the morphology of the auditory organs. In addition, no studies have been conducted to date on any aspect of TTS in sirenians and so the thresholds have been based on marine mammal data (Southall et al. 2019).

The results of the sound modelling have been compared to the underwater sound thresholds (Table 17. Modelling calculations estimate a maximum impact distance in dugongs of <50 m for PTS during low and high tide. It is therefore likely that any dugongs present in the area will avoid impact from piling activities. As for cetaceans, the behavioural responses in dugong may potentially range from brief interruption of normal activities to short or long-term displacement from noisy areas, with some acoustic masking of vocalisations in the lower frequencies (David, 2006). Behaviour responses have the potential to impact sirenians at a distance of 250 m at low and high tide. As calves where often sighted within the area, a marine mammal exclusion zone will be adopted for all piling operations (See Section 7.5.6).

7.5.5.3.3 Potential impacts from vessel activity - sirenians

The responses of dugongs to boat traffic are not well understood. Studies of Florida manatees suggests sirenians can detect vessel noise, with their underwater sensitivities at 1-30 kHz (Erbe et al 2019). Anderson (1981) reported that relatively slow moving vessels (5 to 8 knots) initiate an evasive response in dugongs at a distance of 150 m. Preen (2001) reported that individual dugongs differ greatly in their response to slow and/or fast moving vessels, with some individuals showing no signs of disturbance, while others rapidly moved away from the approaching vessels. Prevailing weather conditions may also affect a dugong’s response to fast vessels. It is possible, for example, that the ambient level of underwater noise during strong wind conditions may mask the sound of an approaching vessel.

Vessel noise as a result of the Project may potentially trigger a range of temporary behavioural responses, including brief interruption of activities or masking of vocalisations. However, vessel noise is not considered to have the potential to have significant negative impact upon dugong populations within the area.

7.5.5.4 Noise impacts on marine reptiles

Turtles spend much of their life underwater, but they breathe at the air-water interface and critical portions of their reproductive cycle, particularly nesting and hatching, take place on land. Thus, turtles are able to detect sound both underwater and in air. Electrophysiological and behavioural studies have demonstrated that turtles are able to detect low-frequency acoustic stimuli and recent investigations of green turtles found them responding to underwater stimuli between 50 and 1600 Hz, with maximum sensitivity between 200 and 400 Hz (Piniak et al. 2016). Lavender et al. (2012) found loggerhead turtle hearing ranged between 50 and 1200 Hz.

There is very little information on the impacts of underwater sound on turtles and, while the biological significance of hearing remains largely unstudied, turtles are known to be able to detect and respond to acoustic stimuli (e.g. Bartol and Ketten, 2006; Lavender et al. 2014). They may also use sound for navigation, locating prey, avoiding predators, and general environmental awareness.

There is evidence of behavioural responses to anthropogenic underwater sound in turtles. For example, studies of caged turtles (green and loggerhead) recorded reactions to seismic sound (an impulsive source), noticeably an increase in swimming behaviour, at sound pressure levels of 166 dB re 1µPa (McCauley et al. 2000). In this study reactions were seen to become increasingly erratic beyond a sound level of 175 dB re 1 µPa and could result in avoidance behaviour.

7.5.5.4.1 Potential impacts from dredging activities – marine reptiles

The results of the sound modelling have been compared to the underwater sound thresholds for turtles to show the estimated distance from the sound source at which the different impact categories may occur (Table 18). Modelling estimates an impact distance in turtles of ~150 m for TTS and ~90 m for PTS during low tide and of ~360 m for TTS and ~170 m for PTS during high tide.

The dredging program will be of short duration (approximately two weeks) and the peak mating, nesting and hatching season (October to February) will be taken into account during its planning. If undertaken outside of this season, dredging-related noise will only have the potential to impact upon, turtles that are foraging, or are transiting to foraging grounds. With the implementation of appropriate mitigation measures as detailed in Section 7.5.5, it is considered that dredging activities will not have the potential to significantly impact upon marine turtles. There may be some minor observable behavioural responses (such as swimming away or avoiding the area) in turtles foraging in proximity to the Project area during dredging, but these will be localised and short-term.

7.5.5.4.2 Potential impacts from piling activities – marine reptiles

There are very limited data on the impacts of pile driving on turtles. It is suggested that, because of their rigid external anatomy, it is possible that turtles are highly protected from impulsive sound effects, at least with regard to pile driving. Modelling predicts an impact distance in marine turtles of 450 m for TTS and 250 m for PTS during low tide and of 1,200 m for TTS and 550 m for PTS during high tide (Table 17.

Marine turtles generally demonstrate a startle response to sudden noises (Lenhardt et al. 1983; McCauley et al. 2000) and as such there may be some temporary behavioural changes to turtle behaviour, such as avoidance as the noise generated by pile driving activities will deter marine turtles from the area surrounding the piling activities.

The beaches surrounding the Project support low density nesting; however, the peak mating, nesting and hatching season (October to February) will still be taken into account when scheduling the piling activities. Piling outside of this season will reduce the potential for impacts to mating and nesting turtles, and to hatchlings, in the nearshore area.

Turtles foraging or transiting to foraging grounds in the nearshore area during piling activities may be susceptible to disturbance from piling noise. However, any effect of noise will be temporary during construction and there is no indication that turtles are permanently disturbed away from offshore areas due to a previous occurrence of noise (see Whittock et al. 2017 for an example of turtle response around temporary noise). Based on known responses of marine turtles to underwater noise, any turtles in the vicinity of the jetty construction may initially avoid the area due to the disturbance (see Lenhardt et al. 1983; McCauley et al. 2000). However, repeated noise exposure is likely to reduce their avoidance response over time resulting in a habituation of turtles to the area (see Moein et al. 1995; Whittock et al. 2017). Therefore, with the implementation of appropriate mitigation measures as detailed in Section 7.5.5, the risk of potential impacts to turtles as a result of the piling activities will be minimised. Any behavioural responses will likely be short-term in duration, until piling ceases.

7.5.5.4.3 Potential impacts from vessel activity – marine reptiles

Much of the acoustic research for marine turtles has primarily focused on studying anatomy and auditory sensory capabilities . These studies have demonstrated that sea turtles are able to detect and respond to sounds at low frequencies, with a range of 200-700 Hz (with peak hearing at 400 Hz). Of the studies that have been conducted, marine turtle behaviour response to anthropogenic noise varies greatly. Some turtles, including juveniles, have been observed resting at the sea floor while vessels pass overhead, while others have shown a startle response or even no response to approaching vessels (Tyson et al 2017).

There may be some minimal behavioural responses (such as avoidance or swimming away from operational vessels) in juvenile and adult turtles as a result of Project construction and operation. Modelling for this Project suggests turtles may express behavioural responses to underwater noise from a continuous source, such as vessel movements, at a distance of 75 metres (Table 14). However, given the implementation of the VMP and mitigation strategies outline in sections 7.7.5.4.3 and 7.8.3 it is considered unlikely that vessel noise will pose a risk of significant impact upon marine turtles within the Project area.

7.5.5.5 Noise impacts on invertebrate species

There is very limited information on the impact of underwater sound to marine invertebrates, including crustaceans (Edmonds et al. 2016). However, many aquatic invertebrates appear to use hydrodynamic receptors to detect, localise and identify predators, prey and conspecifics, and several crustaceans appear to be especially sensitive to sound transmitted through the seabed substratum (Hawkins and Popper 2017). It is estimated that many invertebrates are likely to perceive high intensity sounds at very close range only (up to 20 m), via mechano-receptors (McCauley 1994; Hirst and Rodhous, 2000; McCauley et al. 2000). Thus, invertebrates are considered to have very low sensitivity to underwater sound.

Prawns are believed to be sensitive to the motion of water particles displaced by low-frequency sounds ranging from 100 Hz up to 3000 Hz, with a hearing acuity similar to that of a generalist fish (Lovell et al. 2005). The prevalence of sounds from aquatic crustaceans suggests sound is important for communication between individuals (Spiga et al. 2012). There have been anecdotal reports of reduced catch rates of shrimp shortly after exposure to seismic surveys, but in other studies no significant changes have been observed. For example, a study in Brazil suggested that shrimp stocks were resilient to the disturbance by airguns with an SSL of 196 dB re 1µPa (Andriguetto-Filho et al. 2005).

André et al. (2011) found evidence that suggested balance organs of selected cephalopod species can be injured from controlled exposure to low frequency (50 to 400 Hz) sound.

There are no underwater sound thresholds available for invertebrates but, based on current evidence, significant impacts from all sound sources are expected only in very close proximity to each source. Thus, it is considered that any impacts upon invertebrates (including prawns) due to underwater sound from vessels and piling would be very localised and of very low magnitude.

7.5.6 Underwater noise mitigation measures

7.5.6.1 Dredging sound management

It is predicted from underwater sound modelling that an observation zone of 350 m from the source, and an exclusion zone of 170 m from the source, for marine mammals and turtles, would be more than adequate to avoid the onset of injury (predicated as the threshold for the onset of TTS and PTS) and the avoidance of adverse behavioural effects (see Section 7.5.5). These zones have been derived using worst case (most sensitive) animal group threshold levels for non-impulsive noise sources, sawfish and marine turtles at high tide (see Table 16). Based upon the predicted sound exposure risk, the following management procedures will be implemented for dredging activities:

- Scheduling of dredging operations will take account of key ecological windows such as;
- Sawfish pupping window (September – November).
- Turtle mating, nesting and hatching window (October - February).
- Southern migration of Humpback Whales (August-December).
- The protected marine species observation (350 m) and exclusion zones (170 m) will be included within the DDSMP for dredging activities.
- Implementation of an Underwater Noise Management Plan (UNMP), detailing both dredging and piling noise mitigation measures.
- From ten minutes prior to the commencement of any dredging activities, a dedicated Marine Fauna Observer (MFO) will monitor the observation and exclusion zones to check for the presence of any protected marine species. If any protected species are observed within these zones, dredging activities will not commence until they are observed to have left the observation zone, or until ten minutes have elapsed since the last sighting, and no other protected species have entered the zone during this period.
- On each occasion that a dredge has been non-operational for a period exceeding 30 minutes, a visual assessment will be undertaken of the observation and exclusion zones by the MFO for a period of ten minutes. Dredging will not recommence until no protected marine species have been sighted within the observation zone for a period of ten minutes.
- Once dredging has commenced, the MFO will maintain ongoing visual scanning of the observation and exclusion zones for protected marine fauna and, every 30 minutes, will dedicate a period of five minutes for observation (from an elevated position) for protected marine fauna. Dredging activities will be temporarily suspended if an individual of a protected marine species encroaches within the pertinent exclusion zone. Dredging will not recommence until no protected marine species have been sighted within the observation zones for a period of ten minutes.
- Dredging operations will be undertaken during daylight hours where practicable.

7.5.6.2 Piling sound management

It is predicted from underwater noise modelling that an observation zone of 1,200 m from the source, and an exclusion zone of 550 m from the source, for marine mammals and turtles, would be more than adequate to avoid the onset of injury (predicated as the threshold for the onset of TTS and PTS) from piling activities. It is assumed that piling activities will be undertaken outside of the southern whale migration period (September to November), to avoid any sound exposure risks to mother and calf pairs that travel closer to the coast. Therefore, these zones have been derived using worst case (most sensitive) animal group threshold levels for impulsive noise sources, sawfish and marine turtles at high tide (Table 17).

The following management measures will be implemented to help mitigate impacts to protected marine fauna:

- Pile driving activities will be undertaken only during daylight hours. Where practicable, impact piling activities will be undertaken during low tide.
- Scheduling of pilling operations will take account of key ecological windows such as:
  - Sawfish pupping window (September – November).
  - Turtle mating, nesting and hatching window (October - February).
  - Southern migration of humpback whales (August-December).
- Implementation of a UNMP that contains specific measures to mitigate the potential for significant adverse effects upon protected marine species from noise associated with piling operations.
- The establishment of protected marine species observation (1,200 m) and exclusion zones (550 m) as derived from the underwater noise modelling described in Section 7.5.4.2.
- A watch, by a dedicated MFO, will be established and maintained for the presence of any protected marine species, commencing ten minutes before the "soft start" of pile driving activities. The watch will be made from an elevated position, where a clear LOS is achievable to a distance of 1,200 m from the pile driving location. The MFO will not be engaged in any other activities during the ten-minute watch period. If any individuals are observed, the "soft start" will not proceed until they have been observed to move outside the observation zone or have not been sighted for a period of ten minutes, and no other protected species are present within the observation and exclusion zones.
- Pile driving will commence each day with a "soft start", where pile driving impact force is gradually scaled up over a five-minute period. This is considered to provide an opportunity for any sensitive marine animals to leave the area before full hammering energy is applied.
- Once pile driving has commenced, the MFO will maintain ongoing visual scanning of the observation and exclusion zones and, every 30 minutes, will dedicate a period of five minutes for observation (from an elevated position) for protected marine fauna.
- Where protected marine fauna is observed in the exclusion zone (550 m) then piling operations shall cease until protected marine fauna have existed the observation zone or have not been sighted for 10 minutes. Once protected species have exited the observation zone, soft-start piling may recommence.
- Where protected marine fauna is not observed in the exclusion zone, then normal operations may continue.

7.5.6.3 Vessel sound management

Vessel noise and vibrations during construction and operations will be managed by the following measures:

- All equipment and vessels will be operated and be maintained in accordance with appropriate industry and equipment standards including specifications for noise levels and manufacturer's specifications.
- Avoid, where possible, leaving engines and thrusters in standby or running mode unnecessarily.
- Regular monitoring will be conducted to assess compliance with noise and vibration levels
- Vessel master and crew will maintain a vigilant watch for all protected marine fauna species. If protected fauna is identified within 500 m of the vessel, the operator must steer a course away from the animal at 9 knots or less until the 500 m minimum separation distance has been established.

7.5.7 Predicted outcome

Underwater noise generating activities have the potential to result in behavioural responses to some marine fauna species. However, timing activities outside of key ecological windows (collectively September to January), and implementing a DDSMP and Piling Procedure with the mitigation measures detailed in the sections above, it is considered that the Project can minimise the potential for underwater noise to have significant impacts upon the biological diversity and/or ecological integrity of marine fauna populations in the region.

7.6 Assessment and Management of Anthropogenic Light Spill

7.6.1 Description of sources of impact

Light and physical movement are the two primary sources of visual stimuli which are used by marine species, along with a range of other environmental signals (including sound and vibrations, odours, temperature and changes in the earth's magnetic field strength) to manage their activity patterns, find food, avoid predation, socialise and reproduce.

It can often be very difficult to separate out the relative contribution of different stimuli in causing a disturbance to marine organisms. However, for plankton and larger taxa which occur in shallow or surface waters (e.g. invertebrates, fish, turtles and marine mammals) and those that migrate onto land (e.g. turtles breeding on beaches), changes in visual cues (particularly light) are known to strongly influence behaviours.

Most living organisms are sensitive to changes in the intensity and spectral quality of natural light (Longcore and Rich 2004). The dominant source of natural light is the sun, through daylight and reflected moonlight. At night, the brightest possible light source is a full moon. Factors such as weather, fire, lightning, bioluminescence and starlight may contribute to night-time illumination under natural conditions (Longcore and Rich 2016). Dusk and dawn are transitional periods where light intensity and spectral changes occur, triggering circadian rhythms in many organisms (Sweeney et al. 2011). Life has evolved with predictable daily, monthly and seasonal patterns of light and dark, which underlie the natural rhythms of most organisms. Such rhythms can be disrupted, particularly by artificial light at night (Longcore and Rich 2016).

During the construction phase of the Project the following are anticipated to be sources of potential visual disturbance within the site:

- marine construction activities: lighting, personnel and equipment will be required in order to undertake marine construction activities;
- vessels and marine structures: lighting will be required on vessels and marine structures at night. Some vessels and structures may also be manned 24/7; and
- marine navigational buoys: lighting will be required in certain marine areas for vessel navigation at night.

The following sources are anticipated to produce artificial light at night-time during the operational phase:

- transhipment vessel.
- marine infrastructure: the jetty will require lighting; and
- marine navigational buoys: lighting will be required in certain marine areas for vessel navigation at night.

Pendoley Environmental (2020) undertook a benchmark light survey and light modelling from several locations to assess the potential changes to the light environment from the Project (see Section 5.2.3).

7.6.1.1 Benchmark light survey

The Wheatstone LNG development, situated near Onslow, was the largest source of sky brightness and was visible from all survey locations. This was followed by the Wheatstone accommodation village and Macedon gas treatment facility, visible from all sites other than LM1 due to the larger distance and presence of high dunes between the survey location and light source. With the exception of LM3, the town of Exmouth was also visible as a small source of brightness from all survey locations (see Figure 28 and Figure 30).

7.6.1.2 Light spill modelling results

Light spill modelling was undertaken to predict project related light change at two locations: 1) Locker Island; and 2) LM3 located 1 km north of Locker Point (Figure 8). Modelling considered two scenarios: 1) Worst case - the jetty and conveyor lights always switched on; and 2) Best case - the jetty and conveyor lights switched off when not in use. The potential light spill impacts on marine fauna are summarised below (Pendoley Environmental, 2020),

7.6.1.2.1 Scenario 1 – jetty and conveyor lights always switched on

The largest increase in WOS and horizon brightness for this scenario was at LM3 (10.4% and 16.9% respectively) (Figure 27). Visible point sources include the Project's jetty and part of the conveyor. These sources partially merge with the Wheatstone LNG development and Macedon gas treatment facility also located along the same bearing. While a substantial amount of the Project's point source lighting is shielded behind the dunes (bearing 85°–180°), sky glow from these sources is predicted to still be visible up to approximately 20° above the horizon over this area.

The survey location at Locker Island showed a minimal increase in WOS and horizon brightness (0.9% and 1.8% respectively) (Figure 28). This increase was lower when compared to LM3 due to the greater distance from the proposed development. Individual point sources are not visible from the island, however, low-intensity sky glow from the cumulative Project lighting is predicted to be visible (bearing 185°) from this location.

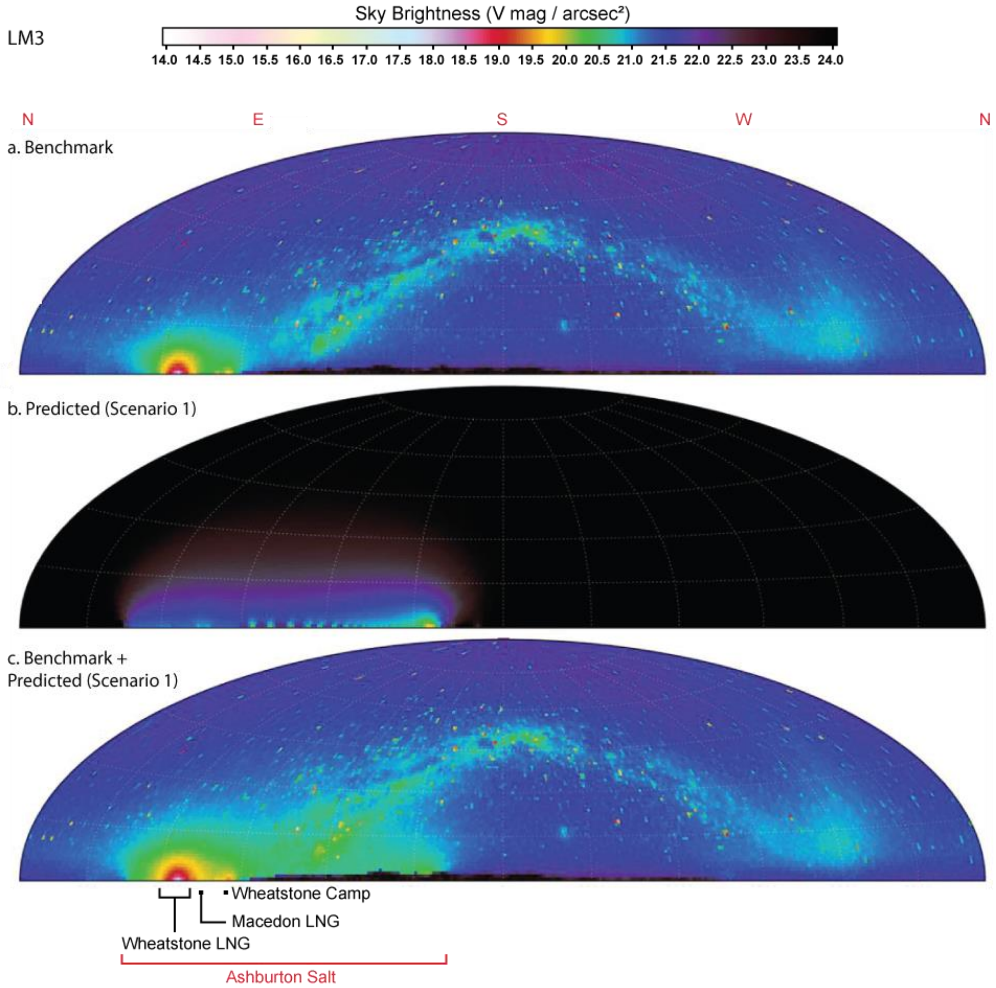

Figure 27 Artificial light modelling results for LM3 using Scenario 1: a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 1; c. Median benchmark image + modelled brightness

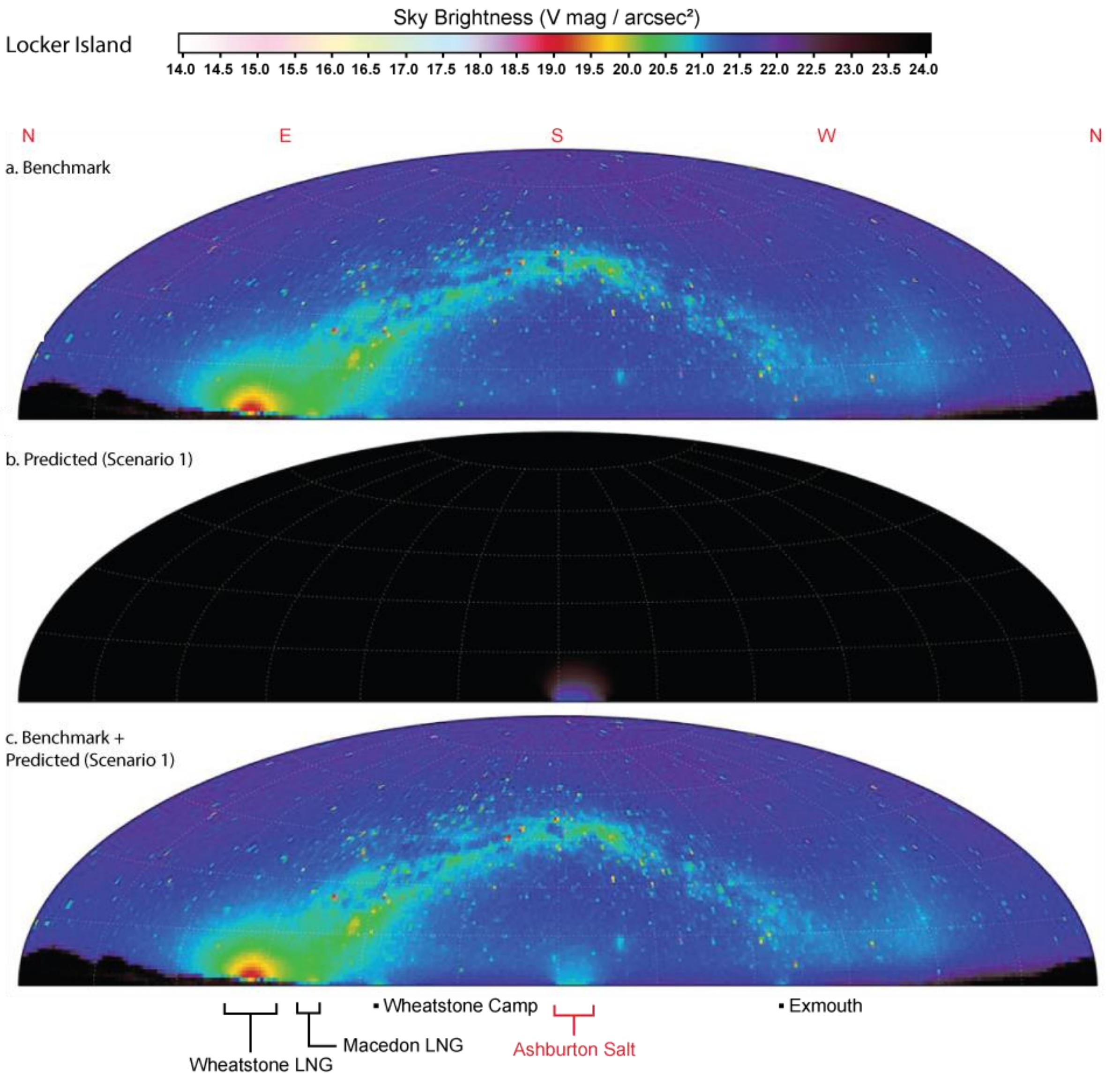

Figure 28 Artificial light modelling results for Locker Island using Scenario: a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 1; c. Median benchmark image + modelled brightness

7.6.1.2.2 Scenario 2 – jetty and conveyor lights switched off when not in use

There was a small predicted increase in WOS and horizon brightness by 1.5% and 2.8% respectively at LM3 (Figure 29). As all jetty and conveyor lighting is off in this scenario, these point sources were no longer visible from LM3. The remainder of the project lighting cumulatively forms a small region of glow at bearing 155° that was partially shielded by dunes.

There is no visibility of the Project site from Locker Island in this scenario (Figure 30). While there is a small change in WOS and horizon brightness (0.9% and 2.1%, respectively), this is likely to be indistinguishable from ambient light levels.

Therefore, when Scenario 2 lighting management is implemented (i.e. jetty and conveyor lights are turned off), light emissions are substantially reduced at both locations. At LM3, no point sources from the Project are predicted to be visible, and glow from the Project as a whole is predicted to be barely visible from Locker Island.

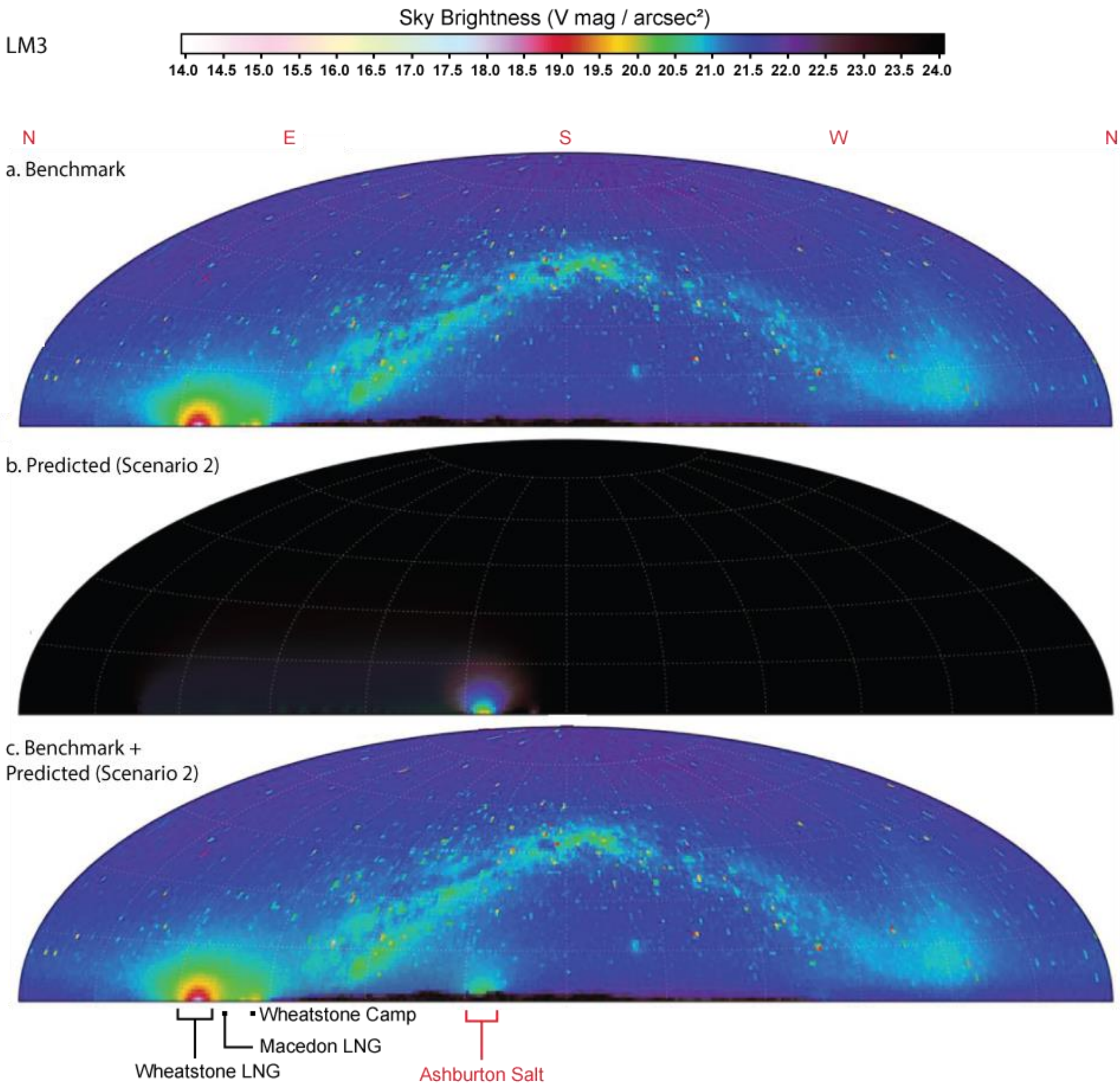

Figure 29 Artificial light modelling results for LM3 Scenario 2: a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 2; c. Median benchmark image + modelled brightness

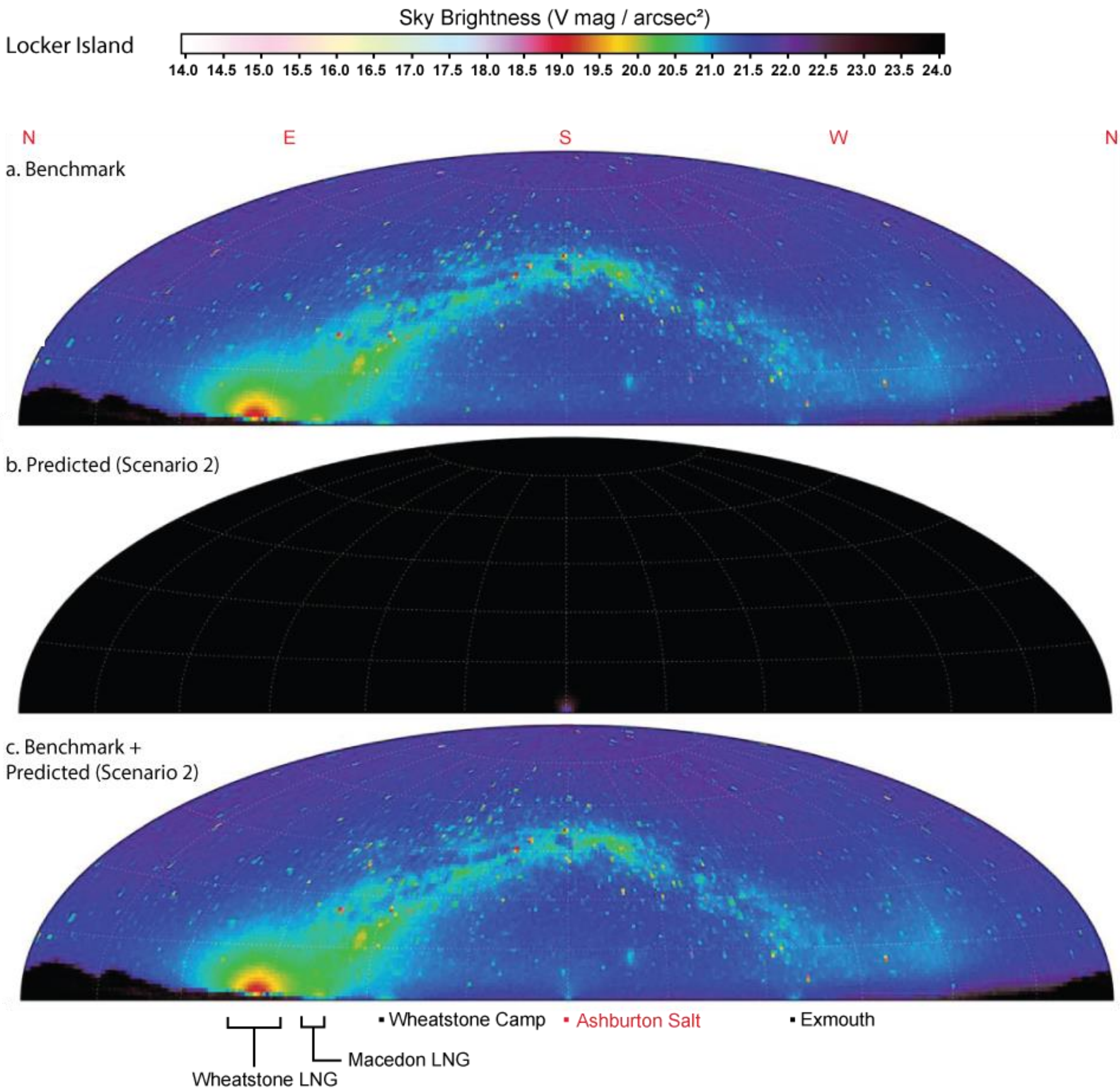

Figure 30 Artificial light modelling results for Locker Island Scenario 2: a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 2; c. Median benchmark image + modelled brightness

7.6.2 Assessment of potential impacts

Artificial light at night (ALAN) can alter critical behaviours in wildlife. For some species, artificial lighting may extend diurnal or crepuscular behaviours by improving an animal's ability to forage (Commonwealth of Australia 2020). For nocturnal species, artificial light can result in detrimental changes in behaviour.

An increase in visual stimuli due to the Project activities listed above could potentially lead to disturbance of marine species, triggering either avoidance or attraction. This in turn could affect breeding and foraging activities, which could have wider implications for populations.

Artificial light pollution is one of the principal sources of visual disturbance to marine species. It has the capacity to affect:

- **Orientation** – natural light is used by many species for orientation and navigational purposes. Artificial light is widely reported to have impacts on turtle movements.

- **Predation** – species have evolved a variety of anti-predator defences, some of which include colour patterns or bioluminescence, to blend in with the surrounding environment and nocturnal behaviours to avoid coming into contact with predators. Increased intensity of light and a broad spectral range may enable predators to identify prey with greater ease. This may ultimately displace both prey and predator species from areas of light pollution and can increase predation, resulting in reductions in species populations.
- **Communication** – many marine organisms have evolved methods of inter and intra-species communication through development of complex eyes able to depict displays of colour and pattern in other organisms. The introduction of increased levels of broad-spectrum artificial light may make certain features more recognisable, thereby altering the appearance of an individual.

7.6.2.1 Elasmobranchs and fish

Most fish species are photoreceptive, with key activity rhythms and behavioural patterns (e.g. feeding) stimulated by light. Daytime feeders, which are typically planktivorous, detritivores or grazers, are generally attracted to light (Marchesan et al. 2005). Conversely, nocturnal species, which are typically carnivores, show a strong avoidance of light. Crepuscular species that show peaks of activity during the twilight periods are likely to exhibit a varied behavioural response (Marchesan et al. 2005).

The most common reaction of fish to the presence of artificial light is to move towards the light source. This behaviour has the potential to affect the structure and abundance of fish populations through disruptions of predator-prey interactions, often to the benefit of the predator (Becker et al. 2013). This behavioural change may also disrupt migration patterns, and aggregations of fish in illuminated areas are also more vulnerable to fishing.

Artificial light may also have impacts on the reproductive success of some marine fish species. However, impacts are likely to be highly species-specific and artificial light may not have the same negative impacts on species with different reproductive strategies, such as pelagic spawning fish whose eggs are not fixed in a single location, and species whose embryos hatch during the day. In addition to hatching success rate, the duration of the embryonic stage before hatching and swim bladder inflation upon hatching may be affected by artificial light at night in some species. Any such changes have the potential to reduce the overall fitness and resilience of a population.

The distance of the jetty from Urala Creek North (8 km) and Urala Creek South (19 km) will likely preclude significant light impacts from this source within the creeks. Light spill may occur in Urala Creek South if lighting is associated with the seawater intake pump station. Additional light spill will be introduced along the shoreline between Urala Creek North and the Ashburton River mouth from jetty operations. The effects of light pollution on sawfish are unknown, with no previous work investigating effects of changes in lighting regimes on the movement and behaviour of wild sawfish (Morgan et al. 2020). However, considering that sawfish are largely crepuscular or nocturnal, artificial light during night-time hours has the potential to alter both the movements of sawfish around lighted areas and the timing of movements and activity, as has been suggested for other elasmobranch species (e.g. Hammerschlag et al. 2017). Impacts to Elasmobranchs will be considered and minimised within the Lighting Management Plan (LMP).

7.6.2.2 Marine mammals

Disturbance by an external visual influence can cause marine mammals to stop feeding, resting, travelling and/or socialising, with possible long-term impacts of repeated disturbance including loss of weight, condition and a reduction in reproductive success (JNCC 2008).

Some marine mammals (such as dolphins and some whale species) can be inquisitive and will approach marine vessels (Gregory and Rowden 2001) whilst other species are known to actively avoid both small and large vessels (Seawatch Foundation 2007). In the latter case, it is more likely that species will respond to sound stimuli and show avoidance response before visual cues can be detected. There is no specific visual disturbance information available for the marine mammals considered to be potentially be present, although it is anticipated that most species would be more responsive to sound rather than visual stimuli.

It is possible that indirect impacts may occur as a result of changes in the assemblage and distribution of prey species (i.e. fish and invertebrates) potentially leading to displacement and reduced fitness of marine mammals. However, given the small increase in WOS and horizon brightness modelled using both scenarios (Pendoley Environmental 2020), there is little evidence to suggest that marine mammals will be adversely affected.

7.6.2.3 Marine reptiles

The visual acuity of marine turtles both within and out of the water is believed to be sufficient to discern relatively small prey items, differentiate between colours and to navigate back to the sea after nesting (Moein Bartol and Musick 2003; Narazaki et al. 2013). As such, turtles are known to be particularly sensitive to visual disturbance (Witherington and Martin 2000). Artificial light that is considered most disruptive are those rich in short wavelength blue and green light (Fritsches 2012; Pendoley 2005; Witherington 1992). The attractiveness to light differs by species (Horch et al. 2008; Pendoley 2005; Wang et al. 2007; Witherington & Bjorndal 1991), however, green, flatback and loggerhead turtles all show increased sensitivity to wavelengths <600 nm (Fritsches 2012; Pendoley 2005; Levenson et al. 2004). Further, green and flatback turtles show stronger preference for blue light <500 nm (Fritsches 2012; Pendoley 2005).

Although longer wavelengths of light are less attractive than shorter wavelengths, long wavelength light has still been shown to disrupt sea-finding of hatchlings (Robertson et al. 2016; Pendoley 2005; Kamrowski et al. 2015), and if bright enough can elicit a similar response to shorter wavelength light (Kamrowski et al 2015; Cruz et al. 2018). Hence, the disruptive effect of light on hatchlings is also strongly correlated with intensity. Red light must be almost 600 times more intense than blue light before green turtle hatchlings show an equal preference for the two colours (Mrosovsky 1972).

Artificial light that are visible from marine turtle nesting habitat can cause a direct impact on the sea-finding ability of recently emerged hatchling turtles on the beach and when initially dispersing offshore. Sources of artificial light also have the potential to cause indirect impact through altered predator behaviour, with illuminated areas of beach improving the detection of hatchling turtles by predators and thus increasing the rate of predation.

The most prominent source of disturbance resulting from artificial light pollution has two main impacts on turtles: disorientation and disturbance.

Disorientation primarily relates to turtle hatchlings because they rely on light cues in order to find their way to the ocean upon hatching (Tuxbury and Salmon 2005). Turtle hatchlings naturally orientate towards the ocean because the sea is brighter than land due to the light reflecting properties of water (Mrosovsky 1967). This is one of the primary cues turtle hatchlings rely on in order to correctly orientate themselves. Horizon elevation and silhouettes also play important roles in hatchling orientation though these alone are often inadequate orientation cues (Salmon et al. 1992).

When natural light regimes are disrupted by artificial light, hatchlings often become disorientated regardless of other cues. Disorientation can result in hatchlings taking longer to reach the sea, thereby resulting in increased risk of predation and exhaustion. Disorientation can also result in hatchlings moving away from the sea towards inland light sources, resulting in exhaustion, dehydration and mortality.

Artificial light can also disorientate hatchlings whilst in nearshore waters as they attempt to move to offshore waters. Thums et al. (2016) experimentally tracked turtle hatchlings under ambient and artificial light regimes upon release at the shoreline. Where artificial light was present, 88% of hatchlings orientated themselves towards the artificial light and spent more time in the nearshore environment compared to those released under ambient light conditions; the latter followed natural dispersal trajectories.

In addition to hatchling disorientation, artificial light pollution is known to have disturbance impacts on adult turtles. Disturbance primarily relates to female turtles who are known to alter nesting behaviours where artificial light is present (Deem et al. 2007; Kamrowski et al. 2012). Artificial light has even been reported to discourage females from nesting on particular stretches of beach. In some areas this results in high concentrations of nests on alternative beaches without artificial light pollution (Salmon 2006).

This increases the likelihood of nest destruction by other females and may also result in increased hatchling predation. Shifts in nesting distribution may also shift hatchlings away from oceanographic features favourable for dispersal (Putman 2010). Reliance on a reduced area of coastline for nesting may also increase the overall vulnerability of a population to environmental changes (Kamrowski et al. 2012).

The marine turtle nesting habitat adjacent to LM3 is considered to have low-density turtle nesting activity. When all Project lighting is on, the brightest sources are likely to be offshore (the jetty and vessel), and thus have a lower potential to cause hatchling disorientation inland. When the jetty and conveyor lighting is turned off, the brightest source of light from the development is situated onshore, behind the dunes. While this may potentially create a risk for hatchling disorientation, this source is darker relative to other existing sources including the nearby Wheatstone LNG Development (Commonwealth of Australia, 2020).

At Locker Island, due to the darkness of the modelled light emissions and its large distance from the Project, there is a very low potential for the Project to cause hatchling disorientation even under a 'worst case' scenario with all Project lighting on (Commonwealth of Australia 2020).

Impacts to Turtles will be considered and minimised within the LMP.

7.6.2.4 Migratory shorebirds

Shorebirds typically show a preference for daytime foraging, which occurs over a greater area and at a faster rate, than nocturnal foraging (as cited in Commonwealth of Australia 2020). There is evidence that artificial lighting of migratory shorebird foraging areas may benefit the birds by allowing greater visual foraging opportunities. However, artificial lighting could act as an ecological trap by drawing shorebirds to foraging areas with increased predation risk (Commonwealth of Australia 2020).

Migratory shorebirds with a nocturnal component to their life history are at greatest risk of experiencing negative impacts from artificial light at night. Nocturnal shorebirds are typically burrow-nesting procellariform (petrel) species that forage at night on bioluminescent, vertically migrating prey, may use the night sky to navigate (Reed et al. 1985) and also use natural light source cues for sea finding when fledging (Telfer et al. 1987). The southern giant petrel is the only petrel listed as protected within the Project area, however it is not known to nest in burrows and unlikely to occur within the area (see Appendix A and B).

Migratory shorebirds have been recorded as present or fly through the region between July and December, and again between March and April as they complete migrations between Australia and offshore locations (Section 0). During the Biota (2021) survey, the largest number of shorebirds were observed using the bare intertidal flats habitat type for foraging, particularly the intertidal mudflats in the north arm of Urala Creek, followed by the sandy beaches, while small numbers were observed in the mangroves (likely roosting). Neither of the two shorebird areas within the Biota (2021) survey area met the criteria for internationally important migratory shorebird habitat.

The migratory shorebirds near the Project are likely to occur within their prime foraging grounds around the intertidal mudflats and creeks during the day. However, there is the potential for attraction for shorebirds to utilise the Project concentration ponds (refer Section 7.9.4). This may therefore increase the presence of shorebirds in the area and attraction to artificial light at night for foraging purposes.

Impacts to shorebirds will be considered and minimised within the LMP.

7.6.2.5 Commercial species

It is widely reported that artificial lighting attracts fish species. The attraction of fish to fishing vessels have been shown to impact fish foraging and schooling behaviour, spatial distribution and predation risk (Nightingale et al. 2006). Feeding of predators increases when artificial lights are turned on due to the abundance of fish prey in the illuminated area, whereas predators have more failures to attack their prey under dark conditions (as cited in Nguyen and Winger 2018). Artificial light spill may also impact the diel migration of prawns, causing them to be less active, and increasing the predation from fish.

Attraction of commercial species will likely occur around the jetty structure whilst artificial lit for night-time operations. However, the jetty structure will only be lit when vessels are loading, lights will then be turned off when not in use. Any impacts are therefore expected to be reasonably short term in duration and with the mitigation measures implemented (as detailed in Section 7.6.3) the impact on commercial species is expected to be low.

7.6.3 Mitigation measures

Lighting design principles for external light sources detailed in the *National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds* (Commonwealth of Australia 2020) have been used to inform the appropriate mitigation measures and lighting design for implementation on the Project. These principles are summarised in Figure 31.

Figure 31 Summary of best practice lighting design principles applicable to the proposed Project (Source: Pendoley 2020)

To reduce the potential for visual disturbance impacts to marine fauna, the following mitigation measures are proposed:

- Implement a Lighting Management Plan (LMP) that details the mitigation measures below.
- Use a minimum number and intensity of lights.
- Adapt lighting for colour, intensity and timing:
  - Offshore lights to utilise amber LED emitters (~585 nm 'true amber' emitters, 'phosphor-converted amber').
  - Onshore lights above 10 m height to utilise amber LED emitters (~585 nm 'true amber' emitters, 'phosphor-converted amber').
  - Onshore lights <10 m in height and where there is a need for good colour rendition, to utilise LEDs with a CCT equal to or lower than 2700 K.
  - Green and blue lights only used where required by navigation law.

- Use non-attracting lights, such as low-pressure sodium bulbs, in all coastal lighting (other than to meet regulatory requirements – marine and aircraft navigational lighting).
- If specific, intermittent tasks require a brighter white light (i.e. higher CCT), personnel are to use head torches.
- Lighting design to identify lights that are not required to be continuously lit.
- Lights that are not required to be continuously lit to be motion activated, put on a timer, or can be manually switched off.
- Flashing/intermittent lights, or reflectors to be installed onshore instead of fixed beam to identify an entrance or delineate a pathway.

- Light only the area intended:
  - All lights to be directed downwards using targeted asymmetrical distribution to illuminate only the specific areas of need, while minimising the reflectance.
  - All lights to be mounted at a height as low as possible while meeting lighting objectives.
  - The existing vegetation/dune between the turtle nesting habitat and onshore lights to be maintained and enhanced where feasible.
  - Onshore lights to be directed away from turtle nesting beaches. For lights required to be directed towards nesting beaches, lights should be placed so that buildings provide inherent shielding, where practicable.
  - Offshore lights to be directed downwards and direct light spill onto the ocean surface avoided unless operationally required.
  - Jetty design to prevent gaps in the floor which would result in light shining directly onto the ocean below the jetty, where compliant with technical and safety requirements. Shielding of all lights to achieve an upward waste light output ratio (ULR) of 0 %. Shielding can be achieved by recessing the light fitting into roof structures, eaves or building ceilings, or the light housing which prevents horizontal light above a 45-degree angle.
  - All glass (windows/doors) of buildings to have a glass light transmissivity rating of 0.5 or less.
  - All glass (windows/doors) of buildings to have opaque (block-out) blinds/curtains/shutters fitted.
  - Vessel windows fitted with opaque (block-out) blinds/curtains/shutters unless continuous visibility is required (e.g. on the bridge).
- Use of non-reflective, dark coloured surfaces:
  - Exterior finishes on all buildings to be matte and have a maximum reflective value of 30 %.
  - All other surfaces, including roads, and jetty, to be matte and have a maximum reflective value of 30 %, unless not technically feasible or presents a health and safety risk.
- Prevent mobile light sources shining onto nesting beaches and keep the height of these to a minimum.
- All non-essential lighting to be switched off when not in use.
- Building and vessel window blinds to be closed between sunset and sunrise.
- Vessel lighting should be reduced to navigational lighting where practicable.
- Minimise use of high beam vehicle lighting.

7.6.4 Predicted outcome

Given the relatively low magnitude of light spill from the Project (excluding offshore vessels) under ‘best case’ light model scenario i.e. where lights on the jetty and conveyor are switched off at all times, in comparison to the light from the other three sources, it is considered that the Project will not contribute significantly to the overall light climate in the region, and therefore will not raise the risk of significant impacts upon marine fauna (from light spill) to a substantially greater degree than presently exists in the region (AECOM, 2021a, Talis, 2021, Pendoley Environmental 2020). With the implementation of the mitigation measures detailed above, and the low light glow anticipated from the Project (in comparison to the Wheatstone LNG Development), it is considered unlikely that light emissions from the Project will present a risk of significant impact upon the biological diversity and/or ecological integrity of marine fauna populations on the region.

7.7 Assessment and Management of Seawater Intakes

7.7.1 Description of source of impact

The Project includes a seawater intake that will be located within Urala Creek South. The intake will operate throughout the year; however, it is estimated that peak seawater intake will occur during the summer months when evaporation is highest.

The seawater intake will consist of a rock armoured pump inlet well, excavated within the creek bank and positioned in an attempt to minimise environmental impacts such as erosion and scour. The inlet well will be screened to reduce the risk of entrapment of floating debris and large fauna. The inlet well screen will be oriented, and the intake velocity managed, so as to reduce the risk of fauna impingement (i.e. ‘trapping’ against the screens) by maintaining a water flow velocity at the screens of less than 0.15 m/s, in line with USEPA recommendations for protection of 96% of motile species concluded from fish swim speeds (USEPA, 2014).

Several seawater intake pipes will sit inside the inlet well. These pipes will have screens across their downward facing openings. The pipes will extract seawater from the inlet well. The seawater extraction process will be driven via a pump station situated on the creek bank which will transport seawater into a connecting intake channel leading to the first evaporation pond. Pumping will not occur at low tide.

USEPA (2014) concluded from fish swim speed analysis that water velocities at screens would be protective of 96% of motile species. The proposed screening concept employs Johnson screens that extend from above the water line, to the bottom of the inlet well, with a total length of approximately 50 m (Vortex Australia, 2020). The mean flow velocity produced by the operating pumps has been calculated at 0.11 m/s, 25% less than the USEPA (2014) guideline of 0.15 m/s (Vortex Australia 2020).

Velocities at the pump cut-off tide peak at 0.4 m/s and hence marine fauna that swim slower will be drawn into the well but unlikely to be trapped against the screen (Vortex Australia 2020). Pumping down time during the tidal cycle is approximately 6 hours a day and at the lowest swim-rate of 0.15 m/s, marine fauna can swim back out through the well in roughly 3 minutes (Vortex Australia 2020).

7.7.2 Assessment of potential impacts

7.7.2.1 Entrapment

Entrapment refers to the trapping of marine fauna against intake screens due to the velocity of the intake water. If fauna are unable to extricate themselves from the screens, then mortality is inevitable. The rate and degree of entrapment is a function of the large fauna present, water velocity, intake design and intake location.

Dugongs, marine turtles (including juveniles) and sawfish are the key marine fauna of concern in relation to entrapment. The average swimming speed of the dugong is about 10 km/hr (2.8 m/s) compared to the projected mean water velocity at the intake screen of 0.11 m/s. The maximum swimming speed of a dugong is reported around 5.6 m/s (Huffman, 2006), which suggests that a dugong would be quite capable of swimming away from an intake screen should it find itself in the vicinity of the screen at pump start-up.

The swim speed of juvenile green turtles was evaluated by Prange (1976), who found juveniles (less than 26cm CCL) were capable of short bursts of up to 2 m/s, with sustainable speeds of 0.14-0.35 m/s. This research suggests juvenile turtles are capable of swimming away from an intake screen which has a velocity of 0.11 m/s. Dolphins found locally are capable of swimming faster than the dugong and could also be reasonably expected to swim away from the intake screens without becoming entrapped and are unlikely to occur at the intake location.

Sawfish species are easily caught and entrapped in nets and lines due to their toothed rostrum, which is a major reason for their global decline (Dulvey et al. 2016). To avoid sawfish and juvenile turtles becoming entrapped in the seawater intake within Urala Creek South, an exclusion device is required. This device is required to be rigid and of a relatively small grid size to prevent sawfish rostra becoming entangled or suck in grid openings (Morgan et al. 2020). The screening of the intake inlet well will act as a suitable exclusion device.

7.7.2.2 Entrainment

Entrainment occurs when fauna (including zooplankton, gametes, larval, post-larval, sub-adult and adult stages of certain species) are small enough to pass through feed water intake screens. The intake pumps mean water velocity has been calculated to operate at 0.11 m/s, potentially reducing the number of biota passing through the intakes. However, depending upon the resilience of the fauna to the forces exerted upon them as they pass through the intake pumps, varying degrees of mortality will occur.

All of Western Australia's solar salt operations have biota resident in the salt ponds which have originated from the adjacent marine environment. In current pond designs, the biota are generally unable to leave the ponds, thus a locally unique ecosystem is created within the ponds.

Fish resources within the Port Hedland concentrator ponds of Dampier Salt Limited (2006) were found to exceed 60 tonnes throughout the year and exceeded 100 tonnes in May 2000. Although the number of species found was lower than typically recorded in other tropical estuaries, a large number of recreational and/or commercial species were present, sometimes in large numbers. It is expected that a number of fish species will inhabit the concentrator ponds of the Project and become part of the pond ecosystem. This ecosystem is also expected to provide habitat for migratory waders and other shorebirds which have been observed congregating at concentrator ponds of other Western Australian solar salt operations.

Independently to the PER process, a modelling exercise is being undertaken with K+S, Water Technology, Murdoch University, DPIRD and Kailis to model potential proportional loss of prawns from the EGPMF as a result of the Project (including an assessment of potential entrainment by the seawater intake). The results of this prawn modelling exercise are intended to be provided to DPIRD as the managers of the fishery.

7.7.3 Mitigation measures

The engineering design of the seawater intake pumps mitigate any potential impacts on marine fauna. These include;

- Dual screening of the intake structures. Firstly, screening of the inlet well from which water will be extracted. Secondly, screening of the pipe openings within the inlet well which will extract seawater. These dual screens will prevent and minimise entrapment and entrainment of marine fauna.
- K+S have committed to ensuring the flow velocity of the intake pumps is less than 0.15 m/s. The inlet well screening concept design employs Johnson screens that extend from above the water line, to the bottom of the inlet well, with a total length of approximately 50 m (Vortex Australia, 2020). The mean flow velocity produced by the operating pumps has been calculated at 0.11 m/s, 25% less than the USEPA (2014) guideline of 0.15 m/s (Vortex Australia 2020).
- Velocities at the pump cut-off tide peak at 0.4 m/s and hence marine fauna that swim slower will be drawn into the inlet well but unlikely to be trapped against the screen (Vortex Australia 2020). Pumping down time during the tidal cycle is approximately 6 hours a day and at the lowest swim-rate of 0.15 m/s, marine fauna can swim back out through the well in roughly 3 minutes (Vortex Australia 2020).

- When the pump stations are being commissioned the screens will be intensively monitored for the first 14 days. If there are any incidences of fauna entrapment, the pumps will be immediately shut down to allow:
  - Any entrapped fauna to swim out of the well; and
  - Improvements to the screening or the seawater intake design/operation until entrapment no longer occurs.

7.7.4 Predicted outcome

With the implementation of inlet and passive screens, and intake pumps water velocity designed to remain below the recommended 0.15 m/s, it is considered that the risk of entrapment of marine fauna will be sufficiently low that it will not present a risk of significant impact to the biological diversity or ecological integrity of marine fauna populations in the region. It will not be possible to avoid entrainment of juvenile fish prawn larvae into the concentration ponds, however the restricted intake pump velocity and pumping cycles will also assist in reducing the number volume of larvae entrained. Due to the size of the prawn nursery area, it is not anticipated that the project will result in a reduction of biological diversity and or ecological integrity of the commercial prawn industry. However, separate to the PER process K+S is undertaking a modelling exercise to understand the potential implications of entrainment on the EGMPF.

Entrainment of fauna small enough to pass through water intake screens will likely lead to an abundance of biota within the concentration ponds. Fisheries WA (2002) has estimated the fish populations within existing Western Australian concentration ponds to range in mass from 8–105 tonnes, depending on the method of estimation (refer Section 8.2.2).

7.8 Assessment and Management of Vessel Collisions with Marine Fauna

7.8.1 Description of source impact

Moving vessels could collide with marine wildlife such as marine mammals and turtles, resulting in physical injuries (e.g. corkscrew injuries), and in extreme instances mortality (Pace et al. 2006; Hazel et al. 2007). Marine wildlife is most at risk from collision when:

- the level of vessel traffic is high (Pace et al. 2006);
- vessels are greater than 80 m in length; and
- when vessels are travelling at speeds faster than 14 knots (Laist et al. 2001).

The Project will have a number of vessels operating during both the construction and operational phase. During construction, vessels will include a dredge (cutter suction dredge or backhoe dredge), potentially a piling barge, and support vessels (e.g. crew transfer vessels, tender vessels). During operations a transhipment vessel will traverse 14 nautical miles, between the jetty and the transhipment location, daily.

7.8.2 Assessment of potential impacts

The main risk of physical interaction with marine fauna during construction will be in relation to the movement of support vessels for the dredge and, potentially, a piling barge. These will be stationary during most of the works, with the most mobile parts of the equipment generating noise and vibration which is likely to discourage any species that may be present from approaching sufficiently close for them to be exposed to the risk of direct impact. When moving within the Project footprint, the dredge and barge will transit at low speeds and only over small distances during each move (typically tens of metres).

Physical interaction between marine fauna and the transhipment vessel will remain a possibility throughout operations. Turtles, dugongs, humpback whales, and whale sharks, may potentially occur within proximity to the jetty, transhipping route and offshore anchorage site. However, the transhipment vessel is relatively small, easily manoeuvrable and will be restricted to a maximum speed of 9 knots in the navigation channel. Given its slow pace and predictable path, the transhipment vessel will pose a low risk of collision with marine fauna. With the implementation of additional mitigation measures presented in section 7.8.3, and implementation of the VMP, it is considered there is a low likelihood of impacts upon protected marine species from vessel movements associated with the Project.

7.8.2.1 Elasmobranch (whale sharks, sawfish and rays)

Elasmobranchs are not known to be naturally inquisitive and are therefore not expected to approach vessels whilst in operation. They are also sufficiently mobile that there would be negligible potential for physical impacts upon them during vessel movements. While some elasmobranchs (such as sawfish and rays) may be attracted to the disturbance of the seabed at the dredge head or bucket (e.g. to feed upon fauna liberated from the sediments), it is considered there will be negligible potential for the dredge to physically impact upon them during operations.

Whale sharks are unlikely to be impacted by nearshore construction activities for the Project, however there is potential for encounters to occur during operational activities along the transhipping channel and offshore anchorage site. Whale Sharks congregate at Ningaloo Reef from March to July each year and spend a significant amount of time in surface waters, and therefore there is a possibility of vessel strike. Lester *et al* (2020) found that 38.8% of whale sharks identified in Ningaloo Reef exhibited some form of scarring from vessel strikes. However, with implementation of mitigation measures presented in section 7.8.3, vessel movement resulting from the Project is considered unlikely to impact whale sharks or other elasmobranchs.

7.8.2.2 Marine mammals

Dugongs are distributed throughout the coastal water to the 20 m isobath, with a couple of individuals recorded foraging in nearshore areas close to the mouths of Urala Creek South and Urala Creek North. Dugongs are considered to be vulnerable to being struck by marine vessels as they are slow moving and often found at the surface . It has also been suggested that sirenians are unable to avoid vessels due to a phenomenon called the Lloyd's mirror effect; this can lower the sound frequency emitted from the propeller of the oncoming vessel within surface waters to below levels detectable by sirenians (Erbe et al. 2019; Gerstein 2002). In such instances, underwater sound no longer acts as an early warning signal alerting an individual of approaching vessels and allowing opportunity for a behavioural response which may reduce the risk of collision (i.e. movement out of the collision path). Dugongs have also been shown to exhibit a delayed avoidance response to fast approaching vessels, reacting only when they are approximately 20–25 m away, which is often insufficient time for avoidance (Maitland et al. 2006). This combination of factors renders sirenians particularly vulnerable to collisions with vessels.

Exmouth Gulf is located within the humpback whale migration (north and south) biologically important area (BIA) and has been identified as one of four important resting areas along the Western Australian coast during the southern migration (DAWE 2021a). Cetaceans are agile organisms that possess quick reflexes, with fast swimming abilities and good sensory recognition which means they are capable of avoiding most vessels (Hoelzel 2002). However, cetaceans which may be distracted by activities such as foraging and social interactions may not perceive the threat of moving vessels and could therefore be vulnerable to vessel strikes (Wilson et al., 2007). Additionally, females with a dependant calf are at higher risk of vessel strike as they spend more time resting near the surface (Smith et al 2020). The high proportion of whale calves and juveniles among collision victims also suggests that perception of vessels as a threat is something that is learnt later in life (ASCOBANS, 2003).

Given this area is part of the known migration route of Western Australian humpback whales and within proximity to known nursery grounds, mitigation measures will be implemented to reduce the risk of vessel strike throughout construction and operation of the Project.

7.8.2.3 Marine reptiles

Marine turtles are also subject to the risk of injury or mortality from vessel strikes, although there are fewer reported incidences compared to marine mammals (Hazel et al. 2007). Hazel and Gyuris (2006, reported in Hazel et al. [2007]) found 14% of dead turtles stranded in Queensland could be attributed to vessel collisions. Stranding records from the US Atlantic coast and the Gulf of Mexico between 1997 and 2005 also found that 14.9% of all stranded loggerhead turtles had sustained some type of propeller or collision injury (CSA Ocean Science Inc. 2019).

Unlike marine mammals, turtles are not fast or agile and may not have the ability to avoid vessels travelling faster than 4 km/h (~2 knots) (Hazel et al 2007). Individuals that occur close to the sea surface to bask, mate or breathe are more vulnerable to vessel collisions or being struck by propellers. Similarly, individuals foraging, nesting or swimming in water depths insufficient to allow the draft of the vessel and propellers to pass over are also vulnerable to impacts (Shimada et al. 2017).

7.8.3 Mitigation measures

This section addresses measures to reduce the risk of physical interaction between protected marine species and Project vessels whilst they are under way; measures to reduce the risk of indirect (sound and vibration) effects on protected marine species are detailed in Section 7.5.6.

It should be noted that physical interactions between dredging vessels and protected marine species are a higher risk when mobile dredges such as trailer suction hopper dredges are used, which is not applicable to this Project.

A VMP will be implemented to reduce the risk of physical interaction with protected marine species during vessel movements. These measures will apply to the movement of the dredge and piling barge, and to any other vessels engaged during construction and operation:

- Operational vessels will travel no faster than 9 knots.
- Vessel master and crew will maintain a vigilant watch for all protected marine fauna species and slow down, or alter course, as appropriate, to avoid striking any protected species. The presence of a single individual at the surface may indicate the presence of submerged animals in the vicinity; therefore, precautionary measures should always be exercised.
- All vessel crew members must be briefed in the identification of protected marine fauna species that may occur in the survey area and in regulations and best practices for avoiding vessel collisions.
- Any time a vessel is underway, an observer must monitor a Vessel Strike Avoidance Zone (500 m) or greater from any sighted whales and 50 m or greater from any other marine fauna species visible at the surface, unless the marine fauna is actively approaching the vessel) to ensure detection of that animal in time to take necessary measures to avoid striking the animal.
- If a whale (including mother and calf pair) or whale shark are identified within 500 m of the forward path of any vessel, the vessel master must steer a course away from the animal at 6 knots or less until the 500 m minimum separation distance has been established. Vessels may also reduce to idling speed if feasible.
- EPBC Regulations 2000 – Part 8 Division 8.1 Interacting with cetaceans (DoEE 2017b) will be applied as follows:
    - Project vessels will not travel faster than six knots within 300 m of a cetacean or turtle (caution zone) and not approach closer than 100 m from a whale (Figure 32).
    - Project vessels will not approach closer than 50 m for a dolphin or turtle and/or 100 m for a whale (with the exception of animals bow-riding).
    - If the cetacean or turtle shows signs of being disturbed, Project vessels will immediately withdraw from the caution zone at a constant speed of less than six knots.
    - Vessels will not travel faster than eight knots within 250 m of a whale shark and will not approach closer than 30 m to a whale shark.
- Dredging operations will only be undertaken during daylight hours, where practicable.
- If a cutter suction dredge is in operation, rotation of the dredge cutter head will only start when it is positioned near the seafloor, and rotation will be stopped before the cutter is raised through the water column. This will mitigate the risk of contact between a rotating cutter head and protected marine species.
- Vessels will not approach, circle or wait in front of protected marine species for the purposes of casual viewing.
- A watch will be maintained throughout Project operations for stranded, injured or dead marine fauna; if observed, the DBCA Wildcare Helpline (08 9474 9055) will be contacted for advice on retrieval, treatment or post-mortem by the DBCA Parks and Wildlife Service.

7.8.4 Predicted outcome

The implementation of a VMP, and the use of trained MFOs on construction vessels, together with the mitigation measures outlined above, will reduce the risk of marine fauna being struck by vessels throughout construction and operation of the Project. Therefore, it is considered that vessel and dredging operations will not present a risk of significant impact to the biological diversity or ecological integrity of marine fauna populations in the region.

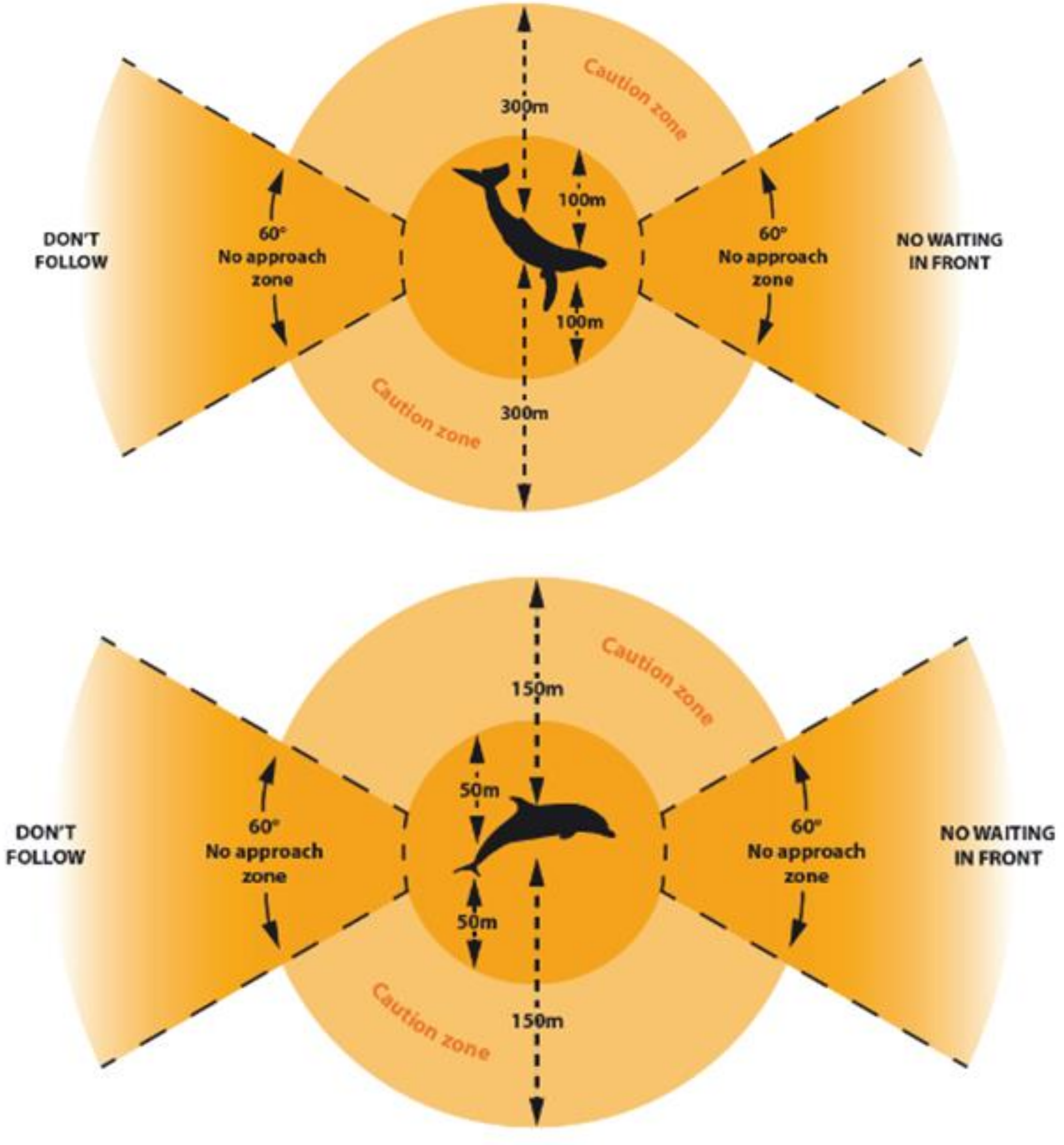

Figure 32 DoEE Guidelines on approach distances for whales (top) and dolphins (bottom) (Source: DoEE 2017)

7.9 Assessment of Altered Nutrient Inputs

7.9.1 Description of potential impacts

Within Exmouth Gulf and the local project catchment, significant biological productivity occurs along the eastern seashore where a system of intertidal and vegetated nearshore areas generate migrations (e.g. of prawns and fish) and movement of organic material (detritus) supporting biological productivity further up the food chain.

Altering nutrient pathways, sources and sinks in intertidal and subtidal areas, has the potential to affect primary and secondary productivity. Local ecosystems are nitrogen limited (Water Technology, 2021b). Therefore, ensuring nitrogen flows into and out of key habitat types is not significantly affected by the proposed Project, is important to the ongoing health of these intertidal and subtidal ecosystems.

7.9.2 Assessment of potential impacts

Water Technology (2021b) undertook a detailed Nutrient Pathways Assessment and Modelling study to:

- Develop a conceptual nutrient pathway model (descriptive diagram – Figure 11) and nutrient budget.
- Develop a numerical model simulating nutrient pathways related to tidal inundation and overland flows.
- Undertake project related impact assessment regarding nutrient pathways including:
  - Modelling impacts to tidal inundation and overland flow nutrient pathways.
  - Calculating nutrient loss, due to habitat loss.

The assessment focussed on nitrogen as previous studies and monitoring conducted for the project indicated it is the key limiting nutrient for local and regional marine and intertidal ecosystems. The assessment was very conservative because:

- Conservative nitrogen import and leaching rates were applied.
- Months which have limited inundation due to seasonally lower water levels were not considered, therefore increasing the potential nitrogen exports from algal mats.
- The annual estimate for nitrogen contribution from offshore waters was conservative, ignoring tidal exchange and using lower observed levels of ocean upwelling.
- The modelling results represent changes to nitrogen exports from the mouth of Urala Creek North and South only and did not account for altered overland flow paths which may result in some nutrients being exported via different land/water interfaces.
- The design rainfall events used were considered extremely conservative as they applied a spatially constant rainfall rate over the entire model domain, which in reality would be very unlikely to occur due to the vast extent of the catchment.
- Estimated habitat modification areas were conservative with larger disturbance areas than expected being included in the salt flats and hinterland.
- Nitrogen losses associated with modelled overland flows and habitat modification overlap in the salt flats, and therefore were accounted for twice.

The full findings of the study are presented within a separate report by Water Technology (2021b). The study predicted small impacts to nutrient pathways in proportion to the total estimated nutrient flows into the project catchment and Exmouth Gulf. Water Technology (2021b) estimated:

- A local post-development proportional reduction in nitrogen flows into the project catchment of 0.8% of land and ocean sources.
- A regional post-development proportional reduction in nitrogen flows into Exmouth Gulf of 0.24% of land and ocean sources.

Based on this highly conservative assessment, it can be concluded that the proposed development will not significantly alter nutrient exports or pathways due to the small scale of the predicted reductions and their infrequent nature, particularly when compared to the overall nitrogen budget of Exmouth Gulf. Impacts related to nutrient pathways are not predicted to compromise existing environmental values including intertidal or subtidal BCH, primary or secondary productivity or marine fauna.

7.9.3 Mitigation measures

Breakouts from the Ashburton River, combined with local runoff create sheet flow conditions across the lower catchment and flows that pass through the dune field and enter the salt flats near the proposed Project, are generally conveyed along more defined flow paths (Water Technology 2021b). Surface water modelling has been used to design drainage diversion and culvert locations for re-directing surface water flows around the Project. This will ensure that some nutrients are still exported around the project footprint via different land/water interfaces.

A Surface Water Management Plan (SWMP) will be implemented to further assess potential changes to surface water and nutrient flows and concentrations. The SWMP will include revised surface water modelling including borrow pits and final culvert /drainage diversion designs to minimise impacts and maintain environmentally important surface water regimes, particularly those important to samphire. The SWMP will include a weather station to monitor rainfall and climatic conditions as well as quarterly and rainfall event-based estuarine and surface water flow/volume and quality monitoring.

7.9.4 Predicted outcome

The salinity conditions required for the survival of mangroves along the Pilbara coast are maintained by tidal inundation and not by freshwater sources such as the fluvial input from the hinterland. Hence, no impacts to mangroves are predicted to occur due to Project-related modification to overland flows. Modelling of coastal hydrodynamics predicts that there will be no changes to tidal inundation patterns within mangroves and algal mats.

The nutrient pathway modelling indicates that the nutrient-related changes are small in proportion to the total estimated nutrient flows into the local catchment and Exmouth Gulf with offshore sources of nutrient being by far the largest source of nutrients. Based on the modelling conducted, it can be concluded that the proposed development is not predicted to significantly alter nutrient exports or pathways due to the small scale of the predicted reductions and their infrequent nature, particularly when compared to the overall nitrogen budget of Exmouth Gulf. Impacts related to nutrient pathways are not predicted to compromise existing environmental values including intertidal and subtidal BCH primary or secondary productivity.

7.10 Assessment and Management of Accidental Release of Hydrocarbons

7.10.1 Description of sources of impacts

The accidental release of fuel, oil, waste and chemicals all have the potential to negatively impact fish, marine mammals, turtles and seabirds due to smothering. This can cause toxicity or inhibition of normal behaviours (e.g. feeding and egg laying) and ultimately lead to mortality.

Minor hydrocarbon spills may occur as a result of leaking hydraulic hoses, equipment, storage containers, or spillages during refuelling/bunkering. The type of accidental release most likely to occur during the Project would be as a result of bunkering fuel at the jetty. Spill volumes for this kind of event are typically small (e.g. less than 7 tonnes, as per ITOPF [International Tanker Owners Pollution Federation] definitions).

It is expected that Project vessels will use either marine diesel or natural gas as fuel. Diesel will typically undergo rapid dispersion and evaporation if released into the marine environment when subjected to wave action, winds, currents and light, as well as degradation via bacterial action. Consequently, any small releases are likely to break up and disperse in a short space of time. Larger spills have the potential to impact flora and fauna.

The potential sources of hydrocarbon spills to the marine environment from the Project include:

- vessel discharges;
- vessel spills – e.g. hydraulic fluids or fuel from piling barge or dredge;

- vessel collisions; and
- refuelling or maintenance of the transhipment vessel.

7.10.2 Assessment of potential impacts

Given the number of Project vessels which are anticipated during the construction phase of the Project, it is possible that unplanned spills may occur, though these spills would be expected to be small in scale.

Potential impacts from spills to marine fauna may include:

- potential oiling of fauna (particularly seabirds) leading to injury of mortality;
- loss or disturbance to critical habitat to marine fauna; and
- toxic effects to marine fauna.

Fish, marine mammals, marine reptiles and seabirds that come into contact with marine diesel may be directly affected. A diesel spill may also result in the localised mortality of planktonic organisms as they are unable to move away from affected areas.

Within this area there is potential for fish, marine mammals, marine reptiles and seabirds to be affected by acute toxicity of diesel, however given the localised nature of a single spill trajectory and the fact that the majority of species are highly mobile, avoidance behaviour would be likely and high levels of mortality of fish and other species is not predicted.

The potential impacts of the diesel spill from bunkering and the pedestal tank are likely to be similar to those described for the diesel spill from a vessel collision, though at a much more localised scale due to the smaller volume and duration of the spill.

7.10.3 Mitigation measures

Mitigation measures to reduce the potential for releases of hydrocarbons to the marine environment will be documented with a Hydrocarbon and Spill Management Plan (HSMP) and will include:

- Implementation of Marine Order 30 (prevention of collisions) 2016 of the Commonwealth *Navigation Act 2012*, including;
  - adherence to steering and sailing rules including maintaining lookouts (e.g. visual, hearing, radar, etc.), proceeding at safe speeds, assessing risk of collision and taking action to avoid collision (monitoring radar).
  - adherence to navigation light display requirements, including visibility, light position/shape appropriate to activity.
  - adherence to navigation noise signals as required.
- Implementation of Marine Order 21 (safety of emergency arrangements) 2016, including;
  - adherence to minimum safe manning levels.
  - maintenance of navigation equipment in efficient working order (compass/radar).
  - navigational systems and equipment required are those specified in Regulation 19 of Chapter V of Safety of Life at Sea.
  - Automatic Identification System (AIS) that provides other users with information about the vessel's identity, type, position, course, speed, navigational status and other safety-related data.
- Marine Order 91 (marine pollution prevention—oil) 2014, requires Shipboard Oil Pollution Emergency Plan (SOPEP) (as appropriate to vessel class).
- Notification of dredging and piling activities and movements to allow generation of navigation warnings (Maritime Safety Information Notifications [MSIN] and Notice to Mariners [NTM]).
- Spill kits positioned in high risk locations on the jetty and on vessels.
- Project vessels will have self-containing hydraulic oil drip tray management systems.

7.10.4 Predicted outcome

With the implementation of a Construction Environmental Management Plan (CEMP) and VMP, it is considered that the risk of accidental releases of hydrocarbons will be sufficiently low that they will not present a risk of significant impact to the biological diversity or ecological integrity of marine fauna populations in the region.

7.11 Assessment and Management of IMP

7.11.1 Description of sources of impacts

Because of the small number of vessels involved, there will be limited potential for IMP introduction resulting from the Ashburton Salt Project.

Potential vessels required during the construction phase include:

- backhoe or cutter suction dredge;
- barges and offshore support vessels; and
- small vessels for local transport.

Potential vessels required during the operational phase include:

- transhipment vessel;
- Panamax oceangoing vessels for salt export; and
- small vessels for local transport.

7.11.2 Assessment of potential impacts

The vessels have two potential introduction nodes for IMP:

- ballast water; and
- biofouling.

There are clear Australian and Western Australian government protocols for managing the risk of both ballast water and biofouling. These protocols will be followed for all vessels mobilised for the Ashburton Salt Project.

7.11.2.1 Ballast water

Ballast water and ballast tank sediments are managed by the Australian Commonwealth to comply with the requirements of:

- *Commonwealth Biosecurity Act 2015.*
- International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Convention).

DAWE (2020b) provides detailed information on meeting the Australian ballast water management requirements. Several key documents are required by each vessel and are explained in detail in DAWE (2020b):

- a valid Ballast Water Management Plan;
- a valid International Ballast Water Management Certificate;
- vessels with a Ballast Water Management System (BWMS) must carry a Type Approval Certificate specific to the type of BWMS installed; and
- a complete and accurate record of all ballast water movements.

Voluntary adherence to the Australian ballast water management protocols commenced in 1991 and compliance became mandatory in 2001, so they are well known to vessel operators. However, regulations change from time to time and the latest version of DAWE (2020b) should be consulted early in the planning phase for any vessel mobilising to the Ashburton Salt site to ensure all current requirements are met. There have been two major changes to ballast water management protocols in recent years:

- in line with international practice, Australia is moving to vessels using a BWMS rather than exchanging high risk for low risk ballast water in the open sea
- domestic ballast water is now also managed.

Vessels intending to discharge internationally sourced ballast water must submit a Ballast Water Report through the Maritime Arrivals Reporting System (MARS) at least 12 hours prior to arrival. It is strongly recommended by DAWE that high risk ballast water not be brought into Australian waters even if there is no intention to release it as there may be changes in plans which require release of the ballast water.

7.11.2.2 Biofouling

The Australian Government has issued two biofouling management guidelines that are relevant to the Ashburton Salt Project:

- National biofouling management guidelines for commercial vessels (MPSC 2018a).
- National biofouling management guidelines for non-trading vessels (MPSC 2018b).

These are generalised guidelines that should be followed. The Fisheries section of DPIRD initially managed biofouling issues in Western Australia under the *Fish Resources Management Act 1994*, which was replaced by the *Aquatic Resources Management Act 2016* (ARMA). DPIRD has developed a Vessel Check system for assessing the IMP risk of vessels entering Western Australian state waters. This will be used to help manage the IMP risk of vessels operating on the Ashburton Salt Project.

7.11.3 Mitigation measures

7.11.3.1 IMP risk minimisation

All vessels working on the Ashburton Salt Project will comply fully with both ballast water and biofouling management protocols.

Ballast water management will be undertaken in accordance with Australian Government protocols detailed in the latest version of Australian ballast water management requirements.

To manage biofouling risk, vessels mobilising to the project will register for Vessel Check and complete the online risk assessment. Vessels assessed as low risk by Vessel Check will mobilise. Vessels assessed as medium or high risk by Vessel Check will be inspected and any required remedial action undertaken before mobilisation.

7.11.3.2 Introduced Marine Pest Monitoring and Management Plan (IMPMMP)

The project will develop an appropriate IMP Monitoring and Management Plan (IMPMMP) to reduce the risk of pest and/or disease introduction and proliferation. The resulting pest management strategy will include IMP mitigation prior to entry of vessels into State waters and IMP monitoring and reporting, with the aims of:

a. preventing the establishment and proliferation of IMPs;

b. control (and eradication) any IMP that has established and proliferated; and

c. minimising transfer of any established IMPs further within Western Australia.

7.11.3.3 Response to IMP detection

Any IMP, or potential IMP species, detected in Western Australian waters will be reported to the Fisheries section of DPIRD within 24 hours on the Fishwatch number (1800 815 507) or aquatic.biosecurity@dpird.wa.gov.au. DPIRD must also be notified within 24 hours if the identification of any potential IMP species is subsequently confirmed.

7.11.4 Predicted outcome

With the implementation of an appropriate IMPMMP and the government regulations surrounding IMP controls and management, the risk of IMP impacting the biological diversity and or ecological integrity of marine fauna habitat is considered negligible.

8.0 Summary of Impacts, Mitigation Measures and Predicted Outcomes

8.1 Summary of Direct and Indirect Impacts

The EPA's objective for marine fauna is to protect them so that biological diversity and ecological integrity are maintained and, as part of the approvals and regulatory framework, proponents are expected to mitigate potential impacts by following a hierarchy of mitigation principles (i.e. Avoid, Minimise, Rehabilitate and Offset).

The mitigation measures that have been detailed in this assessment have been derived according to this hierarchy and as per best practice guidelines. These have been summarised in Table 20 and described in more detail in the preceding sections.

8.2 Cumulative Impact Assessment

8.2.1 Within Exmouth Gulf

It is noted that potential impacts to the Gulf from the Ashburton Salt Project are limited due to the Project's North-eastern Exmouth Gulf location and limited interface with Exmouth Gulf itself. The only feasible potential impacts would arise from changes to nutrient inputs; though, as described in Section 7.9 (and the reports cited therein), the contribution of nutrients from terrestrial sources to the eastern side of the Gulf is estimated to be far less than the contribution of nutrients from ocean upwelling and impacts predicted due to the project are small as follows (Water Technology 2021b):

- A local post-development proportional reduction in nitrogen flows into the project catchment of 0.8% of land and ocean sources.
- A regional post-development proportional reduction in nitrogen flows into Exmouth Gulf of 0.24% of land and ocean sources

Hence, it is considered that the Project does not pose a risk of contributing to cumulative impacts upon marine fauna within the Gulf. Further, there have been no past developments, there are no current developments, and there are no reasonably foreseeable future developments, in the vicinity of that portion of the Project area that abuts Exmouth Gulf to which potential Project impacts upon marine fauna could be considered cumulative.

8.2.2 External to Exmouth Gulf

Outside of Exmouth Gulf, there are no past developments, or reasonably foreseeable future developments, in the immediate vicinity of the Project area to which potential Project impacts upon marine fauna could be considered cumulative.

The only current developments for which it can feasibly be considered that the Project could represent a source of potential cumulative impact are the Wheatstone LNG plant and accommodation village, and the Macedon gas treatment plant, all of which are some 20-25 km to the north-east of the Project. As discussed in Section 7.6, light spill from the Project will be additive to the light generated at the other three sources. However, given the relatively low magnitude of light spill from the Project, in comparison to the light from the other three sources, it is considered that the Project will not contribute significantly to the overall light climate in the region, and therefore will not raise the risk of significant impacts upon marine fauna (from light spill) to a substantially greater degree than presently exists in the region.

Current activities in the vicinity of the jetty, the ocean going vessel loading anchorages, and the transhipment vessel route between them, primarily comprise vessel movements. These may be recreational vessels (e.g. those transiting between fishing locations) or commercial vessels (e.g. transiting between Exmouth and ports to the east, or vessels engaged in commercial fishing activities). Transhipment vessel movements and Panamax loading will add to the potential for noise disturbance to, and vessel strike upon, marine fauna (as discussed in Section 7.5 and Section 7.8.2, respectively).

However, it is considered that the frequency of transhipment vessel movements and ocean going vessel loading, in conjunction with existing vessel movements, will be insufficiently great to pose a risk of significant impacts upon marine fauna within the Project area of operation. Therefore, the Project is not expected to significantly contribute to cumulative impacts due to vessel movements.

Ocean going vessels will be loaded whilst anchored at the Transhipment Area approximately 14 nm offshore (see Figure 1). Within the transhipment area, suitable anchorage areas will be designated in sandy areas to ensure sufficient anchor holding capacity. These areas will be identified through a combination of bathymetric and side scan sonar survey. Once target locations have been selected, video footage of the seabed will be taken at each location to confirm substrate is sand, with sparse to nil benthic habitat present. Final site selection will be done in consultation with PPA. Selection of transhipment points and management of transhipment operations will be covered within the VMP K+S is confident of achieving no loss of benthic communities and habitats in the anchorage area. In addition, the IMPMMP will reduce, to the extent practicable, the risk of introducing marine pests to the Project area. Therefore, the anchorage of ocean going vessels is not expected to present a risk of significant impacts to the surrounding marine environment.

The area of marine fauna habitat that is likely to be impacted as a result of the Project is negligible when compared to the availability of similar habitat in the surrounding areas:

- Mangroves – habitat for juvenile green turtles (4.57 ha loss, 0.85% of LAU, 0.04% of East Exmouth Gulf habitat).
- Soft sediment (nearshore) – habitat for turtles, dugong, green sawfish and other elasmobranchs (3.97ha loss, 0.08% of LAU, <0.01% of East Exmouth Gulf habitat).
- Sandy beach - turtles nesting habitat (0.99 ha loss of low quality nesting habitat (0.78% of LAU, 0.10% of Exmouth Gulf habitat).
- Offshore waters - habitat for humpback whales, dolphins, turtles, elasmobranchs (no habitat loss).

There are large areas of suitable surrounding habitat which are easily accessible to highly mobile marine fauna species and therefore it is considered that there is no potential for significant impacts upon the biological diversity and ecological integrity of marine fauna habitat and / or marine fauna populations in the region as a result of potential habitat loss. In comparison to disturbance of subtidal benthic habitat in the region (such as the Wheatstone dredging program which was of much larger scale) the Ashburton Salt Project will not contribute significantly to the cumulative disturbance of subtidal BCH in the region, and therefore will not raise the risk of significant impacts upon marine fauna to a substantially greater degree than presently exists in the region.

Table 20 Summary of potential impacts on marine fauna

Environmental Value	Potential Direct Impact	Potential Indirect Impact	Mitigation Measures	Predicted Outcome
Marine fauna habitat	• Permanent removal of 226.39 hectares of potential marine fauna habitat as a result construction of the jetty and dredging of the berth pocket. • 4.28 ha direct loss of mangroves due to construction of the seawater intake. • 0.99 ha of direct loss of sandy beach (low quality turtle nesting habitat due to jetty construction.	• Indirect impact to of marine fauna habitat due to the dredging and bitterns related discharges. • Indirect impact of mangroves due to the barrier effect of the seawater intake. • Potential smothering of foraging habitat as a result of the dredge plume, however the risk of this is considered low and not considered to persist longer than a week after dredging cessation (AECOM 2021a). • Potential indirect impacts to low quality turtle nesting beaches due to hatchling attraction to lighting at night.	• Optimisation of project design to minimise impacts to BCH. • Implementation of a DDSMP and a BDEMMP to minimise disturbance of marine fauna habitat to the extent practicable. • Implementation of a LMP to minimise potential for turtle hatchling attraction to lighting at night.	The Project will result in significant loss of Critical Habitat for several protected marine species including, green sawfish, giant guitar fish, green turtle, and dugong. However, the area of marine fauna habitat that is likely to be impacted as a result of the project is negligible when compared to the availability of similar habitat in the surrounding areas (AECOM, 2021a): • <0.01% of Exmouth Gulf subtidal habitat. • 0.04% of Mangroves of Exmouth Gulf East • 0.10% of sandy beaches along Exmouth Gulf East and offshore islands. There are large areas of suitable surrounding habitat which will be easily accessible to highly mobile marine fauna species and therefore it is considered that there is no potential for significant impacts upon the biological diversity and ecological integrity of marine fauna habitat and / or marine fauna populations in the region as a result of potential habitat loss.
Marine mammals Humpback whale, dolphins and dugongs (note habitat loss covered in first row of this table)	• Potential vessel strike. Potential entrapment or injury in seawater intake.	• Potential for hearing related damage or behavioural responses as a result of underwater noise (in particular piling). • Potential smothering of foraging habitat as a result of the dredge plume, however the risk of this is considered low and not considered to persist longer than	• Conducting underwater noise generating activities (piling and dredging) outside of the southern migration period for humpback whales (September to November). • Implementation of an UNMP that details mitigation measures to reduce the potential for impacts to marine fauna, such as designated	Soft sediment habitat will be disturbed as a result of construction of the jetty and berth pocket. This is potential seagrass habitat (though no seagrass was recorded in this area during surveys) and thus may be foraging habitat for dugongs. However, due to the relatively small area that will be impacted in comparison to the available habitat in the surrounding area, the highly mobile nature of marine mammal species, and the implementation of appropriate

Environmental Value	Potential Direct Impact	Potential Indirect Impact	Mitigation Measures	Predicted Outcome
		a week after dredging cessation (AECOM 2021a).	safety zones, MFO procedures, noise procedures (such as soft starts) and limitations on when underwater noise generating activity can occur. • Implementation of a VMP that details designated speed limits, marine fauna observation records, approach distances etc. • Implementation of a DDSMP which details mitigation measures to reduce the potential for marine fauna interactions with the dredge head/bucket, sediment controls and MFO procedures. • Seawater intake and screen design to minimise entrapment risk, pump velocity below USEPA (2014) Guideline and monitoring for entrapment during commissioning with remedial action if necessary.	mitigation measures and management plans, it is considered that there is no potential for significant impacts upon the biological diversity and ecological integrity of marine mammal populations in the region.
Marine reptiles Turtles and sea snakes (note habitat loss covered in first row of this table)	• Death or injury as a result of vessel strike or interaction with dredge head. • Potential entrapment or injury in seawater intake. • Potential attraction/ alteration in marine turtle hatchling and adult nesting	• Potential for hearing related damage or behavioural responses as a result of underwater noise (in particular piling). • Increased predation of turtle hatchlings under the jetty due to increased abundance of predators sheltering under the jetty structure.	• Implementation of a DDSMP which details mitigation measures to reduce the potential for marine fauna interactions with the dredge head/bucket, sediment controls and MFO procedures. • Conducting underwater noise generating activities (piling and dredging) outside of turtle mating and nesting seasons (October to January).	The Project is located in an area of low-density nesting for flatback turtles, though a considerable number of turtles were recorded foraging in the nearshore and creek habitats. However, with the implementation of appropriate mitigation measures and management plans, the low numbers of nesting turtles, and the availability of suitable foraging habitat in the wider region, the Project is not anticipated to have a negative impact on the biological

Environmental Value	Potential Direct Impact	Potential Indirect Impact	Mitigation Measures	Predicted Outcome
	behaviour as a result of light spill.		• Implementation of an UNMP that details mitigation measures to reduce the potential for impacts to marine fauna, such as designated safety zones, MFO procedures, noise procedures (such as soft starts) and limitations on when underwater noise generating activity can occur. • Implementation of a VMP that details designated speed limits, marine fauna observation records, approach distances etc. • Implementation of a LMP that details lighting requirements and management measures to reduce light spill. • Seawater intake and screen design to minimise entrapment risk, pump velocity below USEPA (2014) Guideline and monitoring for entrapment during commissioning with remedial action if necessary.	diversity or ecological integrity of turtle populations in the region.
Elasmobranchs and bony fish Sawfish, sharks, rays and bony fish (note habitat loss covered in first row of this table)	• Death or injury as a result of vessel strike or interaction with dredge head/bucket. • Potential entrapment or injury in seawater intake.	• Potential for localised short-term turbidity increases due to 2 week dredging program. • Potential for hearing related damage or behavioural responses as a result of underwater noise (in particular piling).	• Implementation of a DDSMP which details mitigation measures to reduce the potential for marine fauna interactions with the dredge head/bucket, sediment controls and MFO procedures. • Implementation of an UNMP that details mitigation measures to reduce the	There is a potential for the Project to impact on protected sawfish species due to project infrastructure proximity to foraging and nursery areas identified in both Urala Creek North and Urala Creek South. However, with implementation of appropriate mitigation measures, it is considered that the potential for impacts to protected elasmobranch species can be minimised and the biological

Environmental Value	Potential Direct Impact	Potential Indirect Impact	Mitigation Measures	Predicted Outcome
		• Potential alteration of movement pathways as a result of jetty construction. • Potential alteration to nursery habitat in Urala Creek South as a result of the seawater intake operations.	potential for impacts to marine fauna, such as designated safety zones, MFO procedures, noise procedures (such as soft starts) and limitations on when underwater noise generating activity can occur. • Implementation of a VMP that details designated speed limits, marine fauna observation records, approach distances etc. • Conducting underwater noise generating activities (piling and dredging) outside of sawfish pupping season, believed to occur between September and November. • Seawater intake and screen design to minimise entrapment risk, pump velocity below USEPA (2014) Guideline and monitoring for entrapment during commissioning with remedial action if necessary.	diversity and ecological integrity of local sawfish habitat.
Commercial species Prawns (note habitat loss covered in first row of this table)	• Entrainment of larval and juvenile phases of commercial prawn species by seawater intake.	• Reduced nutrient inputs into Exmouth Gulf ecosystem.	• Project designed to minimise impacts to nutrient pathways. • Intake pump designed to achieve the USEPA (2014) recommended 0.15 m/s pump speed to reduce the potential for entrainment and entrapment of motile species.	Water Technology (2021b) found that the project will not significantly impact nutrient flows into Exmouth Gulf given the majority of nutrients come from ocean upwelling and tidal exchange which will not be affected by the project. Entrainment of larval and juvenile phases of commercial prawn species is being considered in a separate modelling exercise being undertaken in addition to the PER

Environmental Value	Potential Direct Impact	Potential Indirect Impact	Mitigation Measures	Predicted Outcome
				process to be delivered to DPIRD as the manager of the prawn fisheries.
Biological Integrity and Diversity Introduced Marine Pests	• None predicted.	• Potential for introduction of IMPs to the region as a result of vessel movements.	• Implementation of an IMPMMP that will include measures to: - reduce the potential for establishment and/or proliferation of IMPs - potentially control (and eradicate) any IMP that has established and/or proliferated - minimise the risk of transfer of any established IMPs further within Western Australia. • Implementation of a VMP that details the controls regarding ballast water in accordance with government protocols.	With the implementation of an appropriate IMPMMP, and the government regulations surrounding IMP controls and management, it is considered that there will be negligible risk of the introduction of IMP that could significantly impact upon the biological diversity and/or ecological integrity of marine fauna habitat in the region.

8.3 Mitigation of Potential Impacts

Measures by which K+S has mitigated potential impacts to marine fauna are summarised below.

8.3.1 Avoidance of impacts on marine fauna

K+S has undertaken significant design optimisation to minimise the potential for environmental impacts, both direct and indirect on marine fauna. These include detailed analysis of:

- Seawater intake options and locations.
- Bitterns disposal options and locations.
- Dredging options and dredged material disposal.
- Product transhipment methodology and options.

As a result of design optimisation, the following design measures to avoid impacts have been applied:

- Reduction in size of development envelopes.
- Reduction in size of evaporation pond and support infrastructure footprint.
- Optimisation of jetty location and alignment moving into deeper water, to achieve improved bitterns mixing and reduce dredging requirements.
- Optimisation of seawater intake to minimise footprint and reduce pump velocity.
- Transhipping with low draft transhipment vessels to avoid dredging a large shipping channel.
- Land disposal of dredge spoil to minimise marine sediment impacts.
- Design of a diffuser to achieve the best practicable dilution of bitterns discharged to the marine environment.
- Minimisation of disturbance of BCH including locating the majority of disturbance away from mangrove habitat.

8.3.2 Minimisation of impacts to marine fauna

The following principles have been considered in the minimisation of impacts to marine fauna:

- Timing of impacting processes such as pile driving and dredging outside of key ecological windows (whale migration, turtle mating and nesting season and sawfish pupping).
- The use of Turtle Exclusion Devices during dredging operations.
- Optimisation of lighting implementing best practice lighting guidelines and turning off lighting on the jetty and other infrastructure (such as the conveyor) when not in use to reduce light spill.
- Implementation of marine fauna observation procedures, so to make sure that protected marine fauna species presence is monitored at all times during construction.
- Implementation of speed limits to avoid marine fauna collisions.
- Ensuring that the seawater intake pump velocity does not exceed 0.15m/s and screening of intake well so to minimise the likelihood of fauna entrapment.

In addition to avoidance and minimisation of loss by consideration of design options, the proponent's approach to the EIA process has been to undertake rigorous assessments for key factors to enable realistic predictions of potential impacts. Detailed and conservative modelling studies related to coastal hydrodynamics, nutrient pathways, bitterns discharge, dredging-related turbidity, underwater sound and light spill were undertaken to provide for an informed assessment of Project-related changes and potential impacts, while recognising the inherent limitations in the modelling.

8.3.3 Management and monitoring

In addition to measures that will be implemented through the detailed design phase of the Project to avoid and/or minimise impacts to marine fauna (such as detailed lighting design and seawater intake design), a number of management plans will be prepared prior to construction activities taking place to capture additional mitigation measures that will be implemented throughout the construction and operational phases of the Project. Those pertaining to marine fauna are detailed in the following sub-sections.

8.3.3.1 Construction Environmental Management Plan (CEMP)

The CEMP will include management measures to reduce sediment and turbidity related impacts. Such measures are:

- Incorporate a buffer area between the outer disturbance boundary and the outer construction boundary (e.g. toe of the perimeter bund).
- Use of silt curtains during dredging operations where possible.
- Implementation of procedures to reduce the risk of accidental releases, such as use of bunds and correct storage of chemicals etc.

8.3.3.2 Surface Water Management Plan (SWMP)

A SWMP will be implemented to further assess potential changes to surface water and nutrient flows and concentrations. The SWMP will include revised surface water modelling including borrow pits and final culvert /drainage diversion designs to minimise impacts and maintain environmentally important surface water regimes, particularly those important to samphire. The SWMP will include a weather station to monitor rainfall and climatic conditions as well as quarterly and rainfall event-based estuarine and surface water flow/volume and quality monitoring.

8.3.3.3 Dredging and Dredge Spoil Management Plan (DDSMP)

The DDSMP will be developed and approved prior to any dredging taking place. The DDSMP will identify:

- Monitoring to be undertaken of the duration of dredging.
- Specific management measures to be implemented based on trigger levels and results of monitoring.

The management measures to be implemented through the DDSMP will be dependent on the dredging method to be employed and may include:

- Timing dredging to coincide with favourable tidal conditions.
- Reducing the cutter suction dredge or backhoe dredge speed.
- Increasing pump speeds.
- Temporarily suspending dredging.
- Increasing tailwater residence time within the onshore dredged material dewatering pond. Turbidity levels within the pond will be monitored and tailwater will only be released when the level is below a defined trigger level. The latter will be determined on the basis of measured turbidity levels at nearshore reference locations established prior to the commencement of dredging.

It is anticipated that the development and implementation of the DDSMP, including the development of suitable trigger levels based on tolerance limits of sensitive marine habitats, and of management actions in the event of an exceedance of trigger levels, will effectively mitigate the risk of long-term impacts to the ecological function of the BCH in the Project area.

8.3.3.4 Bitterns Discharge Environmental Monitoring and Management Plan (BDEMMP)

A BDEMM will be developed and implemented to mitigate the risk of impacts from bitterns discharge on the receiving environment. The plan will be in line with EPA guidance (EPA 2016d) and will stipulate all aspects of monitoring including, but not limited to, delineation of a mixing zone, monitoring parameters and locations, monitoring frequencies and methods, management triggers, and management responses to trigger exceedances.

8.3.3.5 Underwater Noise Management Plan (UNMP)

An UNMP will be implemented to detailed the mitigation measures to reduce impacts on marine fauna as a result of noise generating activities. The UNMP will provide mitigation measures for all underwater noise sources (piling and dredging) and will include:

- Scheduling Project activities with consideration of key ecological windows for protected marine species (as described in Section 7.4.4).
- Detailing appropriate observation and exclusion zones for the particular noise source.
- Implementation of MFO watch regimes as described in Section 7.5.6.1(dredging) and Section 7.5.6.2(piling), 7.5.6.3 (vessel).
- Limiting underwater noise generating activities to daylight hours, where practicable.

8.3.3.6 Lighting Management Plan (LMP)

A LMP will be implemented to reduce the volume of light spill that is emitted from the project and will detail the following mitigation measures such as:

- Recommendations regarding the number and intensity of lights to be used.
- Adaptive management of lighting such as the colour, intensity and timing of lighting to be used.
- Procedures regarding appropriate positioning of lights.
- Use of non-reflective, dark coloured surfaces.
- Non-essential lighting to be switched off when not in use.
- Use of window blinds on both buildings and vessels to be used between the hours of sunset and sunrise.
- Vessel lighting guidelines

8.3.3.7 Vessel Management Plan (VMP)

A VMP will be implemented to reduce the risk of physical interaction with protected marine species during vessel movements. These measures will apply to the movement of the dredge and piling barge, and to any other vessels engaged during the construction works:

- Vessels will not travel faster than 9 knots
- EPBC Regulations 2000 – Part 8 Division 8.1 Interacting with cetaceans (DoEE 2017);
  - Project vessels will not travel faster than six knots within 300 m of a cetacean or turtle (caution zone) and not approach closer than 100 m from a whale (Figure 32).
  - Project vessels will not approach closer than 50 m for a dolphin or turtle and/or 100 m for a whale (with the exception of animals bow-riding).
  - If the cetacean or turtle shows signs of being disturbed, Project vessels will immediately withdraw from the caution zone at a constant speed of less than six knots.
  - Vessels will not travel faster than eight knots within 250 m of a whale shark and will not approach closer than 30 m to a whale shark.
- Dredging operations will only be undertaken during daylight hours, where practicable.

- If a cutter suction dredge is in operation, rotation of the dredge cutter head will only start when it is positioned near the seafloor, and rotation will be stopped before the cutter is raised through the water column. This will mitigate the risk of contact between a rotating cutter head and protected marine species.
- Vessels will not approach, circle or wait in front of protected marine species for the purposes of casual viewing.
- A watch will be maintained throughout Project operations for stranded, injured or dead marine fauna; if observed, the DBCA Wildcare Helpline (08 9474 9055) will be contacted for advice on retrieval, treatment or post-mortem by the DBCA Parks and Wildlife Service.

8.3.3.8 Hydrocarbon and Spill Management Plan (HSMP)

A HSMP will be developed including prevention and management of marine spills. It will include management measures as outlined in Section 7.10.3.

8.3.3.9 Introduced Marine Pest Monitoring and Management Plan (IMPMMP)

The project will develop an IMPMMP to reduce the risk of pest and/or disease introduction and proliferation. The resulting pest management strategy will include IMP mitigation prior to entry of vessels into State waters and IMP monitoring and reporting, with the aims of:

a. preventing the establishment and proliferation of IMPs;

b. control (and eradication) any IMP that has established and proliferated; and

c. minimising transfer of any established IMPs further within Western Australia.

8.4 Offsets / Benefits

There is a range of environmental benefits to the local coastal ecosystem that may develop due to the presence and operation of the salt ponds. Based on investigations into salt pond ecology, and the results of environmental monitoring at salt fields in the Pilbara, the examples below provide an indication of the environmental benefits that may potentially develop as a result of the Project as described below.

8.4.1 Potential benefits

8.4.1.1 Biological productivity within salt ponds

At both the Dampier and Port Hedland solar salt fields, the pumping of large volumes of seawater into the primary concentration pond, and the movement and concentration (via evaporation) of seawater through a series of subsequent ponds has developed a biological system composed of a sub-set of species from adjacent tidal creeks and nearshore waters (Sammy 1976; DSL 1992; LDM 1996; Fisheries WA 2000; URS 2004).

Seawater pumped from adjacent tidal creeks passes through a screen mesh which allows small crustaceans, plankton and the eggs, larvae and juveniles of fish to pass through the pumps into the primary concentration pond. Individuals that survive passage through the pump system can then develop in the quiescent pond environment. Due to the large areas of the concentration ponds and volumes of water pumped, the abundance of biota such as fish can be considerable. Fisheries WA (2002) has estimated the fish populations to range in mass from 8 – 105 tonnes, depending on the method of estimation.

Some of the biota within the concentration ponds are reported to be important in the salt production process as some species ([e.g. filter-feeding fishes, brine shrimp [*Artemia*]) increase water clarity and therefore evaporation rates within the ponds, making salt production more efficient (Burnard 1991). There are also other species of fish and biota that do not necessarily contribute to water clarity to the same degree as filter feeding fishes (Fisheries WA 2002) but may play a significant role in maintaining the pond ecosystem.

8.4.1.2 Formation of sedimentary deltas within salt ponds – Migratory shorebird habitat

Within the concentration ponds at the Port Hedland salt field, deltas have formed from the accumulation of fine sediments transported into the ponds by the pumping of tidal waters. The deltas support high densities of infauna and thereby attract a large number and diversity of migratory shorebirds (regularly up to 27 shorebird species) (LDM 1998; WABN 2021). Shorebird surveys conducted periodically since the early 1980s have identified the salt ponds as an important stop-over point for migratory shorebirds on the East Asia – Australian Flyway.

The Directory of Important Wetlands in Australia (ANCA 2005) has recognised the value to migratory shorebirds of the sedimentary deltas and shoreline habitats that have formed within the Port Hedland salt ponds. Within the “Human-made wetland” classification, ANCA (2005) identifies the Port Hedland saltworks as a nationally important wetland by meeting the following criteria:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance.

The Port Hedland saltworks are considered a “site of outstanding importance (up to 66,800 counted, national rank 8) for migrant shorebirds particularly during southward migration” (ANCA 2005). The number of waterbirds using the site annually is more than 20,000; allowing for onward movement of migrants, the number would probably exceed 50,000. The site supports at least 1% of the national populations of five abundant shorebird species, as well as the Mongolian plover (up to 668, WA rank 2), red-necked avocet (3000, national rank 10, WA rank 2), marsh sandpiper (500, national rank 4, WA rank 2), and broad-billed sandpiper (6000, national rank 1). The site also supports thousands of feeding Australian pelican, many of which are associated with a breeding colony on North Turtle Island in the Indian Ocean (ANCA 2005).

Birdlife Western Australia conducts annual migratory shorebird surveys at the Pond Hedland salt ponds and has identified that the estuarine ecosystems that have developed within the ponds are:

- A Key Biodiversity Area for red-necked stint and sharp-tailed sandpiper because the saltworks support >1% of the world population for these species.
- Is the most important known Australian site for broad-billed sandpiper and the endangered Asian dowitcher (WABN 2019).

Birdlife Western Australia has also conducted annual migratory shorebird surveys at the Dampier saltworks since 2012 and these surveys have identified the area (particularly Pond 0 and Pond 1A) is a Key Biodiversity Area as they support >1% of the world population for red-necked stint, curlew sandpiper and red-capped plover (WABN 2021).

Similarly, the importance of solar salt operations to shorebirds has been recognised in the recently released *Australian National Directory of Important Migratory Shorebird Habitat* (Weller et al. 2020). This report recognises the following existing salt operations as nationally important shorebird areas:

- Dampier Salt, Karratha
- Dampier Salt (formerly Leslie Salt or Cargill Salt), Port Hedland
- Onslow Salt.

The nearby Onslow salt operation is described by the national directory as follows:

"Onslow is located in the southern extent of the Pilbara region in Western Australia, approximately 1,386 kilometres north of Perth. There is one major salt production facility in Onslow. The surrounding coastal environment is characterised by extensive areas of coastal intertidal sand flats and tidal creeks and inlets. There are several high tide roosting areas for shorebirds utilising the area, as well as significant areas of supratidal claypan. Most of these systems have been modified to control tidal inundation for the production of salt. The saltfield was built by enclosing a vast natural flat area facing the Indian Ocean with sea wall levees. The saltfield encompasses an area of 220 square kilometres, of which 87 square kilometres are occupied by operational ponds. The saltfield's operational ponds are closely interconnected. They consist of six evaporation ponds of 77 square kilometres and 15 crystalliser ponds of 10 square kilometres. Seawater is pumped into the first evaporation pond, and brine flows through most of the evaporation ponds by gravity. Like other expansive salt evaporation facilities in the Pilbara region, the site continues to be a major migration stop-over area for shorebirds in the East Asia-Australasian Flyway. Despite the size of the site, and prevalence of a range of habitats for shorebirds, there is not much structured monitoring data available for the general area. With more data available the area would most likely identify as international significance for several species of migratory shorebird."

On the basis of the information above, it is likely, that if developed, the Ashburton Salt Project would form additional valuable habitat for shorebirds to that existing at the nearby Onslow Salt operation and also be recognised in the future as internationally important shorebird habitat.

8.4.1.3 Creation of habitat from jetty structure

Artificial structures increase habitat diversity by providing 'hard' surfaces in largely 'soft' natural habitats (United States Army Corps of Engineers, 1989, as cited in Derbyshire 2006). These hard artificial surfaces develop diverse, productive biological communities (United States Army Corps of Engineers, 1993, as cited in Derbyshire 2006) and form part of the complex of habitats available locally to fish. Structures such as jetties and seawalls are common in many developed estuaries and bays, and provide potential additional fish habitat over a relatively large spatial scale (Clynick, 2002, as cited in Derbyshire 2006)

Jetties can provide a number of ecological functions, including as:

- substrate for epibiota;
- nursery habitat for juvenile fish;
- adult fish habitat/sanctuary; and
- spawning habitat.

The additional fish habitats provided by artificial structures attract fish for many reasons, including protection from predators, feeding opportunities, shelter from currents, and extra settlement habitat for recruitment. Both the presence of artificial structures and the organisms growing on those structures influence associated fish assemblages. The physical characteristics (material, complexity, size, etc) of the structure also influence fish assemblages. The location of artificial structures is important in encouraging biological exchange between habitats. Exposure of structures to currents carrying larvae and other biological material may be significant (Derbyshire 2006).

There is a potential that the Project jetty over time will increase the habitat diversity of the surrounding area. However, it is also recognised that fish habitat created by the installation of a man made structure, such as a jetty, in areas close to turtle nesting may increase the likelihood of predation of turtle hatchlings, as was identified by Wilson 2019 during a study conducted on Thevenard Island which identified high predation of marine turtle hatchlings near a coastal jetty. However, as the Project is located in an area classified as low quality nesting habitat and low nesting density, it is not anticipated that the presence of the jetty will have a negative impact on turtle populations in the local area.

8.4.1.4 Marine fauna observations

Throughout the construction phase of the project, all marine based activities will have suitably trained marine fauna observers on board vessels recording all marine fauna activity that is spotted in proximity to the Project area, this will include when transiting to and from site. This information will be made publicly available to allow people access to additional information regarding marine fauna activity in the local area.

8.4.2 Potential offsets

The following could be considered as offsets if these are deemed required by the EPA.

8.4.2.1 Provision of prawn modelling to key stakeholders

Independently to the PER process, a modelling exercise is being undertaken with K+S, Water Technology, Murdoch University, DPIRD and Kailis to model potential proportional loss of prawns from the EGPMF as a result of the Project. The results of this prawn modelling exercise are intended to be provided to DPIRD as the managers of the fishery. This modelling exercise is ground-breaking and one of the first of its kind to be conducted in Australia and may be the subject of a scientific paper to be written by DPIRD researchers. It could be considered an offset under the EPA factor Social Surroundings (economic - prawn fishery).

8.4.2.2 Increased understanding of sawfish populations in the local area

The Ashburton River mouth, approximately 30 km north of Urala Creek North, has been identified as an important nursery area for green sawfish (Morgan et al. 2015, 2017). It is likely that sawfish are pupped just outside the river mouth and use the Ashburton River as a nursery for their first several months. When the river floods following storms in summer, acoustic tracking has shown that the young-of-year sawfish leave the river, and while some return after flooding has subsided, others do not (Morgan et al. 2017). It is hypothesized that these sawfish begin to use other nearby tidal creeks along the coastline when the freshwater pulse pushes them out of the Ashburton. As the second and third major creeks found south of the Ashburton, it is likely that Urala Creek North and South are important secondary nurseries for sawfish (Morgan et al., 2020).

The identification of Urala Creek North and South as potential secondary nursery areas for green sawfish as well as nurseries and habitat for several other threatened elasmobranchs was suggested during the 2019 survey, and previous acoustic surveys in Ashburton River indicate that small sawfish (<2.5 m TL) exclusively use shallow habitats and move between creeks using the shallow areas close to shore, likely due to predator avoidance (Morgan et al., 2017). However, very little is understood about the size, importance and habitat use of sawfish populations south of Ashburton River, with the 2019 survey the only research undertaken in this area.

A sawfish monitoring program could be considered as a potential offset for the project under the EPA Factor Marine Fauna.

8.5 Maintenance of Biological Diversity and Ecological Integrity

The marine fauna assessments and associated studies undertaken for this Project demonstrate that the EPA's environmental objective to "protect marine fauna so that biological diversity and ecological integrity are maintained" can be met with the implementation of appropriate management measures and monitoring plans as detailed throughout Section 8.0.

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Appendix A

Commonwealth Protected Matters Search Tool Results

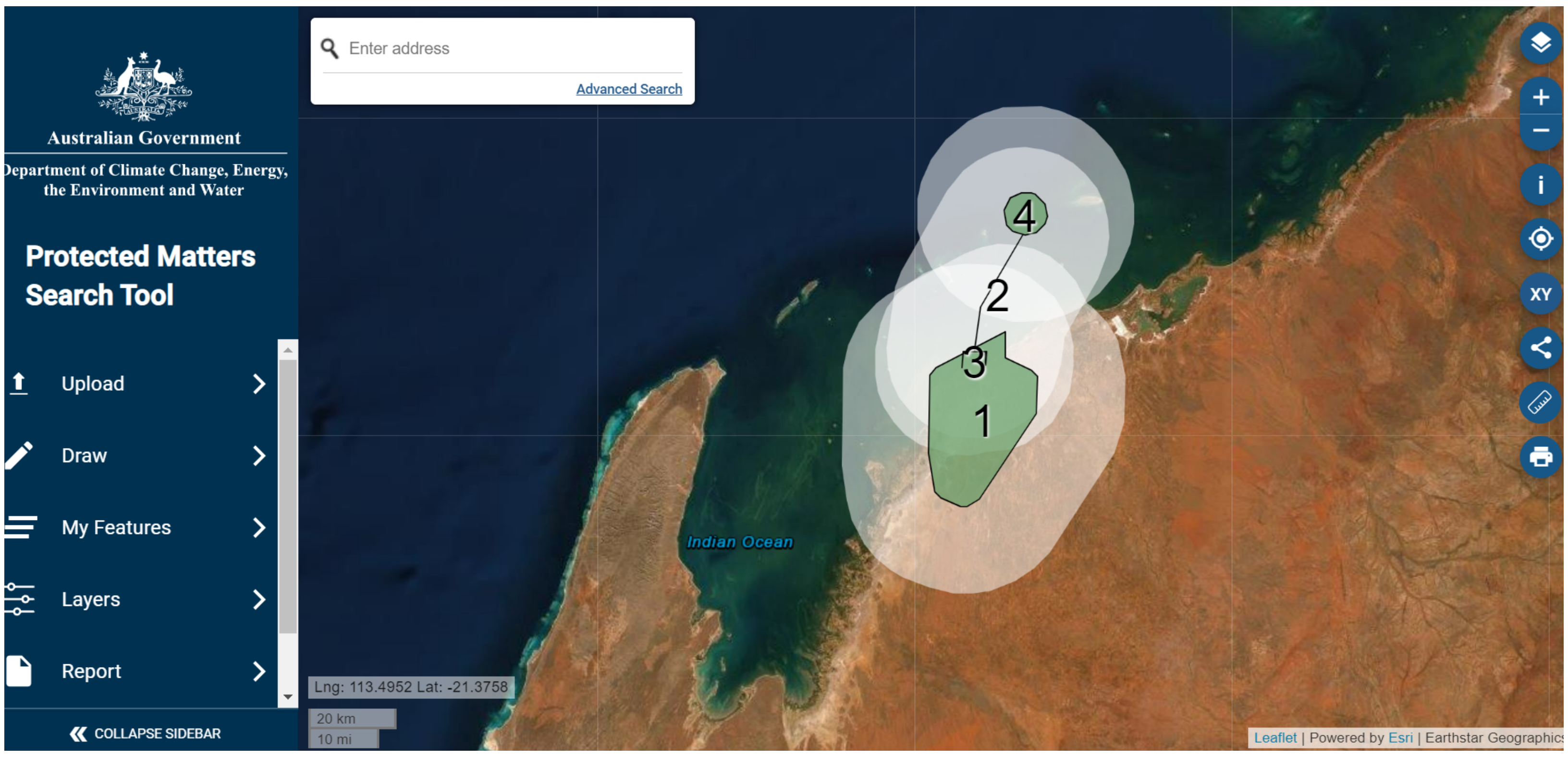
Australian Government

Department of Climate Change, Energy, the Environment and Water

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 28-Oct-2022



Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	1
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	34
Listed Migratory Species:	58

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at https://www.dcceew.gov.au/parks-heritage/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	1
Commonwealth Heritage Places:	None
Listed Marine Species:	91
Whales and Other Cetaceans:	27
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	4

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	10
Regional Forest Agreements:	None
Nationally Important Wetlands:	1
EPBC Act Referrals:	26
Key Ecological Features (Marine):	3
Biologically Important Areas:	18
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

Commonwealth Marine Area [Resource Information]

Approval is required for a proposed activity that is located within the Commonwealth Marine Area which has, will have, or is likely to have a significant impact on the environment. Approval may be required for a proposed action taken outside a Commonwealth Marine Area but which has, may have or is likely to have a significant impact on the environment in the Commonwealth Marine Area.

Feature Name	Buffer Status
EEZ and Territorial Sea	In buffer area only

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area	In feature area
Erythrotriorchis radiatus Red Goshawk [942]	Vulnerable	Species or species habitat may occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Limosa lapponica menzbieri Northern Siberian Bar-tailed Godwit, Russkoye Bar-tailed Godwit [86432]	Critically Endangered	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Macronectes giganteus			
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area	In feature area
Numenius madagascariensis			
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Pezoporus occidentalis			
Night Parrot [59350]	Endangered	Species or species habitat may occur within area	In feature area
Rostratula australis			
Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area	In feature area
Sternula nereis nereis			
Australian Fairy Tern [82950]	Vulnerable	Breeding known to occur within area	In feature area
Thalassarche carteri			
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area	In feature area
Thalassarche impavida			
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area	In buffer area only
FISH			
Thunnus maccoyii			
Southern Bluefin Tuna [69402]	Conservation Dependent	Species or species habitat likely to occur within area	In feature area
MAMMAL			
Balaenoptera borealis			
Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Balaenoptera musculus			
Blue Whale [36]	Endangered	Species or species habitat likely to occur within area	In feature area
Balaenoptera physalus			
Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area	In feature area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area	In feature area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area	In feature area
REPTILE			
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area	In feature area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area	In feature area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area	In feature area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area	In feature area
SHARK			
Carcharias taurus (west coast population) Grey Nurse Shark (west coast population) [68752]	Vulnerable	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area	In feature area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area	In feature area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area	In feature area
Rhincodon typus Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area	In feature area
Sphyrna lewini Scalloped Hammerhead [85267]	Conservation Dependent	Species or species habitat known to occur within area	In feature area

Listed Migratory Species

[Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Ardenna pacifica Wedge-tailed Shearwater [84292]		Breeding known to occur within area	In buffer area only
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area	In feature area
Hydroprogne caspia Caspian Tern [808]		Breeding known to occur within area	In buffer area only
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area	In feature area
Onychoprion anaethetus Bridled Tern [82845]		Breeding known to occur within area	In buffer area only
Phaethon lepturus White-tailed Tropicbird [1014]		Species or species habitat may occur within area	In feature area
Sterna dougallii Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area	In buffer area only
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area	In feature area
Thalassarche carteri Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area	In feature area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Migratory Marine Species			
Anoxypristis cuspidata Narrow Sawfish, Knifetooth Sawfish [68448]		Species or species habitat likely to occur within area	In feature area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area	In feature area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area	In feature area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat likely to occur within area	In feature area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area	In feature area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area	In feature area
Dugong dugon Dugong [28]		Breeding known to occur within area	In feature area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area	In feature area
Eubalaena australis as Balaena glacialis australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area	In feature area
Isurus oxyrinchus Shortfin Mako, Mako Shark [79073]		Species or species habitat likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Isurus paucus Longfin Mako [82947]		Species or species habitat likely to occur within area	In buffer area only
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area	In feature area
Mobula alfredi as Manta alfredi Reef Manta Ray, Coastal Manta Ray [90033]		Species or species habitat known to occur within area	In feature area
Mobula birostris as Manta birostris Giant Manta Ray [90034]		Species or species habitat known to occur within area	In feature area
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area	In feature area
Orcaella heinsohni Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area	In feature area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area	In feature area
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area	In buffer area only
Pristis clavata Dwarf Sawfish, Queensland Sawfish [68447]	Vulnerable	Species or species habitat known to occur within area	In feature area
Pristis pristis Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat known to occur within area	In feature area
Pristis zijsron Green Sawfish, Dindagubba, Narrowsnout Sawfish [68442]	Vulnerable	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Rhincodon typus			
Whale Shark [66680]	Vulnerable	Foraging, feeding or related behaviour known to occur within area	In feature area
Sousa sahulensis as Sousa chinensis			
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area	In feature area
Tursiops aduncus (Arafura/Timor Sea populations)			
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area	In feature area
Migratory Terrestrial Species			
Hirundo rustica			
Barn Swallow [662]		Species or species habitat may occur within area	In feature area
Motacilla cinerea			
Grey Wagtail [642]		Species or species habitat may occur within area	In feature area
Motacilla flava			
Yellow Wagtail [644]		Species or species habitat may occur within area	In feature area
Migratory Wetlands Species			
Actitis hypoleucos			
Common Sandpiper [59309]		Species or species habitat known to occur within area	In feature area
Calidris acuminata			
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area	In feature area
Calidris canutus			
Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area	In feature area
Calidris ferruginea			
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Calidris melanotos			
Pectoral Sandpiper [858]		Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area	In feature area
Charadrius veredus Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area	In feature area
Glareola maldivarum Oriental Pratincole [840]		Species or species habitat may occur within area	In feature area
Limnodromus semipalmatus Asian Dowitcher [843]		Species or species habitat may occur within area	In feature area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area	In feature area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Pandion haliaetus Osprey [952]		Breeding known to occur within area	In feature area
Thalasseus bergii Greater Crested Tern [83000]		Breeding known to occur within area	In buffer area only
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area	In buffer area only

Other Matters Protected by the EPBC Act

Commonwealth Lands [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Commonwealth Land Name	State	Buffer Status
Unknown		
Commonwealth Land - [51887]	WA	In buffer area only

Listed Marine Species [Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area	In feature area
Anous stolidus Common Noddy [825]		Species or species habitat may occur within area	In feature area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
Ardenna pacifica as Puffinus pacificus Wedge-tailed Shearwater [84292]		Breeding known to occur within area	In buffer area only
Bubulcus ibis as Ardea ibis Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area	In feature area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area overfly marine area	In feature area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat likely to occur within area overfly marine area	In feature area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Chalcites osculans as Chrysococcyx osculans			
Black-eared Cuckoo [83425]		Species or species habitat known to occur within area overfly marine area	In feature area
Charadrius leschenaultii			
Greater Sand Plover, Large Sand Plover [877]	Vulnerable	Species or species habitat known to occur within area	In feature area
Charadrius veredus			
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area overfly marine area	In feature area
Chroicocephalus novaehollandiae as Larus novaehollandiae			
Silver Gull [82326]		Breeding known to occur within area	In buffer area only
Fregata ariel			
Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat likely to occur within area	In feature area
Glareola maldivarum			
Oriental Pratincole [840]		Species or species habitat may occur within area overfly marine area	In feature area
Haliaeetus leucogaster			
White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area	In feature area
Hirundo rustica			
Barn Swallow [662]		Species or species habitat may occur within area overfly marine area	In feature area
Hydroprogne caspia as Sterna caspia			
Caspian Tern [808]		Breeding known to occur within area	In buffer area only
Limnodromus semipalmatus			
Asian Dowitcher [843]		Species or species habitat may occur within area overfly marine area	In feature area
Limosa lapponica			
Bar-tailed Godwit [844]		Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Macronectes giganteus			
Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area	In feature area
Merops ornatus			
Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area
Motacilla cinerea			
Grey Wagtail [642]		Species or species habitat may occur within area overfly marine area	In feature area
Motacilla flava			
Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In feature area
Numenius madagascariensis			
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Onychoprion anaethetus as Sterna anaethetus			
Bridled Tern [82845]		Breeding known to occur within area	In buffer area only
Onychoprion fuscatus as Sterna fuscata			
Sooty Tern [90682]		Breeding known to occur within area	In buffer area only
Pandion haliaetus			
Osprey [952]		Breeding known to occur within area	In feature area
Phaethon lepturus			
White-tailed Tropicbird [1014]		Species or species habitat may occur within area	In feature area
Rostratula australis as Rostratula benghalensis (sensu lato)			
Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area overfly marine area	In feature area
Sterna dougallii			
Roseate Tern [817]		Foraging, feeding or related behaviour likely to occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Sternula albifrons as Sterna albifrons			
Little Tern [82849]		Species or species habitat may occur within area	In feature area
Sternula nereis as Sterna nereis			
Fairy Tern [82949]		Breeding known to occur within area	In buffer area only
Thalassarche carteri			
Indian Yellow-nosed Albatross [64464]	Vulnerable	Species or species habitat may occur within area	In feature area
Thalassarche impavida			
Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Thalasseus bengalensis as Sterna bengalensis			
Lesser Crested Tern [66546]		Breeding known to occur within area	In feature area
Thalasseus bergii as Sterna bergii			
Greater Crested Tern [83000]		Breeding known to occur within area	In buffer area only
Tringa nebularia			
Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area overfly marine area	In buffer area only
Fish			
Acentronura larsonae			
Helen's Pygmy Pipehorse [66186]		Species or species habitat may occur within area	In feature area
Bulbonaricus brauni			
Braun's Pughead Pipefish, Pug-headed Pipefish [66189]		Species or species habitat may occur within area	In feature area
Campichthys tricarinatus			
Three-keel Pipefish [66192]		Species or species habitat may occur within area	In feature area
Choeroichthys brachysoma			
Pacific Short-bodied Pipefish, Short-bodied Pipefish [66194]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Choeroichthys latispinosus Muiron Island Pipefish [66196]		Species or species habitat may occur within area	In feature area
Choeroichthys suillus Pig-snouted Pipefish [66198]		Species or species habitat may occur within area	In feature area
Doryrhamphus dactyliophorus Banded Pipefish, Ringed Pipefish [66210]		Species or species habitat may occur within area	In feature area
Doryrhamphus janssi Cleaner Pipefish, Janss' Pipefish [66212]		Species or species habitat may occur within area	In feature area
Doryrhamphus multiannulatus Many-banded Pipefish [66717]		Species or species habitat may occur within area	In feature area
Doryrhamphus negrosensis Flagtail Pipefish, Masthead Island Pipefish [66213]		Species or species habitat may occur within area	In feature area
Festucalex scalaris Ladder Pipefish [66216]		Species or species habitat may occur within area	In feature area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area	In feature area
Halicampus brocki Brock's Pipefish [66219]		Species or species habitat may occur within area	In feature area
Halicampus grayi Mud Pipefish, Gray's Pipefish [66221]		Species or species habitat may occur within area	In feature area
Halicampus nitidus Glittering Pipefish [66224]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Halicampus spinirostris Spiny-snout Pipefish [66225]		Species or species habitat may occur within area	In feature area
Haliichthys taeniophorus Ribboned Pipehorse, Ribboned Seadragon [66226]		Species or species habitat may occur within area	In feature area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area	In feature area
Hippocampus angustus Western Spiny Seahorse, Narrow-bellied Seahorse [66234]		Species or species habitat may occur within area	In feature area
Hippocampus histrix Spiny Seahorse, Thorny Seahorse [66236]		Species or species habitat may occur within area	In feature area
Hippocampus kuda Spotted Seahorse, Yellow Seahorse [66237]		Species or species habitat may occur within area	In feature area
Hippocampus planifrons Flat-face Seahorse [66238]		Species or species habitat may occur within area	In feature area
Hippocampus trimaculatus Three-spot Seahorse, Low-crowned Seahorse, Flat-faced Seahorse [66720]		Species or species habitat may occur within area	In feature area
Micrognathus micronotopterus Tidepool Pipefish [66255]		Species or species habitat may occur within area	In feature area
Phoxocampus belcheri Black Rock Pipefish [66719]		Species or species habitat may occur within area	In feature area
Solegnathus hardwickii Pallid Pipehorse, Hardwick's Pipehorse [66272]		Species or species habitat may occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Solegnathus lettiensis Gunther's Pipehorse, Indonesian Pipefish [66273]		Species or species habitat may occur within area	In feature area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area	In feature area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area	In feature area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area	In feature area
Trachyrhamphus longirostris Straightstick Pipefish, Long-nosed Pipefish, Straight Stick Pipefish [66281]		Species or species habitat may occur within area	In feature area
Mammal			
Dugong dugon Dugong [28]		Breeding known to occur within area	In feature area
Reptile			
Acalyptophis peronii Horned Seasnake [1114]		Species or species habitat may occur within area	In feature area
Aipysurus apraefrontalis Short-nosed Seasnake [1115]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Aipysurus duboisii Dubois' Seasnake [1116]		Species or species habitat may occur within area	In feature area
Aipysurus eydouxii Spine-tailed Seasnake [1117]		Species or species habitat may occur within area	In feature area
Aipysurus foliosquama Leaf-scaled Seasnake [1118]	Critically Endangered	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Aipysurus laevis Olive Seasnake [1120]		Species or species habitat may occur within area	In feature area
Astrotia stokesii Stokes' Seasnake [1122]		Species or species habitat may occur within area	In feature area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Chelonia mydas Green Turtle [1765]	Vulnerable	Breeding known to occur within area	In feature area
Chitulia ornata as Hydrophis ornatus Spotted Seasnake, Ornate Reef Seasnake [87377]		Species or species habitat may occur within area	In feature area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area	In feature area
Disteira kingii Spectacled Seasnake [1123]		Species or species habitat may occur within area	In feature area
Disteira major Olive-headed Seasnake [1124]		Species or species habitat may occur within area	In feature area
Emydocephalus annulatus Turtle-headed Seasnake [1125]		Species or species habitat may occur within area	In feature area
Ephalophis greyi North-western Mangrove Seasnake [1127]		Species or species habitat may occur within area	In feature area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Breeding known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Hydrophis elegans Elegant Seasnake [1104]		Species or species habitat may occur within area	In feature area
Leioselasma czeblukovi as Hydrophis czeblukovi Fine-spined Seasnake, Geometrical Seasnake [87374]		Species or species habitat may occur within area	In buffer area only
Natator depressus Flatback Turtle [59257]	Vulnerable	Breeding known to occur within area	In feature area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area	In feature area

Whales and Other Cetaceans

[Resource Information]

Current Scientific Name	Status	Type of Presence	Buffer Status
Mammal			
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area	In feature area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat likely to occur within area	In feature area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat likely to occur within area	In feature area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area	In feature area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat may occur within area	In feature area

Current Scientific Name	Status	Type of Presence	Buffer Status
Feresa attenuata Pygmy Killer Whale [61]		Species or species habitat may occur within area	In buffer area only
Globicephala macrorhynchus Short-finned Pilot Whale [62]		Species or species habitat may occur within area	In buffer area only
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area	In feature area
Kogia breviceps Pygmy Sperm Whale [57]		Species or species habitat may occur within area	In buffer area only
Kogia sima as Kogia simus Dwarf Sperm Whale [85043]		Species or species habitat may occur within area	In buffer area only
Megaptera novaeangliae Humpback Whale [38]		Breeding known to occur within area	In feature area
Orcaella heinsohni as Orcaella brevirostris Australian Snubfin Dolphin [81322]		Species or species habitat known to occur within area	In feature area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area	In feature area
Peponocephala electra Melon-headed Whale [47]		Species or species habitat may occur within area	In buffer area only
Physeter macrocephalus Sperm Whale [59]		Species or species habitat may occur within area	In buffer area only
Pseudorca crassidens False Killer Whale [48]		Species or species habitat likely to occur within area	In buffer area only

Current Scientific Name	Status	Type of Presence	Buffer Status
Sousa sahulensis as Sousa chinensis			
Australian Humpback Dolphin [87942]		Species or species habitat known to occur within area	In feature area
Stenella attenuata			
Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area	In feature area
Stenella coeruleoalba			
Striped Dolphin, Euphrosyne Dolphin [52]		Species or species habitat may occur within area	In buffer area only
Stenella longirostris			
Long-snouted Spinner Dolphin [29]		Species or species habitat may occur within area	In buffer area only
Steno bredanensis			
Rough-toothed Dolphin [30]		Species or species habitat may occur within area	In buffer area only
Tursiops aduncus			
Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area	In feature area
Tursiops aduncus (Arafura/Timor Sea populations)			
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) [78900]		Species or species habitat known to occur within area	In feature area
Tursiops truncatus s. str.			
Bottlenose Dolphin [68417]		Species or species habitat may occur within area	In feature area
Ziphius cavirostris			
Cuvier's Beaked Whale, Goose-beaked Whale [56]		Species or species habitat may occur within area	In buffer area only

Habitat Critical to the Survival of Marine Turtles

Scientific Name	Behaviour	Presence	Buffer Status
Aug - Sep			
Natator depressus			
Flatback Turtle [59257]	Nesting	Known to occur	In feature area
Dec - Jan			

Scientific Name	Behaviour	Presence	Buffer Status
Chelonia mydas Green Turtle [1765]	Nesting	Known to occur	In feature area
Nov-Feb			
Caretta caretta Loggerhead Turtle [1763]	Nesting	Known to occur	In feature area
Nov - May			
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur	In feature area

Extra Information

State and Territory Reserves

[Resource Information]

Protected Area Name	Reserve Type	State	Buffer Status
Bessieres Island	Nature Reserve	WA	In buffer area only
Burnside And Simpson Island	Nature Reserve	WA	In buffer area only
Gnandaroo Island	Nature Reserve	WA	In buffer area only
Locker Island	Nature Reserve	WA	In buffer area only
Rocky Island	Nature Reserve	WA	In buffer area only
Round Island	Nature Reserve	WA	In buffer area only
Serrurier Island	Nature Reserve	WA	In buffer area only
Tent Island	Nature Reserve	WA	In buffer area only
Thevenard Island	Nature Reserve	WA	In buffer area only
Unnamed WA44665	5(1)(h) Reserve	WA	In buffer area only

Nationally Important Wetlands

[Resource Information]

Wetland Name	State	Buffer Status
Exmouth Gulf East	WA	In feature area

EPBC Act Referrals

[Resource Information]

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Action clearly unacceptable				
Highlands 3D Marine Seismic Survey	2012/6680	Action Clearly Unacceptable	Completed	In buffer area only
Controlled action				

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Controlled action				
Ashburton Infrastructure Project	2021/9064	Controlled Action	Guidelines Issued	In buffer area only
Construct and operate LNG & domestic gas plant including onshore and offshore facilities - Wheatston	2008/4469	Controlled Action	Post-Approval	In feature area
Construction and operation of a Solar Salt Project, SW Onslow, WA	2016/7793	Controlled Action	Assessment Approach	In feature area
Greater Gorgon Development - Optical Fibre Cable, Mainland to Barrow Island	2005/2141	Controlled Action	Completed	In buffer area only
Proposed West Pilbara Iron Ore Project	2009/4706	Controlled Action	Post-Approval	In buffer area only
Yannarie Solar Salt Project	2004/1679	Controlled Action	Completed	In buffer area only
Not controlled action				
Baniyas-1 Exploration Well, EP-424, near Onslow	2007/3282	Not Controlled Action	Completed	In buffer area only
Construct 110km buried natural gas pipeline from Onslow, connecting to Dampier/Bunbury natural gas p	2013/7039	Not Controlled Action	Completed	In buffer area only
HCA05X Macedon Experimental Survey	2004/1926	Not Controlled Action	Completed	In buffer area only
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area
Infill Production Well (Griffin-9)	2001/417	Not Controlled Action	Completed	In buffer area only
Klammer 2D Seismic Survey	2002/868	Not Controlled Action	Completed	In buffer area only
Onslow Rare Earths Plant	2021/9046	Not Controlled Action	Completed	In buffer area only
Subsea Gas Pipeline From Stybarrow Field to Griffin Venture Gas Export Pipeline	2005/2033	Not Controlled Action	Completed	In buffer area only
Thevenard Island Retirement Project	2015/7423	Not Controlled Action	Completed	In buffer area only
Wanda Offshore Research Project, 80 km north-east of Exmouth, WA	2018/8293	Not Controlled Action	Completed	In buffer area only
Not controlled action (particular manner)				

Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Not controlled action (particular manner)				
'Kate' 3D marine seismic survey, exploration permits WA-320-P and WA-345-P, 60km	2005/2037	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
2D and 3D seismic surveys	2005/2151	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Babylon 3D Marine Seismic Survey, Commonwealth Waters, nr Exmouth WA	2013/7081	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Harpy 1 exploration well	2001/183	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Huzzas MC3D Marine Seismic Survey (HZ-13) Carnarvon Basin, offshore WA	2013/7003	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Huzzas phase 2 marine seismic survey, Exmouth Plateau, Northern Carnarvon Basin, WA	2013/7093	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Macedon Gas Field Development	2008/4605	Not Controlled Action (Particular Manner)	Post-Approval	In feature area
Munmorah 2D seismic survey within permits WA-308/9-P	2003/970	Not Controlled Action (Particular Manner)	Post-Approval	In buffer area only
Ocean Bottom Cable Seismic Survey	2005/2017	Not Controlled Action (Particular Manner)	Post-Approval	In feature area

Key Ecological Features [Resource Information]

Key Ecological Features are the parts of the marine ecosystem that are considered to be important for the biodiversity or ecosystem functioning and integrity of the Commonwealth Marine Area.

Name	Region	Buffer Status
Ancient coastline at 125 m depth contour	North-west	In buffer area only
Canyons linking the Cuvier Abyssal Plain and the Cape Range Peninsula	North-west	In buffer area only

Name	Region	Buffer Status
Continental Slope Demersal Fish Communities	North-west	In buffer area only

Biologically Important Areas

Scientific Name	Behaviour	Presence	Buffer Status
Dugong			
Dugong dugon Dugong [28]	Breeding	Known to occur	In feature area
Dugong dugon Dugong [28]	Calving	Known to occur	In feature area
Dugong dugon Dugong [28]	Foraging (high density seagrass beds)	Known to occur	In feature area
Dugong dugon Dugong [28]	Nursing	Known to occur	In feature area
Marine Turtles			
Caretta caretta Loggerhead Turtle [1763]	Internesting buffer	Known to occur	In buffer area only
Chelonia mydas Green Turtle [1765]	Internesting buffer	Known to occur	In buffer area only
Eretmochelys imbricata Hawksbill Turtle [1766]	Internesting buffer	Known to occur	In feature area
Eretmochelys imbricata Hawksbill Turtle [1766]	Nesting	Known to occur	In buffer area only
Natator depressus Flatback Turtle [59257]	Internesting buffer	Known to occur	In feature area
Natator depressus Flatback Turtle [59257]	Nesting	Known to occur	In feature area
Seabirds			
Ardenna pacifica Wedge-tailed Shearwater [84292]	Breeding	Known to occur	In feature area
Sterna dougallii Roseate Tern [817]	Breeding	Known to occur	In buffer area only

Scientific Name	Behaviour	Presence	Buffer Status
Sternula nereis Fairy Tern [82949]	Breeding	Known to occur	In feature area
Thalasseus bengalensis Lesser Crested Tern [66546]	Breeding	Known to occur	In feature area
Sharks			
Rhincodon typus Whale Shark [66680]	Foraging	Known to occur	In buffer area only
Whales			
Balaenoptera musculus brevicauda Pygmy Blue Whale [81317]	Distribution	Known to occur	In feature area
Megaptera novaeangliae Humpback Whale [38]	Migration (north and south)	Known to occur	In feature area
Megaptera novaeangliae Humpback Whale [38]	Resting	Known to occur	In feature area

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact us page.

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Appendix B

EPBC Act Species Likelihood and Risk

Table B 1 EPBC Threatened and Migratory Species Likelihood of Occurrence and Project Risks

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status			Classification	Details	
Sharks, fish and rays								
Whale shark	*Rhincodon typus*	Vulnerable	Migratory – marine	Schedule 7: Other specially protected fauna	The whale shark is an oceanic and coastal, pelagic fish, generally found in tropical areas where the surface temperature is 21–25°C. It is a filter feeder and commonly ranges in size from 4–10 m (Colman 1997). This species was listed as Vulnerable under the EPBC Act in 2001 and is also classified as Vulnerable on the World Conservation Union's Red List of Threatened Species (IUCN 2020). In Western Australia, whale sharks are protected under the BC Act, the *Conservation and Land Management Act 1984* and the *Fish Resources Management Act 1994*. There is a general lack of knowledge on many aspects of whale shark biology, including definitive migration patterns. They are normally oceanic and cosmopolitan in their distribution and are known to aggregate in the reef front waters adjacent to Ningaloo Reef between March and June (Colman 1997; Wilson et al. 2006) with the highest frequency of sightings occurring in April (Wilson et al. 2001). However, the season is variable and individual whale sharks have been recorded at other times of the year. While the species spends the majority of its time in deeper water, it is also encountered close to, or at, the surface. Whale shark presence coincides with the coral mass spawning period, when there is an abundance of food (krill, planktonic larvae and schools of small fish) in the waters adjacent to the reef. Estimates of the size of the population participating in the Ningaloo aggregation range between 300 and 500 individuals (Meekan et al, 2006). Preliminary research on the migration patterns of whale sharks in the western Indian Ocean, and isolated and infrequent observations of individuals, indicate that a small number of the Western Australian population migrate through the North-west Marine Region. Wilson et al. (2006) tagged 19 whale sharks in 2003 and 2004, with long-term movements patterns successfully recorded from six individuals. All travelled north-east into the Indian Ocean after departing Ningaloo Reef, with one tracked to Ashmore Reef and another to Scott Reef. The local area has been identified as a foraging BIA. Whale sharks have been sighted within the northern end of Exmouth Gulf; however, this is not a key site of interest as the aggregation is focussed on the food available at the Ningaloo Reef edge (Oceanica 2006).	May Occur	A foraging BIA has been identified within the local area, however the known distribution for the species is outside this area. The species has not been recorded in close proximity to the Project area or locally and generally occurs in deeper water. The offshore anchorage site is within proximity to BIA of these species; therefore it is considered possible that, on occasions, individuals may be present in the shipping route and anchorage site.	• Vessel strike • Underwater sound
White shark	*Carcharodon carcharias*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna	The great white shark is listed as Vulnerable under the EPBC Act. They are known to prey on humpback whales and have been recorded in North West Cape waters during humpback migrations. Study into great white shark populations is difficult (Cailliet 1996) given the uncertainty about their movements, emigration, immigration and difficulty in estimating the rates of natural or fishing mortality. In Australia, great white sharks have been recorded from central Queensland around the south coast to north-west Western Australia but may occur further north on both coasts (Last and Stevens 2009). They are widely, but not evenly, distributed in Australian waters and they are considered uncommon to rare compared to most other large sharks (CITES 2004). Great white sharks can be found from close inshore around rocky reefs, surf beaches and shallow coastal bays to outer continental shelf and slope areas. They also make open ocean excursions and can cross ocean basins (for instance from South Africa to the western coast of Australia, and from the eastern coast of Australia to New Zealand).	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	• Underwater sound
Grey nurse shark (west coast population)	*Carcharias taurus*	Vulnerable	N/A	Schedule 3: Vulnerable fauna	In Australia, the grey nurse shark has an inshore coastal distribution, primarily in sub-tropical to cool temperate waters on the continental shelf. There are two separate, genetically distinct grey nurse shark populations in Australian waters—one on the east coast and one on the west coast (DoE 2014). The range of the west coast population is not well known; however, records indicate that the species is widely distributed from the North West Shelf (including coastal waters in Exmouth Gulf), south to the Great Australian Bight (DoE 2014). Available information suggests that grey nurse sharks are still widely distributed along the Western Australian coast and are still regularly encountered, albeit with little or	Likely to occur	It is considered possible that, on occasions, individuals may be present locally. The species has not been recorded in close proximity to the Project area however suitable habitat is present.	• Underwater sound

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
					indeterminate frequency (Chidlow et al. 2006). There is a possibility that grey nurse sharks do not aggregate to the same degree or in the same areas/habitat types as off the east coast of Australia (Chidlow et al. 2006). Grey nurse sharks are often observed aggregating above the seabed (at depths 10–40 m) near deep sandy-bottomed gutters or rocky caves in the vicinity of inshore rocky reefs and islands (DoE 2014). Grey nurse sharks have also been recorded in the surf zone, around coral reefs, and to depths of around 200 m on the continental shelf (Pollard et al. 1996). No key aggregation sites have been identified to date in Western Australian waters (Chidlow et al. 2006).			
Green sawfish	*Pristis zijsron*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna	Green sawfish are protected under both State and Commonwealth legislation and are listed as Critically Endangered by the International Union for Conservation of Nature (IUCN) and Vulnerable under the BC Act and the EPBC Act. In Australian waters, green sawfish have historically been recorded in the coastal waters off Broome, Western Australia, around northern Australia and down the east coast as far as Jervis Bay, NSW (Stevens et al. 2005). The green sawfish inhabits muddy bottom habitats and enters estuaries (Allen 1997). It has been recorded in inshore marine waters, estuaries, river mouths, embankments and along sandy and muddy beaches (Stevens et al. 2005; Thorburn et al. 2004). Green sawfish have been recorded in very shallow water (<1 m) to offshore trawl grounds in over 70 m of water (Stevens et al. 2005). Smaller specimens (<2.5 m in length) are more common in foreshore and offshore coastal waters (Thorburn et al. 2004), as well as estuaries and river mouths at slightly reduced salinities, but are not known to venture into freshwater. Larger individuals (>2.5 m in length) are found in both inshore and offshore waters. The Sawfish and River Shark Multispecies Recovery Plan (DoE 2015a) indicates where pupping is known, and likely, to occur along the Pilbara coastline, with main areas being along Eighty Mile Beach. The Ashburton River delta, approximately 20 km north of the Project site, is home to potentially the most critical pupping site for green sawfish in the world (Morgan et al. 2015). Targeted sawfish surveys were conducted in Urala Creek North and Urala Creek South in February 2019 (Morgan et al. 2020). The observations led to three individual juvenile (<1.4 m) green sawfish being observed in the shallow northern entrance of Urala Creek North, and a single green sawfish being captured in a gill net at this location. It was captured in waters that were a depth of ~30 cm; and the three individuals observed in the same locality were also observed in 30-50 cm depth. The sighting of even at least three individuals in our study over a short time period in Urala Creek North suggests that this area may be an important secondary nursery for sawfish. The Ashburton River mouth, approximately 30 km north of Urala Creek North, has been identified as an important nursery area for green sawfish (Morgan et al. 2015; 2017). It is likely that sawfish are pupped just outside the river mouth and use the Ashburton River as a nursery for their first several months. When the river floods following storms in summer, acoustic tracking has shown that the young-of-year sawfish leave the river, and while some return after flooding has subsided, others do not (Morgan et al. 2017). It is hypothesized that these sawfish begin to use other nearby tidal creeks along the coastline when the freshwater pulse pushes them out of the Ashburton. As the second and third major creeks found south of the Ashburton, it is likely that Urala Creek North and South are important secondary nurseries for sawfish, which was confirmed in the present work by the sighting of at least three individuals ranging in size from approximately 1.2 to 1.4 m. These individuals are likely less than one year old, based on age-growth curves estimated by Peverell (2008). A Review of Exmouth Gulf Prawn Managed Fishery report (MRAG 2020) revealed that 20 sawfish were caught in commercial fishing activities during 2016, 13 during 2017, ten in 2018 and 13 in 2019, again indicating that sawfish are present locally.	Likely to occur	The local area is within the known distribution for the species, suitable habitat is present, and the species has been recorded in close proximity to the Project area (Morgan et al., 2020).	• Dredging activities • Underwater sound • Anthropogenic light spill • Seawater intakes • Habitat loss

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Dwarf sawfish	*Pristis clavata*	Vulnerable	N/A	Priority 1	The dwarf sawfish is listed as Vulnerable under the EPBC Act. The Australian distribution of the dwarf sawfish is considered to extend across northern Australia and along the Kimberley and Pilbara coasts (Last and Stevens 2009; Stevens et al.,2005). The majority of records of dwarf sawfish in Western Australia have come from shallow estuarine waters of the Kimberley region which are believed to be nursery areas, with immature juveniles remaining in these areas up until three years of age (Thorburn et al., 2004). Sawfish regularly use the tidal creeks and mangrove areas of Roebuck Bay for breeding and refuge. The Sawfish and River Shark Multispecies Recovery Plan (DoE 2015a) indicates that adults are known to occur along the coast north of Exmouth.	May occur	The species has not been previously recorded in proximity to the Project, however there is suitable habitat is present locally.	• Dredging activities • Underwater sound • Anthropogenic light spill • Seawater intakes • Habitat loss
Narrow sawfish	*Anoxypristis cuspidata*	N/A	Migratory – marine	N/A	The narrow sawfish occurs from the northern Arabian Gulf to Australia and north to Japan. The species inhabits inshore and estuarine waters, and offshore waters down to depths of 100 m (D'Anastasi et al. 2013), and are most commonly found in sheltered bays with sandy bottoms. They are not currently listed as threatened but are commonly caught as by-catch. Narrow sawfish are the most commonly caught sawfish species in Australian fisheries, including Western Australia (D'Anastasi et al. 2013; MRAG 2020).	May occur	The species has not been recorded in the region, however suitable habitat is present locally. The extent of species distribution is poorly understood.	• Dredging activities • Underwater sound • Anthropogenic light spill • Seawater intakes • Habitat loss
Shortfin mako	*Isurus oxyrinchus*	N/A	Migratory – marine	N/A	The shortfin mako is a wide-ranging oceanic pelagic shark that is widespread in Australian waters, though rarely recorded in water temperatures below 16°C (DEWHA 2010). Tagged shortfin makos have been found to spend most of their time in water less than 50 m deep but with occasional dives up to 880 m deep (Stevens et al., 2010; Abascal et al. 2011). Little is known about the population size and distribution of shortfin mako sharks in Western Australia.	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Longfin mako	*Isurus paucus*	N/A	Migratory – marine	N/A	The longfin mako is a widely distributed but rarely encountered oceanic tropical shark found in Australian waters south to Geraldton in Western Australia and to at least Port Stephens in New South Wales (DEWHA 2010). The longfin mako is often confused with the shortfin mako. There is very little information about these sharks in Australia, with no available population estimates or distribution trends.	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Reef manta ray	*Manta alfredi*	N/A	Migratory – marine	N/A	The reef manta ray is globally distributed in tropical and subtropical waters. It is a planktivorous species and is thought to migrate relatively long distances, travelling up to 70 km per day and moving between specific productive areas (Couturier et al. 2011; Van Duinkerken 2010). The reef manta ray is most often sighted inshore, around coastal areas and coral reefs. Species residency has been recorded along the Western Australian coastline, most notably at Ningaloo Marine Park. Aerial surveys during May/June 2007 recorded reef manta ray presence in Exmouth Gulf in close proximity to Heron Point and in association with shallow mangrove areas (Hodgson 2007).	May occur	Suitable habitat is present locally; however the species has not been recorded in close proximity to the Project area.	• Dredging activities • Underwater sound • Anthropogenic light spill • Seawater intakes • Altered nutrient inputs
Giant manta ray	*Manta birostris*	N/A	Migratory – marine	N/A	The giant manta ray is very common in tropical waters of Australia and the Montebello Islands Marine Park/Barrow Island Marine Management Area. The giant manta ray primarily inhabits nearshore environments along productive coastlines with regular upwelling, but they appear to be seasonal visitors to coastal or offshore sites including offshore island groups, offshore pinnacles and seamounts (Marshall et al. 2011).	May occur	Suitable habitat is present locally; however the species has not been recorded in close proximity to the Project area.	• Dredging activities • Underwater sound • Anthropogenic light spill • Seawater intakes • Altered nutrient inputs
Marine mammals						**Classification**	**Details**	
Sei whale	*Balaenoptera borealis*	Vulnerable	Migratory – marine	Schedule 2: Endangered fauna	The sei whale is a baleen whale which, like many species of baleen whales, was significantly reduced in numbers by commercial whaling operations. The species has a worldwide oceanic distribution and is expected to seasonally migrate between low	May occur	The species has not been recorded in close proximity to	• Underwater sound • Vessel strike

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
					latitude wintering areas and high latitude summer feeding grounds (Bannister et al. 1996; Prieto et al. 2012). Sei whales have been infrequently recorded in Australian waters (Bannister et al. 1996), which could be due to the similarity in appearance of sei whales and Bryde's whales leading to incorrect recordings. There are no known mating or calving areas, or other BIAs for sei whales in Australian waters (DoE, 2016). The species prefers deep waters, and typically occurs in oceanic basins and continental slopes (Prieto et al., 2012); records of the species occurring on the continental shelf (<200 m water depth) are uncommon in Australian waters (Bannister et al., 1996).		the Project area. Predominantly found in deeper waters.	
Fin whale	*Balaenoptera physalus*	Vulnerable	Migratory – marine	Schedule 2: Endangered fauna	The fin whale is a large baleen whale with a cosmopolitan distribution in all ocean basins between 20 and 75°S (DEH 2005b). The global population of fin whales was reduced significantly by commercial whaling, with the species being targeted due to its large size and broad distribution. Like other baleen whales, fin whales migrate annually between high latitude summer feeding grounds and lower latitude over-wintering areas (Bannister et al. 1996). Fin whales are thought to follow oceanic migration paths and are uncommonly encountered in coastal or continental shelf waters. The Australian Antarctic waters are important feeding grounds for fin whales but there are no known mating or calving areas in Australian waters (Morrice et al. 2004). There are no known BIAs for fin whales in the north of Western Australia. As such, the species is likely to infrequently occur within the Project area, mainly during winter months when the species may move away from Antarctic feeding areas.	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area. Predominantly found in deeper waters.	• Underwater sound • Vessel strike
Humpback whale	*Megaptera novaeangliae*	Vulnerable	Migratory – marine	Schedule 6: conservation dependent fauna	Humpback whales are moderately large baleen whales that occur throughout Australian waters and are the most commonly sighted whale in the North-west Marine Region (Threatened Species Scientific Committee 2015d). The Western Australian humpback whale population (known as the Group IV population) is genetically distinct from the eastern Australian population and was severely depleted by whaling activities. The population was estimated at 12,000 to 16,000 individuals in 1934 and continued to decline to an estimated 800 individuals prior to the moratorium on whaling in the southern hemisphere in 1962 (Chittleborough 1965). More recent population estimates have suggested whale numbers have increased to ~28,830 in 2008 (Threatened Species Scientific Committee 2015d). Numbers have increased further in recent years and the Action Plan for Australian Mammals 2012 by Woinarski et al. (2014), and a paper from Bejder et al. (2015) recommend that humpback whales no longer meet any criteria for listing as threatened under the EPBC Act. Humpback whales migrate annually between summer feeding grounds in Antarctica and breeding aggregation areas in the southern Kimberley between Broome and the northern end of Camden Sound. The Conservation Advice for Megaptera novaeangliae (humpback whale) (Threatened Species Scientific Committee 2015d) identifies that the humpback whale migration pathway is within the continental shelf boundary or 200 m bathymetry along the Western Australian coastline. However actual sightings recorded by Jenner et al. (2001) and Double et al. (2010 and 2012) indicate that the route is actually much closer to shore, particularly along the Pilbara coast, with migrating whales tending to travel within 50 km of the coast between North West Cape and Camden Sound. Humpback whales pass north along the waters west of Barrow Island to the Montebello Islands during their annual winter migration from the Antarctic. Once past the Montebello Islands their migration route heads east towards their breeding grounds in the Kimberley. The northward migration past Montebello and Barrow Islands generally occurs from mid-July with the peak in late July, though this can vary by up to three weeks. Unlike the northern migration, which tends to follow the deeper water of the continental shelf, the southward migration concentrates whales closer to the mainland with a peak from August to mid-September (Threatened Species Scientific Committee 2015d).	Likely to occur	The local area is within the known distribution for the species, suitable habitat is present, and the species has been recorded in close proximity to the Project.	• Underwater sound • Vessel strikes

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
					Humpback whales visit Exmouth Gulf annually from early August until late November. Whales are predominantly found in water depths greater than 7 m with the greatest number of whales being sighted in the deeper (~20 m) areas of the Gulf. It is likely that water temperature plays a role in determining when whales, particularly cow/calf pairs trying to minimise metabolic expenditures, enter the Gulf. Cow/calf numbers inside Exmouth Gulf peak during the first two weeks of October, at a similar time that the sea surface temperature inside the Gulf becomes equal to that found offshore at the same latitude (Jenner and Jenner 2005). In this period, cows minimise energy spent on movement, focusing instead on investing energy in the growth of their newborn calves (Centre for Whale Research [CWR] 2010; Braithwaite et al. 2012; Christiansen et al. 2016). During this time mother calf pairs whisper to avoid detection by predators (Bejder et al. 2019).			
Blue whale	*Balaenoptera musculus*	Endangered	Migratory – marine	Schedule 2: Endangered fauna	Blue whales are found in all oceans of the world. They are the largest living animal and can grow to a length of over 30 m and weigh an average of 100–120 t. There are two recognised subspecies in Australia; the 'true' blue whale (*Balaenoptera musculus intermedia*) and the 'pygmy' blue whale (*Balaenoptera musculus brevicauda*) (Commonwealth of Australia 2015a). Both of these species are covered by the Blue Whale Conservation Management Plan 2015 (Commonwealth of Australia, 2015a). In general, the southern blue whale is found south of 60°S and pygmy blue whales are found north of 55°S. As southern blue whales feed predominantly in polar waters it has been suggested that all blue whales sighted in Australian waters are pygmy blue whales (Commonwealth of Australia, 2015a). During summer–autumn true blue whales feed mainly in the Antarctic, mostly on krill, while pygmy blue whales are thought to feed in productive regions in temperate latitudes (Branch et al. 2007). Satellite tagging (2009–2012) confirmed the general distribution of pygmy blue whales was offshore in water depths over 200 m and commonly over 1000 m (Double et al. 2012). These data were revisited in 2014 and showed that whales tagged in Western Australia during March and April migrated northwards post tag deployment. The tagged whales travelled relatively near to the Australian coastline (100.0 ± 1.7 km) in water depths of 1369.5 ± 47.4 m, until reaching the North West Cape, after which they travelled offshore (238.0 ± 13.9 km) into progressively deeper water (2617.0 ± 143.5 m). Whales reached the northern terminus of their migration and potential breeding grounds in Indonesian waters by June (Double et al. 2014).	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area. Predominantly found in deeper waters.	• Underwater sound • Vessel strike
Southern right whale	*Eubalaena australis*	Endangered	Migratory – marine	Schedule 3: Vulnerable fauna	Southern right whales from Australian populations probably forage between about 40°S and 65°S, generally south of Australia. In the region of the Sub-Tropical Front (41–44°S) they mainly consume copepods, while at higher latitudes (south of 50°S) krill is the main prey item. The species feeds in the Southern Ocean in summer, moving close to shore in winter. The migratory paths between calving and feeding areas are not well understood (DSEWPaC,2012a). The Conservation Management Plan for the Southern Right Whale 2011-2021 (DSEWPaC 2012a) indicates that the core coastal range for southern right whale is from Perth along the southern coastline to Sydney. Although sightings have been recorded as far north as Exmouth these are rare (Bannister et al. 1996) and no BIAs occur locally. Given that major calving areas and aggregations occur in proximity to the Great Australian Bight, southern right whales are unlikely to be present in high numbers locally, and any occurrence would be infrequent and limited to transiting individuals.	May occur	The species has not been recorded in close proximity to the Project area. The distribution of this species occurs significantly south of the Project area.	N/A
Antarctic minke whale	*Balaenoptera bonaerensis*	N/A	Migratory – marine	N/A	Antarctic minke whales primarily inhabit offshore pelagic habitats within cold temperate to Antarctic waters (Bannister et al. 1996; Thiele and Gill 1999). They have been recorded in all Australian states with exception of the Northern Territory. The distribution along the west coast of Australia is unknown; however they appear to be distributed off the continental shelf edge, potentially as far north as 8º S (Best 1985; Zerbini et al. 1997).	Unlikely to occur	The species has not been recorded in close proximity to the Project area. Predominantly found in deeper waters.	N/A

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Bryde's whale	*Balaenoptera edeni*	N/A	Migratory – marine	N/A	Bryde's whales occur in temperate to tropical oceanic and inshore waters, generally bounded by latitudes 40º N and 40º S, or the 20º C isotherm (Bannister et al., 1996). The coastal form of Bryde's whale appears to be limited to the 200 m depth isobar, moving along the coast in response to availability of suitable prey (Best et al. 1984). The offshore form is found in deeper water (500 m to 1000 m). They have been recorded in all Australian states with the exception of the Northern Territory (Bannister et al. 1996). The area of occupancy of Bryde's whales in pelagic waters off Australia is poorly understood, due to the lack of data, however it is likely to be greater than 2000 km^2 (DoEE 2017).	Unlikely to occur	The species has not been recorded in close proximity to the Project area. Predominantly found in deeper waters. This species may, on occasion be found within the transhipment route and anchorage site.	N/A
Sperm whale	*Physeter macrocephalus*	N/A	Migratory – marine	N/A	Sperm whales tend to inhabit offshore areas with a water depth of 600 m or more and are uncommon in waters less than 300 m deep (NOAA Fisheries Fact Sheet 2006). Sperm whales have been recorded in all Australian states (Bannister et al. 1996). Key localities for sperm whales in Western Australia include the area between Cape Leeuwin and Esperance and close to the edge of the continental shelf (averaging 20-30 nm offshore). Off the Western Australian coast, where the continental shelf slopes less steeply, sperm whales appear to be less concentrated close to the edge shelf and more widely dispersed offshore (Bannister et al. 1996).	Unlikely to occur	The species has not been recorded in close proximity to the Project area. Predominantly found in deeper waters.	N/A
Killer whale	*Orcinus orca*	N/A	Migratory – marine	N/A	Killer whales are the largest of the dolphin family and occur throughout all oceans, and contiguous seas, from equatorial regions to the polar pack ice zones. They are most numerous in coastal waters and cooler regions where productivity is high (Dahlheim and Heyning 1999). Their preferred habitat includes oceanic, pelagic and neritic regions and they are most often seen along the continental slope and shelf, particularly near seal colonies (DoEE 2017).	Unlikely to occur	The species has not been recorded in close proximity to the Project area. Predominantly found in deeper waters.	N/A
Spotted bottlenose dolphin	*Tursiops aduncus*	N/A	Migratory – marine	N/A	The spotted bottlenose dolphin (Arafura/Timor Sea populations) is generally considered to be a warm water subspecies of the spotted bottlenose dolphin, occurring in shallow (often <10 m deep) inshore waters (Bannister et al. 1996; Hale et al. 2000). The known distribution of the spotted bottlenose dolphin extends from Shark Bay north to the western edge of the Gulf of Carpentaria in Australia (Hale et al. 2000). No BIA for the spotted bottlenose dolphin occurs locally, however pods of this species were frequently recorded in and near Heron Point (Bay of Rest) suggesting that this area is may provide habitat for this population (Fitzpatrick et al. 2019).	Likely to occur	The species has not been recorded in close proximity to the Project area however, the local area includes suitable habitat.	• Underwater sound • Vessel strikes
Australian humpback dolphin	*Sousa Saluhensis*	N/A	Migratory – marine	Priority 4	The Australian humpback dolphin, previously referred to as the Indo-Pacific humpback dolphin, is typically found in water less than 20 m deep but has been recorded in water down to 40 m deep. This species is generally found in association with river mouths, mangroves, tidal channels and inshore reefs (Parra and Cagnazzi 2016). This species of dolphin is known to have resident groups that forage, feed, breed and calve in the waters of Roebuck Bay and areas further north (Parra and Cagnazzi 2016). No BIA for the Australian humpback dolphin is located within the Project area.	May occur	The species has not been recorded in close proximity to the Project area however, the local area includes suitable habitat.	• Underwater sound • Vessel strikes

Common Name	Scientific Name	EPBC Act Threatened Status	EPBC Act Migratory Status	BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
Dugong	*Dugong dugon*	N/A	Migratory – marine	Schedule 7: Other specially protected fauna	Dugongs are large herbivorous marine mammals (up to 3 m in length) that feed off seagrass and generally inhabit coastal areas in shallow waters (less than 5 m deep). Dugong distribution and movement is based on the abundance, size and species composition of seagrass meadows. Key populations along the Western Australian coast are principally located at: Shark Bay (the largest resident population in Australia), Ningaloo Marine Park, the Pilbara coast and offshore areas including Montebello/Barrow/Lowendal Islands, and further north at Eighty Mile Beach and off the Kimberley Coast, particularly Roebuck Bay and Dampier Peninsula (Marsh et al. 2002). Exmouth Gulf (including the project area) and Ningaloo reef are recognised as a foraging, breeding, nursing, pupping and calving BIA. The CWR undertook a program of aerial surveys within Exmouth Gulf in 2004 (Jenner and Jenner 2005). Of the dugong herds sighted during these surveys, 76% were in the shallow (<6 m deep) south-eastern portion of Exmouth Gulf and 24% contained cow/calf pairs. Dugong activity is thought to be focussed on the eastern side of the Gulf, associated with the shallow seagrass habitat in this area. Dugongs have been sighted in the vicinity of the Project area, close to Locker Point and Tubridgi Point. Dugong favour seagrass species that are lower seral or 'pioneer' species, particularly *Halophila* spp. (highly digestible) and *Halodule* spp. (high nutrient content). This highly specialised behaviour suggests that not all seagrass meadows are suitable dugong foraging grounds (Marsh et al., 2002). The benthic habitat mapping undertaken by Geo Oceans (2020) surrounding the Project area reported areas of seagrass. Seagrass species were estimated to colonise 19% (1,597 ha) of the sand substrates (8,199 ha) in the survey area. *Halodule* spp. were the most common species recorded (1098 ha). *Halophila* spp. were recorded (mixed with *Halodule* spp.) near Urala Creek South. These seagrass areas are likely to support, at least partially, the feeding activities of local dugong populations. Dugongs were often recorded foraging in the near shore area to the south of Urala Creek South and were recorded in the near shore area near Urala Creek North.	Likely to occur	The species has been recorded in close proximity to the Project area and the local area includes suitable habitat for local dugong populations.	• Underwater sound • Vessel strikes • Habitat loss
Marine reptiles						**Classification**	**Details**	
Hawksbill turtle	*Eretmochelys imbricata*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna	Western Australia supports one genetic stock of hawksbill turtles with nesting centred on the Dampier Archipelago. The Western Australian stock is the largest in the Indian Ocean and is one of the largest hawksbill turtle populations remaining in the world (Limpus 2009a). In Western Australia, their nesting range is relatively small and extends from the Muiron Islands to the Dampier Archipelago, a distance of ~400 km. The most significant breeding areas are within the Dampier Archipelago, Montebello Islands, Lowendal Islands and Barrow Island, supporting hundreds of nesting females annually (Pendoley 2005; Limpus 2009a). Rosemary Island (within the Dampier Archipelago) may support in the order of 1,000 nesting females annually and may be the largest remaining hawksbill nesting population globally. Low density nesting is also known along the North West Cape/Ningaloo coast and Muiron Islands (Limpus 2009a), the closest known breeding/nesting grounds to the Project area. A total annual hawksbill turtle stock in Western Australia of approximately 1000–1500 animals. With an interbreeding period of 2–4 years, a total of 2000–4500 hawksbill turtles probably nest in Western Australian waters. Although hawksbills are known to nest year-round, the Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) indicates that peak nesting periods occur between October and February. The location of feeding areas and the biology of the species within this region is largely undocumented (Limpus 2009a) but it is thought that individuals may migrate up to 2,400 km between their nesting and foraging grounds (Commonwealth of Australia 2017a).	Likely to occur	The species has been recorded in close proximity to the Project area and the local area includes suitable habitat for local turtle populations.	• Underwater sound • Vessel strikes • Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Flatback turtle	*Natator depressus*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna	The flatback turtle is endemic to the northern Australian continental shelf and no nesting is known to occur outside of Australia. Approximately one third of the known total breeding for the species occurs in Western Australia, which supports two genetic stocks: the Pilbara Stock characterised by summer nesting and the Southwest Kimberley stock which breeds year-round with a winter peak (Limpus 2008a). Pendoley (2005) focussed on documenting the activity of flatback turtles on Barrow Island, Lowendal Islands and Montebello Islands and identified that the east coast of Barrow Island supports an important rookery for flatbacks. Females inter-nest close to their nesting beaches, typically in 0–10 m of water (Chevron 2008). However, flatback turtles also travel approximately 70 km and inter-nest in shallow nearshore water off the adjacent mainland coast, before returning to Barrow Island to lay another clutch of eggs. The average recorded inter-nesting period is 13–16 days. There have been occasional records of nesting by flatback turtles on the Muiron Islands (CALM 2005), the closest known breeding/nesting grounds to the Project area. No breeding sites for this species are known on the eastern side of Exmouth Gulf, however the coastal area to the north-east from Urala Creek North, is included within the breeding and interesting BIA for flatback turtles with historic snapshot surveys indicating that the mainland coastal area in close proximity to the Project area support low density nesting.	Likely to occur	The species has been recorded in close proximity to the Project area and the local area includes suitable habitat for local turtle populations.	• Underwater sound • Vessel strikes • Anthropogenic light spill
Green turtle	*Chelonia mydas*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna	Green turtles are the most widespread and abundant turtle species in Western Australian waters, nesting from the Ningaloo coast to the Lacepede Islands and out to Scott and Ashmore Reefs (Prince 1994; Limpus 2008a), with three distinct breeding stocks: the North West Shelf stock, the Scott Reef stock and the Ashmore Stock (Dethmers et al. 2006; Limpus 2008a). The North West Shelf population is one of the largest in the world and the most significant rookery is the western side of Barrow Island (Prince 1994; Limpus, 2008a). Other principal rookeries include North West Cape (specifically the Jurabi Coastal Park on the western coast of the Cape), the Montebello Islands, the Lacepede Islands and Browse Island (Prince, 1994; Limpus, 2008a). Numerous other small rookeries also occur in Western Australia. The green turtle is also known to breed in large numbers in the dunes above the extensive beaches found on Serrurier Island, with counts indicating the island supports the second largest rookery in the Pilbara. Low numbers of green turtles have also been observed nesting on Airlie Island and Varanus Island (Pendoley Environmental 2011). The closest known breeding/nesting grounds to the Project area are those in the Jurabi Coastal Park. Green turtle nesting abundance fluctuates significantly from year to year, depending on environmental variables and food availability at feeding sites. In an aerial survey of Pilbara waters in April 2000, Prince (2001) estimated a mixed species population of 57,000 turtles, of which most were green turtles. Chevron (2005, 2008) reported that green turtles nest predominantly on the sandy west coast beaches of Barrow Island. In addition to nesting, green turtles mate and forage close to Barrow Island during the summer breeding season. Aggregations of green turtles have been reported from the shallow areas along the west coast of Barrow Island, with turtles foraging on and around nearshore reefs. Green turtles have also been observed to the south and south-east of Barrow Island, around Dugong Reef and over Barrow Shoals (Chevron 2005, 2008). The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) identifies Barrow Island and all waters within a 20 km radius of the island as critical habitat to the survival of the green turtles. The Recovery Plan for Marine Turtles in Australia (Commonwealth of Australia 2017a) identifies the nesting period for the North West Shelf stock as November to March, with peaks in January and February.	Likely to occur	The species has been recorded in close proximity to the Project area and the local area includes suitable habitat for local turtle populations.	• Underwater sound • Vessel strikes • Anthropogenic light spill • Habitat loss

Common Name	Scientific Name	EPBC Act Threatened Status	EPBC Act Migratory Status	BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
					There are no known nesting beaches locally; however, the mangrove creeks and vegetated shallows of the east side of Exmouth Gulf, and along the majority of the nearshore mangrove habitats, are an important nursery for this species.			
Loggerhead turtle	*Caretta*	Endangered	Migratory – marine	Schedule 2: Endangered fauna	Western Australia supports one genetic stock of loggerhead turtles with nesting encompassing Muiron Islands, Ningaloo Coast south to about Carnarvon and islands near Shark Bay, including Dirk Hartog Island (Limpus 2008b), with occasional nesting recorded at Varanus and Rosemary Islands (Commonwealth of Australia, 2017). Low numbers of loggerheads have also been observed on Barrow Island (Chevron 2008). The annual nesting population in the region is thought to be in the order of several thousand (Limpus 2008b). Within the Ningaloo Marine Park, loggerhead turtles tend to nest in higher proportions in the southern areas of the reserve (CALM 2005). Loggerhead turtles are likely to occur in Exmouth Gulf; the mangroves of the Gulf are an important nursery for the hatchlings, and an important foraging ground for juveniles.	Likely to occur	The species has been recorded in close proximity to the Project area and the local area includes suitable habitat for local turtle populations.	• Underwater sound • Vessel strikes • Anthropogenic light spill
Leatherback turtle	*Dermochelys coriacea*	Endangered	Migratory – marine	Schedule 3: Vulnerable fauna	The leatherback turtle is a pelagic feeder, found in tropical, subtropical and temperate waters, but is uncommon throughout their Australian range (Commonwealth of Australia 2017a). No major leatherback turtle nesting areas have been recorded in Australia, although scattered isolated nesting (1–3 nests per annum) occurs in southern Queensland and Northern Territory (Limpus and McLachlan 1994). At least two nesting attempts have been reported in Western Australia (Limpus 2009b). Leatherback turtles feed mainly on pelagic, soft-bodied marine organisms such as jellyfish, which occur in greatest concentrations in areas of upwelling or convergence (Commonwealth of Australia, 2017). The leatherback turtle is a highly pelagic species with adults only going ashore to breed. Individuals may be encountered locally but are unlikely to be encountered in significant numbers given that no confirmed breeding occurs in Western Australia and that leatherbacks in Western Australia are most commonly sighted feeding in the south-west region (Commonwealth of Australia 2017a).	May Occur	It is considered possible that, on occasions, individuals may be present locally, particularly within the shipping channel or offshore anchorage site. However, the species has not been recorded in close proximity to the Project area.	• Underwater sound • Vessel strike
Short-nosed sea-snake	*Aipysurus apraefrontalis*	Critically Endangered	N/A	Schedule 1: Critically Endangered fauna	The short-nosed sea snake is listed as Critically Endangered under the EPBC Act. This species is believed to show strong site fidelity to shallow coral reef habitats in <10 m of water. Recently, populations of the short-nosed sea snake were identified in coastal Western Australia, in Exmouth Gulf and Shark Bay, resulting in a substantial range expansion than previously known (Fitzpatrick et al.,2019).	May occur	The species has not been recorded in close proximity to the Project area, however the area provides suitable habitat and is within the known distribution of the species.	• Underwater sound • Vessel strikes • Anthropogenic light spill
Birds						**Classification**	**Details**	
Curlew sandpiper	*Calidris ferruginea*	Critically Endangered	Migratory – marine	Schedule 1: Critically Endangered fauna Schedule 5: Migratory birds - international agreement (IA)	The curlew sandpiper is a Migratory shorebird that breeds in north Siberia and spends the non-breeding season from western Africa to Australia (Bamford et al. 2008). The curlew sandpiper occurs around coastal Australia and preferred habitats include coastal brackish lagoons, tidal mud and sand flats, estuaries, saltmarshes and, less often, inland. Their diet is mainly comprised of polychaete worms, molluscs and crustaceans (Garnet et al. 2011). The curlew sandpiper is a common species found in Exmouth Gulf. Curlew Sandpipers were recorded on all five of the Biota (2021) surveys with a high count of 355 in March, though the remaining counts were significantly lower (<45). Total counts from previous surveys in the broader Gulf region ranged from 0 to 35. The high count in March may indicate that the study area is used as a migratory staging point for birds migrating north from further south (Biota, 2021). It is also possible that this usage extends more broadly within the Gulf but was missed on previous surveys which were not conducted during northward migration (Biota 2021).	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Bar-tailed godwit (menzbieri)	*Limosa lapponica menzbieri*	Critically Endangered	Migratory – marine	Schedule 1: Critically Endangered fauna Schedule 5: Migratory birds - IA	Two subspecies of the bar-tailed godwit exist, as determined by their breeding locations in Siberia and Alaska (Bamford et al. 2008). Non-breeding birds migrate to the coasts of Australia. The western Alaskan subspecies occurs especially on the north and east coasts of Australia whilst the northern Siberian subspecies occurs especially along the coasts of northern Western Australia (Marchant and Higgins,1993). Non-breeding birds are found on muddy coastlines, estuaries, inlets, mangrove-fringed lagoons and sheltered bays, feeding on annelids, bivalves and crustaceans (Garnet et al. 2011). The bar-tailed godwit is a common species found in Exmouth Gulf. Bar-tailed godwit were proportionally under-represented in the study area during the recent Biota (2021) field surveys. All previous counts recorded over 1,000 bar-tailed godwits, compared to a high count of 137 for the study area during the Biota (2021) surveys.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Eastern curlew	*Numenius madagascariensis*	Critically Endangered	Migratory – marine	Schedule 1: Critically Endangered fauna Schedule 5: Migratory birds - IA	The eastern curlew is a Migratory shorebird that breeds in Siberia, Kamchatka and Mongolia and migrates to coastal East Asia and Australia. The South Korean Yellow Sea is an important staging post for this species. Non-breeding birds occur around coastal Australia, are more common in the north and have disappeared or become much rarer at many sites along the south coast (Garnet et al. 2011). Non-breeding birds are present at estuaries, mangroves, saltmarshes and intertidal flats, particularly those with extensive seagrass (Zosteraceae), where they feed on marine invertebrates, especially crabs and small molluscs (Garnet et al. 2011). The eastern curlew is a common species found in Exmouth Gulf. However, the eastern curlew was proportionally under-represented in the study area during the recent Biota (2021) field surveys. This may partly reflect variation in populations using the Gulf between years, particularly given that 200 eastern curlew were counted within the study area in 2018 (BirdLife Australia 2020).	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Great knot	*Calidris canutus*	Critically Endangered	Migratory – marine	Schedule 1: Critically Endangered fauna Schedule 5: Migratory birds - IA	The great knot is listed as Critically Endangered and Migratory under the EPBC Act and the BC Act, and Near Threatened on the IUCN Red List. The great knot has been recorded around the entirety of the Australian coast, with a few scattered records inland. The species is common on the coasts of the Pilbara and Kimberley, from the Dampier Archipelago to the Northern Territory border. In Australia, great knots prefer sheltered coastal habitats with large intertidal mudflats or sandflats. This includes inlets, bays, harbours, estuaries and lagoons (Department of Biodiversity, Conservation and Attractions 2018). Great knots were recorded in all five of the Biota (2021) surveys with a high count of 126 in March, though the remaining counts were significantly lower (<45). The high count in March may indicate that the study area is used as a migratory staging point for birds migrating north from further south (Biota 2021).	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Red knot	*Calidris canutus*	Endangered	Migratory – marine	Schedule 2: Endangered fauna Schedule 5: Migratory birds - IA	The red knot is a Migratory shorebird and the species includes five subspecies, including two found in Australia, *Calidris canutus piersmai* and *Calidris canutus rogersi*. The red knot breeds in Siberia and spends the non-breeding season in Australia and New Zealand. Non-breeding season is spent on tidal mudflats or sandflats where they feed on intertidal invertebrates, especially shellfish (Garnet et al. 2011). The red knot is a common species found in Exmouth Gulf. The red knot was recorded during the recent Biota (2021) field surveys during all Urala Creek surveys.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Lesser sand plover	*Charadrius mongolus*	Endangered	Migratory – marine	Schedule 2: Endangered fauna Schedule 5: Migratory birds - IA	The lesser sand plover breeds in the northern hemisphere and undertakes annual migrations to and from southern feeding grounds for the austral summer. Within Australia, the lesser sand plover is widespread in coastal regions and has been recorded in all states. The lesser sand plover is gregarious and usually occurs in small to large flocks often with more than 100 individuals at favoured sites in northern Australia. This species often occurs with other shorebird species when feeding, especially the greater sand plover (Marchant and Higgins, 1993). The species is mainly diurnal but may forage on moonlit nights (BirdLife International 2015). The lesser sand plover was recorded during four of the five Biota (2021) field surveys at Urala Creek. A maximum of 100 lesser sand plovers were recorded during the April 2019 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Greater sand plover	*Charadrius leschenaultii*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna Schedule 5: Migratory birds - IA	The greater sand plover distribution in Australia during the non-breeding season is widespread, although the most are found in northern Australia (Ward, 2012). They are especially widespread between North West Cape and Roebuck Bay and occasionally recorded along the coast of southern Western Australia. The species is almost entirely coastal, inhabiting littoral and estuarine habitats (Department of Biodiversity, Conservation and Attractions, 2018). The greater sand plover was recorded during four of the five Biota (2021) field surveys at Urala Creek. A maximum of 189 greater sand plovers were recorded during the March 2019 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Whimbrel	*Numenius phaeopus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	It is common and widespread from Carnarvon to the north-east Kimberley Division, Western Australia. The whimbrel is often found on the intertidal mudflats of sheltered coasts. The Whimbrel generally forages on intertidal mudflats, along the muddy banks of estuaries and in coastal lagoons, either in open unvegetated areas or among mangroves. The whimbrel is commonly observed in Exmouth Gulf. The whimbrel was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of 23 whimbrels were recorded during the March 2018 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Pacific golden plover	*Pluvialis fulva*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The Pacific golden plover is listed as Migratory under the EPBC Act, Migratory under the BC Act and Least Concern on the IUCN Red List. Within Australia, the Pacific Golden Plover is widespread in coastal regions, though there are also a number of inland records. In Western Australia, the species is widespread along the Pilbara and Kimberley coasts. The number of Pacific golden plovers recorded in Australia can vary significantly between years (DAWE 2021). The Pacific golden plover was recorded in low numbers during the Biota (2021) field surveys at Urala Creek. A maximum of four Pacific golden plovers were recorded during the November 2018 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Grey plover	*Pluvialis squatarola*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	In Australia, the grey plover has been recorded in all states, where it is found along the coasts, and it especially abundant on the western and southern coastlines. Grey plovers usually forage on large areas of exposed mudflats and beaches of sheltered coastal shores such as inlets, estuaries and lagoons. They also occasionally feed in pasture and at the muddy margins of inland wetlands such as lakes, swamps and bores (Marchant and Higgins 1993). The grey plover was recorded during four of the five Biota (2021) field surveys at Urala Creek. A maximum of 24 grey plovers were recorded during the March 2019 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Ruddy turnstone	*Arenaria interpres*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The ruddy turnstone is listed as Migratory under the EPBC Act, Migratory under the BC Act and Least Concern on the IUCN Red List. The ruddy turnstone is widespread within Australia during its non-breeding period of the year (Bamford et al. 2008). Australian sites of international importance in Western Australia include Barrow Island, Ashmore Reef, Roebuck Bay and Eighty Mile Beach (Bamford et al. 2008). The ruddy turnstone is mainly found on coastal regions with exposed rock coast lines or coral reefs. The ruddy turnstone is commonly observed in Exmouth Gulf. The ruddy turnstone was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of 95 ruddy turnstones were recorded during the April 2019 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Sanderling	*Calidris alba*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The sanderling is listed as Migratory under the EPBC Act, Migratory under the BC Act and Least Concern on the IUCN Red List. They occur on most of the coast of Western Australia. They are more often recorded on the south and south-west coasts, north to around southern Shark Bay, with more sparsely scattered records further north in the Pilbara region. In Australia, the species is almost always found on the coast, mostly on open sandy beaches. The sanderling is commonly observed in Exmouth Gulf. The sanderling was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of 51 sanderlings were recorded during the March 2019 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Red-necked stint	*Calidris ruficollis*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The red-necked stint is listed as Migratory under the EPBC Act, Migratory under the BC Act and Near Threatened on the IUCN Red List. The red-necked stint has been recorded in all coastal regions of Australia and found inland in all states when conditions are suitable. The red-necked stint mostly forages on bare wet mud on intertidal mudflats or sandflats, or in very shallow water; mostly in areas with a film of surface water and mostly close to edge of water. During high tides they sometimes forage in non-tidal wetlands. The red-necked stint is commonly observed in Exmouth Gulf. The red-necked stint was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of approximately 680 red-necked stints were recorded during the December 2018 survey.	Likely to occur	The species has been recorded locally in close proximity to the Project area.	• Anthropogenic light spill
Southern giant-petrel	*Macronectes giganteus*	Endangered	Migratory – marine	Schedule 5: Migratory birds - IA	The southern giant petrel is listed as Endangered and Migratory under the EPBC Act. It is a migratory bird which has a large natural range. This species occurs in Antarctic to subtropical waters, so while this species may over-fly the Project area in transit or for foraging, they do not use the area for breeding (August and September) or resting as there are no critical nesting habitats (eggs hatch between October and November) or feeding areas locally.	Unlikely to occur	It is considered possible that, on occasions, individuals may fly over the Project area. However, the species has not been recorded in close proximity to the Project area.	N/A
Australian painted snipe	*Rostratula australis*	Endangered	Migratory – marine	Schedule 5: Migratory birds - IA	The Australian painted snipe is a wading bird that has been recorded at wetlands in all states of Australia (DoE 2020). It is most common in eastern Australia and has been recorded less frequently in Western Australia (Marchant and Higgins 1993; Rogers et al. 2005; DoE 2020). The Australian painted snipe generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans. They also use inundated or waterlogged grassland or saltmarsh, dams, rice crops, sewage farms and bore drains. Typical sites include those with rank emergent tussocks of grass, sedges, rushes or reeds, or samphire; often with scattered clumps of lignum Muehlenbeckia or canegrass, or sometimes tea-tree (Melaleuca). The Australian painted snipe sometimes utilises areas that are lined with trees, or that have some scattered fallen or washed-up timber (Marchant and Higgins 1993). The species is not known to utilise Exmouth Gulf area and is considered unlikely to transit through the Project area.	Unlikely to occur	The species is not known to utilise Exmouth Gulf and is considered unlikely to transit through the Project area.	N/A

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Bar-tailed godwit (baueri)	*Limosa lapponica baueri*	Vulnerable	Migratory – wetland	Schedule 3: Vulnerable fauna Schedule 5: Migratory birds - IA	At both state and Commonwealth level, bar-tailed godwit ssp. *menzbieri* is listed as Critically Endangered, and ssp. *baueri* listed as Vulnerable – field identification with certainty is challenging, but most birds in NW Australia belong to ssp. *menzbieri*.	May occur	The species may have been recorded locally (due to difficulty in identification) and includes suitable habitat.	• Anthropogenic light spill
Campbell albatross	*Thalassarche impavida*	Vulnerable	Migratory – marine	Schedule 3: Vulnerable fauna Schedule 5: Migratory birds - IA	The Campbell albatross predominantly occurs in subantarctic to subtropical waters and breeds on islands in the southern oceans (Commonwealth of Australia 2015b). The National Recovery Plan for Threatened Albatrosses and Giant Petrels 2011-2016 (DSEWPaC 2011c) does not identify any BIAs locally; however, the Campbell albatross has been recorded within Exmouth Gulf (Fitzpatrick et al. 2019).	Unlikely to occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Common noddy	*Anous stolidus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The common noddy is found in tropical and sub-tropical seas off the west, north and east coasts of Australia, from the Arbolhos islands in Western Australia to the islands of the Great Barrier Reef in Queensland, as well as Norfolk and Lord Howe Islands. It also ranges across tropical parts of the Pacific, Indian and Atlantic Oceans. The common noddy breeds on islands and is generally found on offshore tropical islands (Birdlife 2017). The species feeds mainly on fish and will often forage in offshore areas, sometimes being recorded hundreds of kilometres from breeding sites (Serventy et al. 1971). There are no seasonal migration movements associated with breeding, however movement patterns are poorly known.	Unlikely to occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Fork-tailed swift	*Apus pacificus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	Fork-tailed swifts are non-breeding visitors to all states and territories of Australia (Higgins 1999) and are widespread in coastal and subcoastal areas between Augusta and Carnarvon, including some nearshore and offshore islands. The fork-tailed swift leaves it's breeding grounds in Siberia around September and heads to Australia on their southern migration, arriving around October – November. They depart Australia for their breeding grounds around April.	Unlikely to occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Streaked shearwater	*Calonectris leucomelas*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	Streaked shearwaters forages in both shelf and pelagic waters, often forming large flocks that prey on small fish pursued by larger predatory fish. No streaked shearwaters were recorded during the Biota (2021) field survey.	Unlikely to occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Lesser frigatebird	*Fregata ariel*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The lesser frigatebird is said to be the most common and widespread frigatebird in Australian seas (Lindsey 1986). It is common in tropical seas, breeding on remote islands, between May and December in the Australian region. No lesser frigatebirds were recorded during the Biota (2021) field survey.	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Flesh-footed shearwater	*Puffinus carneipes*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The flesh-footed Shearwater is a trans-equatorial migrant and is a locally common visitor to waters of the continental shelf and continental slope off Southern Australia (south-western Western Australia to south-eastern Queensland). The species is a trans-equatorial migrant and breeds at three geographically distinct locations within Australian jurisdiction; one of which include 41 islands off the coast of the south-west Western Australia from late August to mid-May. Birds from the breeding colonies off south-western Western Australian range north to Bunbury and east to South Australia. On completion of the breeding season the species migrates north across the southern Indian Ocean to the Arabian Sea and Gulf Oman.	Unlikely to occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Wedge-tailed shearwater	*Puffinus pacificus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The wedge-tailed shearwater is a pelagic, marine bird known from tropical and subtropical waters and breeds colonially on the east coast and west coasts of	May occur	It is considered possible that, on occasions, individuals may be present locally. However, the	N/A

Common Name	Scientific Name	EPBC Act Threatened Status	EPBC Act Migratory Status	BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
					Australia and off-shore islands between August to May, areas within Western Australia includes North West Shelf, Houtman Abrolhos and islands south of Jurien Bay. Migratory populations from the southern hemisphere generally winter in the Tropics north of the equator, with birds from Western Australian breeding sites heading north to the Indian Ocean. In Australia, wedge-tailed shearwaters have been observed feeding along the junction between inshore and offshore water masses. In tropical waters, they mainly forage within the Equatorial Counter current, extending north and south into Equatorial Currents, and birds may be associated with current boundaries and associated upwellings (Drummond 1985; Reid et al. 2002).		species has not been recorded in close proximity to the Project area.	
Bridled tern	*Sterna anaethetus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	Bridle terns inhabit tropical and subtropical seas, breeding on islands (including vegetated coral cays, rocky continental islands and rock stacks) (Chatto 2001). In Australia, bridled terns are widespread, breeding on offshore islands in western, northern and north-eastern Australia and ranges north from Cape Leeuwin around northern Australia to mid-eastern Queensland. In Western Australia, breeding is widespread from islands off Cape Leeuwin (extending round the southern coast to Seal Rocks) north to Shark Bay and in Pilbara region and Kimberley Division. Breeding in Western Australia generally occurs between September and April. During the species northern passage from Western Australia, bridled terns appear to move through the Timor Sea during April, with loose flocks, including that season's young, observed moving north through the Lombok and Lintah Straits and Sabu and Banda Seas, in late April to late May, en route to the north-western Sulawesi Sea. During the Biota (2021) field surveys, bridled terns were recorded on Brown Island (21 individuals) and the islet north of Brown Island (~100 individuals).	May occur	The species has been recorded locally.	• Anthropogenic light spill
Caspian tern	*Sterna caspia*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The Caspian tern is mostly found in sheltered coastal embayment's and those with sandy or muddy margins are preferred. They also occur on near-coastal or inland terrestrial wetlands that are either fresh or saline, especially lakes (including ephemeral lakes), waterholes, reservoirs, rivers and creeks. They also use artificial wetlands, including reservoirs, sewage ponds and saltworks. In offshore areas the species prefers sheltered situations, particularly near islands, and is rarely seen beyond reefs (Higgins and Davis 1996). Within Australia, the Caspian tern has a widespread occurrence and can be found in both coastal and inland habitat. In Western Australia, Caspian terns are widespread in coastal regions, from the Great Australian Bight to the Dampier Peninsula and breeding occurs from the Recherche Archipelago to Dirk Hartog Island and Faure Island in Shark Bay. Caspian terns tend to forage in open wetlands, including lakes and rivers. They often prefer sheltered shallow water near the margins but can also be found in open coastal waters. In coastal inlets they may prefer to forage in tidal channels, or over submerged mudbanks (Higgins and Davies 1996). During the Biota (2021) field surveys, Caspian terns were recorded at Urala Creek North (up to six individuals) and Urala Creek South (up to two individuals) and surrounding habitats.	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Roseate tern	*Sterna dougallii*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The roseate tern occurs in coastal and marine areas in subtropical and tropical seas. The species inhabits rocky and sandy beaches, coral reefs, sand cays, and offshore islands and is rarely recorded in inshore waters or near the mainland. The roseate tern generally forages along the seaward margin of coral reefs, within reef lagoons, or over the reef itself. The species may also forage around islands on the continental shelf, either in lagoons or offshore. They are rarely recorded foraging in shallow sheltered inshore waters (Higgins and Davies 1996). Breeding mainly occurs off the coasts of Western Australia, the Northern Territory and Queensland. Breeding in Western Australia occurs from Second Rock, near Penguin Island, to Lacepede Island. During the Biota (2021) field surveys, bridled terns were recorded at Locker Island (33 individuals), Fly Island (~500 individuals), Observation Island (~90 individuals) and the islet north of Brown Island (~20 individuals).	May occur	The species has been recorded locally.	• Anthropogenic light spill
Common sandpiper	*Actitis hypoleucos*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	Found along all coastlines of Australia and in many areas inland, the common sandpiper is widespread in small numbers. The population when in Australia is concentrated in northern and western Australia (Blakers et al. 1984; Higgins and Davies 1996). The species utilises a wide range of coastal wetlands and some inland wetlands, with varying levels of salinity, and is mostly found around muddy margins or rocky shores and rarely on mudflats. Generally, the species forages in shallow water and on bare soft mud at the edges of wetlands; often where obstacles project from substrate, e.g. rocks or mangrove roots. Birds sometimes venture into grassy areas adjoining wetlands (Higgins and Davies 1996). During the Biota (2021) field surveys, common sandpipers were recorded at Urala Creek North (~seven individuals).	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill
Sharp-tailed sandpiper	*Calidris acuminata*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The sharp-tailed sandpiper spends the non-breeding season in Australia. Most of the population migrates to Australia, mostly to the south-east and are widespread in both inland and coastal locations and in both freshwater and saline habitats (Higgins and Davies 1996). Small numbers arrive in north-west Australia during mid-August, with large numbers in early September. The sharp-tailed sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. During the Biota (2021) field surveys, sharp-tailed sandpipers were recorded at Urala Creek South (~four individuals).	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill
Pectoral sandpiper	*Calidris melanotos*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	In Western Australia, the species is rarely recorded. The species is usually found in coastal or near coastal habitat but occasionally found further inland (Higgins and Davies 1996). During the Biota (2021) field surveys, pectoral sandpipers were recorded at Ashburton River at Urala Causeway (~one individual).	May occur	The species has been recorded locally but rarely recorded in the area.	• Anthropogenic light spill
Terek sandpiper	*Xenus cinereus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The Terek sandpiper is listed as Migratory under the EPBC Act, Migratory under the BC Act and Least Concern on the IUCN Red List. The species is widespread in the Pilbara region and Kimberley Division, from Dampier to Wyndham, with occasional records around Shark Bay. Approximately 23,000 spend the non-breeding season in Australia (Geering et al. 2007). The Terek sandpiper mostly forages in the open, on soft wet intertidal mudflats or in sheltered estuaries, embayment's, harbours or lagoons (Marchant and Higgins 1993). The Terek sandpiper was recorded during two Biota (2021) field surveys at Urala Creek, December 2018 and March 2019. A maximum of 26 Terek sandpiper were recorded during the March 2019 survey.	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Broad-billed sandpiper	*Limicola falcinellus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The broad-billed sandpiper is listed as Migratory under the EPBC Act, Migratory under the BC Act and Least Concern on the IUCN Red List. In Western Australia, they mostly occur on the coasts of the Pilbara and Kimberley between Onslow and Broome (Higgins and Davies 1996). Very few adults arrive during August and early-September. By late October both adults and first-year birds have arrived. The broad-billed sandpiper occurs in sheltered parts of the coast, favouring estuarine mudflats and is commonly observed in Exmouth Gulf. The broad-billed sandpiper was recorded during four of the five Biota (2021) field surveys at Urala Creek. A maximum of approximately 175 broad-billed sandpipers were recorded during the December 2018 survey.	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill
Grey-tailed tattler	*Tringa brevipes*	N/A	Migratory – marine	Priority 4 Schedule 5: Migratory birds - IA	Within Australia, the grey-tailed tattler has a primarily northern coastal distribution and is found in most coastal regions (Higgins and Davies 1996). The Grey-tailed Tattler usually forages in shallow water, on hard intertidal substrates. It has also been recorded foraging on exposed intertidal mudflats, especially with mangroves and possibly seagrass nearby (Higgins and Davies 1996). The grey-tailed tattler is commonly observed in Exmouth Gulf. The grey-tailed tattler was recorded during all five Biota (2021) field surveys at Urala Creek. A maximum of 228 grey-tailed tattlers were recorded during the March 2019 survey.	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill
Oriental plover	*Charadrius veredus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The Oriental Plover is a non-breeding visitor to Australia, where the species occurs in both coastal and inland areas, mostly in northern Australia. Most records are along the north-western coast, between Exmouth Gulf and Derby. The species is generally gregarious, and usually occurs in small parties or flocks of hundreds or occasionally thousands, though some are seen singly (Marchant and Higgins 1993). During the Biota (2021) field surveys, oriental plovers were recorded incidentally (~15 individuals).	May occur	The species has been recorded locally.	• Anthropogenic light spill
Oriental pratincole	*Glareola maldivarum*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	Most of the migratory population of the species is thought to spend the non-breeding season in Australia (Higgins and Davie, 1996). Within Australia the oriental pratincole is widespread in northern areas, especially along the coasts of the Pilbara Region and the Kimberley Division in Western Australia, the Top End of the Northern Territory, and parts of the Gulf of Carpentaria. It is also widespread but scattered inland, mostly north of 20° S (Blakers et al. 1984; Barrett et al. 2003). Oriental pratincole usually inhabits open plains, floodplains or short grassland (including farmland or airstrips), often with extensive bare areas (Jaensch 2004). No oriental pratincole were recorded during the Biota (2021) field survey.	Unlikely to occur	It is considered possible that, on occasions, individuals may be present locally. However, the species has not been recorded in close proximity to the Project area.	N/A
Osprey	*Pandion haliaetus*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The breeding range of the osprey extends around the northern coast of Australia (including many offshore islands). Ospreys occur in littoral and coastal habitats and terrestrial wetlands of tropical and temperate Australia and offshore islands. They are mostly found in coastal areas but occasionally travel inland along major rivers, particularly in northern Australia (Marchant and Higgins 1993; Olsen 1995). The osprey breeds from April to February in Australia. No ospreys were recorded during the Biota (2021) field survey.	Unlikely to occur	It is considered possible that, on occasions, individuals may be present within the Project area. However, the species has not been recorded in close proximity to the Project area.	N/A
Crested tern	*Thalasseus bergii*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	The crested tern is the second largest of the terns found in Australia and one of the most commonly seen species. Crested terns form small to large flocks, often with other species, along coastal areas throughout Australia and Tasmania. They are seldom seen on inland waterways, preferring islands, beaches, lakes and inlets. During the Biota (2021) field surveys, bridled terns were recorded at Urala Creek North (5-10 individuals), Tubridgi Coast (six individuals), Locker Island (~70 individuals), Fly Island (~80 individuals), Observation Island (~three individuals) and the islet north of Brown Island (~50 individuals).	Likely to occur	The species has been recorded i locally.	• Anthropogenic light spill

Common Name	Scientific Name	EPBC Act		BC Act *	Preferred Habitat	Likelihood of Occurrence		Potential Project Risk Which May Cause Population Impact
		Threatened Status	Migratory Status					
Common greenshank	*Tringa nebularia*	N/A	Migratory – marine	Schedule 5: Migratory birds - IA	Common greenshanks are found both on the coast and inland, in estuaries and mudflats, mangrove swamps and lagoons. They are common throughout Australia in the summer. During the Biota (2021) field surveys, common sandpipers were recorded during four of the five Biota (2021) field surveys at Urala Creek. A maximum of 93 grey-tailed tattlers were recorded during the March 2019 survey within Urala Creek North.	Likely to occur	The species has been recorded locally.	• Anthropogenic light spill

Note: * As per Wildlife Conservation (Specially Protected Fauna) Notice 2018.
N/A: Not applicable

Appendix C

Light Spill Modelling

AECOM

ASHBURTON SALT: BENCHMARK LIGHT MONITORING AND MODELLING

Prepared by

Pendoley Environmental Pty Ltd

For

AECOM

21st September 2020

DOCUMENT CONTROL INFORMATION

TITLE: ASHBURTON SALT: BENCHMARK LIGHT SURVEY AND MODELLING

Disclaimer and Limitation

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1 INTRODUCTION

K plus S Salt Australia (K+S) is proposing to develop a green field solar salt project on the coast of Western Australia approximately 40 km south-west of Onslow, adjacent to Tubridgi Point. The Ashburton Salt Project (the project) includes a development envelope with approximately 46,537 ha of terrestrial habitat, 13,345 ha of potential intertidal habitat, and 7,553 ha of marine habitat. The project will include the construction of solar salt concentration and crystallisation ponds and associated infrastructure, including:

- Sea water intake pipeline/s;
- Internal site roads;
- A jetty and loading facilities;
- A salt wash plant;
- Salt stockpiles and conveyors;
- Onsite buildings such as offices, storage and workshops;
- Equipment parking and laydown areas;
- Bitterns discharge infrastructure and pipeline or channel dilution pond; and
- Drainage diversion/s.

The EPA-approved Environmental Scoping Document (EnviroWorks 2017) for the project recognised marine turtles as a sensitive receptor that were potentially present in the area and identified artificial light as a specific impact factor. AECOM, who were awarded the environmental monitoring work for the project, engaged Pendoley Environmental (PENV) to undertake a benchmark light survey and light modelling from several locations (**Figure 1**) to assess the potential changes to the light environment from the project.

2 METHODOLOGY

2.1 Benchmark Light Survey

2.1.1 Survey Locations and Schedule

Four survey locations were selected for benchmark light data collection: three situated on the mainland and the one on the south side of Locker Island (see **Figure 1**). There was no road access to the survey locations and therefore a helicopter was used to reach each location.

Light data was collected for three monitoring nights between 22nd and 25th May 2019.

GPS coordinates of each survey location were recorded to enable comparison with future lighting surveys if required. The survey sites and GPS positions for the cameras are shown in **Table 1**.

Table 1: Survey locations and GPS positions. Refer to **Figure 1** for geographical location.

Survey location	Latitude	Longitude
LM1	-21.88959	114.64261
LM2	-21.83138	114.67015
LM3	-21.80092	114.73666
Locker Island	-21.71672	114.76704

2.1.2 Data Capture

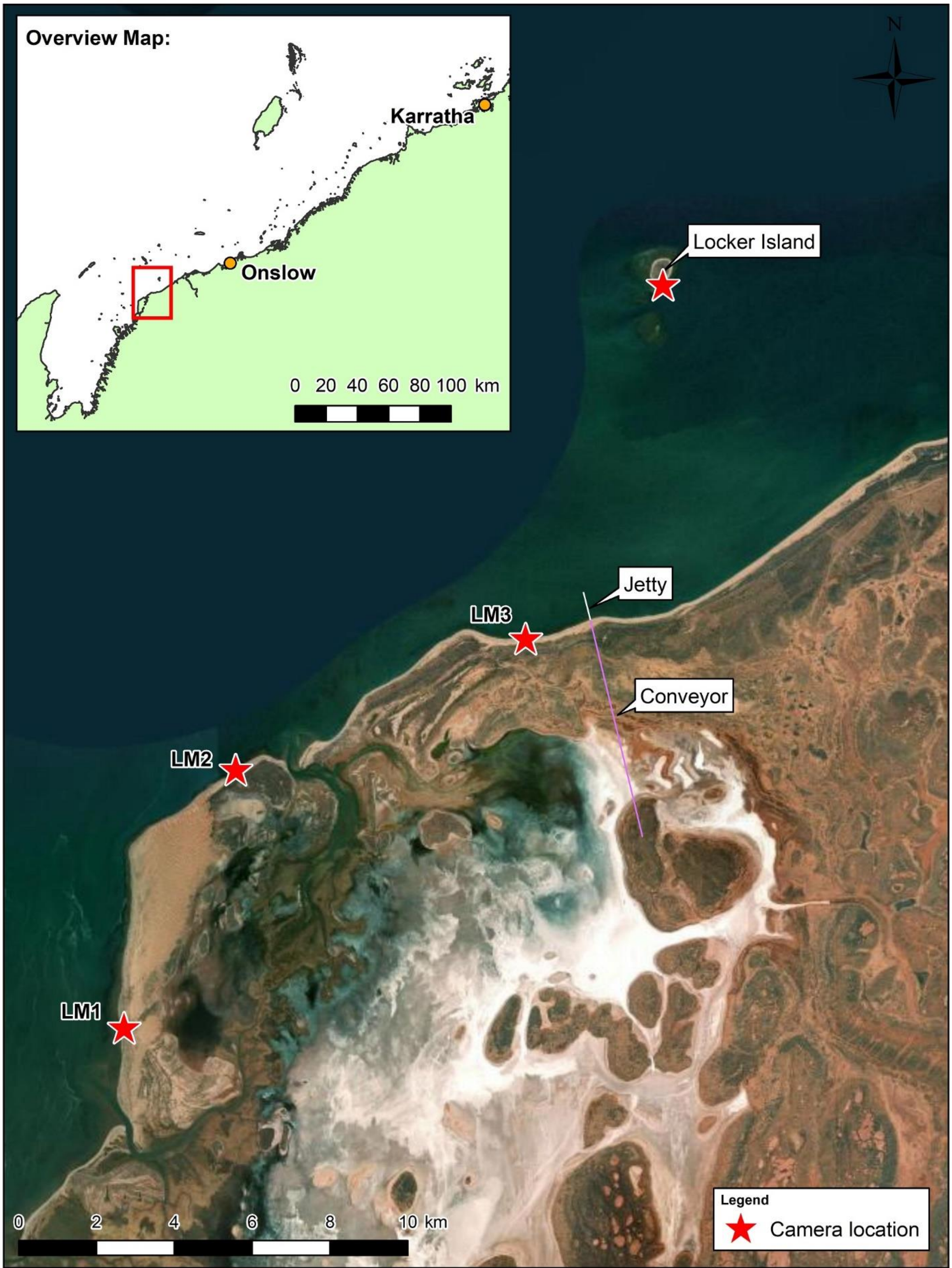
Light data was gathered at each survey location using a Sky42™ light monitoring camera. The camera is a calibrated Canon EOS 700D combined with a fish-eye lens and custom-built hardware to acquire low-light images of the entire night sky. The cameras are built into a rigid housing with a protective lid that automatically opens during image capture and closes between capture intervals. The cameras were deployed at each survey location and were programmed to automatically begin taking photos in 15-minute intervals between sunset and sunrise. Images were downloaded from the cameras each day.

2.1.3 Data Analysis

The quality of an image captured by a Sky42 light monitoring camera can be influenced by atmospheric factors such as the presence of the moon, twilight, cloud, rain, dust, humidity, or physical factors such as accumulation of sand or dust on the lens. Any images that were affected by physical factors were removed from the analysis, as well as any images that were affected by the moon or twilight.

All suitable images were processed into isophote maps using specialised software to determine "whole-of-sky" and "horizon" sky brightness levels. Whole-of-sky (WOS) is the mean value of sky glow in the entire image, and horizon is the mean value of sky glow within the 60° – 90° outer band (**Figure 2**).

Sky brightness was quantified in units of visual magnitudes/arcsec^2 (V mag). A standard unit used in astronomical measurements and emerging as a standard for sky glow monitoring globally. V mag quantifies light intensity on an inverted logarithmic scale i.e. higher values represent lower intensity light, while lower values represent higher intensity light (**Table 2**). The image with the median value of



J08006 Ashburton Salt Artificial Light Monitoring 2019

Figure 1: Benchmark light survey locations.

Drawn: P. Whittock
Date: 17/05/2019
Drawing File Ref:
PENV-J08006-948-A
Coordinate System: GDA 1994 MGA Zone 50

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sky brightness for each site on a clear night was selected for complete analysis and presentation in this report.

Note that the colour coding used in the isophote map represents the scale of intensity of light and is not representative of the colour of light as perceived by a human/turtle eye or Sky42 camera.

Table 2: Qualitative interpretation of visual magnitude band values (source: Unihedron Sky Quality Meter). Use as guide only. *Values <17 V mag not provided by source (considered to represent light level greater than 'very high' and representative of skies brighter than an urban night sky horizon).

V mag range	Qualitative interpretation	Qualitative example of interpretation
21 – 22	Very low	Ideal natural dark night sky horizon
20 – 21	Low	Typical rural night sky horizon
19 – 20	Moderate	Typical suburban night sky horizon
18 – 19	High	Typical urban night sky horizon
17 – 18	Very High*	Poor urban night sky horizon

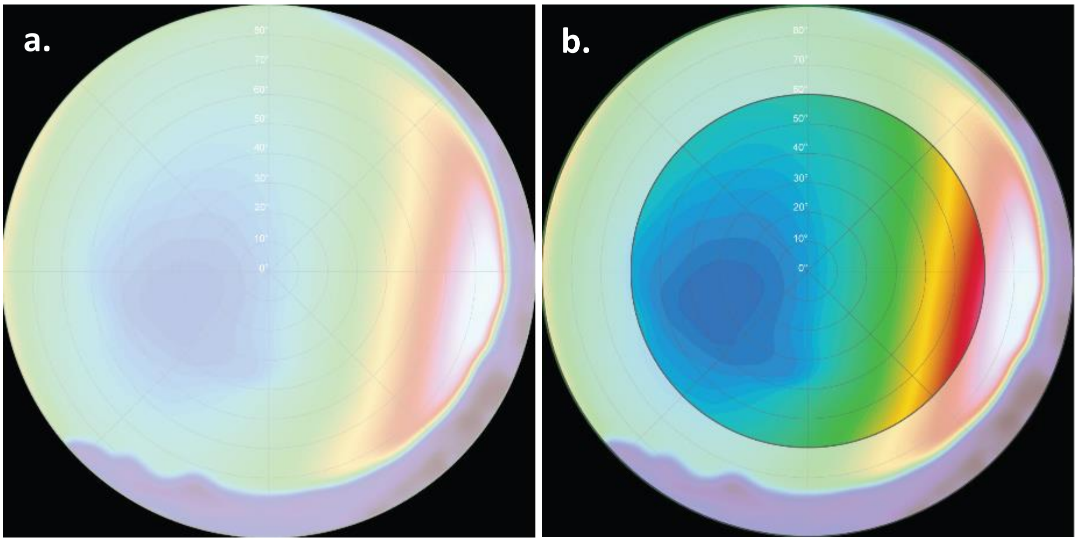

Figure 2: Measurement of mean pixel values; a. Whole-of-sky brightness (full image); b. Horizon brightness (60° – 90°). White shaded areas denote the region of the sky being measured.

2.2 Light Modelling

Modelling of predicted light from the project was undertaken using the imagery captured as part of the benchmark light survey as a base that represented existing lighting conditions (as of May 2019).

Of the four locations surveyed in the benchmark light survey, two were selected to be used in the artificial light modelling (Locker Island and LM3). These locations were selected due to their close proximity to the project location and marine turtle nesting habitat.

2.2.1 Scenarios

The potential for marine turtles to be impacted by artificial light can be minimised by reducing or removing visibility of point sources of light. This can be achieved by several means, including shielding of fixtures or smart controls such as curfews, motion sensors, and dimming.

Specifically, for the project, K+S stated that the jetty and conveyor lighting could be completely switched off when no vessel loading is taking place. This therefore formed the basis for the two scenarios:

- **Scenario 1:** 'Worst case' with all jetty and conveyor lights switched **on** at all times.
- **Scenario 2:** 'Best case' with all jetty and conveyor lights switched **off** when not in use (other lighting remains on).

2.2.2 Generation of Lighting Inventory

As detailed information on the lighting design was not available at this stage of the project, a lighting inventory was generated based on high level assumptions determined in consultation with AECOM and K+S. A summary of the included lights types and generated inventory is shown in **Tables 3** and **4**, and the detailed inventory used as input into the model is provided in **Appendix A**. Assumptions are detailed in **Section 2.2.2.1**.

Table 3: Light types used for generating the lighting inventory.

Fixtures	Type	Colour temperature	Shielding (%)	Power (Lumens)
Type 1	LED	3000K	50	1500
Type 2	LED	5000K	50	2000
Type 3	LED	3000K	50	3000

Table 4: Lighting inventory containing a summary of lights used in the modelling.

Location	Description	Number of lights	Height (m)	Fixture type
Jetty		72	14.5	Type 1
Conveyor		740	3	Type 1
Stacker + Reclaimer	Arms	10	20	Type 1
Stacker + Reclaimer	Arms - safety	4	20	Type 2
Stacker + Reclaimer	Body	12	15	Type 1
Stacker + Reclaimer	Body - safety	10	15	Type 2
Dumping Bridge	Top	12	15	Type 1
Dumping Bridge	Spotlight	5	10	Type 3
Dumping Bridge	Bottom	8	5	Type 2
Admin	A1	160	3	Type 1
Admin	A1 - safety	16	3	Type 2
Admin	A2	114	3	Type 1
Admin	A2 - safety	11	3	Type 2
Admin	A3 (x2)	32	3	Type 1
Admin	A3 (x2) - safety	3	3	Type 2
Wash Plant	standard	68	3	Type 1
Wash Plant	safety	7	3	Type 2

2.2.3 Lighting Assumptions

Assumptions made to generate the lighting inventory are as follows:

- In the absence of a detailed lighting inventory, photographs of an existing salt project in the Pilbara were used to predict the type and quantity of lights used as part of this projects lighting.
- Only one dumping bridge will be illuminated at a time. The central bridge was selected for inclusion in the light modelling.
- 10 % of the admin and wash plant lights are task lighting (whiter and brighter).
- Lights on the jetty and conveyor are 3 m above the height of the structure.
- Lighting of the loading vessel is not accounted for in the model.
- There are two potential locations for the jetty. For the light modelling, the NW-facing jetty was selected for inclusion. Note there is unlikely to be any significant difference in light emissions and visibility between the two potential jetty locations.

3 RESULTS

3.1 Benchmark Light Survey

Data was successfully collected from the four survey locations during each night of monitoring. There was no adverse weather and all nights were free of rain and cloud cover.

The sky brightness from the median image at each survey location is shown in **Table 5**. All locations had similar WOS brightness levels, with LM3 (21.33 V mag) and Locker Island (21.33 V mag) slightly brighter than LM1 (21.48 V mag) and LM2 (21.42 V mag). Horizon brightness followed a similar trend, with LM3 brightest (21.21 V mag) and LM1 darkest (21.49 V mag).

Table 5: Mean sky brightness (V mag) for whole-of-sky and horizon brightness from a median image captured on a clear night at each survey location.

Survey location	Sky brightness (V mag)	
	Whole-of-sky	Horizon
LM1	21.48	21.49
LM2	21.44	21.39
LM3	21.33	21.21
Locker Island	21.33	21.24

The Wheatstone LNG Development situated near Onslow was the largest source of sky brightness and was visible from all survey locations (see **Figures 3** – **6**). This was followed by the Wheatstone Accommodation Village and Macedon LNG Development, visible from all sites other than LM1 due to the larger distance and presence of high dunes between the survey location and light source. With the exception of LM3, the town of Exmouth was also visible as a small source of brightness from all survey locations.

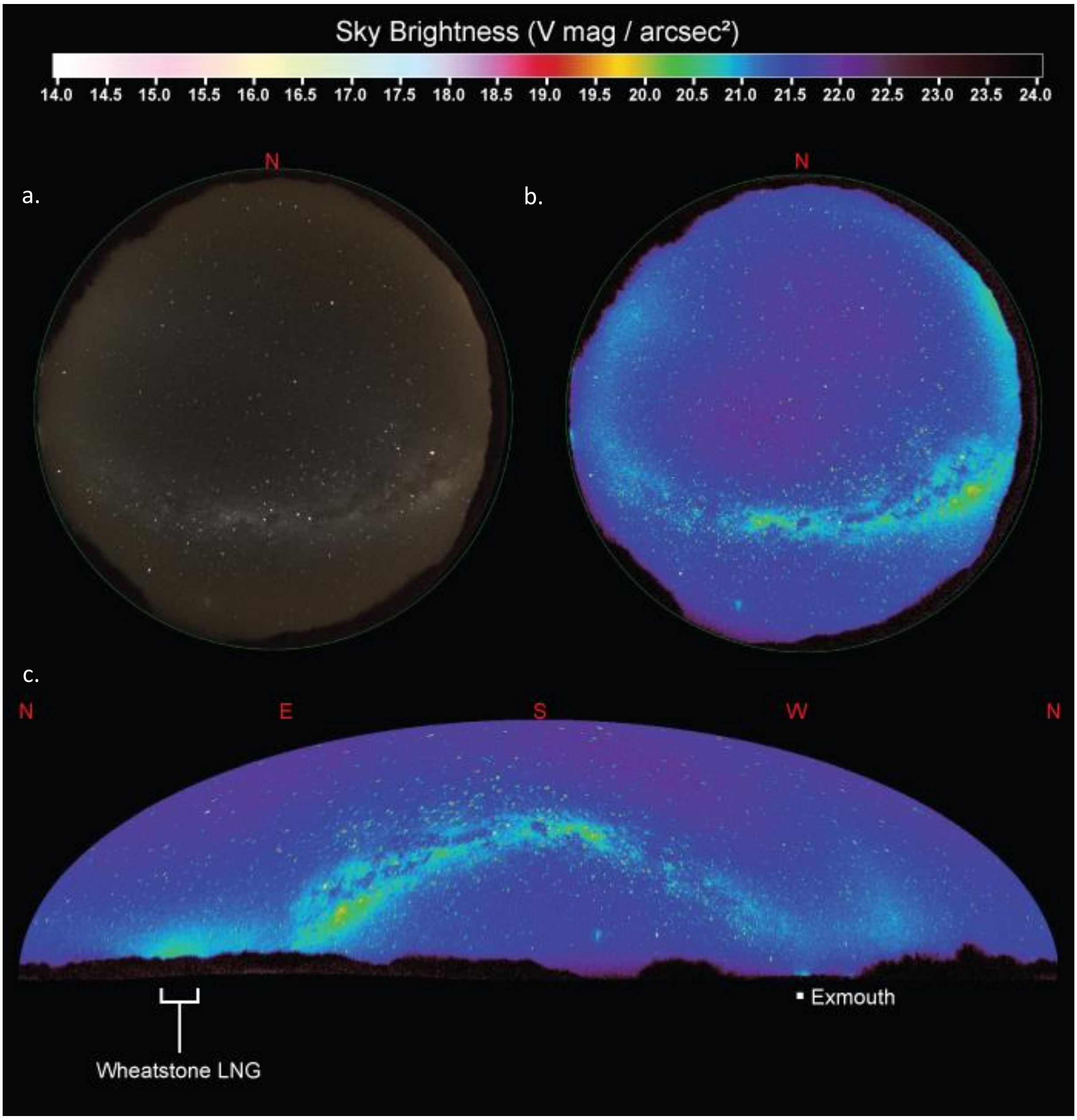

Figure 3: Artificial light monitoring results at LM1 on 23rd May 2019; a. Median raw image; b. Processed isophote image; c. Processed hammer-aitoff projected panorama showing location of visible light sources.

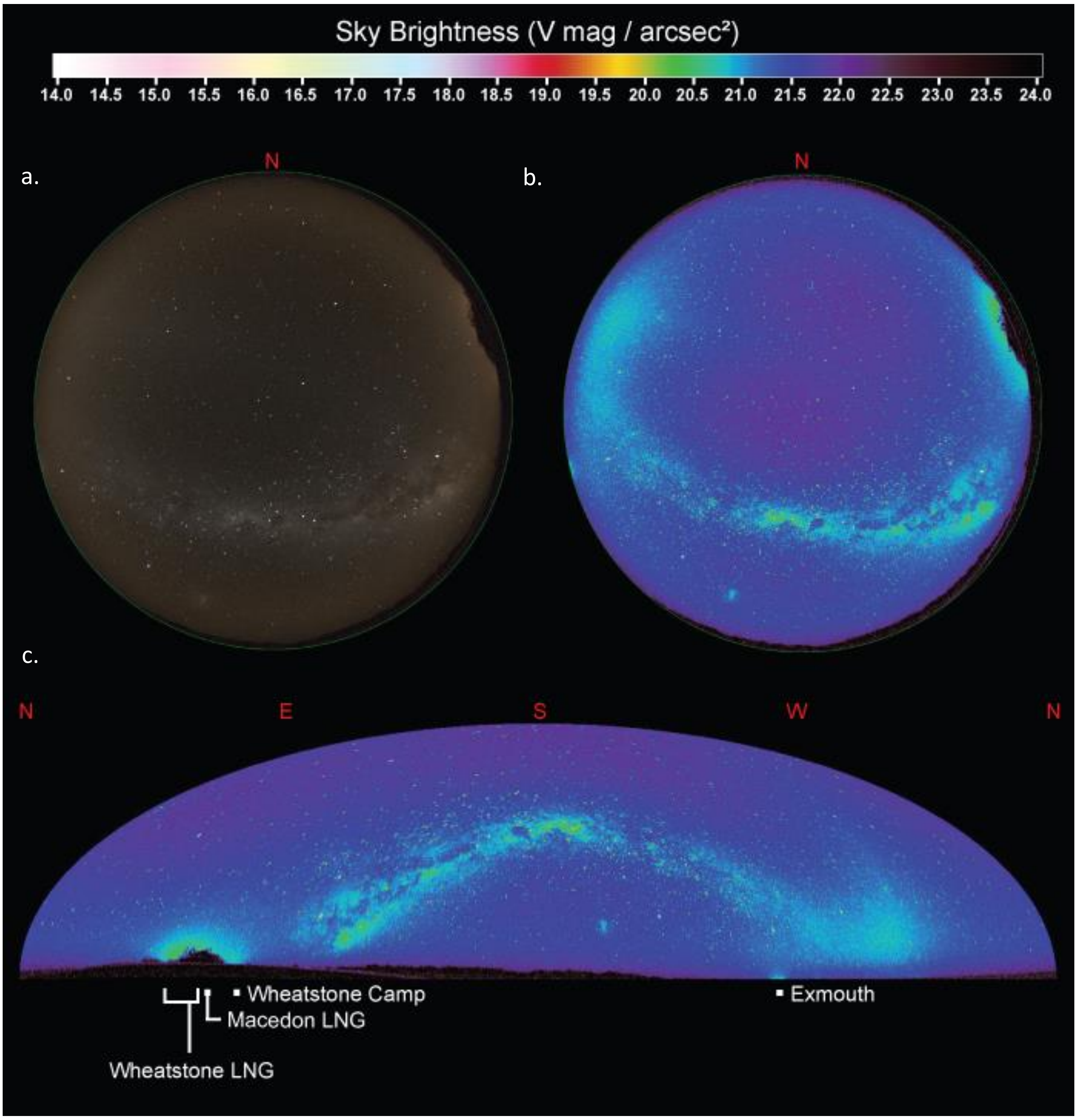

Figure 4: Artificial light monitoring results at LM2 on 23rd May 2019; a. Median raw image; b. Processed isophote image; c. Processed hammer-aitoff projected panorama showing location of visible light sources.

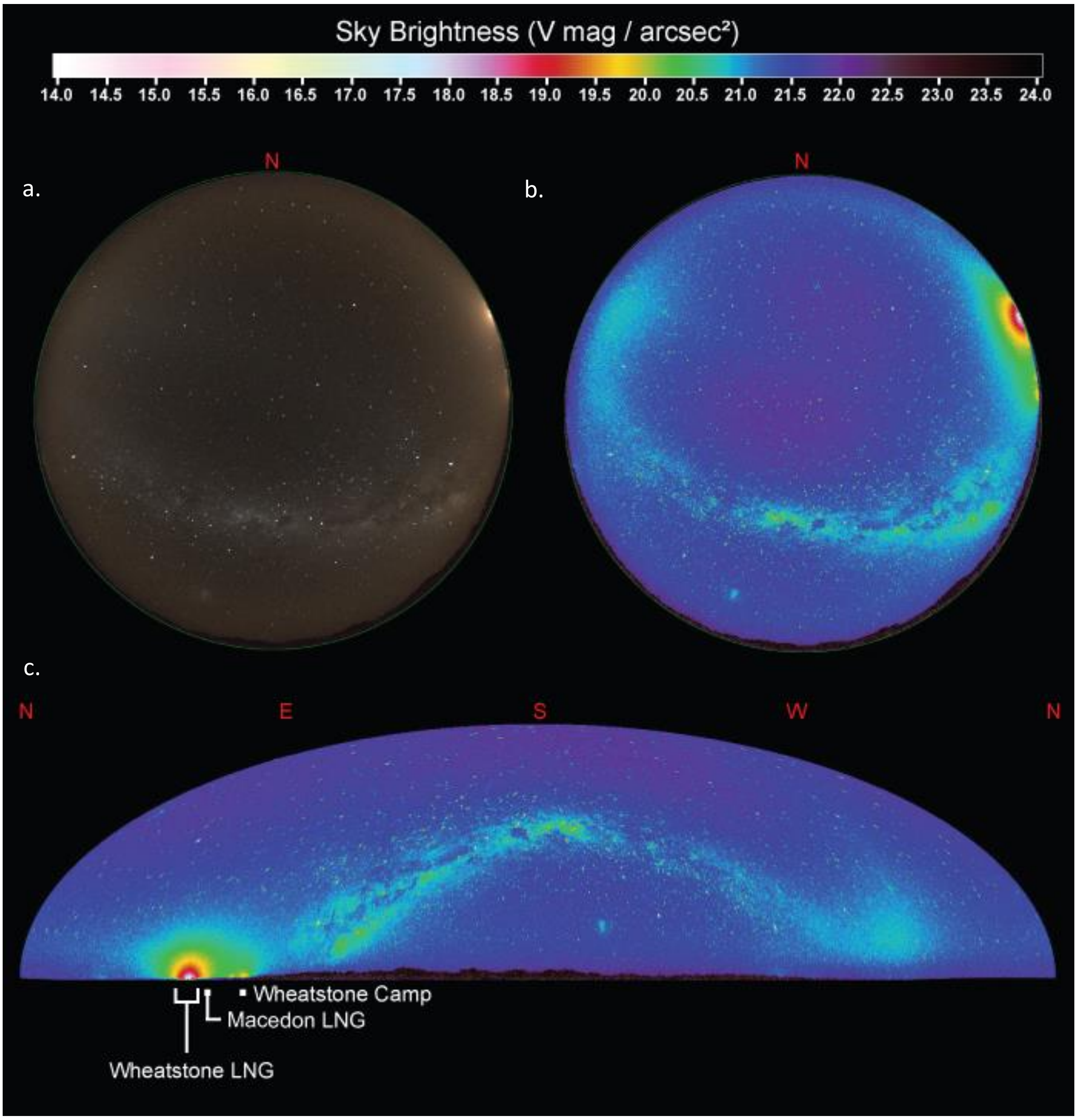

Figure 5: Artificial light monitoring results at LM3 on 23rd May 2019; a. Median raw image; b. Processed isophote image; c. Processed hammer-aitoff projected panorama showing location of visible light sources.

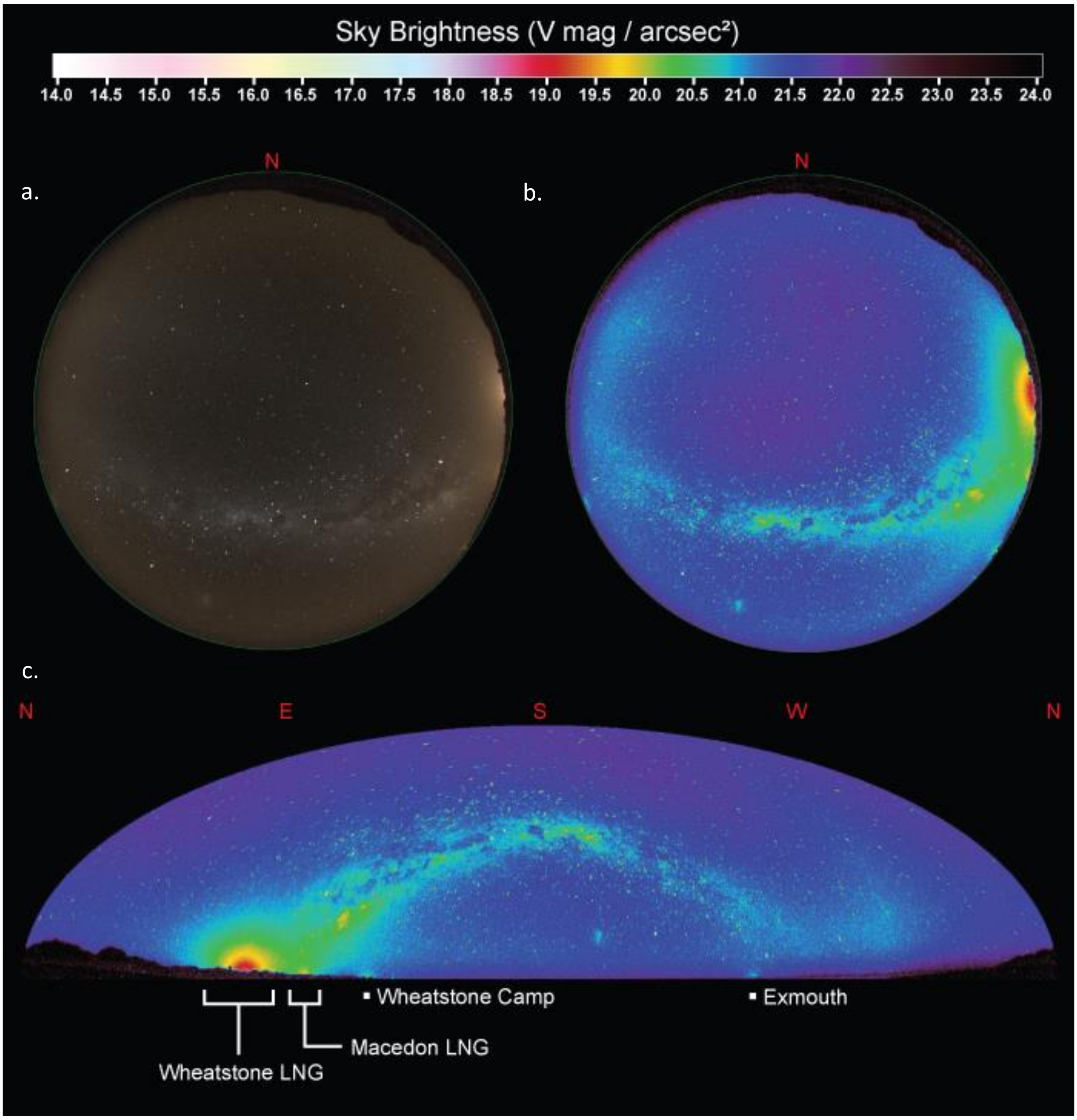

Figure 6: Artificial light monitoring results at Locker Island on 23rd May 2019; a. Median raw image; b. Processed isophote image; c. Processed hammer-aitoff projected panorama showing location of visible light sources.

3.2 Light Modelling

3.2.1 Scenario 1: Worst Case

Scenario 1 light modelling results are presented in **Figures 7** and **8**.

The largest increase in WOS and horizon brightness for this scenario was at LM3 (10.4 % and 16.9 % respectively; see **Table 6**). Visible point sources include the project's jetty and part of the conveyor (**Figure 7**). These sources partially merge with the Wheatstone and Macedon LNG Developments also located along the same bearing.

While a substantial amount of the project's point source lighting is shielded behind the dunes (bearing 85° – 180°), sky glow from these sources is still visible up to approximately 20° above the horizon over this area.

The survey location at Locker Island showed a minimal increase in WOS and horizon brightness (0.9 % and 1.8 % respectively; see **Table 6**). This increase was lower when compared to LM3 due to the greater distance from the proposed development. Individual point sources are not visible from the island, however, low-intensity sky glow from the cumulative project lighting is visible (bearing 185°) from this location (**Figure 8**).

Table 6: Comparison of benchmark and Scenario 1 modelled sky brightness values (V mag).

View	Survey location	Sky brightness (V mag)		Change in brightness (%)
		Benchmark	Scenario 1	
Whole-of-sky	LM3	21.32	21.20	10.4
	Locker Island	21.32	21.31	0.9
Horizon	LM3	21.21	21.04	16.9
	Locker Island	21.24	21.22	1.8

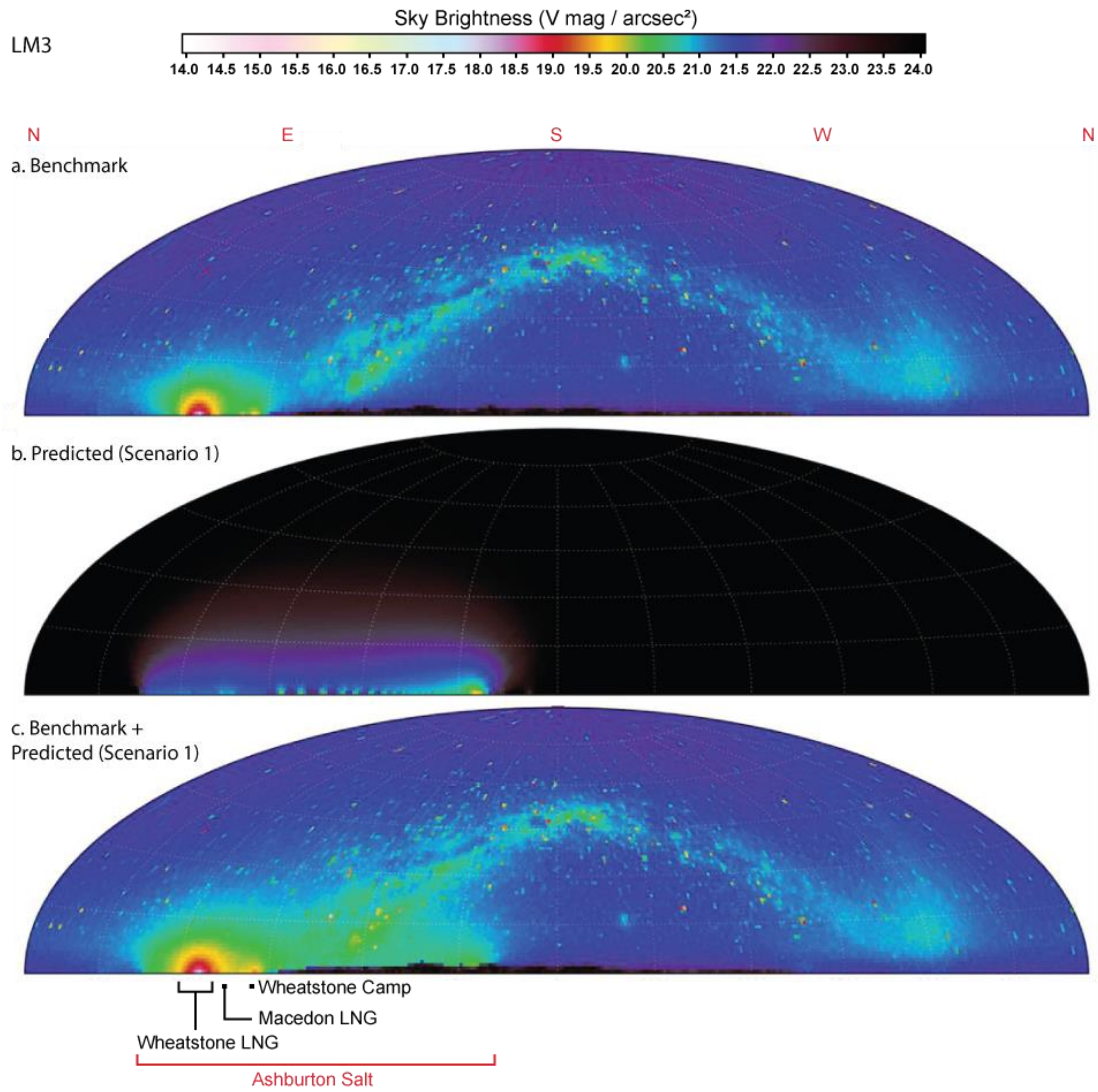

Figure 7: Artificial light modelling results for LM3 using Scenario 1 (worst case): a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 1; c. Median benchmark image + modelled brightness.

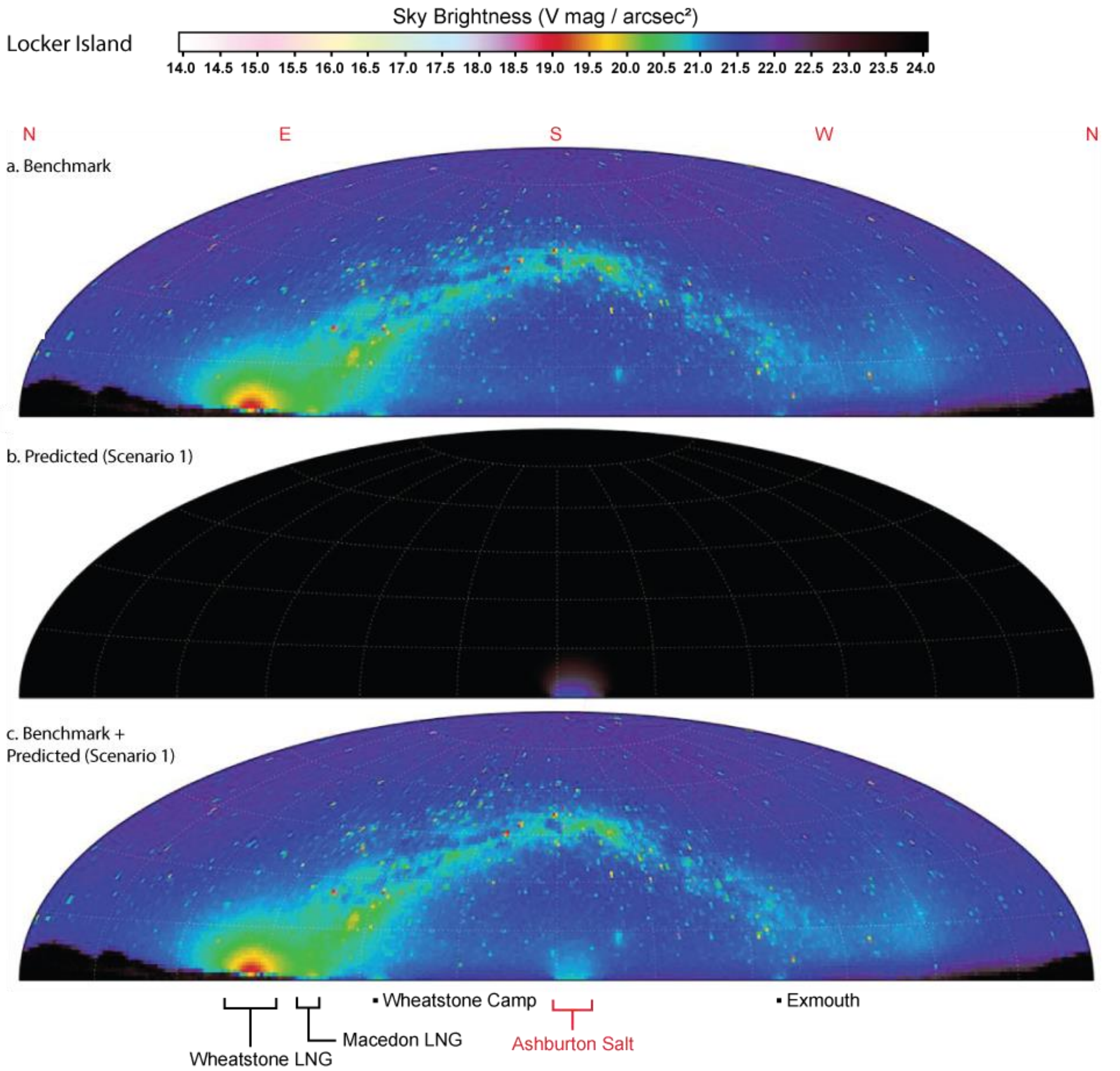

Figure 8: Artificial light modelling results for Locker Island using Scenario 1 (worst case): a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 1; c. Median benchmark image + modelled brightness.

3.2.1 Scenario 2: Best Case

Scenario 2 light modelling results are presented in **Figures 9** and **10.**

There is a small increase in WOS and horizon brightness by 1.5 % and 2.8 % respectively at LM3 (**Table 7**). As all jetty and conveyor lighting is off in this scenario, these point sources were no longer visible from LM3. The remainder of the project lighting cumulatively forms a small region of glow at bearing 155° that was partially shielded by dunes (**Figure 9**).

There is no visibility of the project site from Locker Island in this scenario (**Figure 10**). While there is a small change in WOS and horizon brightness (0.9 % and 2.1 %, respectively), this is likely to be undetectable from ambient light levels.

Table 7: Comparison of benchmark and Scenario 2 modelled sky brightness values (V mag).

View	Survey location	Sky brightness (V mag)		Change in brightness (%)
		Benchmark	Scenario 2	
Whole-of-sky	LM3	21.32	21.31	1.5
	Locker Island	21.32	21.31	0.9
Horizon	LM3	21.21	21.18	2.8
	Locker Island	21.24	21.22	2.1

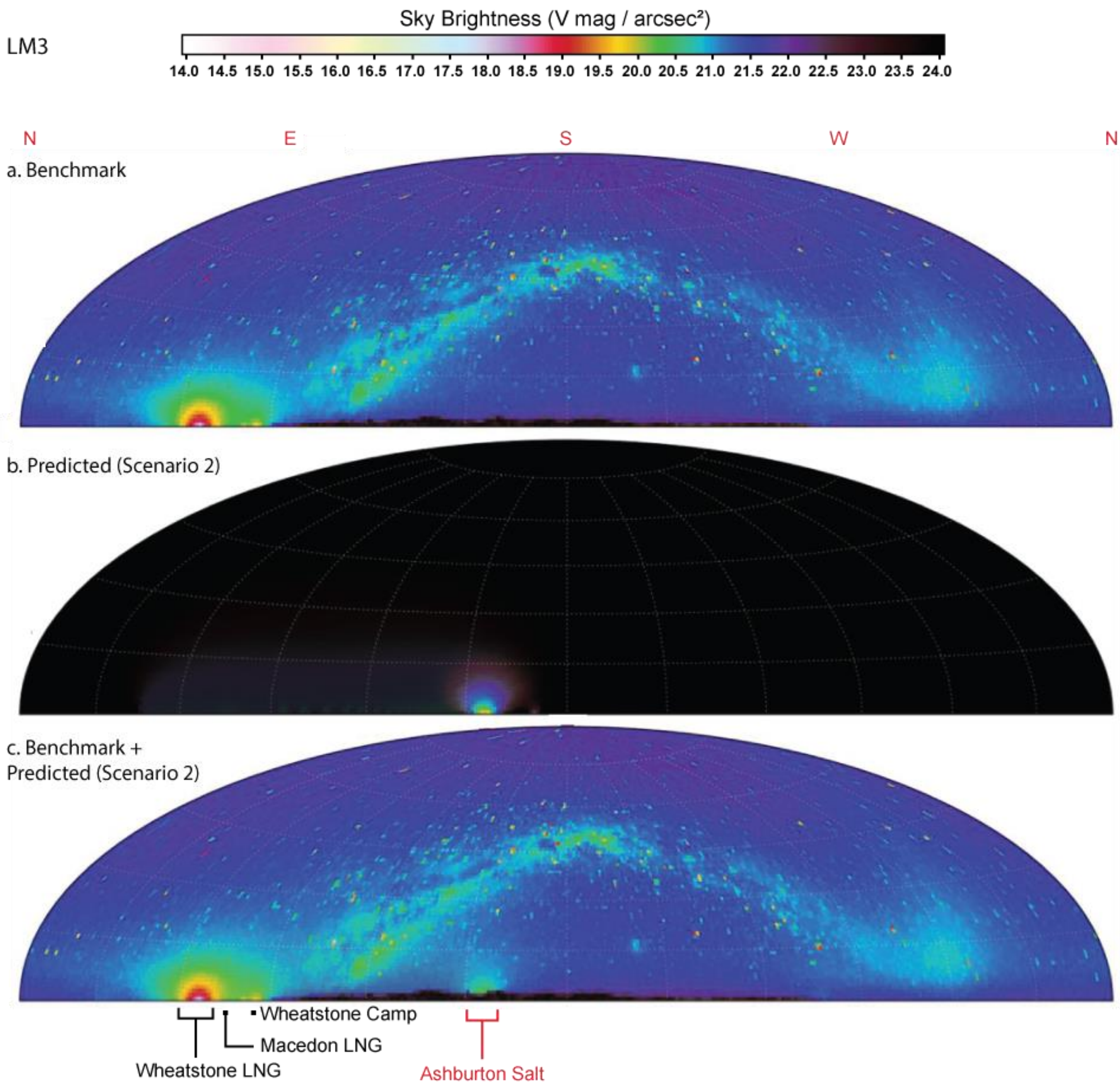

Figure 9: Artificial light modelling results for LM3 Scenario 2 (best case): a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 2; c. Median benchmark image + modelled brightness.

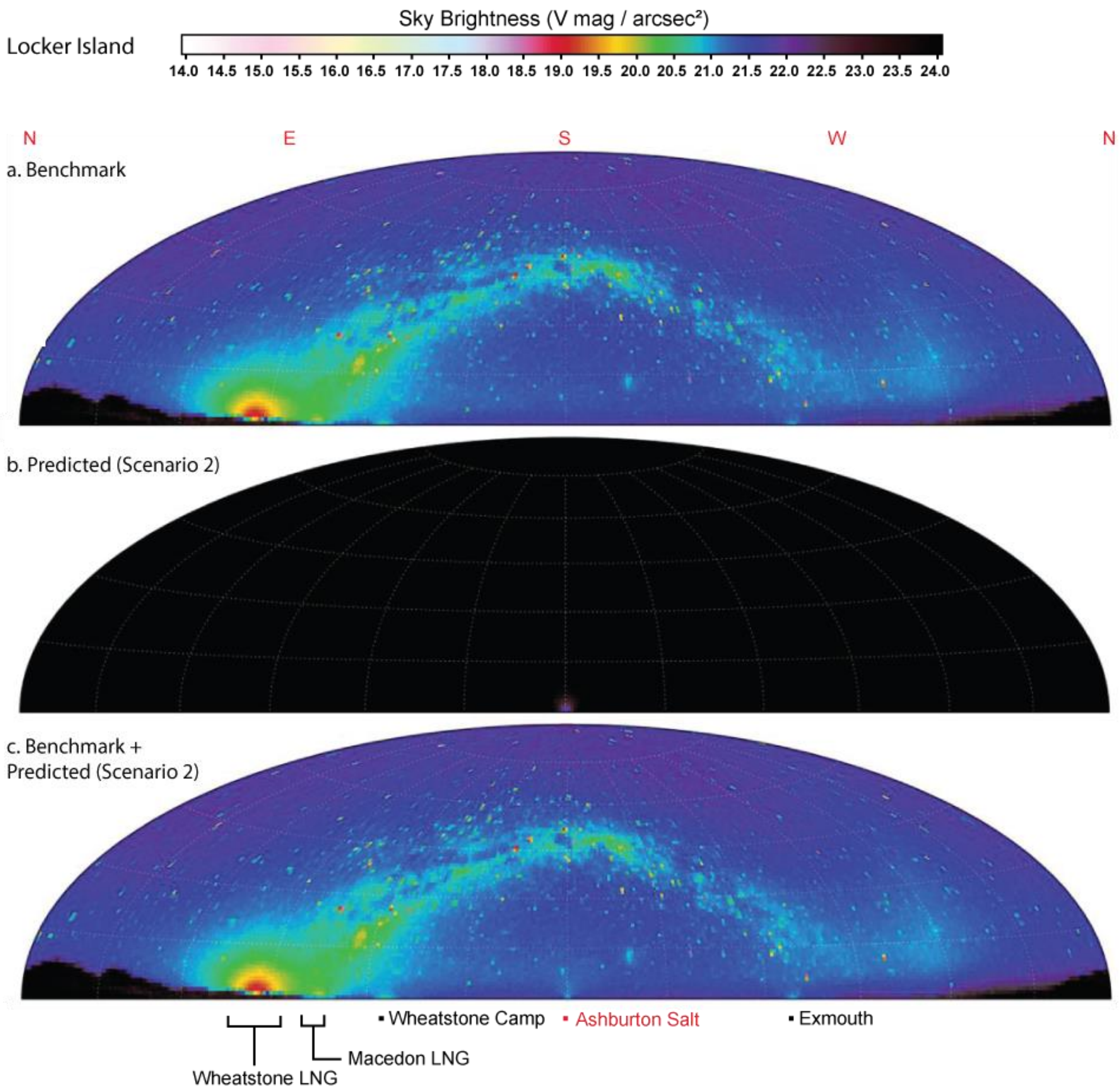

Figure 10: Artificial light modelling results for Locker Island Scenario 2 (best case): a. Median benchmark image recorded during the light survey; b. Modelled brightness based on lighting design for Scenario 2; c. Median benchmark image + modelled brightness.

4 DISCUSSION

The benchmark light survey identified the Wheatstone LNG Development as the brightest source of light within the region. All survey locations showed a spatial relationship with distance from this development, with the brightest values recorded at those survey locations situated closest (i.e. LM3 and Locker Island).

The modelled scenarios at LM3 indicate that light emissions from the project could increase WOS brightness between 1.5 % (best case) and 10.4 % (worst case), and horizon brightness between 2.8 % (best case) and 16.9 % (worst case) from current benchmark levels. The majority of this increase is due to the direct visibility of the project's jetty lighting and partial conveyor lighting from the survey location (bearing 45 - 85°).

Sky glow from some of the project's point sources is likely to merge with sky glow from the Wheatstone LNG Development. However under Scenario 1, due to the length of the conveyor, there is potential for sky glow to spread across a wide portion of dune horizon, and will constitute a permanent brightening of the horizon over this area (bearing 85 - 190°). If the jetty and conveyor lighting are switched off (Scenario 2), this brighter area becomes confined to a much smaller area on the horizon (bearing 180° – 190°).

At Locker Island, the modelled scenarios show a minimal increase in WOS brightness of 0.9 % (Scenario 1 & 2), and horizon brightness between 1.8 % (best case) and 2.1 % (worst case). These overall increases are much smaller compared to LM3 due to the larger distance from the project (LM3: 1.5 km, Locker Island: 8.5 km). However, under Scenario 1, the project will be clearly visible as a cumulative point source on the horizon at bearing 155°. When the Scenario 2 lighting controls are implemented (best case), this source is hardly detectable on the horizon.

In summary, the modelling indicates that a Scenario 1 lighting regime (i.e. all lights on) will create new point sources on part of the horizon visible at LM3. A larger part of the horizon behind the dunes will have a substantial increase in sky glow. As Locker Island is further from the project, individual point sources merge to create a singular, bright source visible over a small area of the horizon. When Scenario 2 lighting management is implemented (i.e. jetty and conveyor lights are turned off), light emissions are substantially reduced at both locations. At LM3, no point sources from the project will be visible, and glow from the project as a whole is hardly visible at all from Locker Island.

The marine turtle nesting habitat adjacent to LM3 is considered to have low-density turtle nesting activity. When all project lighting is on, the brightest sources are likely to be offshore (the jetty and vessel), and thus have a lower potential to cause hatchling disorientation inland. When the jetty and conveyor lighting is turned off, the brightest source of light from the development is situated onshore, behind the dunes. While this may potentially create a risk for hatchling disorientation, this source is darker relative to other existing sources including the nearby Wheatstone LNG Development. At Locker Island, due to the darkness of the modelled light emissions and its large distance from the project, there is a very low potential for the project to cause hatchling disorientation even under a 'worst case' scenario with all project lighting on.

5 RECOMMENDATIONS FOR BEST PRACTICE LIGHTING DESIGN

The following best practice light design principles for external light sources, summarised in **Figure 11**, are modified from Appendix A of the National Light Pollution Guidelines (Commonwealth of Australia 2020) to be specific to the proposed project.

1. Use minimum number and intensity of lights

- Base case of no lights.
- Lights added as required by legislation and engineering standards.
- Use modelling to compare light designs exploring trade off between number and intensity of lights.

2. Adapt lighting for colour, intensity and timing

- Identify lights that do not have legislative requirement for colour, intensity or timing and duration of operation.
- Use recommended light type.
- Adapt lights for preferred wavelength.
- Apply smart control options for switching off, dimming or flashing.

3. Light only the area intended

- Use shielding to prevent vertical and horizontal light spill.

4. Use non-reflective, dark coloured surfaces

- Consider reflective properties of surfaces to prevent sky glow.

Figure 11: Summary best practice lighting design principles applicable to the proposed project.

5.1 Lighting Design Control Measures

5.1.1 Use minimum number and intensity of lights

Starting from a base case of no lights, use only the minimum number and intensity of lights needed to provide safe and secure illumination required to meet the lighting objectives, including navigation, and health and safety requirements. Avoiding light fixtures surplus to needs will decrease overall light emissions. The intensity of light is thought to be as important a cue as colour for both marine turtles and some seabirds (Raine et al. 2017; Rodriguez et al. 2017a; Mrosovsky 1972; Mrosovsky & Shettleworth 1968; Pendoley & Kamrowski 2015; Cabrera-Cruz et al. 2018) and, therefore, intensity should be reduced to as low as possible, regardless of the type, colour and planned operation of the light.

5.1.2 Adapt lighting for colour, intensity and timing

Potential for impacts from white light is universal across the fauna groups (Commonwealth of Australia 2020). However, the optimum wavelength for reducing potential impacts differs between the species and the behaviours being undertaken. Marine turtles are more sensitive to short wavelength (UV to blue/green). Therefore, where compliant with health and safety requirements, white lights should be replaced with amber/orange lights. If white lights are required, filters to block green, blue, violet, and ultra-violet wavelengths should be applied. For lights that are not required to be continuously lit, smart LED technology should be implemented to allow for switching off when not in use, or the use of intermittent flashing lights.

The suitability of different commercial lights with respect to marine turtles is summarised in **Table 15**.

Table 8: Suitability of commercial lights. Source: Commonwealth of Australia (2020).

Light type	Suitability
Low Pressure Sodium Vapour	Recommended * 'Filtered' means this type of luminaire can be used only if a filter is applied to remove the short wavelength light
High Pressure Sodium Vapour	
Amber/orange LED	
Filtered* LED	
Filtered* metal halide	
Filtered* white LED	
White LED	Not recommended
Metal halide	
White fluorescent	
Halogen	
Mercury vapour	

Suggested control measures:

- Offshore lights to utilise amber LED emitters (~585 nm 'true amber' emitters, 'phosphor-coated amber').
- Onshore lights above 10 m height to utilise amber LED emitters (~585 nm 'true amber' emitters, 'phosphor-coated amber').
- Onshore lights <10 m and where there is a need for good colour rendition, to utilise LEDs with a CCT equal to or lower than 2700K.
- Green and blue lights only used where required by navigation law.
- If specific, intermittent tasks require a brighter white light (i.e. higher CCT), personnel are to use head torches.
- Lighting design to identify lights that are not required to be continuously lit.
- Lights that are not required to be continuously lit to be motion activated, put on a timer, or can be manually switched off.
- Flashing/intermittent lights, or reflectors to be installed onshore instead of fixed beam to identify an entrance or delineate a pathway.

5.1.3 Light only the area intended

Light spill is light that falls outside the area that is intended to be lit. Vertical light spill is light that spills above the horizontal plane, which contributes directly to artificial sky glow. Light spill that spills into adjacent areas, including the sea surface, is known as light trespass, and can potentially impact wildlife, such as marine turtle hatchlings, present in adjacent areas. To avoid any form of light spill, light fittings should be designed, located, and directed to avoid lighting anything but the target area, both onboard and overboard vessels and on land-based facilities.

Suggested control measures:

- All lights to be directed downwards using targeted asymmetrical distribution to illuminate only the specific areas of need, while minimising the reflectance.
- All lights to be mounted at a height as low as possible while meeting lighting objectives.
- The existing vegetation / dune between the nesting habitat and onshore lights to be maintained and enhanced where feasible.
- Onshore lights to be directed away from turtle nesting beaches. For lights required to be directed towards nesting beaches, lights should be placed so that buildings provide inherent shielding, where practicable.
- Offshore lights to be directed downwards and direct light spill onto the ocean surface avoided unless operationally required.
- Jetty design to prevent gaps in the floor which would result in light shining directly onto the ocean below the jetty, where compliant with technical and safety requirements. Shielding of all lights to achieve an upward waste light output ratio (ULR) of 0 %. Shielding can be achieved by recessing the light fitting into roof structures, eaves or building ceilings, or the light housing which prevents horizontal light above a 45-degree angle.
- All glass (windows/doors) of buildings to have a glass light transmissivity rating of 0.5 or less.
- All glass (windows/doors) of buildings to have opaque (block-out) blinds/curtains/shutters fitted.
- Vessel windows fitted with opaque (block-out) blinds/curtains/shutters unless continuous visibility is required (e.g. on the bridge).

5.1.4 Use non-reflective, dark coloured surfaces

Light reflected from highly polished, shiny, or light-coloured surfaces can contribute to sky glow. Use of dark matte surfaces can reduce reflectance and scattering of light that contributes to sky glow.

Suggested control measures:

- Exterior finishes on all buildings to be matte and have a maximum reflective value of 30 %.
- All other surfaces, including roads and conveyors within the CLF and jetty, to be matte and have a maximum reflective value of 30 %, unless not technically feasible or presents a health and safety risk.

5.2 Construction Control Measures (temporary)

- Prevent mobile light sources shining onto nesting beaches and keep the height of these to a minimum.

5.3 Operational Control Measures

- All non-essential lighting to be switched off when not in use.
- Building and vessel window blinds to be shut during hours between sunset and sunrise.
- Vessel lighting should be reduced to navigation lighting only when not operational.
- Vehicle headlights to be dipped when operating.

Appendix A: Detailed Lighting Inventory

Appendix D

Sawfish Survey

Sawfish surveys
Urala Creek, Exmouth Gulf, February 2019

Report to AECOM

August, 2020

Compiled by David Morgan, Karissa Lear and Bradley Norman

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Disclaimer:

While all responsibility has been taken to ensure that the contents of this report are factually correct, no responsibility is accepted for any loss or damage that may be occasioned directly or indirectly through the use of or reliance on the contents of this publication.

Summary

Targeted sawfish surveys were conducted in Urala Creek in the eastern side of the Exmouth Gulf, Western Australia, during February 2019. Urala Creek is a relatively large mangrove creek that drains into the north-eastern Exmouth Gulf south of Onslow in two entrance channels, which we term Urala Creek North and Urala Creek South. The northern entrance channel was surveyed on the 3^{rd} and 4^{th} of February 2019, and the southern entrance channel on the 5^{th} and 6^{th} of February 2019 to determine whether the area is used by green sawfish (*Pristis zjisron*), which is listed under the Australian Government's Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) as *Vulnerable*. Sampling methods consisted of gillnet and visual surveys conducted throughout the entrances and shallow channels of both creek systems. One green sawfish was captured in Urala Creek North, with three additional individuals observed in the same area; all sawfish being between ~1.2 and 1.4 m total length and were most likely to be young juveniles in their first year of life (see Morgan et al. 2015, 2017). The presence of sawfish in the creeks and the sighting of four individuals over a short time indicates that this area could be an important secondary nursery habitat for Critically Endangered green sawfish. Additionally, several other elasmobranchs were captured or observed during the surveys, and included two species that are listed as *Critically Endangered* under the IUCN Red List. These included numerous juvenile giant guitarfish (*Glaucostegus typus*) that were observed in the shallows and were captured by cast net and gillnet in Urala Creek north and south, indicating that this system may be an important nursery for this species. Additionally, a bottlenose wedgefish (*Rhynchobatus australiae*) was captured during gillnet sampling in Urala Creek South. Other elasmobranchs captured and sighted in the two creeks included juvenile to subadult lemon sharks (*Negaprion acutidens*), neonate to adult nervous sharks (*Carcharhinus cautus*), juvenile blacktip reef sharks (*Carcharhinus melanopterous*), Australian sharpnose sharks (*Rhizoprionodon taylori*) and spotted whiprays (*Himantura* sp.). Numerous green turtles (*Chelonia mydas*) were also sighted in the area and caught and released from gillnets.

Sampling methods

Gillnet sampling

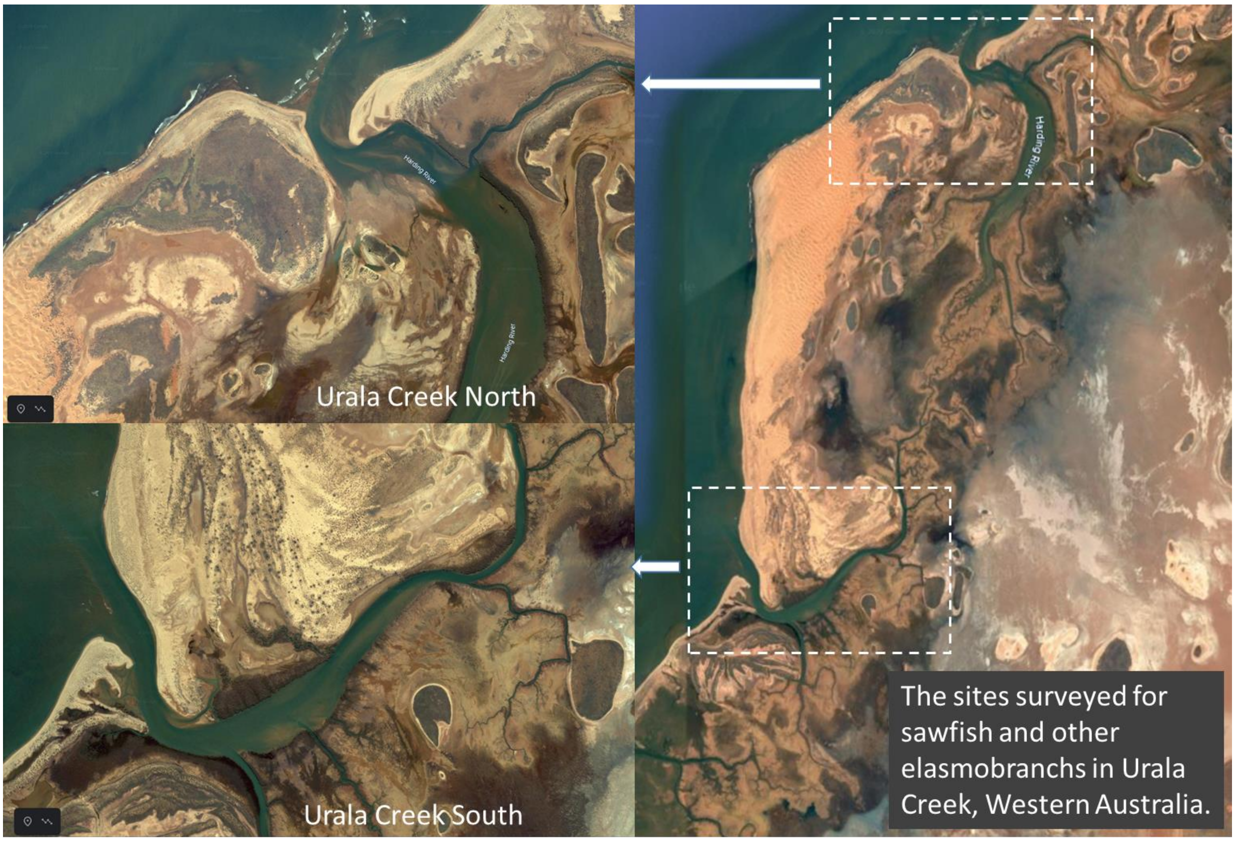
Gillnet sampling consisted of setting one to two 60 m sinking lengths of 152 mm (stretched mesh) monofilament gill nets. Nets were most often set perpendicular to the bank fishing from the shallows (0-0.1 m) to deeper water (up to 2 m), and were used to survey a variety of habitats in both creeks, including shallow sand flats, deeper channels, tidal flats close to mangroves, and mangrove lined side creeks. Nets were set for between 1.5 and 5 h, and were monitored constantly and checked when activity was observed in the net, or at a minimum of once per hour.

Any elasmobranchs or other taxa caught in the nets were immediately carefully removed, identified to the species level, and the total length and sex recorded. For sawfish, the total rostral length, standard rostral length, and number of rostral teeth on each side of the rostrum were also measured or counted. Tissue samples were also taken from sawfish, giant guitarfish, and wedgefish to contribute to the genetic tissue bank for these species. After measurements, all animals were released at the sight of capture. To determine the Catch Per Unit Effort (CPUE) of specific species, the total number of individuals of a species caught was divided by the total number of 20 m net hours fished.

Visual surveys

In addition to gillnet surveys, visual surveys from the shoreline and from the boat were conducted in each creek to provide additional information on the species diversity and densities present. Walking surveys were conducted by researchers either walking along the shoreline or along straight transect lines in shallow areas at different times of the day, recording any elasmobranchs or other notable taxa seen. Small juveniles of species tended to aggregate in certain areas near the shoreline, and for these aggregations the number of individuals was counted and the area occupied by the aggregation approximated. Surveys from the boat were conducted by driving the 3.75 m tender slowly along straight transect lines throughout the mouth and shallow areas of both creeks and noting any elasmobranchs spotted. While these visual surveys are less precise than net surveys in quantifying the densities of species present, visual surveys can cover a greater area than stationary gillnets. They were also particularly relevant here as, while sawfish of all sizes catch well in nets due to their toothed rostrum, other rays of all sizes and small sharks do not often get caught by the large mesh gillnets used here. The visual surveys when combined with the net surveys therefore provided a more complete picture of the elasmobranch diversity present in Urala Creeks North and South.

When possible, some individuals spotted during visual shoreline surveys were captured using cast nets. These individuals were used to confirm species identification, and, similar to individuals caught in gillnets, were measured, tissue sampled, and released at the site of capture.



The sites surveyed for sawfish and other elasmobranchs in Urala Creek, Western Australia.

Results and Discussion

Several green sawfish were sighted or caught during gillnet and visual surveys in Urala Creek North. Seven other elasmobranch species were also observed, including two *Critically Endangered* rays in addition to green sawfish: giant guitarfish (*Glaucostegus typus*) and bottlenose wedgefish (*Rhynchobatus australiae*) (see Kyne et al. 2019a, b). A total of 23 elasmobranchs were caught during the 58.8 x 20 m net effort hours of gillnet surveys in the north and south entrance channels of Urala Creek. Other species captured or observed during the surveys included juvenile lemon sharks (*Negaprion acutidens*), neonate to adult nervous sharks (*Carcharhinus cautus*), juvenile blacktip reef sharks (*Carcharhinus melanopterous*), Australian sharpnose sharks (*Rhizoprionodon taylori*) and spotted whiprays (*Himantura* sp.). Several green turtles (*Chelonia mydas*) were also captured and release from gill nets, and many more visually observed.

Sawfish

Three individual juvenile (<1.4 m) Green Sawfish (*Pristis zijsron*) were observed simultaneously in the shallow northern entrance of Urala Creek North on the 3/2/2019, two were observed in the same area in the morning of 4/2/2019, and a single *P. zijsron* was captured in a gill net on 4/2/2019 at this location (Fig. 3). It is possible that the three sawfish observed or caught on 4/2/2019 were the same individuals sighted on 3/2/2019, and therefore a minimum of three or a maximum of six individuals were observed in Urala Creek North. The individual caught (see frontispiece and Fig. 1) was a male of 1225 mm in total length (TL), and possessed a total of 52 rostral teeth (27 of the left side of the rostrum, and 25 on the right side of the rostrum). It was captured in waters that were a depth of ~30 cm; the five individuals observed in the same locality were also observed in 30-50 cm depth. This one gillnet capture resulted in a catch per unit effort (CPUE) for green sawfish of 0.03 sawfish per 20 m net per hour in Urala Creek North.

Figure 1: Green Sawfish (*Pristis zijsron*) captured in Urala Creek North on 4th February 2019.

No green sawfish were sighted in Urala Creek South, but it must be noted that only limited gillnet and visual surveys were possible. Surveys were largely conducted during daylight hours due to logistical and safety concerns related to hazardous weather conditions. However, the periods of highest activity for sawfish are typically at dusk and during night hours. Therefore, while only a few sawfish were captured or sighted during the sampling efforts, it is possible that the use of Urala Creek North and South by sawfish is much higher than indicated by the preliminary sampling conducted here. Future studies should aim to increase sampling effort during peak times of sawfish activity.

The sighting of even at least three individuals in our study over a short time period in Urala Creek North suggests that this area may be an important secondary nursery for sawfish. The Ashburton River mouth, approximately 30 km north of Urala Creek North, has been identified as an important nursery area for green sawfish (Morgan et al. 2015, 2017). It is likely that sawfish are pupped just outside the river mouth and use the Ashburton River as a nursery for their first several months. When the river floods following storms in summer, acoustic tracking has shown that the young-of-year sawfish leave the river, and while some return after flooding has subsided, others do not (Morgan et al. 2017). It is hypothesized that these sawfish begin to use other nearby tidal creeks along the coastline when the freshwater pulse pushes them out of the Ashburton. As the second and third major creeks found south of the Ashburton, it is likely that Urala Creek North and South are important secondary nurseries for sawfish, which was confirmed in the present work by the sighting of at least three individuals ranging in size from approximately 1.2 to 1.4 m. These individuals are likely less than one year old, based on age-growth curves estimated by Peverell (2008).

Other fauna

As described above, several elasmobranch species in addition to green sawfish were observed and/or caught during gillnet and visual surveys in Urala Creek North and South (Table 1). The most numerous species were Giant Guitarfish (*Glaucostegus typus*) and Nervous Sharks (*Carcharhinus cautus*), which were both sighted in large numbers in both creeks, in sizes ranging from neonates to juveniles for Giant Guitarfish and neonates to adults for Nervous Sharks. Aggregations of neonate giant guitarfish (~400-500 mm TL) were observed in both creeks, and gillnets captured this species ranging in length from 462 to 799 mm TL. The species attains almost 3000 mm TL, and is listed as *Critically Endangered* on the IUCN Red List (Kyne et al. 2019a). Similarly, aggregations of neonate nervous sharks (~400 mm TL) were observed in both creeks, including 23 simultaneously observed in an area of approximately 1000 m^2. A total of 16 nervous sharks were caught in gillnets, ranging in size from 718-1180 mm TL, for a CPUE of 0.27 sharks per 20 m net per hour. The high numbers of neonates and juveniles of giant guitarfish and nervous sharks in both creeks suggest that these habitats may be pupping locations and nursery areas for these species.

Other commonly observed species included Australian sharpnose sharks, which were commonly observed in shallows (>11 sighted during visual surveys), spotted whiprays, of which >5 were sighted in Urala Creek South, and sickle-fin lemon sharks, of which three individuals ranging in size from 795 to 1080 mm TL were caught in the same gillnet set in Urala Creek North. A single juvenile blacktip reef shark was observed in Urala Creek South, and, notably, a bottlenose wedgefish was caught in Urala Creek South, a male measuring 1420 mm TL. Similar to green sawfish and giant guitarfish, bottlenose wedgefish are listed as *Critically Endangered* on the IUCN Red List (Kyne et al. 2019b). Gillnet catches are reported in Table 1, and photos of some elasmobranchs caught other than sawfish are shown in Figure 2.

Potential impacts of Urala Creek development on sawfish

The identification of Urala Creek as a potential secondary nursery for green sawfish as well as nurseries and habitat for several other threatened elasmobranchs introduces several points to consider regarding potential development of the creek. The Ashburton Salt Project, as outlined in the Environmental Scoping Document (2017), proposes to operate a solar salt project which would intake seawater from either or both the north and south entrances to Urala Creek, construct salt evaporation ponds and crystallisers on the supratidal salt flats above the creeks, and construct a bitterns discharge channel and pipeline and export jetty to the north of the creeks between the Ashburton River mouth and Urala Creek North. Additionally, a Site Administration Compound would be built nearby including accommodation, office space, and a washplant, which may increase nutrient runoff into the nearby coastline. These developments have the potential to affect sawfish movement, habitat use, and health in several ways, described as follows.

Obstruction of movement and migration pathways

As discussed above, it is likely that green sawfish are pupped in the Ashburton River mouth, and use nearby tidal creeks, including Urala Creek, as a secondary nursery in their first few years of life after freshwater flows push juveniles from the Ashburton in summer months. Previous acoustic tracking of green sawfish in the Ashburton River mouth and surrounding area indicates that small sawfish (<2.5 m TL) exclusively use shallow habitats and move between creeks using the shallow areas close to shore, likely due to predator avoidance (Morgan et al., 2017), a pattern seen in many juvenile elasmobranchs (Heupel et al., 2007; Grubbs et al., 2010). Movement between creeks is limited when coastal developments obstruct these shallow shoreline migration pathways: small sawfish are unlikely to travel around obstacles in shallow areas if this means they are forced to enter deeper areas (D. Morgan, unpublished data). As such, any physical obstructions to movement along the shoreline associated with construction of the Bitterns Discharge Channel and Pipeline or the Jetty proposed in the Environmental Scoping Document is likely to hinder the movement and migration of juvenile sawfish from the Ashburton River mouth into Urala Creek and other secondary nursery creeks that likely exist to the south. Therefore, care needs to be taken to ensure that the Jetty and Bitterns Discharge do not block shallow migration channels and would not force sawfish into deeper areas (>1-2 m depth) in order to travel between the Ashburton River and Urala Creek.

Noise and light pollution

It is likely that the development of a solar salt project, particularly including the Jetty, Bitterns Discharge, and Seawater Intakes, would introduce both noise and light pollution to sawfish habitats in Urala Creek and along the shoreline between Urala Creek and the Ashburton River mouth. The impacts of increased underwater noise on sawfish behaviour, stress, and movements has not been directly examined for any sawfish species, however, noise pollution has been identified as a potential concern in several past studies and assessments, including as a driver of sawfish population declines (e.g. GBRMPA 2012; Leeney and Poncelet, 2013; Giglio et al., 2015). High noise levels have also been observed to repel some shark species (Casper et al., 2012), and have the potential to mask biologically important sounds including those associated with predator avoidance or prey capture (Jordan et al., 2013), or alter activity patterns and habitat use of elasmobranchs, particularly if noise occurs mainly during a specific time of day or specific location (Hammerschlag et al., 2017). The effects of light pollution on sawfish are even less studied, with no previous work investigating effects of changes in lighting regimes on the movement and behaviour of wild sawfish, to our knowledge. However, considering that sawfish are largely crepuscular or nocturnal, artificial light during nighttime hours has the potential to alter both the movements of sawfish around lighted areas and the timing of movements and activity, as has been suggested for other elasmobranch species (e.g. Hammerschlag et al., 2017). More work is needed to assess how increased noise and light pollution from the intake and discharge and jetty and shipping channel may affect sawfish in this area.

Intake entrapment

Because of their toothed rostrum, all sawfish species are easily caught and entrapped in nets and lines, which is a major reason for their global decline (Dulvey et al., 2016). To avoid sawfish and other species, including the numerous juvenile turtles found in the creeks, entering the seawater intakes from Urala Creek, an exclusion device is likely necessary. In order to not entrap sawfish, this device would have to be rigid and of a relatively small grid size to prevent sawfish rostra becoming entangled or stuck through grid openings.

Potential effects of dredging and coastal development

Dredging is proposed in the development of the Ashburton Salt Project to create a transitable shipping channel for the offloading of processed salt. While the ESD proposes minimal dredging, there are several potential affects on sawfish and other marine life that need to be considered. First, as described above, the juvenile sawfish that are most likely to inhabit this area avoid deep waters and would most likely not transit across a deep channel. Therefore, care needs to be taken to preserve shallow movement pathways for sawfish down the coastline that do not require crossing deep channels. Second, dredging has the potential to destroy benthic habitat in the dredged location. Benthic habitats such as seagrass beds, oyster reefs, and sandy bottoms have been previously shown to be important foraging grounds for several sawfish species (e.g. Papastamatiou et al., 2015; Whitty et al., 2017; May et al., 2019). The foraging areas for the green sawfish found in Urala Creek have not been identified, but it is possible that nearshore areas outside the creeks are important foraging areas for juveniles and subadults of this population. The type of benthic habitat present in the proposed dredging location should be determined, and care should be taken to avoid dredging in specific locations where highly productive benthic habitats exist which may provide important foraging areas for sawfish and other marine fauna.

Finally, dredging has the potential to alter the water quality in the area by increasing turbidity. Not much is known about the sensory systems of green sawfish specifically, although preliminary work suggests they have lower numbers of electrosensory pores compared to freshwater and dwarf sawfish (Wueringer et al., 2011), which together with their relatively large eyes may indicate that they rely more on visual cues than other sawfish species, and therefore would fare better in less turbid water. The green sawfish sighted in the present work were also exclusively found and caught in shallow areas with clear water. However, the water in the Ashburton River mouth, which sports the highest catch rates of green sawfish found in the world (Morgan et al., 2015), ranges from clear to relatively turbid, and therefore green sawfish are likely able to inhabit and successfully forage along the turbidity spectrum. How increased turbidity from dredging may affect sawfish in the areas near Urala Creek is unclear.

An additional consideration for developing the area around Urala Creek is the destruction of mangrove habitat. The proposed developments outlined in the ESD do not appear to involve direct destruction or degradation of mangroves, however it must be noted that strong associations between mangrove health and intactness and sawfish abundance have been noted for several sawfishes (Dulvy et al., 2016), and that mangroves are likely an essential habitat for green sawfish. The utmost care should be taken in all developments to limit destruction or degradation of mangrove forests.

Monitoring and management

As with any developments or construction that has the potential to impact threatened species, and particularly those listed by the EPBC, it is essential to monitor how threatened species respond to such developments and ensure that threatened populations are able to continue to succeed post-development. To assess such potential effects of the Ashburton Salt Project on green sawfish requires first establishing a baseline for population health, movement patterns, habitat use, and ontogenetic movements of sawfish in the area, and second a commitment to monitoring these factors after developments have been completed and throughout the duration of the project. As discussed above, the initial surveys conducted in February 2019 suggest that the Urala Creek area is an important secondary nursery for green sawfish. However, a more thorough survey, particularly including targeted sawfish sampling during dusk and nighttime hours and tracking of sawfish movements around the creeks and across the proposed offloading zone and Bitterns Discharge is crucial to develop a baseline that can be effectively used to assess whether sawfish have been affected by the proposed developments after they have been completed. This survey, including gillnet sampling of sawfish habitats and tracking of sawfish around the area, would then need to be repeated post-development to compare the densities of sawfish found, the types of habitat occupied, and the movement patterns of sawfish around the proposed intake, discharge, and jetty. Gillnet sampling of sawfish in Urala Creek and the surrounding area would be recommended to be continued throughout the life of the project to ensure that impacts of the developments seen over multi-year scales do not harm the sawfish populations in this area.

Conclusions

The number and size of the elasmobranchs caught or sighted in the initial surveys conducted in February 2019 indicate that Urala Creek North is likely a secondary nursery area for green sawfish, and that both Urala Creek North and Urala Creek South are pupping grounds and important nursery areas for giant guitarfish and nervous sharks, as well as being home to diverse and plentiful other elasmobranch fauna. The diversity and abundance of elasmobranchs observed and the capture of three *Critically Endangered* (IUCN) rays (green sawfish, giant guitarfish, and bottlenose wedgefish) in a short period of time indicates that these creeks offer important refuges and nursery habitats for several threatened species, including green sawfish, which are listed by the EPBC Act as 'Vulnerable.' As such, great care needs to be taken in any potential developments associated with the Ashburton Salt Project to ensure that such developments do not limit or cut off crucial resources or movement pathways for sawfish. More detailed surveys of the elasmobranch and teleost fauna in both creeks, including targeted sampling at the mouth of the creeks during dusk and night periods when elasmobranchs are typically most active, are necessary to determine how these animals use the remote and pristine habitats offered by these creeks, and to establish baseline data for these habitats. Continued monitoring of sawfish and other threatened elasmobranchs in these habitats post-development will help to determine if the use of the area by the Ashburton Salt Project impacts sawfish, and to mitigate any potential effects to ensure that the area remains accessible and productive for this vulnerable species.

Table 1: Elasmobranch fauna captured and/or sighted in Urala Creeks North and South. TL = the total length of the fish, CPUE = the catch-per-unit-effort, combined across all sites.

Species	**Locations observed**	***N* caught**	***N* visually sighted**	**TL range of catches (mm)**	**Gillnet CPUE (fish 20 m net^{-1} h^{-1})**
Pristis zjisron Green sawfish	Urala North	1	5	1225	0.02
Carcharhinus cautus Nervous shark	Urala North Urala South	13 3	>46	718 – 1180	0.27
Rhizoprionodon terranovae Australian sharpnose shark	Urala North Urala South	0 0	>11	NA	NA
Carcharhinus melanopterus Blacktip reef shark	Urala South	0	1	NA	NA
Negaprion acutidens Sickle fin lemon shark	Urala North	3	2	780 – 1080	0.05
Himantura sp. Spotted whipray	Urala South	0	>5	NA	NA
Glaucostegus typus Giant guitarfish	Urala North Urala South	1 1	>31	462 – 799	0.04
Rhynchobatus australiae Bottlenose wedgefish	Urala South	1	0	1420	0.02

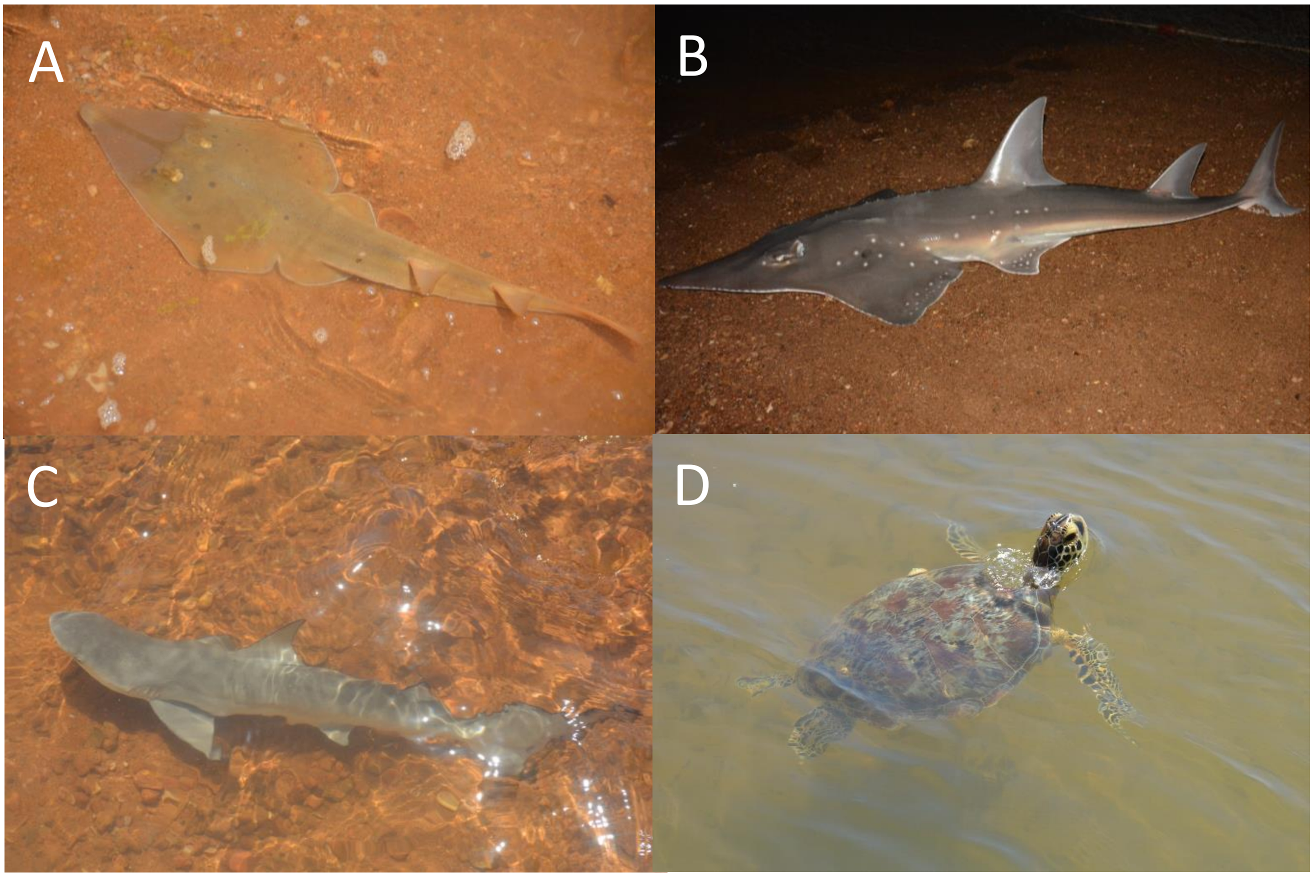


Figure 2: Photographs of some of the fauna sighted and captured in gillnets in Urala Creek North and South, including (A) giant guitarfish, (B) bottlenose wedgefish, (C) nervous sharks, (D) Green turtles.

Figure 3: Approximate locations of green sawfish captured and observed in Urala Creek North.

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Appendix E

Prawn Sampling

Report on prawn sampling Oct-Dec 2019

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July 2020

Summary

Fieldwork was carried out in October, November and December 2019 to sample prawns (including postlarvae and juveniles) within Uralla Creek (UC), the Nearshore area at the mouth of UC South, and the Bitterns Discharge area of the proposed K+S salt production facility in Ashburton, north-eastern Exmouth Gulf. Sampling was conducted using the 12.6 m *Optimus 1000* and the 3.6 m tender *BumbleBee* operated by Terrafirma Offshore, crewed by Daemon Bass (Master) and Corey Ogg (Deckhand). Prawns were sampled using a Benthic "Sled" trawl, towed behind either of the vessels, and zooplankton was captured using a 177 µm plankton net.

Careful planning and favorable conditions allowed samples to be collected from the Nearshore area outside the mouth of Uralla Creek South, where only limited samples (2) had been collected in January and February 2019 due to adverse weather conditions (very strong winds and choppy waves). A total of 39 benthic trawls and 37 zooplankton tows were completed over these three survey trips (Table 1). The highest densities of prawns caught were within UCS, with a mean of 51.8 prawns per trawl. Polychaetes were the most abundant organism in the zooplankton samples, occurring in 29 of the 37 samples. Amphipods, as well as two species of shrimp (Shrimp 1 and 8) were also very abundant, present in 26 of the 37 zooplankton samples respectively. Penaeid larvae occurred in 17 of the zooplankton samples, with 13 of those within Uralla Creek South.

1. Sampling methodology

1.1 Benthic trawls

Prawns were sampled from either *Optimus 1000*, or from *BumbleBee*. Adult and juvenile prawn were collected using a Benthic "Sled" trawl, with the mouth of the net measuring 0.75 m x 0.45 m, with 2.4 m of 26 mm diamond mesh in the body, and 1.2 m of 6 mm mesh in the cod end following the design of a net used for sampling small prawns in estuaries (Taylor and Loneragan, 2019). Two people worked the nets and Daemon Bass operated the vessel. Trawl duration was 15 minutes for all benthic trawls, and upon retrieval, all catch was emptied into a plastic tub for sorting. Prawns were retained, and all other organisms were returned to the water as quickly as possible. Prawns were stored frozen, and transported back to Murdoch University in a cooler for identification and further analysis.

1.2 Plankton

Plankton samples were collected with a 177 µm net with a mouth diameter of 35 cm. Plankton trawls were 10 min in duration. Some plankton trawls were made in water shallower (1.4 m deep) than the beam trawls. If a large amount of sediment was captured in the zooplankton net (due to the net hitting the bottom), the sample was discarded and the tow repeated. Zooplankton samples were preserved in 75% ethanol, and stored in sample jars for identification under a dissecting microscope in the laboratories at Murdoch University.

2. Samples processing

2.1. Prawns

All prawns were identified to species where possible under a dissecting microscope. The main source used for identifying prawns was Grey et al. (1983), which is based on taxonomic features of typically larger specimens, collected in commercial fisheries. These features may not be present or as well developed in juvenile prawns.

Prawns in the genus *Penaeus* are generally readily separated from those in other genera by the presence of teeth under the rostrum (ventral rostral teeth). The brown tiger prawn, *P. esculentus*, is easily identified from the other species by the presence of three ventral rostral teeth and its colouration (in other regions, other features are used to distinguish it from *Penaeus semisulcatus* and *P. monodon*). In contrast, the identification of juvenile *Penaeus latisulcatus* proved especially difficult, as the distinguishing postrostral groove and ventral rostral tooth were difficult to discern in these smaller specimens (Figure 1).

A key-identifying feature for *Metapenaeus endeavouri* is the presence of three movable spines on the telson. Other metapenaeids caught; in particular *M. dalli*, *M. insolitus* and *M. bennettae*; were not as readily distinguished as their morphology is extremely similar, and distinguishing features are based on reproductive structures (which were not fully developed in most specimens that we caught), coverage of hairy surfaces on the carapace (variable), or by geographic location caught (some associated uncertainty with known distributions). The specimens collected have been retained for future confirmation of their identification. For this report, however, these have all been reported as *Metapenaeus spp.*

Figure 1. Some of the penaeid prawns identified in the Ashburton area a) *Metapenaeus endeavouri*; b) *Metapenaeus spp.*; c) *Metapenaeopsis novaeguineae;* d) *Metapenaeopsis wellsi*; e) *Penaeus esculentus*; and f) *Penaeus latisulcatus*. Images not to scale.

Three additional species of prawn were collected in the October to December surveys,that were not identified in the preliminary sampling trips in January and February – *Parpenaeopsis cornuta*, *Trachypenaeus anchoralis* and *T. curvirostris*. *Parapenaeopsis cornuta* can be identified by its distinct telson coloration, caliper-like petasma (in males), as well as a distinguishing tuft of dark hair behind the thelycum (in females). Specimens of *P. cornuta* were collected from the bitterns discharge area (BD) and nearshore (NS) area immediately outside Uralla Creek South (UCS), but not within UCS. *Trachypenaeus anchoralis* and *T. curvirostris*, were collected exclusively in BD. Both these species were identified via their distinct petasma and thelycum as described in Grey *et al.* (1983).

Multivariate analyses were run using PRIMER 7 to determine whether the species composition of prawns varied between the three locations. Prawn data were square root transformed and a Bray-Curtis similarity matrix constructed before analysis with non-metric multi-dimensional scaling (nMDS) and ANOSIM. ANOSIM was used to test whether the composition of prawns differed significantly among locations.

2.2. Plankton

Plankton samples were transferred from the plankton net into plastic jars, and stored in a cooler, and then transferred into the fridge aboard *Optimus 1000.* Previous efforts to identify and count postlarvae in these samples in the field proved ineffective, so samples were stored and chilled, then transferred to 75 % ethanol on shore to be transported to Murdoch University for analysis under the microscope.

Shrimp-like organisms were separated morphologically, with 14 separate ‘species’ identified (Figure 2) consisting of 10 unidentified shrimp ‘species’, penaeid postlarvae (Figure 2k and l), as well as snapping shrimp (*Alpheus*) and glass shrimp (*Palaemonetes*).

Figure 2. Various shrimp ‘species’ caught in zooplankton tows over the 3-month survey period in October, November and December 2019 in the Ashburton area. a to j = shrimp 1 to 10 respectively, k & l = penaeid postlarvae. *Alpheus* and *Palaemonetes* not pictured. Shrimp descriptions available in Appendix 1.

The composition of the plankton assemblages were also analysed using PRIMER, following the procedure outlined for the prawns caught in beam trawls above. However, the nMDS plot and shade plot were based on percentage contribution, and the data were pre-treated with a square root transformation before calculating theBray-Curtis measure of dissimilarity.

3. Results

3.1 Benthic trawls

Uralla Creek South contained the highest density of prawns with 52 prawns/trawl, far exceeding BD (12.1 prawns/trawl) and NS (8.8 prawns/trawl) respectively. A total of 1,034 prawns were collected over the three survey trips; 291 prawns in October, 422 prawns in November and 321 prawns in December (Table 1).

Table 1. Total number of prawns caught in benthic trawls over the 3-month survey period from October to December 2019 in the Ashburton region. BD = Bitterns Discharge area, NS= Nearshore area (in front of UCS), UCS = Uralla Creek South.

	Site			
Month	BD	NS	UCS	Total
October	51		240	**291**
November	72	36	314	**422**
December	46	52	223	**321**
Summary				
Number of samples	14	10	15	**39**
Total prawns	**169**	**88**	**780**	**1034**
Mean	12.1	8.8	51.8	**26.5**

Analysis of Similarity (ANOSIM) revealed that each of the three areas contained statistically distinct prawn assemblages (Global $R = 0.31$, $P = 0.1\%$), with the greatest separation between prawn species composition in the BD on the left hand side of the nMDS and the UCS on the right hand side (BD vs UCS R = 0.377, $P = 0.1$ %) (Figure 3). Samples from the NS were in the central region of the plot, interspersed with samples mainly from BD (BD vs NS, R = 0.294, $P = 0.2$ %; NS vs UCS, R = 0.234, $P = 0.4$ %).

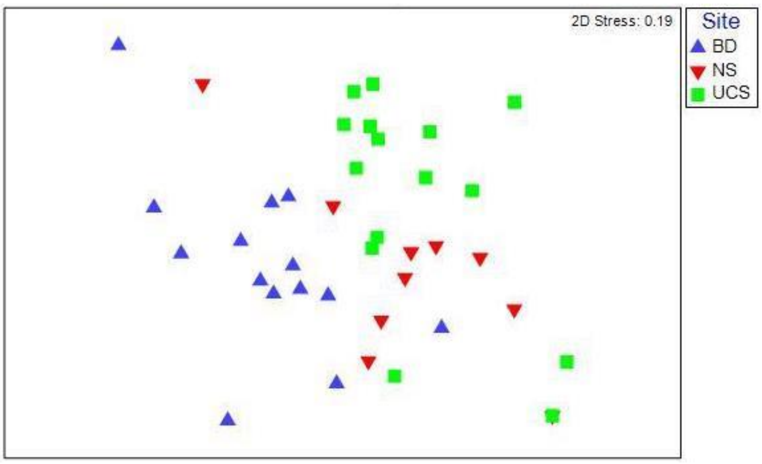

Figure 3. Non-metric multidimensional scaling (nMDS) plot of the prawn catches from beam trawls at three locations in the Ashburton region between October and December 2019. BD= Bitterns Discharge area, NS= Nearshore area (in front of UCS), UCS = Uralla Creek South.

The shade plot shows that the difference in prawn species composition among the three sites appears to be driven by the higher catches of *Metapenaeus spp.*, *M. endeavouri* and *P. latisulcatus* in UCS, and the presence of the two *Trachypenaeus* species in BD (Figure 4). The NS had higher catches of *P. esculentus* and *Metapenaeus rosea* than that at the other two sites (Figure 4).

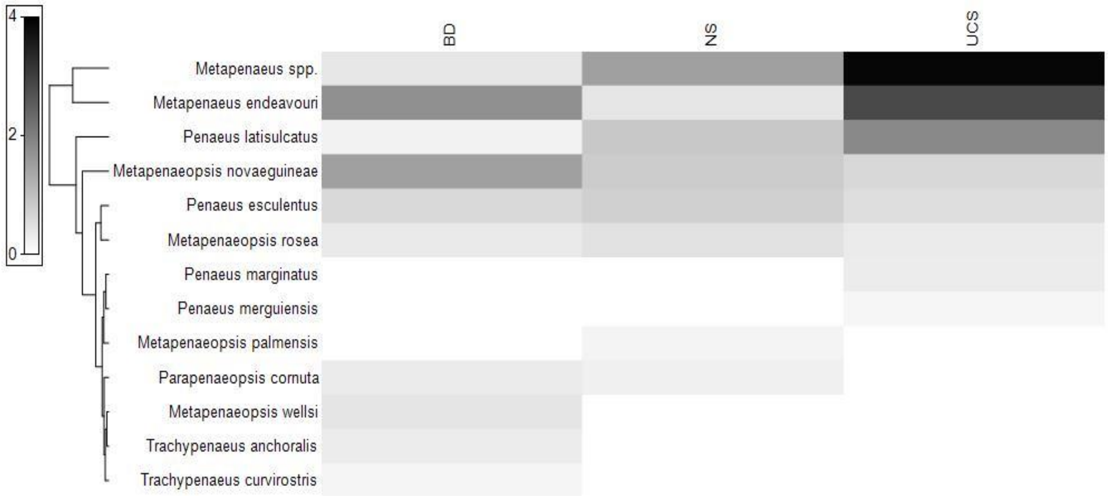

Figure 4. Shade plot of the prawn catches from beam trawls at three locations in the Ashburton region between October and December 2019. . BD = Bitterns Discharge area, NS= Nearshore area (in front of UCS), UCS = Uralla Creek South.

Species of importance to the local commercial prawn fisheries (*P. esculentus*, *P. latisulcatus*, *P. merguiensis* and *M. endeavouri*) accounted for 49.9 % of the total beam trawl catches, with *M. endeavouri* representing 58.7 % of the commercially important prawns caught. *Metapenaeus* was the most abundant genus, accounting for 668 (64.6 %) of the prawns caught, followed by *Penaeus*, with 223 individuals (21.6 %). The School Prawns (*Metapenaeus spp.*, *n* = 365) and the Endeavour Prawn (*M. endeavouri*, *n* = 303) were the two most abundant species. The Western King prawn (*P. latisulcatus*) was the most abundant *Penaeus* species, accounting for the vast majority (79 %, 176 individuals) of *Penaeus* caught (Table 2).

Table 2. Prawn species caught in benthic trawls over the 3-month survey period between October and December 2019 in the Ashburton region. BD= Bitterns Discharge area, NS= Nearshore area (in front of UCS), UCS = Uralla Creek South. Shading = commercially important species in Exmouth Gulf.

Genus	Species	Site			Total
		BD	NS	UCS	
Penaeus		**16**	**25**	**182**	**223**
	P. esculentus	12	12	11	35
	P. latisulcatus	4	13	159	176
	P. marginatus			10	10
	P. merguiensis			2	2
Metapenaeus		**71**	**36**	**561**	**668**
	M. endeavouri	64	5	234	303
	M. spp.	7	31	327	365
Metapenaeopsis		**65**	**24**	**34**	**123**
	M. novaeguineae	45	14	22	81
	M. palmensis		3		3
	M. rosea	11	7	12	30
	M. wellsi	9			9
Trachypenaeus		**12**			**12**
	T. anchoralis	7			7
	T. curvirostris	5			5
Parapenaeopsis		**5**	**3**		**8**
	P. cornuta	5	3		8
Samples (n)		**14**	**10**	**15**	**39**
Total		**169**	**88**	**777**	**1034**
Mean		**12.1**	**8.8**	**51.8**	**26.5**

Members of the genus *Parapenaeopsis* were least common, with only 8 individuals of *P. cornuta* caught over the 3-month period in the BD and NS, but never occurring in UCS. *Trachypenaeus* were also quite elusive, with both *T. anchoralis* (7 individuals) and *T. curvirostris* (5 individuals) detected only in BD, and only in December.

Within UCS, commercially important species made up 52.2 % of the total catches, again dominated by *M. endeavouri* (57.6 %) and *P. latisulcatus* (39.2 %, Table 3). *Metapenaeus* dominated UCS, accounting for 72.2 % of total catches, driven by the abundance of *M. spp.* (n = 327) and *M. endeavouri* (n = 234).

Table 3. Prawn species caught in benthic trawls over the 3-month survey period between October and December 2019 within Uralla Creek South of the Ashburton region. Shading = commercially important in Exmouth Gulf.

Genus	Species	UCS LOWER	UCS MID	UCS UPPER	Total
Penaeus		**34**	**143**	**5**	**182**
	P. esculentus	3	5	3	11
	P. latisulcatus	31	126	2	159
	P. marginatus		10		10
	P. merguiensis		2		2
Metapenaeus		**298**	**180**	**83**	**561**
	M. endeavouri	119	81	34	234
	M. spp.	179	99	49	327
Metapenaeopsis		**17**	**17**		**34**
	M. novaeguineae	5	17		22
	M. rosea	12			12
Samples (n)		**6**	**7**	**2**	**15**
Total		**349**	**340**	**88**	**777**
Mean		**58.2**	**48.6**	**44**	**51.8**

Prawns caught in beam trawls ranged from 1 mm carapace length (CL, *Metapenaeus spp.*) to a maximum of 43 mm CL (*P. esculentus*) (Table 4). *Penaeus esculentus* was the largest species by far, followed up by the Western King Prawn (*P. latisulcatus*) and *Metapenaeopsis novaeguineae* at 28 mm CL (Table 4). *Parapenaeus cornuta* had the highest mean CL (16.6 mm), as only a small number of large adults were captured, and no juveniles. The smallest genus was *Trachypenaeus*, with a maximum CL of 11 mm; however, only 12 individuals were caught in total, and therefore may not represent the population as a whole. *Metapenaeus* were the smallest genus on average, with a mean CL of 6 mm (Table 4).

Table 4. Minimum, mean and maximum carapace lengths for prawn species caught in benthic trawls over the 3-month survey period between October and December 2019 in the Ashburton region. Shading = commercially important in Exmouth Gulf.

Genus	Species		Carapace length (mm)		
		n	Min	Mean	Max
Penaeus		**223**	**2**	**7.0**	**43**
	P. esculentus	35	3	11.3	43
	P. latisulcatus	176	2	6.3	28
	P. marginatus	10	4	5.3	7
	P. merguiensis	2	4	5.5	7
Metapenaeus		**668**	**1**	**6.0**	**23**
	M. endeavouri	303	2	5.7	23
	M. spp.	365	1	6.2	18
Metapenaeopsis		**123**	**2**	**6.2**	**28**
	M. novaeguineae	81	3	6.3	28
	M. palmensis	3	6	6.3	7
	M. rosea	30	2	5.6	18
	M. wellsi	9	5	7.0	10
Trachypenaeus		**12**	**8**	**9.6**	**11**
	T. anchoralis	7	8	9.3	11
	T. curvirostris	5	9	10.0	11
Parapenaeopsis		**8**	**13**	**16.6**	**21**
	P. cornuta	8	13	16.6	21
Total		**1034**	**1**	**6.3**	**43**

Overall, 53 % of the prawns were in the 0-5 mm CL size class (Table 4), and 89 % of all prawns caught were under 10 mm CL, indicating that the large majority of prawns were juveniles/postlarvae. For the commercially important Endeavour Prawn (*M. endeavouri*), over 95 % of individuals were under 10 mm CL (Table 5). Similarly, 89 % of the Western King Prawn (*P. latisulcatus*) were under 10 mm CL, as well as 93 % of the School Prawns (*Metapenaeus spp.*).

Table 5. Size classes (CL; mm) for prawn species caught in benthic trawls over the 3-month survey period between October and December 2019 in the Ashburton region. Highlighted in yellow = commercially important in Exmouth Gulf.

Genus	Species	Carapace length (mm)							
		5	10	15	20	25	30	45	Total
Penaeus		**140**	**51**	**11**	**11**	**4**	**5**	**1**	**223**
	P. esculentus	9	13	6	4		2	1	35
	P. latisulcatus	123	34	5	7	4	3		176
	P. marginatus	7	3						10
	P. merguiensis	1	1						2
Metapenaeus		**342**	**285**	**28**	**11**	**2**			**668**
	M. endeavouri	173	115	7	6	2			303
	M. spp.	169	170	21	5				365
Metapenaeopsis		**62**	**51**	**8**	**1**		**1**		**123**
	M. novaeguineae	45	27	8			1		81
	M. palmensis		3						3
	M. rosea	15	14		1				30
	M. wellsi	2	7						9
Trachypenaeus			**10**	**2**					**12**
	T. anchoralis		6	1					7
	T. curvirostris		4	1					5
Parapenaeopsis				**3**	**4**	**1**			**8**
	P. cornuta			3	4	1			8
Total		**544**	**397**	**52**	**27**	**7**	**6**	**1**	**1034**

3.2 Plankton

The nMDS plot shows a major separation of the zooplankton composition in samples from UCS (left hand side) compared with the BD and NS (right hand side) (Figure 5). The samples from these two latter areas were interspersed. Analysis of Similarity (ANOSIM) demonstrated that the plankton assemblages differed significantly in composition among regions (Global R = 0.33, *P* = 0.1%) and pairwise comparisons showed that those at UCS differed significantly from BD (*R* = 0.44, *P* = 0.1%) and NS (*R* = 0.45, *P* = 0.2%), but did not differ significantly between the BD and NS (*R* = 0.11, P = 7%). The majority of this difference appears to be explained by the greater numbers of Penaeid larvae, as well as Shrimp 1 in samples from UCS than those from BD or NS (Figure 6).

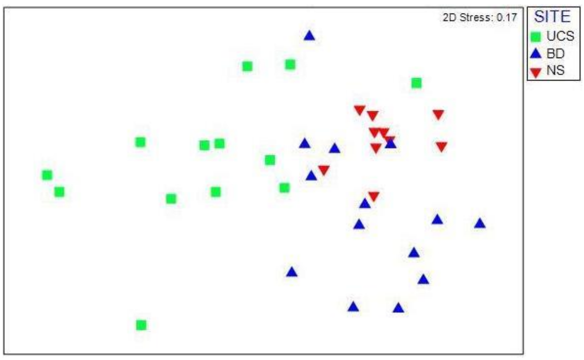

Figure 5. Non-metric multidimensional scaling (nMDS) plot constructed using a using a Bray-Curtis Similarity matrix of the zooplankton percentage composition data at three sites in the Ashburton region. BD = Bitterns Discharge area, NS= Nearshore area (in front of UCS), UCS = Uralla Creek South.

Figure 6. Shade plot constructed using a using a Bray-Curtis Similarity matrix of the zooplankton percentage composition data at three sites in the Ashburton region, Western Australia. BD= Bitterns Discharge area, NS= Nearshore area (in front of UCS), UCS = Uralla Creek South.

Penaeid larvae occurred in 17 of the 37 samples taken, with 13 of those from UCS. Polychaetes were the most commonly occurring organism in the plankton tows, present in 29 of the 37 plankton trawls (Table 6). This frequency was closely followed by amphipods, as well as Shrimp 1 and Shrimp 8 (Table 7), both occurring in 26 of the samples. Crab larvae (both Zoea and Megalopa) were also commonly present (occurred in 24 samples), although juvenile crabs were much less readily captured (2 samples).

Table 6. Frequency of occurrence of organisms captured in the zooplankton trawls over the 3-month survey period between October and December 2019 in the Ashburton region, Western Australia, excluding the unidentified shrimp-like species. Crab larvae = Zoea + Megalopa combined. Number of samples taken shown in parentheses

Taxa	Site			Total (37)
	BD (13)	NS (10)	UCS (14)	
Polychaete	10	9	10	**29**
Amphipod	9	6	11	**26**
Crab larvae	16	5	3	**24**
Fish	8	4	6	**18**
Penaeid larvae	3	1	13	**17**
Ostracod	0	4	4	**8**
Snapping Shrimp	4	1	2	**7**
Mantis Shrimp	3	1	0	**4**
Crab	1	0	1	**2**
Glass Shrimp	0	0	2	**2**

Glass Shrimp were the least commonly caught taxa, and were only found within UCS. In contrast, Mantis Shrimp were only detected outside UCS i.e. in BD and NS.

Table 7. Frequency of occurrence of the shrimp-like organisms captured in the zooplankton trawls over the 3-month survey period. Descriptions are attached in Appendix 1.

Taxa	Site			Total (37)
	BD (13)	NS (10)	UCS (14)	
Shrimp 1	7	7	12	**26**
Shrimp 8	13	10	3	**26**
Shrimp 4	6	7	4	**17**
Shrimp 6	4	1	6	**11**
Shrimp 9	8	1	1	**10**
Shrimp 10	3	2	4	**9**
Shrimp 3	3	1	1	**5**
Shrimp 5	1	1	2	**4**
Shrimp 7	2	1	1	**4**
Shrimp 2	1	0	2	**3**

4. Comparisons with preliminary sampling in January and February

4.1 Earlier survey overviews

The initial survey in January 2019 focused on identifying and addressing the logistical and operational challenges of sampling in the remote region of Exmouth Gulf. Despite the challenges met, four species of penaeids were identified - brown tiger prawn (*P. esculentus*), western king prawn (*P. latisulcatus*), banana prawn (*P. merguiensis*) and endeavour prawn (*M. endeavouri*). On the second survey, a total of 6 species were identified, including 3 that were not detected in January. These included two species of *Metapenaeopsis* (*M. novaeguineae and M. wellsi*), and *Metapenaeus* spp., which morphologically resembles *M. dalli* or *M. bennettae*. In February, a total of 23 beam trawls and 10 plankton trawls were completed over two nights when weather conditions permitted. Samples were collected Six species of penaeid prawn were identified, including four commercially important species (*P. esculentus*, *P. latisulcatus*, *M. endeavouri*). The Endeavour Prawn (*M. endeavouri*) and the Western King Prawn (*P. latisulcatus*) were found in both UCS and Uralla Creek North (UCN). However, the Brown Tiger Prawn (*P. esculentus*) was found only in UCS and the BD. Overall, there were more prawns, and more prawn postlarvae in UCS than in UCN. Plankton assemblages also differed between UCS and UCN. In particular, only four of the 12 distinguished shrimp species were common between the two areas, with five species only found in the UCS, and three others found only in UCN. Interestingly, crab megalopa were also observed in UCS, but not in UCN. Fish larvae were also more speciose in UCS, with 5 > possible species, *vs* the 2 apparent species in the UCN sample.

The total number of prawns caught in February (40) was small compared to those caught in the later months (October = 291, November = 422, December = 321). However, the relative abundances in February was similar to that from October to December (Figure 7), with *Metapenaeus* and *Penaeus* being the most numerous.

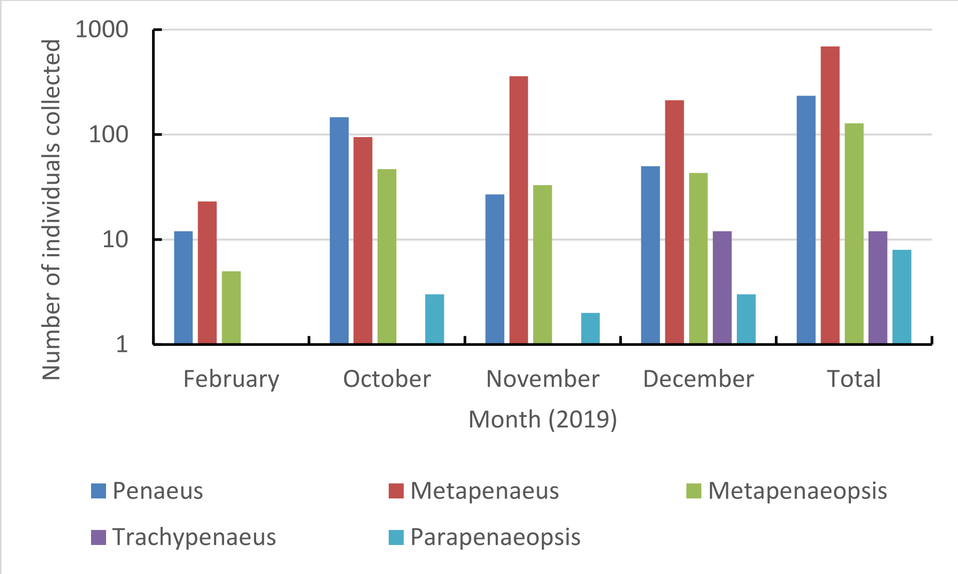

Figure 7. Log 10 total abundances of the various Penaeid genera identified in the Ashburton region, Western Australia in 2019. Note the log scale on the Y-axis.

In total, 13 species of Penaeids were collected over the four sampling surveys, including members of *Parapenaeopsis* and *Trachypenaeus*, that were not detected in the earlier January/February surveys.

Overall, Uralla Creek South appears to be a fairly well-used nursery ground for commercially-important penaeid species (accounting for >50% of the penaeids caught within UCS), as well as many other fish and invertebrates.

APPENDICES

Appendix 1. Detailed fieldwork plan

Fieldwork planning was highly weather-dependent, and the team had to factor in tidal heights, wind conditions, travel times and sampling duration, and have a flexible plan of action for maximizing data collection.

The October survey team comprised of Ian Baxter (SEAPEN Marine Environmental Services) and Brian Poh (Murdoch University). The team was based in Exmouth, crossing the Gulf each night of the survey. *Optimus 1000* proved to be far more comfortable transport for the conditions in the Gulf than FD3, the vessel used in January 2019. On the first night, the team arrived in front of Uralla Creek South (UCS), however rough conditions made entry into UCS unsafe. A decision was made to proceed to the sheltered Bitterns Discharge Area (BDA), where 4 Benthic trawls and 4 Zooplankton tows were conducted before deteriorating conditions made it necessary to return to Exmouth.

On the second day, the team departed Exmouth earlier in the day to allow better visibility for Daemon to navigate into UCS to allow mooring of *Optimus 1000* within the calmer waters of UCS, allowing safe transfer of crew to *BumbleBee* to conduct sampling within UCS, even in windy conditions. This plotted access into UCS increased the flexibility in our highly weather-dependent fieldwork plans for subsequent sampling occasions. A further 5 Benthic trawls and 5 Zooplankton tows were collected within UCS. An attempt was made to collect samples from the Nearshore area (NS) in front of UCS, however wind conditions worsened and this was not possible.

The November survey team comprised of Abigail Ross (AECOM) and Brian Poh. The team was based in Onslow, allowing for a more sheltered transit to the survey sites. For the first time, the team managed to collect samples from NS in front of UCS (4 Benthic trawls, 2 Zooplankton tows), before conditions deteriorated, and the team retreated to the BDA where it was sheltered from the prevailing winds, and conducted a further 5 Benthic trawls and 5 Zooplankton tows. On the second day, weather conditions dictated that sampling occur within UCS. Arrival at NS on high tide allowed *Optimus 1000* to enter UCS using the path tracked previously. 5 Benthic trawls and 4 Zooplankton tows were conducted within UCS off *BumbleBee*.

The December survey team comprised of Marthin Slabber (AECOM) and Brian Poh. The team was based from Onslow as per November. Favourable (below-forecast) wind conditions allowed the collection of 8 Benthic trawls and 8 Zooplankton tows in NS. 2 of these 8 sets of samples occurred before sunset, so as to maximize sampling opportunity in case the weather took a turn for the worst. A further 4 Benthic trawls and 4 Zooplankton tows were conducted at the BDA before returning to Onslow. Weather conditions on the second day were not as favorable, restricting sampling to within UCS. A total of 5 Benthic trawls and 4 Zooplankton tows were collected within UCS off *Bumblebee*. The team then departed for Exmouth, concluding the survey trip.

Appendix 2. Descriptions of the various shrimp found in zooplankton tows between October and December 2019 at three sites in the Ashburton region.

Shrimp	Description
Shrimp 1	Spots on somites, bristled legs, no rostrum. Mysid shrimp?
Shrimp 2	small, 'flared' carapace
Shrimp 3	similar to Shrimp 1, no spots, big eyes
Shrimp 4	short, bulging eyes
Shrimp 5	flowery telson, well developed chelae
Shrimp 6	club-like (buldging carapace), darker colored
Shrimp 7	similar to 7 but smaller, with a smaller tail that curls over the dorsal side of carapace
Shrimp 8	thin/elongate carapace, long stalked eyes
Shrimp 9	small, pronounced buldging eyes, long last pair of legs
Shrimp 10	mantis-shrimp shape

REFERENCES

Grey DL, Dall W, Baker A (1983) A guide to the Australian penaeid prawns. Department of Primary Production, Northern Territory Government, Darwin

Taylor MD, Loneragan NR (2019). Catchment-derived stressors, recruitment, and fisheries productivity in an exploited penaeid shrimp. *Regional Studies in Marine Science* **29:** 100628. https://doi.org/10.1016/j.rsma.2019.100628..13

Appendix F

Underwater Noise Modelling

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Assets | Engineering | Environment | Noise | Spatial | Waste

Underwater Noise Modelling – Ashburton Salt Project

Ashburton, Western Australia

AECOM

Prepared for AECOM

January 2021

Project Number: TN20009-1

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DOCUMENT CONTROL

Version	Description	Date	Author	Reviewer
0	Draft - Internal Review	28/5/2020	RK	GB
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2	Final Release	15/1/2021	RK	GB

Table of Contents

Tables

Figures

Appendices

1 Introduction

This report summarises the outcomes and recommendations of an underwater noise modelling study undertaken for the proposed Ashburton Salt Project (the Project).

1.1 Aim

The aim of this report is to provide modelling results of predicted underwater noise levels from construction activities (i.e. dredging and piling) associated with the Ashburton Salt Project.

1.2 Scope

This report will summarise the method and results of underwater noise modelling undertaken. It excludes an assessment of potential impacts on fauna.

1.3 Applicable Documents

Southall et al, Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects, Aquatic Mammals 2019, 45(2).

Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing, National Oceanic and Atmospheric Administration (NOAA), July 2018.

Criteria and Thresholds for Adverse Effects of Underwater Noise on Marine Animals, Science Applications International, May 2000.

McCauley RD, et al, 2000,'Marine Seismic Surveys: analysis and propagation of air-gun signals and effects of exposure on humpback whales, sea turtles, fishes and squid'. R99-15, Perth Western Australia.

McCauley et al, 'Marine Seismic Surveys- A study of Environmental Implications' APPEA Journal 200, pg 692-708.

Casper, B.M. ,2006, The hearing abilities of elasmobranch fishes. Graduate Theses and Dissertations, University of South Florida.

A. Popper, et al,2014, Sound Exposure Guidelines for Fishes and Sea Turtles, ANSI, ASA S3/SC1.4TR-2014.

D. Cato, Ambient Sea Noise in Australian Waters, Fifth International Congress of Sound and Vibration, 1997.

Dunlop et al., Determining the behavioural dose-response relationship of marine mammals to air gun noise and source proximity.

2 Project Background

K+S Salt Australia Pty Ltd (Australian K+S entity) is proposing to develop a solar salt production and export facility, referred to as the Ashburton Salt Project (the Project). The Project is located in the East Pilbara Region of Western Australia approximately 40 kilometres south west of Onslow in the Shire of Ashburton (Figure 2-1). The Project (Figure 2-2) has an approved Project Development Envelope of over 67,570 hectares with the initial facility planned to operate with a salt export capacity of 3.5 million tonnes per annum.

The Project includes a marine jetty export facility for transhipment operations to transport salt to an offshore anchorage for Panamax vessels. The Project will involve upgrades to the existing port facility which will involve various activities such as dredging and piling to develop a jetty and shipping berth channel.

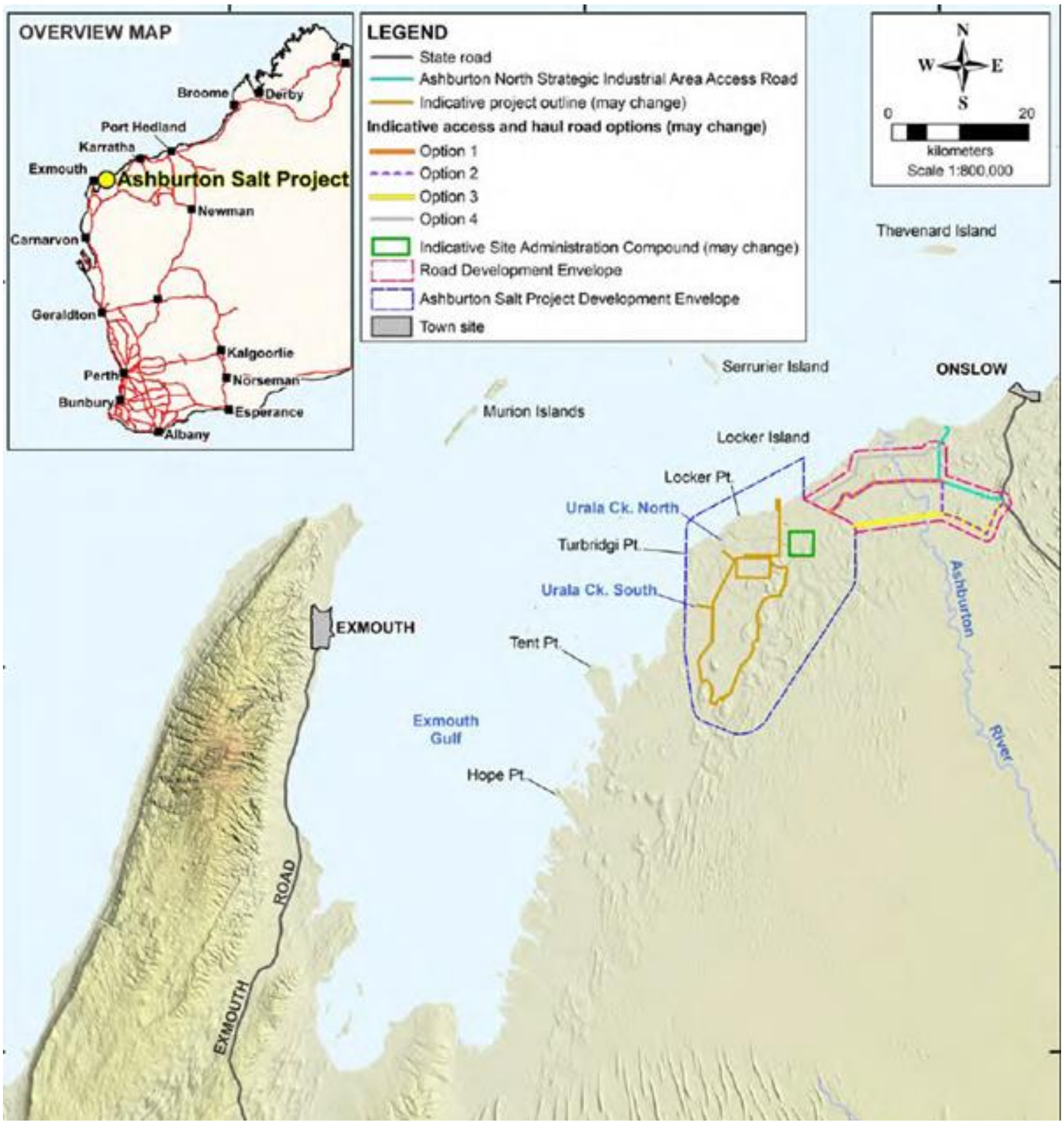


Figure 2-1 : Overview Map

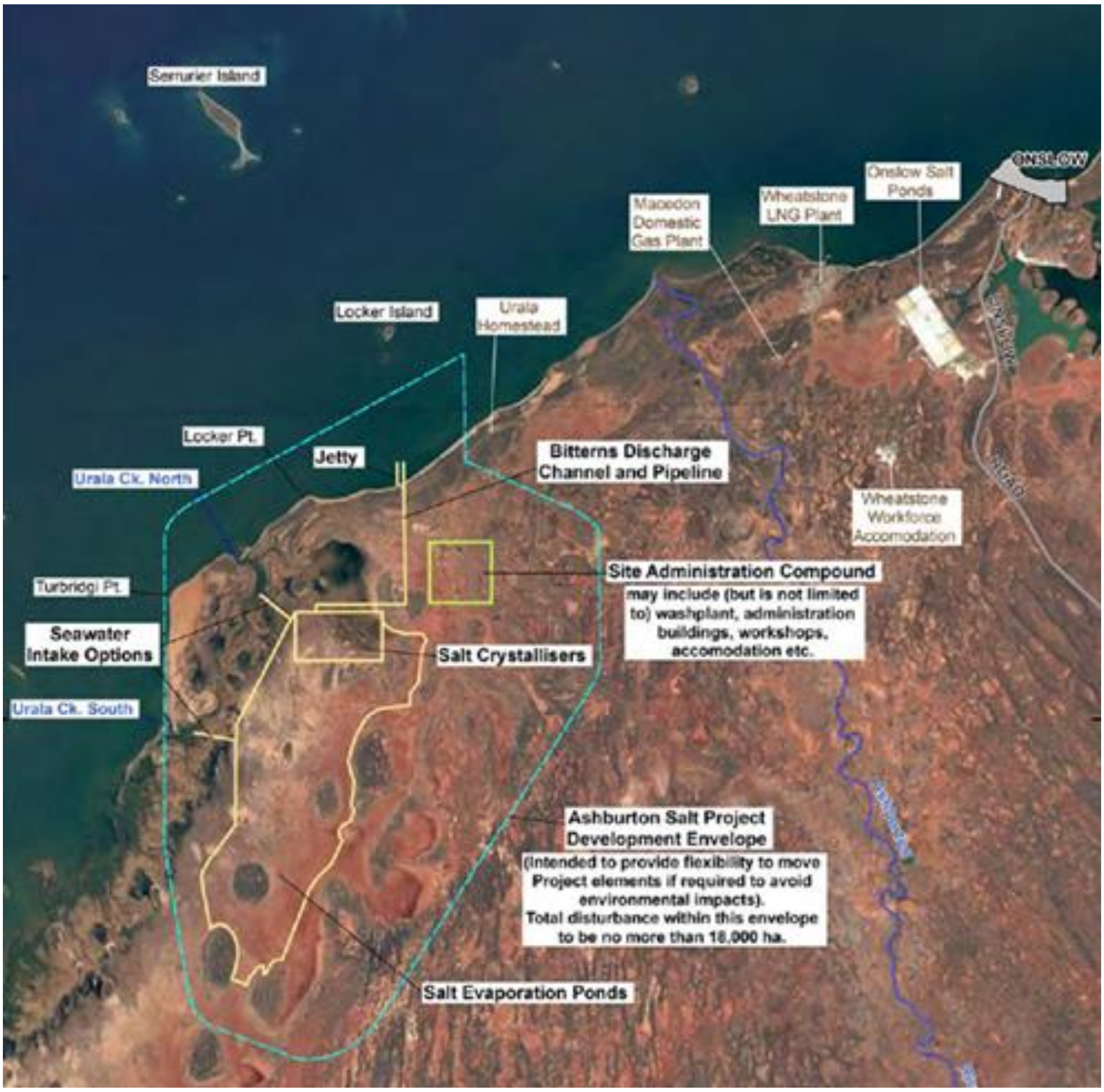


Figure 2-2 : Project Site

2.1 Construction Overview

2.1.1 Dredging

The location of the jetty has been selected to enable the transhipment barges to sail into the port under ballast draft (3.5m maximum draft) without any tidal constraints and moor at the berth. However, for loading of the barge, there is a requirement to dredge a berth pocket and basin for the transhipment barges to be loaded during all tides. As a result, a berth pocket is required to be dredged to a sufficient depth, width and length to allow the transhipment barges to have sufficient under keel clearance and room to navigate away out of the berth pocket. Dredging is also considered to be a significant underwater noise source for the project as it operates between 12 and 24 hours a day.

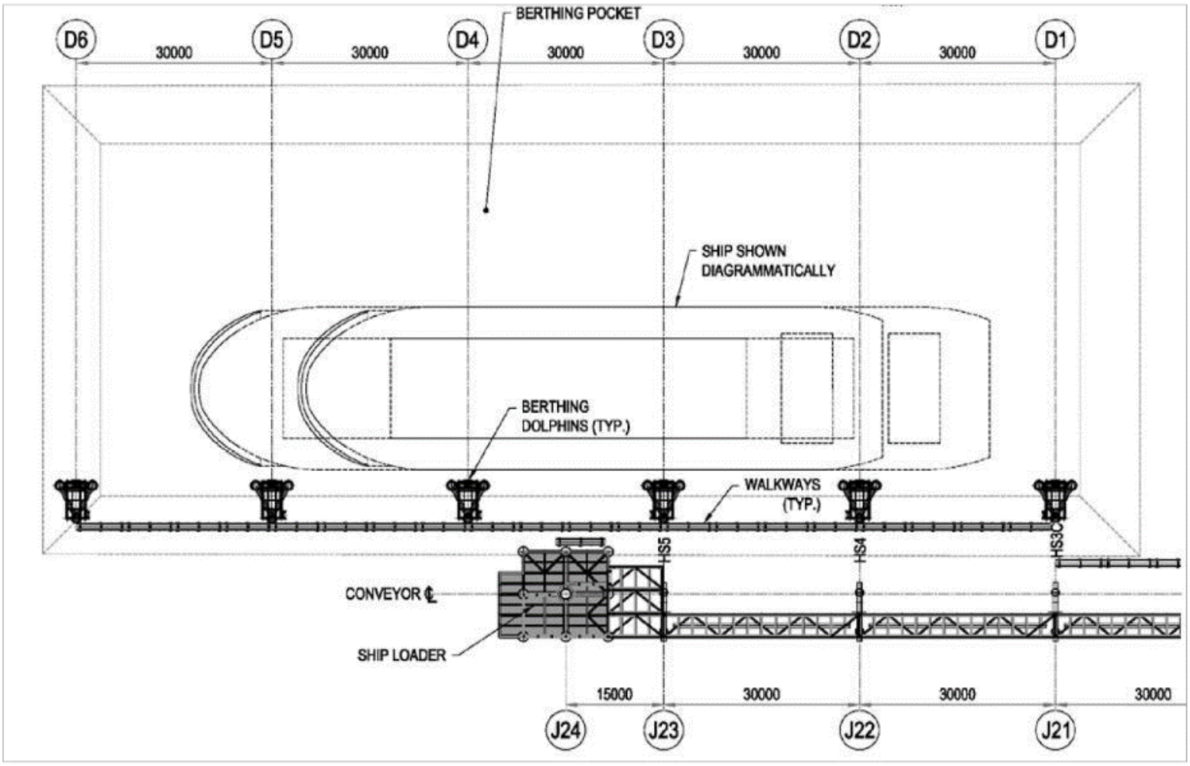


Figure 2-3 : Typical Dredged Berth Pocket / Basin for Transhipment Barge Operations.

2.1.2 Piling

Piling is the most significant source of underwater noise identified for the construction activities of the project. Tubular piles will be driven in using a hydraulic impact hammer for the construction of the 710 m trestle jetty, Dolphins and Restraint Structure. The piles will be driven in one at a time and it is assumed minimal dressing of the piles will be required. The activity of cutting and grinding piles has therefore not been included. The first 180 m of the trestle jetty will be constructed on the mud flat reef which is exposed at low tide. The remaining 530 m will be in shallow water at low tide.

Table 2-1 : Pile Types and Sizes

Activity	Area	Type
Piling	Jetty	900mm tubular piles
	Loading Platform	1100mm tubular piles
	Dolphins	1100mm tubular piles

Figure 2-4 shows a typical jetty design and configuration that may be used.

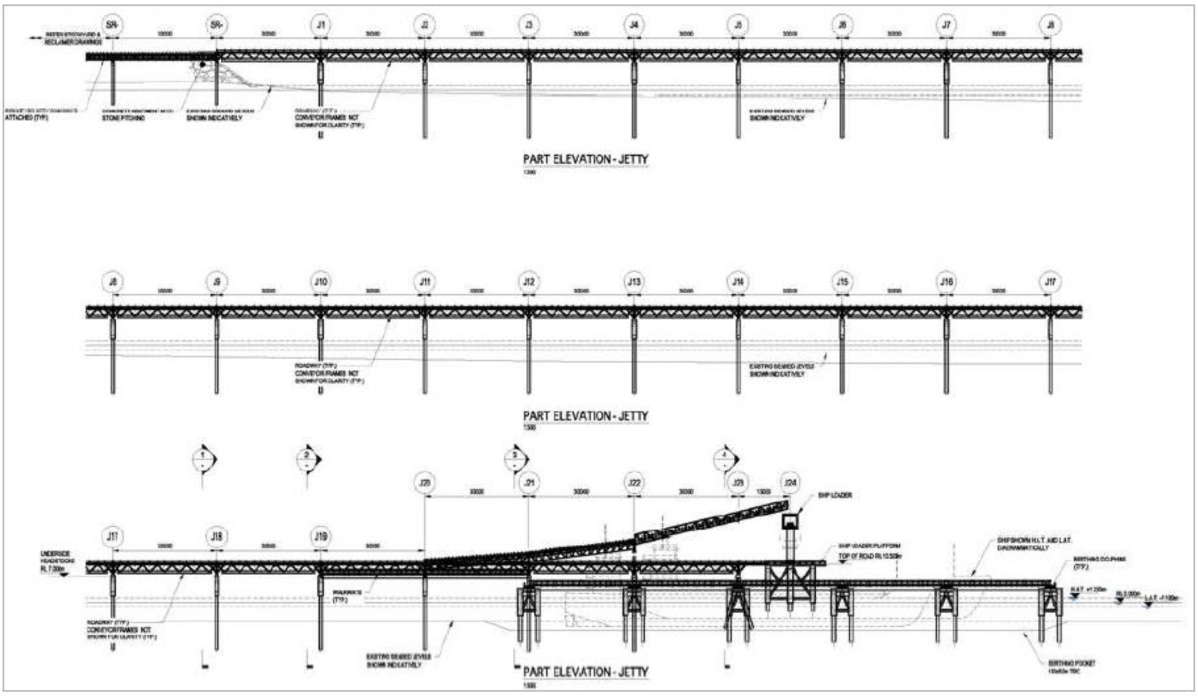


Figure 2-4 : Typical Jetty Design and Configurations

2.2 Operations

Transhipment Shuttle Vessels (TSV) will be used to transport salt from the marine jetty export facility to Panamax vessels anchored 18 nautical miles offshore. A cycle time of 14.76 hours has been calculated by the project of which a total of 2.6 hours will be spent travelling from the marine jetty to the Panamax vessel and back again. The remainder of the time will be spent loading and unloading. The barge is a relatively small slow speed[1] vessel with a displacement of 12,000.

[1] 7 knots

3 Underwater Noise

As shown in Figure 3-1, the ocean is a noisy place, comprised of sounds from both natural and anthropogenic sources. Natural underwater noise occurs from marine life and naturally occurring events such as waves, storms and underwater earthquakes. Anthropogenic noise sources result from activities such as vessel traffic, seismic exploration, marine construction and military activities.

The ambient underwater soundscape tends to be consistent and widespread across large areas of ocean, however, anthropogenic noise generating activities can often form localised noise sources. These localised noise sources, if sufficiently loud, may be detrimental to certain marine species under some circumstances. The degree of impact is influenced by many factors, including the sound's persistence, amplitude and frequency, the distance between the sound source and marine life, the total time that the marine life is exposed to the sound and the sensitivity of marine life to a combination of these factors.

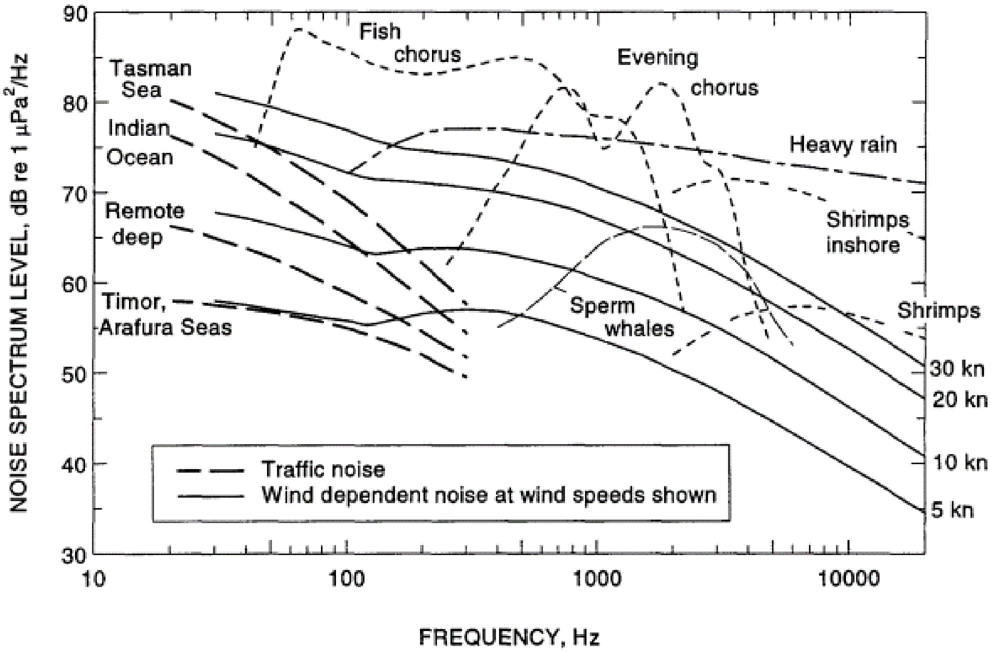


Figure 3-1 Ambient Sea Noise in Australian Waters [8].

In deep water sound travels further in the ocean than in air due to the natural duct created between the surface and the seabed, and the refractive properties of the oceans water column. Additionally, the higher sound speeds in water result in longer wavelengths than in air, which result in low frequencies travelling far distances before they are absorbed to levels below ambient noise levels.

In shallow water, sound attenuates a lot faster than in the open ocean as the natural duct created between the surface and the seabed is very narrow, resulting in the acoustic pressure wave reflecting multiple times off the seabed and surface, with every reflection resulting in the pressure wave losing energy. Additionally, in very shallow water, low frequencies below a cut off frequency[2] attenuate very quickly, thus not having any impact at distance from the source.

[2] Cut-off frequency is determined by depth and the sound speed of the seabed.

4 Marine Fauna

4.1 Species of Interest

The conservation significant species which were identified as being at most risk from underwater noise related impacts have been provided by AECOM and are listed in Table 4-1.

Table 4-1 : Marine Fauna – Species of Interest for this study

Marine Fauna Type	Species
Whales	Humpback
Sirenians	Dugong
Dolphins	Spotted Bottlenose, Australian Humpback Dolphin
Turtles	Loggerhead, Green, Flatback
Sawfish	Green

The impacts of underwater noise on Dugongs and Green Sawfish are not well known. As a result, the assessment criteria adopted for these marine fauna are inferred based on their hearing bandwidths. This study has relied on the following literature:

- **Whales and Dolphins**. For whales and dolphins, it is assumed that the threshold levels for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) for low and high frequency Cetaceans as defined in Southall et al [1] and NOAA's 'Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing' [2], are appropriate for this study.
- **Sirenians (Dugongs)**. There is very little known about the response levels for dugongs. However, the threshold levels for Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) for Sirenians as defined in Southall et al [1] and NOAA's 'Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing' [2], have been used.
- **Turtles**. For marine turtles, the threshold levels for TTS and PTS will be adopted from work undertaken by CMST[3] for behavioural response of turtles to seismic airguns[4]. The threshold levels in Popper et al, [7], were considered, but the CMST levels were more conservative and therefore adopted for the study.
- **Sawfish**. A study of elasmobranch fishes[5] audiograms indicates that their hearing bandwidths range from 10 to 1000 Hz. As the very low frequencies have large wavelengths, it is expected that they will only exist as short duration evanescent waves in the water column of the study area. As a result, it has been assumed that frequencies below 100 Hz will attenuate very quickly. The sawfish will then have a similar hearing bandwidth to that of

[3] Centre of Marine Science and Technology.

[4] 'Marine Seismic Surveys: analysis and propagation of air-gun signals and effects of exposure on humpback whales, sea turtles, fishes and squid' [3] and 'Criteria and Thresholds for Adverse Effects of Underwater Noise on Marine Animals for injury' [2].

[5] Casper, B.M. (2006). The hearing abilities of elasmobranch fishes. Graduate Theses and Dissertations, University of South Florida

turtles. It has therefore been assumed that the TTS and PTS levels for sawfish will be similar to that of turtles.

4.2 Assessment Criteria

Table 4-2 presents the assessment criteria adopted for whales, dolphins, turtles, dugongs and sawfish for this study.

The assessment criteria for each fauna type are divided into different TTS and PTS criteria depending on whether the noise being generated is classed as impulsive or non-impulsive.

- **Impulsive** – sounds produced are typically transient, brief (less than one second), broadband and consistent of high peak pressure with rapid rise time and rapid decay (NOAA, 2018). This noise source is associated with activities such as pile driving, seismic activities and underwater blasting and results in some of the most powerful sounds produced underwater (Gordon *et al*. 2004, cited in Hastie *et al*. 2019).
- **Non-impulsive** – sounds produced can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have the high peak sound pressure with rapid rise / decay times that impulsive sounds do (NOAA, 2018). This noise source is associated with activities such as dredging, vessel noise, drilling and some construction activities.

Behavioural response levels are also provided. Similar to human environmental noise impacts, behavioural levels are not based on cumulative exposure but rather on a single strike for impulsive noise sources and a 1 second RMS level for non-impulsive sources.

Table 4-2 : TTS and PTS Onset Thresholds for Non-Impulsive and Impulsive Noise[6]

Marine Fauna Type	Marine Mammal Hearing Group	Hearing Bandwidth	Noise Type	SEL Onset (Weighted) dB re 1µ Pa².s		Possible Behavioural Response dB re 1µ Pa².s
				TTS	PTS	
Whales	Low Frequency	7 Hz to35 kHz W(LF)[7]	Non-Impulsive	179	199	140[8]
			Impulsive	168	183	
Sirenians (Dugongs)	SI	100 Hz to 1 kHz W(HF)[7]	Non-Impulsive	186	206	
			Impulsive	175	190	
Dolphins	High Frequency	150 Hz to 160 kHz W(HF)[7]	Non-Impulsive	178	198	
			Impulsive	170	185	
Turtles [5] and Sawfish	Turtles and Sawfish	100 Hz to 1 kHz	Non-Impulsive	175	183	175[9]
			Impulsive	175	183	

[6] Threshold levels were obtained from Southall et al [1] and frequency weighting curves from NOAA [2] the W(MF) weighting curve has been interpreted to be equivalent as Southall High Frequency..
7 Frequency weighting as per NOAA technical guidance.
8 Dunlop et al., Determining the behavioural dose-response relationship of marine mammals to air gun noise and source proximity.
9 McCauley et al, 'Marine Seismic Surveys- A study of Environmental Implications' APPEA Journal 200, pg 692-708 [4] and McCauley RD, et al, 2000,'Marine Seismic Surveys: analysis and propagation of air-gun signals and effects of exposure on humpback whales, sea turtles, fishes and squid'. R99-15, Perth Western Australia.

5 Methodology

5.1 Overview

The desktop study has been undertaken using a computer noise model to simulate underwater noise emissions. The underwater software calculation kernel utilises the Monterey Miami Parabolic Equation (MMPE which was developed by the University of Miami and Naval Postgraduate School Monterey in the USA). The model can predict transmission loss from multiple noise emission sources simultaneously in both broadband and narrowband frequency ranges.

Underwater propagation models require inputs including bathymetric data, geo-acoustic information and oceanographic parameters to produce 3D estimates of the acoustic field at any depth and distance from the source. The quality of the model prediction is directly related to the quality of the environmental information used in the model.

The model has been setup to assume worst case environmental conditions for all scenarios (i.e. the conditions which result in the greatest propagation of noise from source to receiver) and therefore provides conservative predictions.

5.2 Noise Sources

5.2.1 General

The only significant operational noise source is the TSV which is a relatively small slow speed vessel with a displacement of 12,000. As the vessel will only be spending 2.6 hours out of every 14.8 hours underway the noise impacts from the TSV will not result in thresholds being exceeded. As a result, operational noise has not been included in the modelling.

Construction will involve various noise generating activities and equipment. The most significant noise generating activities that have been identified are piling and dredging which form the basis for the modelling.

The noise source levels used for modelling have been calculated based on a combination of client proposed operational data and source levels from a database of underwater noise sources. All source levels include overall and spectral levels.

5.2.2 Dredging Noise Source Level

Dredging is an underwater excavation activity used to increase the water depth for shipping purposes. This excavation is carried out by gathering up bottom sediment and disposing of this material to a different location.

It is assumed that this project will utilize a small cutter suction dredger. A cutter suction dredger is a ship that includes a cutter head used to loosen the material and a suction mouth, inlet and pump used to transfer the material from the seabed through piping and onto the vessel or separate barge for transportation and disposal. The source level used for modelling of dredging activities is detailed in Table 5-1 and Figure 5-1.

Table 5-1 : Small Cutter Suction Dredger noise source

Parameter	Value SPL RMS[10]
SPL Source Level (SL)	166 dB re 1µPa @ 1m

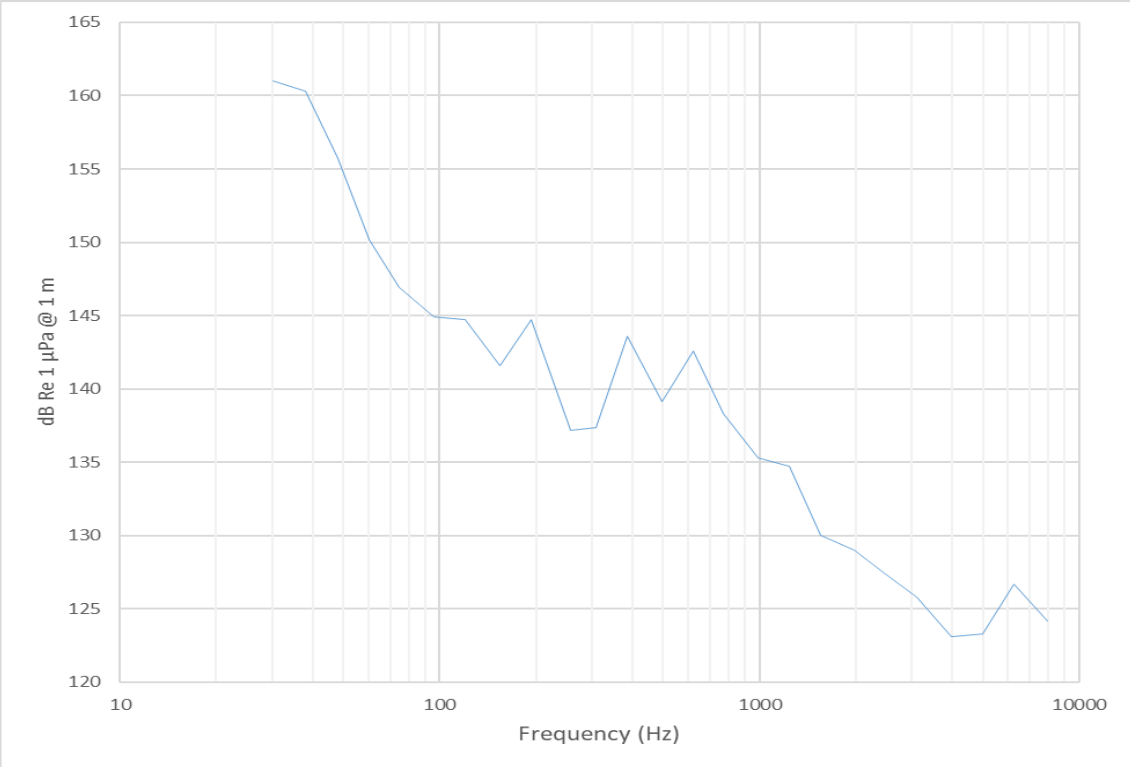


Figure 5-1 : Small Cutter Suction Dredger Noise Source Characteristics

5.2.3 Piling Noise Source Level

Pile driving involves hammering a pile into the seabed to the point of refusal. The noise emanating from a pile is a function of its material type, its size, the force applied to it and the characteristics of the substrate into which it is being driven.

The action of driving a pile into the seabed excites bendy[11] waves in the pile that propagate along the length of the pile and transfer into the sea and seabed. The compression component of the wave propagates into the ocean, while both the compression and transverse components propagate into the seabed. Once in the seabed, the energy will then propagate outwards as compression and shear waves.

Piles can be driven using various methods such as vibration, gravity and hydraulic hammer. The method that is used is dependent on the size of the pile and the substrate into which the pile is being driven. It is planned that hydraulic impact hammers will be used for this piling operation. The

[10] Sound Pressure Level Root Mean Square
[11] Bendy wave is a wave that comprises of a compression wave and a transverse wave.

noise that is generated by an impact hammer hitting the top of the pile is short in duration lasting approximately 90ms and can therefore be described as an impulsive noise.

The pile driving specifications that have been used to calculate the source levels for modelling are given in Table 5-2.

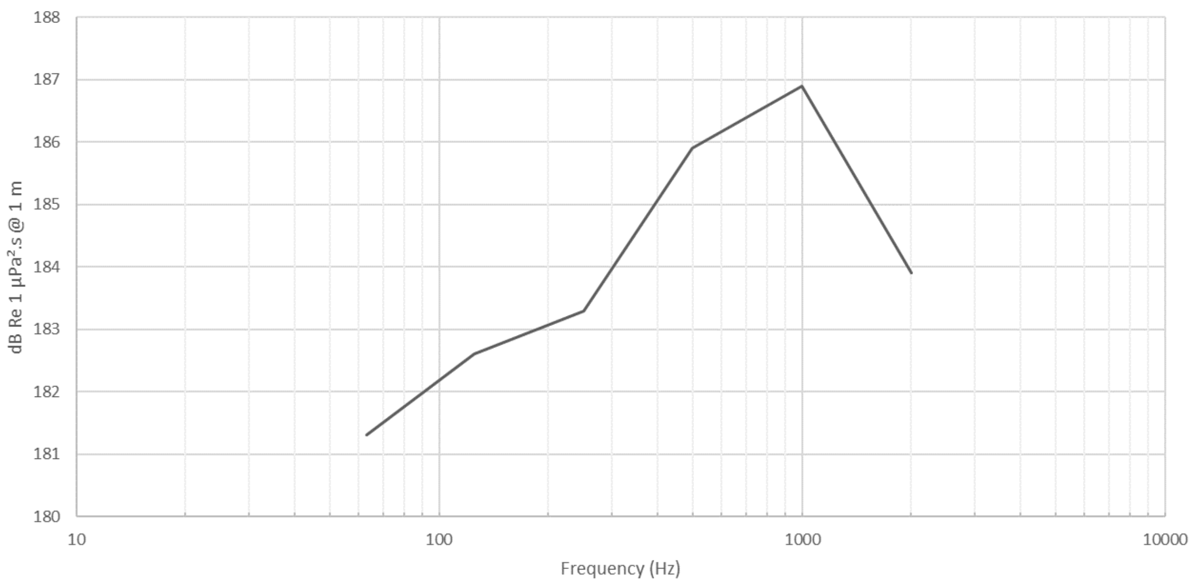
Table 5-2 : Pile driving specifications

Parameter	Value
Pile diameter	900 mm and 1100
Hammer Type and Weight	16t Hydraulic
Hammer Energy	235 kJ
Blow rate	30 bpm
Hammer Model	HHK 16S

Table 5-3 and Figure 5-2 present the pile driving source level for maximum hammer energy. A review of a typical hydraulic hammer energy profile shows that the hammer energies start off low and only achieve maximum energy in the last stages of the piling before the point of refusal. This maximum energy is sustained for approximately 7 minutes. As a result, the cumulative exposure level has been determined assuming maximum energy for ~7 minutes (i.e. 200 hammer strikes) to give an overall cumulative SEL[12].

Table 5-3 : Piling noise source level for maximum hammer energy

Parameter	Value SEL[2] for a single strike
SEL Source Level (SL)	193 dB re 1µPa^2.s @ 1m



[12] 10*log10(N) where N is the number of hammer strikes.

Figure 5-2 : Pile Driving source characteristics (235KJ)

5.2.4 Noise Model Source Locations

Table 5-4, Figure 5-4 and Figure 5-3 show the locations of the piling and dredging noise source relative to the coast. The modelled noise sources were inserted in the deepest possible location. All model scenarios have been run for hightide (i.e. 2.4m above mean sea level (MSL)) and low tide (i.e. 1.3m below mean sea level (MSL)). As the sources have been modelled at the deepest point, the modelling outputs can therefore be considered as conservative and worst case.

Table 5-4 : Noise Source Model locations (MGA zone 50)

Location Name	Eastings and Northings
Dredging	267343, 7588677
Piling	267317, 7588674

Figure 5-3 : Modelled Dredging Location

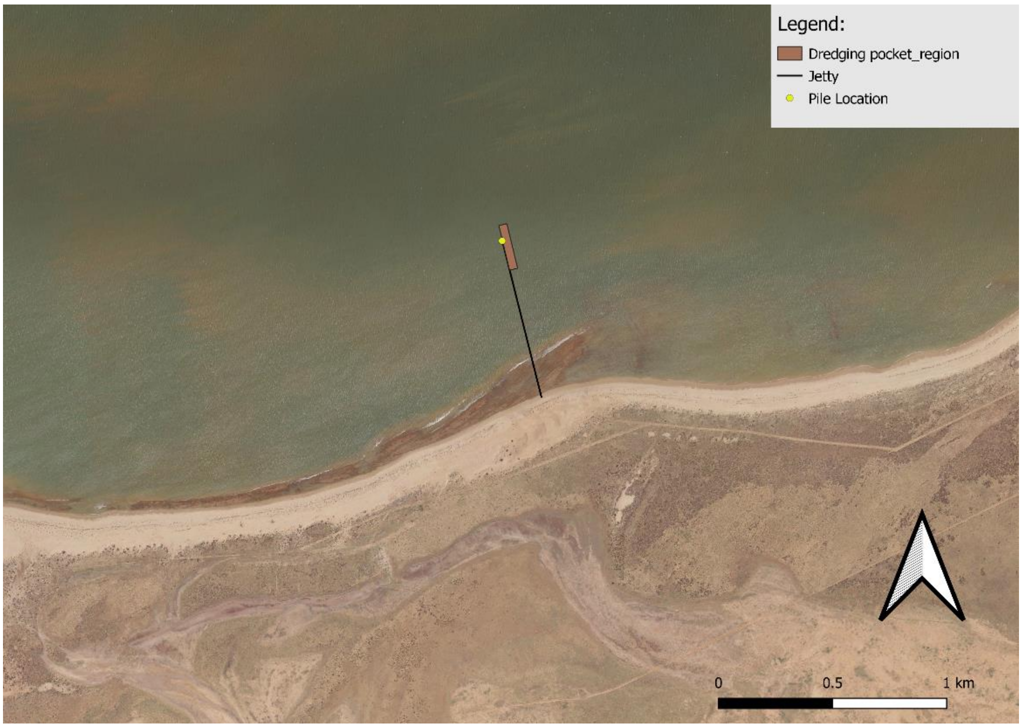


Figure 5-4 : Modelled Piling Location

5.3 Bathymetry

The bathymetry applied to the model for the Ashburton area was provided by AECOM and is shown in Figure 5-5. As can be seen in the figure the water depth is shallow (between 0 and ~4m) within the project area and progressively gets deeper on the seaward side of the jetty.

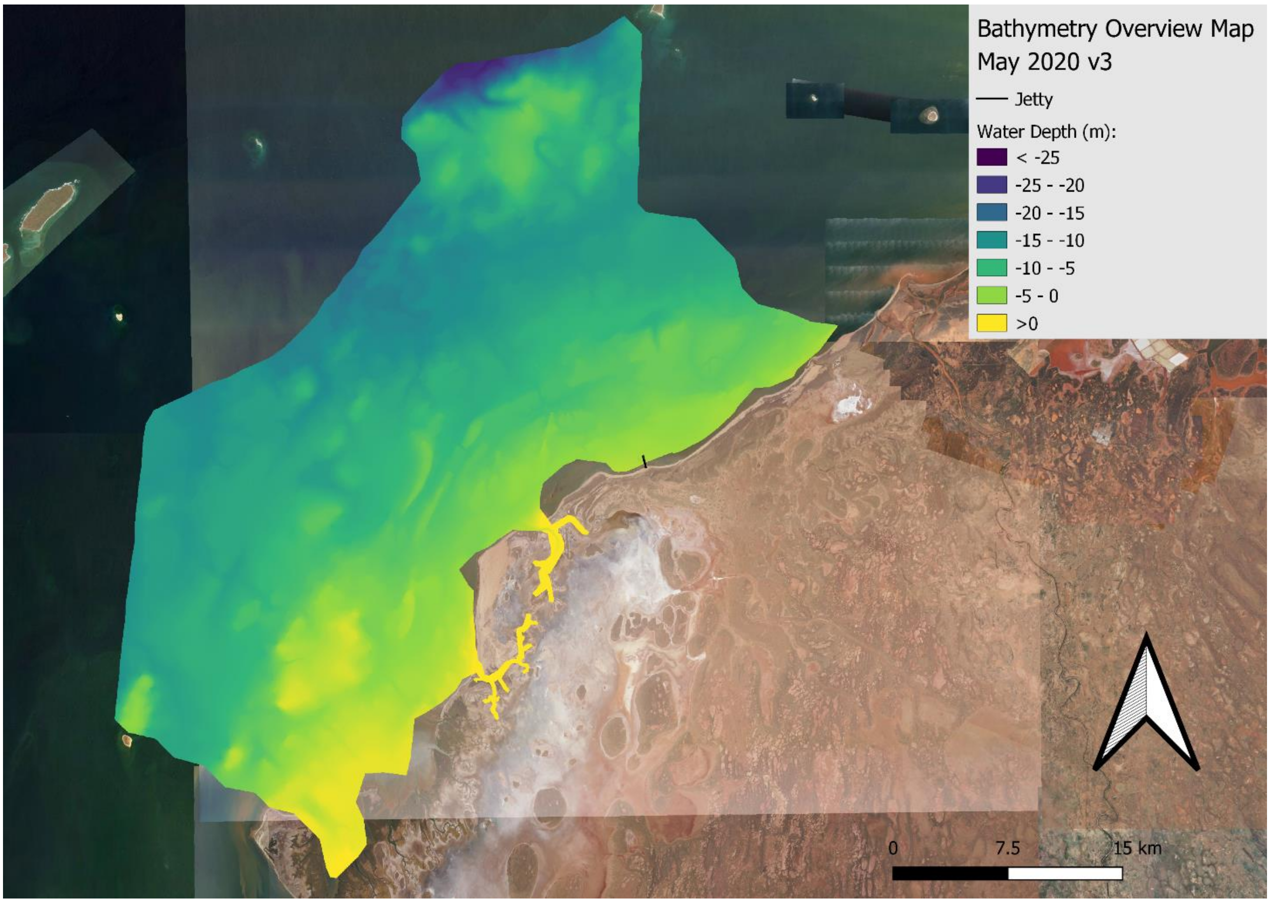


Figure 5-5 : Bathymetry Overview Map

5.4 Seabed Types

A sandy seabed (see Table 5-5 for seabed properties) has been assumed for Ashburton. This is a conservative assumption because sand is more reflective in shallow water environments (i.e. shallow grazing angles) than limestone and other hard materials that absorb more of the pressure waves energy with each reflection due to the excitation of both compression and shear waves in the material.

Table 5-5 : Seabed properties used in the model

Type	Sound Speed (m/s)	Density (g/cm³)	Sound attenuation (dB/m/kHz)		Shear Speed (m/s)
			Compression	Shear	
Fine to medium sand	1774	2.05	0.37	0	0

5.5 Sound Speed Profile

The area of interest for the modelling is in very shallow water (maximum bathymetric depth in the data provided is approximately 25 m). As a result, it is expected that the temperature profile through the water column will be isothermal. Therefore, the sound speed profile used for modelling is for a constant water temperature of 28°C and a constant salinity of 40 parts per thousand (ppt).

5.6 Hearing Threshold Weighting Curves

Hearing weighting curves for Low Frequency (LF) and High Frequency (HF) Cetaceans[13] have been applied to all predicted received levels in accordance with NOAA's technical guidance [2]. For Turtles and Sawfish a flat response between 100 and 1000 Hz has been assumed.

5.7 Data and Model Limitations

The following limitations apply to the noise modelling:

- **Reflection**. Specular reflection due to rough seabed surface and wave action is not accounted for in the model.
- **Airborne Noise**. A small component of the airborne noise generated above the sea surface will be transferred into the water column, however this has not been accounted for in the model.
- **Salinity and Sound Speed Profiles**. The water depth in the modelling area is relatively shallow. It has therefore been assumed that the water column is isothermal. Additionally, salinity will have negligible effect on the sound speed profile. Variation in the sound speed profile has been limited to the effects of water column pressure.
- **Bathymetry**. For near shore modelling, both bathymetry and topography were used in the model.
- **Model Contour Depth** - The model can produce horizontal noise contours for any depth and distance. However, it is not practical for the report to include plots for each depth.

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[13] It has been assumed that the SI hearing curve will be the same as the HF cetacean's curve.

6 Noise Model Results and Discussion

The following sections provide unweighted[14] noise contour maps and tabulated modelling results for dredging (section 6.1) and piling (section 6.2). Unweighted noise contour maps are provided as they provide the highest predicted level expected from each scenario.

Various assumptions have been made regarding the source levels and exposure duration. These assumptions, if necessary, can be verified through measurement once the Project commences.

Assessment criteria has been used to determine distances from the noise sources that result in assessment criteria being exceeded. This information can be used to assist with the determination of potential risks and identification of possible mitigation strategies.

6.1 Dredging

Dredging is a continuous noise source and is therefore considered as non-impulsive. It is expected that dredging will operate continuously for 12 or 24 hours a day. As there are no reef bound species of interest within the area it has been assumed that the maximum exposure of the fauna considered in the study will be 1 hour. The SPL source level was therefore converted to a 1-hour SEL by adding 36 dB. Figure 6-1 to Figure 6-3 shows the predicted maximum SEL for 60 minutes exposure with range and Table 6-1 provides the ranges at which TTS and PTS is expected to exceed for each hearing group. The distances at which the noise level will exceed a threshold level for high tide are between 260m and 150m while for low tide they are 180m to 90m. Figure 6-5 shows the dredgers unweighted (i.e. no hearing curve applied and therefore worst case) cumulative SEL predicted noise contours.

Table 6-1 : Behavioural, TTS and PTS Onset Thresholds from Non-Impulsive Noise

Marine Hearing Group	SEL Onset (Weighted) dB re 1µ Pa^2.s		Tide	TTS Distance Limit (metres)	PTS Distance Limit (metres)	Behavioural Response Distance (metres)
	TTS	PTS				
Low Frequency	179	199	Low	~180	<5	~800
			High	~260	<5	>3,600
High Frequency	178	198	Low	-	-	85
			High	-	-	110
Sirenian	186	206	Low			
			High			
Turtles and Sawfish	175	183	Low	150	90	40
			High	360	170	75

[14] i.e. no hearing weighting applied

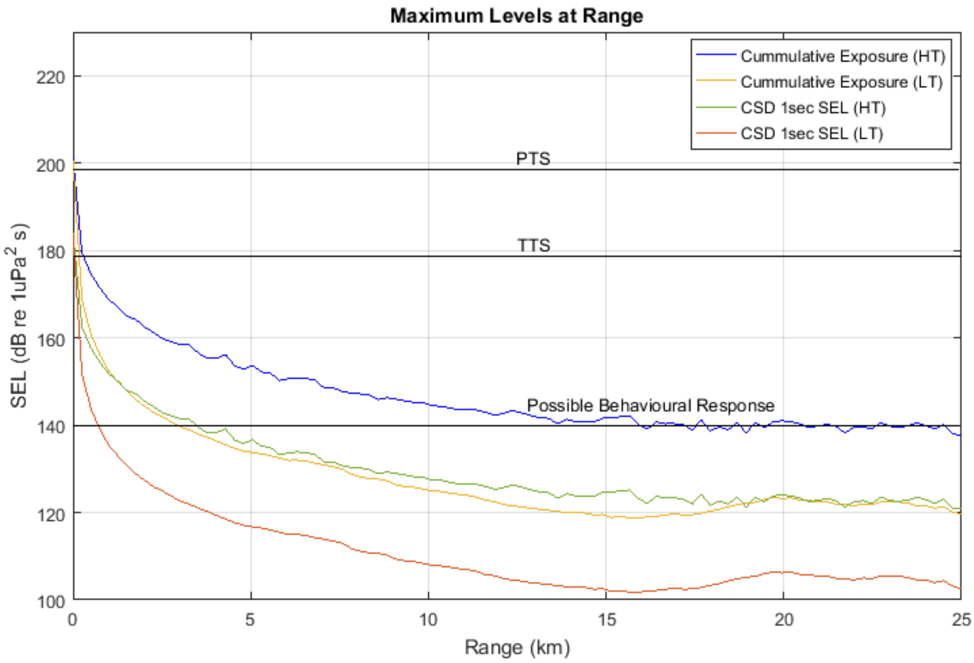

Figure 6-1 : CSD - Low Frequency Hearing Group SEL with range for 1 hour exposure.

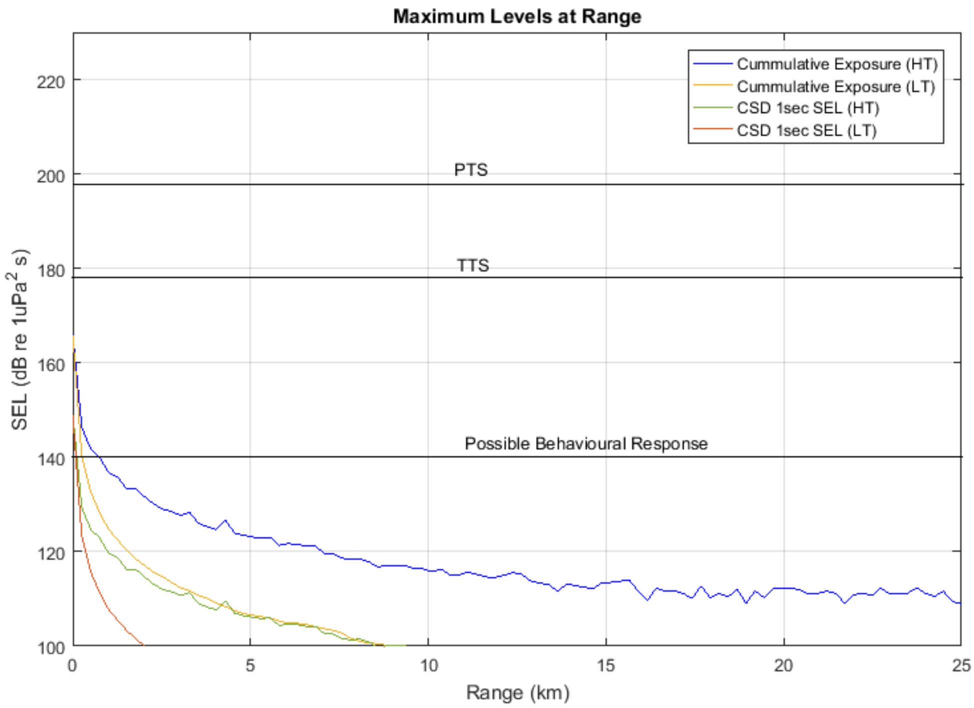

Figure 6-2 : CSD High Frequency Hearing Group SEL with range for 1 hour exposure.

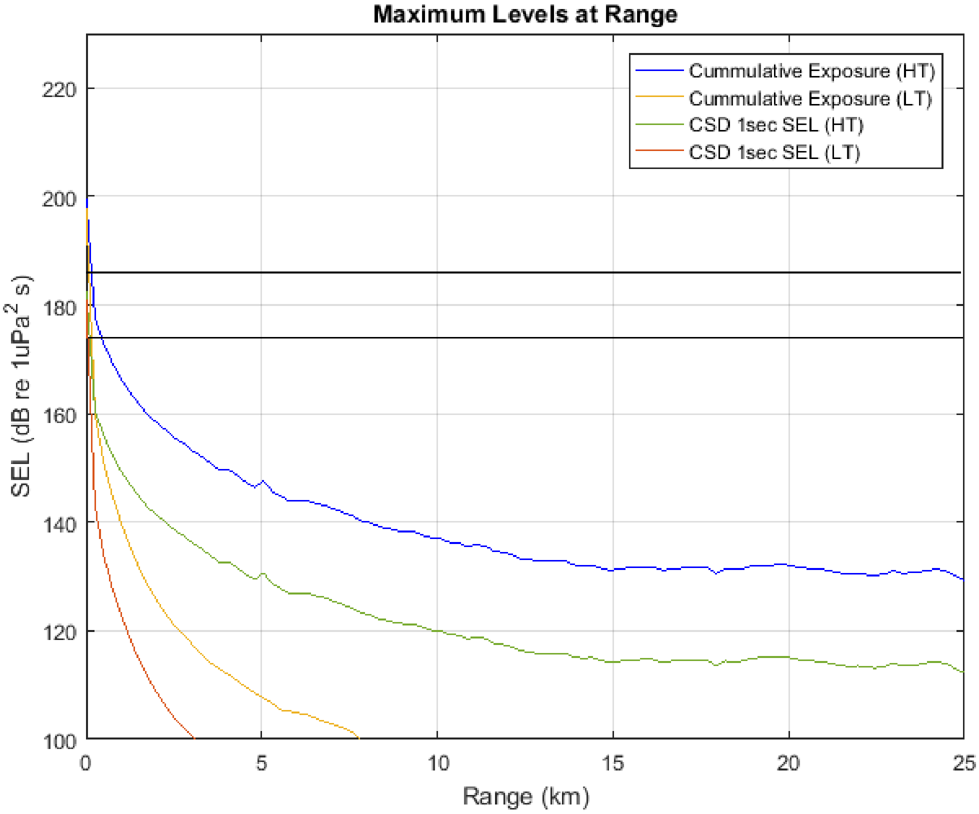

Figure 6-3 : CSD Turtles and Sawfish SEL with range for 1 hour exposure.

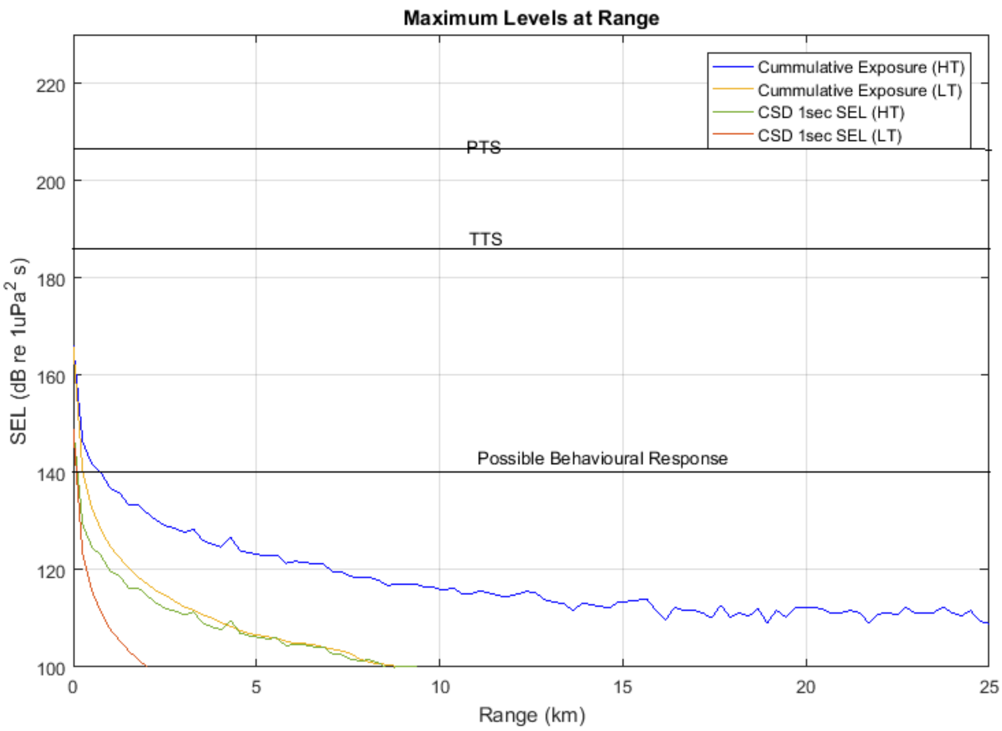

Figure 6-4 : CSD Sirenian SEL with range for 1 hour exposure.

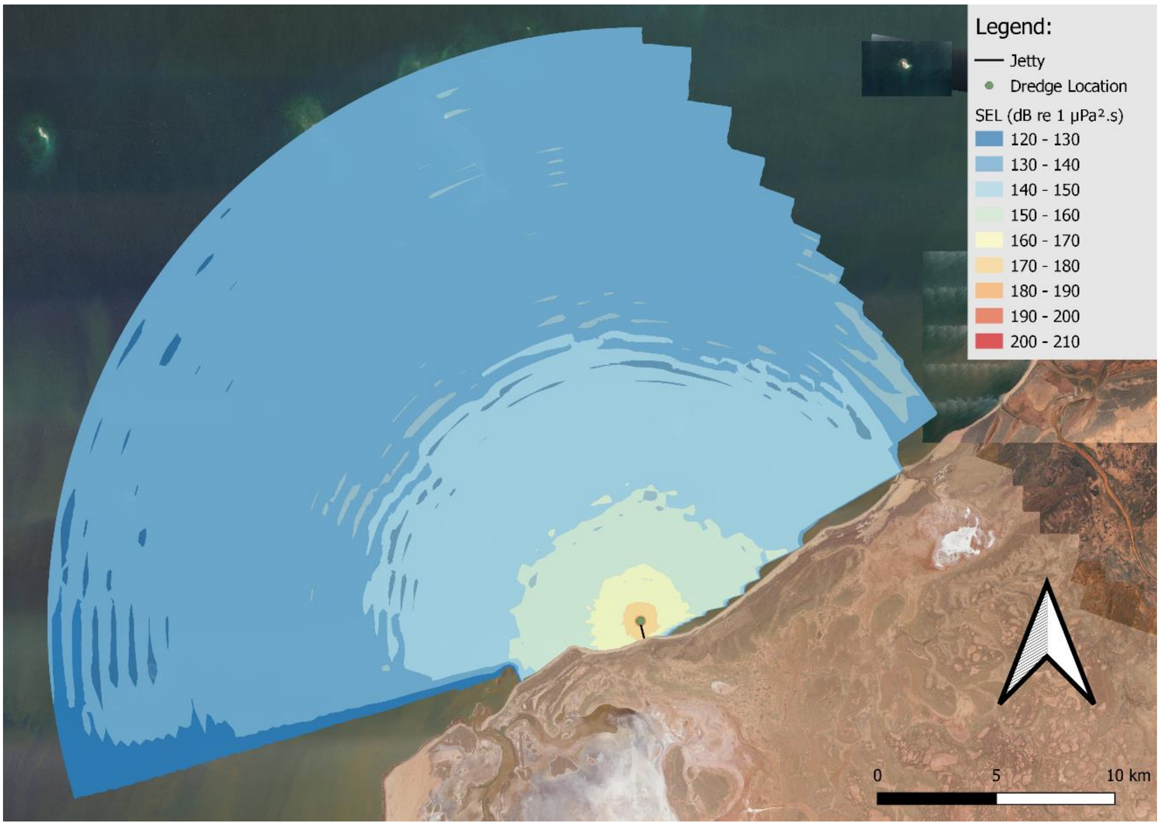

Figure 6-5 : Noise Contour – Dredging Operations – Unweighted (i.e. no frequency weighting curve applied) SEL (High Tide)

6.2 Piling

Piling is an impulsive noise source involving multiple pile strikes. It has been estimated that the maximum exposure will occur when the hammer energy is at its maximum. The maximum hammer energy has been determined to be applied over a period of 7 minutes which equates to 200 hammer strikes. Exposure levels have therefore been determined using 200 strikes.

Figure 6-6 to Figure 6-8 shows the predicted maximum SEL with range and Table 6-2 provides the ranges at which TTS and PTS is expected to exceed for each hearing group. The exposure ranges at which thresholds are exceeded for high tide are 5,000m for low frequency hearing groups and 1,200m for turtles and sawfish. In comparison, low tide ranges are 2,700m for low frequency hearing groups and 450m for turtles and sawfish. This indicates that scheduling piling activities around low tides could potentially be used to reduce exposure ranges. Figure 6-10 shows unweighted (i.e. no hearing curve applied and therefore worst case) cumulative SEL predicted noise contours for piling based at high tide.

Table 6-2 : Behavioural, TTS and PTS Onset Thresholds from Impulsive Noise

Marine Mammal Hearing Group	SEL Onset (Weighted) dB re 1µ Pa^2.s		Tide	TTS Distance Limit (metres)	PTS Distance Limit(metres)	Behavioural Response Distance[15] (metres)
	TTS	PTS				
Low Frequency (LF)	168	183	Low	~2,700	~500	~4,400
			High	~5,000	~900	~10,250
High Frequency (HF)	170	185	Low	-	<50m	~250
			High	-	<50m	~250
Sirenian (SI)	175	190	Low	-	<50m	~250
			High	-	<50m	~250
Turtles and Sawfish	175	183	Low	~450	~250	~160
			High	~1,200	~550	~170

[15] Based on a single pile strike [9].

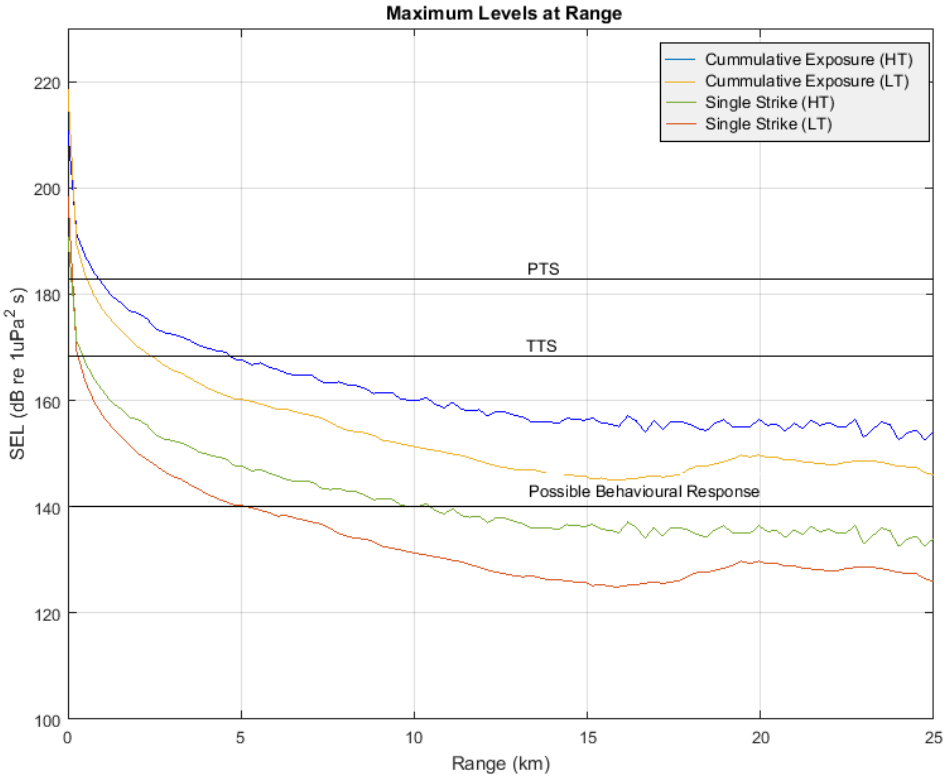

Figure 6-6 : Piling Low Frequency maximum predicted SEL with range.

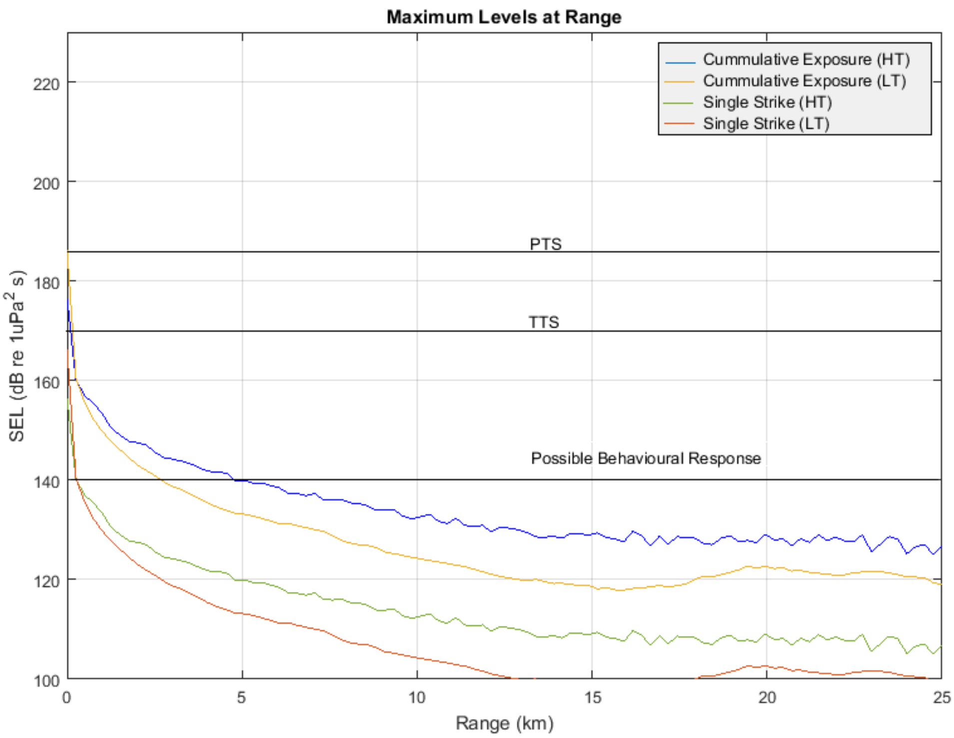

Figure 6-7 : Piling High Frequency maximum predicted SEL with range.

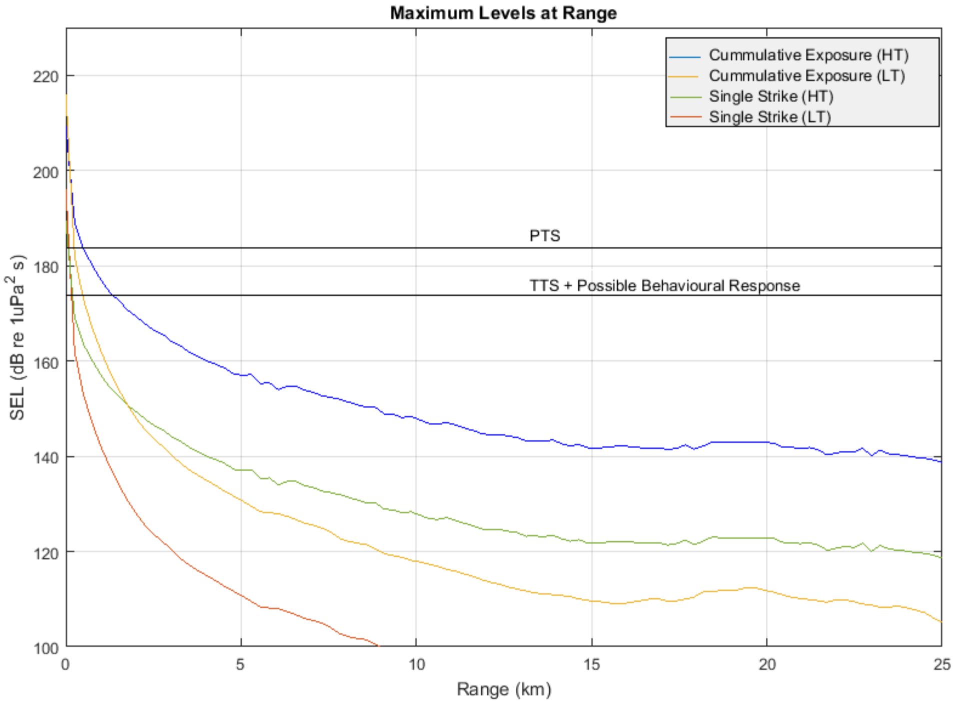

Figure 6-8 : Piling Turtles and Sawfish maximum predicted SEL with range.

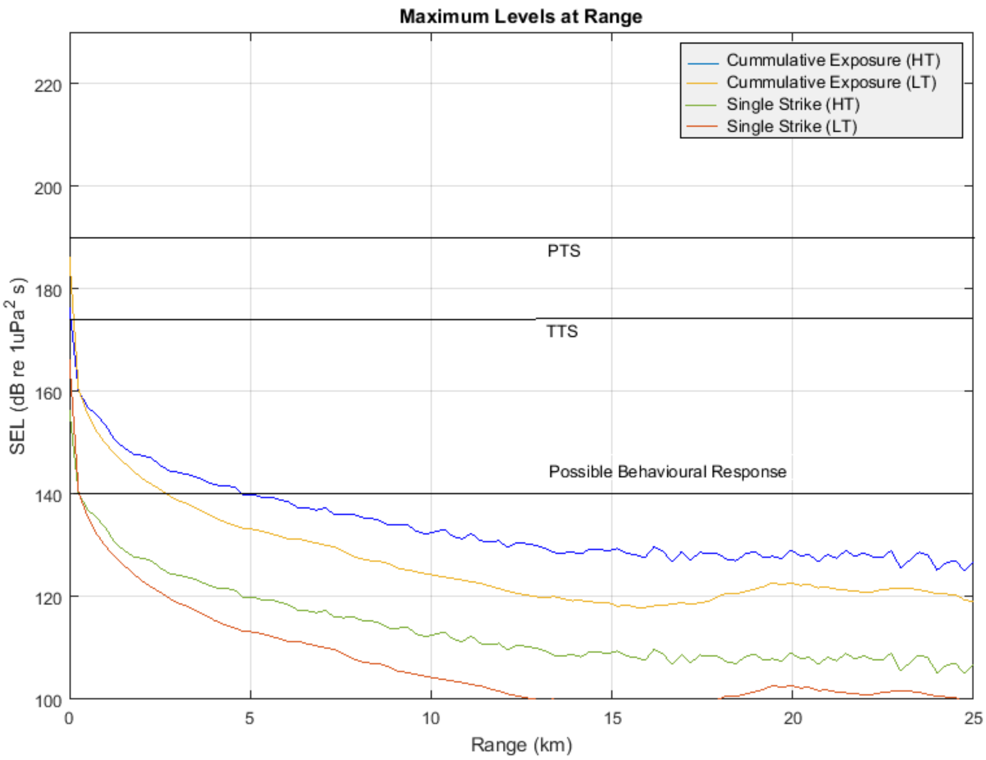

Figure 6-9 : Piling Sirenians maximum predicted SEL with range.

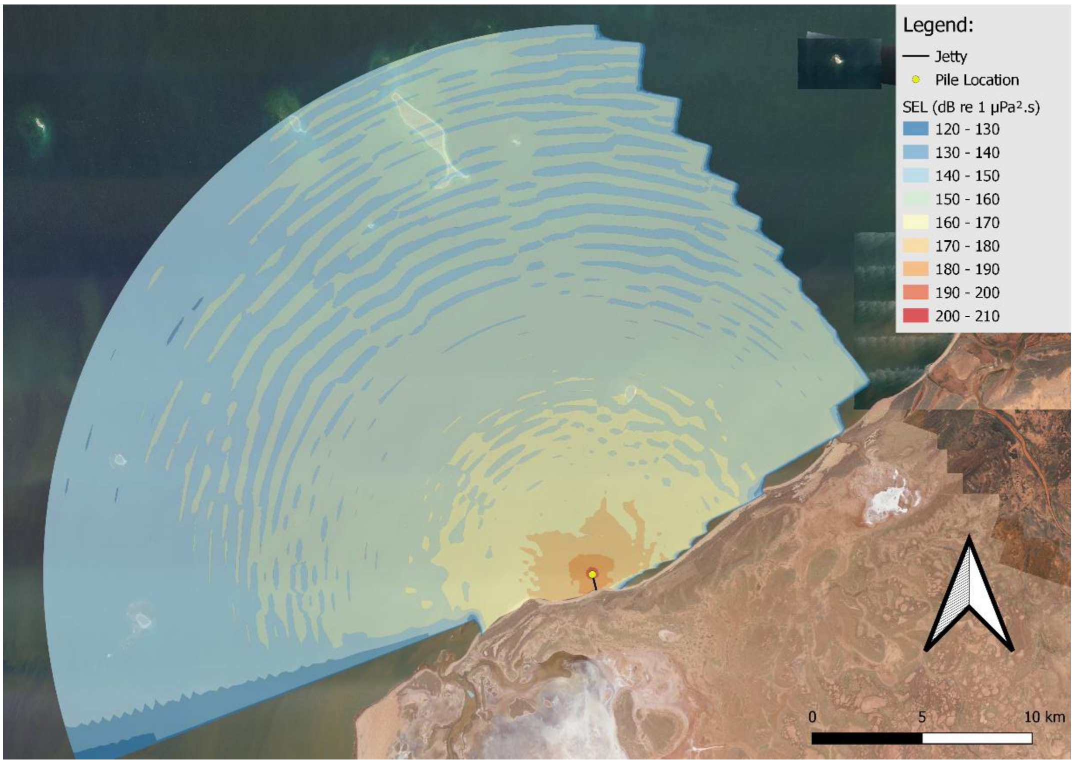

Figure 6-10 : Noise Contour –Piling Operations - Unweighted (i.e. no frequency weighting curve applied) cumulative SEL (High Tide)

7 Conclusion

An underwater model has been created for the Project to predict potential noise levels at distance from the noise sources. The noise sources have been placed at the deepest point of the Project and it is therefore expected that the model outcomes will be conservative. Various assumptions have been made regarding the source levels and exposure duration. As a result, it may be necessary to verify the model outcomes through measurement once the Project has commenced.

Based on the model results for the Project, the following can be concluded:

- **Dredging** – For dredging it has been assumed that fauna will be exposed for 1 hour. The model predicts that distances at which the noise level will exceed a PTS threshold levels for high tide are between 260m and 150m while for low tide they are 180m to 90m for low frequency cetaceans and turtles. Behavioural ranges vary between 40 m and 3.6 km ranges with the shortest distances occurring during low tide.
- **Piling** – For piling the cumulative exposure ranges at which PTS thresholds are exceeded for high tide are ~900 m for low frequency hearing groups and 550 m for turtles and sawfish. In comparison, low tide PTS ranges are 500m for low frequency hearing groups and 250 m for turtles and sawfish. Behavioural ranges vary between 160 m and 10.25 km ranges with the shortest distances occurring during low tide. This indicates scheduling piling activities around low tides could potentially be used to reduce exposure ranges.

Appendix A Equations Used

A variety of units are used in underwater acoustics to define steady-state and impulsive signals, which can include;

- mean square pressure (dB re 1 μ Pa)
- peak pressure (dB re 1 μ Pa)
- equivalent energy or sound exposure level (SEL) (dB re 1 μ Pa^2.s SEL)

The mean squared pressure is the decibel value of the mean of the squared pressure over a defined period of a signal. For steady signals the averaging time is not applicable, however for impulsive signals the averaging time is a significant consideration. Impulsive signals such as piling are better described by a measure of the amount of energy (Sound Exposure Level (SEL) in units of dB re 1 μ Pa^2.s) and measure of the signal peak amplitude (positive and/or negative).

The following equations include the following units of measurement; Pascals (Pa), Metres (m), Seconds (s), kilograms (kg).

Appendix B2 Peak SPL

Peak Sound Pressure Level (SPL) is calculated according to the standard equation (B9);

$$\boldsymbol{SPL_{Peak} = 20\log_{10}\frac{P_{Peak}}{1\ \mu\mathrm{Pa}}} \qquad \textbf{(B9)}$$

The total positive impulse is calculated according to the equation (B10) and (B11)

$$\boldsymbol{Positive\ Impulse = \int P(r,t)dt}$$
(B10)

$$\boldsymbol{Positive\ Impulse = P_{Peak}\,\tau}$$
(B11)

To calculate a source level to enter into the MMPE model, the Sound Exposure Level (SEL) at the limiting radius R_0 is calculated according to equation (B13).

$$SEL(R_0) = 10 * \log_{10}\frac{\int P(t)^2 dt}{10^{-12}Pa^2 s}$$
(B12)

$$SEL(R_0) = 10 * \log_{10}\left(\frac{\frac{1}{2}P_{Peak}(R_0)^2\tau(R_0)}{10^{-12}Pa^2 s}\right)$$
(B13)

The model requires a source level at one metre, and only considers linear effects. Geometric spreading is used to calculate the source level at one metre would that give the required SEL at R_0, as shown in equation (B14).

$$SEL(1\mathrm{m}) = SEL(R_0) + 20\log_{10}\frac{R_0}{1\mathrm{m}}$$
(B14)

The MMPE model is then used to predict sound exposure levels at various radii.

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Appendix G

Ecotoxicology Assessment

Prepared for
K plus S Salt Australia Pty Ltd
ABN: 55607033447

AECOM

Ashburton Salt Project - Ecotoxicology Assessment

18-Jul-2021
Ashburton Salt Project
Doc No. M&C4183 / R1896

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Delivering a better world

Ashburton Salt Project - Ecotoxicology Assessment

Client: K plus S Salt Australia Pty Ltd

ABN: 55607033447

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Quality Information

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Reviewed by Ian Baxter

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1.0 Introduction

The Environmental Scoping Document (ESD) (EnviroWorks Consulting 2017) for the Ashburton Salt project indicated that a Marine Ecotoxicology Assessment would be undertaken in relation to:

- Sediment mobilisation due to dredging.
- Discharge of bitterns.

The methodologies adopted to undertake the assessment, and the outcomes, are detailed in this Report.

1.1 Environmental Scoping Document (ESD) Requirements

The requirement for a Marine Ecotoxicology Assessment is outlined within the ESD (EnviroWorks Consulting 2017) as follows:

ESD Requirement Number 5 *“Determine the likely toxicity of the bitterns to be discharged and use in combination with bitterns plume modelling to determine the potential impacts of the discharge on benthic communities and habitats. Specifically, undertake a marine biota ecotoxicology assessment of local marine indicator species for proposed marine discharges (bitterns, dredging sediment mobilisation). This assessment will:*

a. Identify appropriate local indicator species (including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages);

b. Test the tolerance of indicator species to predicted bitterns discharge and turbidity (under usual operation and extreme events), with consideration given to fertilisation, embryo and larval development, growth, and chronic and acute toxicity.

c. Establish trigger thresholds, below which discharge concentrations may be considered safe.

d. Use the results of the biota ecotoxicology assessment to inform the marine hydrodynamic modelling and design process to determine the likely impact of the discharges modelled on marine biota sensitive receptors.”

1.2 Report Purpose and Structure

The purpose of this report is to detail the Marine Ecotoxicology Assessment undertaken for the Ashburton Salt Project to fulfill the requirements of the ESD.

This report is structured as follows:

- Regulatory Framework
- Approach
- Methods
- Results
- Summary and Outcomes.

2.0 Regulatory Framework – Marine Water Quality and Toxicants

The regulatory framework relevant to the Project, for marine water quality with regards to toxicants, is contained within the following:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018).
- *Technical Guidance – Protecting the Quality of Western Australia's Marine Environment* (EPA, 2016a).
- *Technical Guidance – Environmental Impact Assessment of Marine Dredging Proposals* (EPA, 2016b)
- *National Assessment Guidelines for Dredging (NAGD)* (Commonwealth of Australia [CoA], 2009).

2.1 Dredged Material

The National Assessment Guidelines for Dredging (NAGD) set out the framework for the environmental impact assessment and permitting of the ocean disposal of dredged material. The framework includes:

- Evaluating alternatives to ocean disposal.
- Assessing loading and disposal sites.
- Assessing potential impacts on the marine environment and other users.
- Determining management and monitoring requirements.

With regards to assessing the potential toxicity of dredged material, the NAGD (CoA 2009) endorse the use of "Screening Levels" for potential toxicants within the material to be dredged. The toxicant Screening Levels are based on the interim sediment quality guideline values presented in the ANZECC/ ARMCANZ (2000) *Guidelines for Fresh and Marine Water Quality*, which are superseded by the Default Guideline Values (DGVs) presented in ANZG (2018).

If these Screening Levels are exceeded and ocean disposal of dredged material is proposed, then further testing of bioavailability, bioaccumulation and ecotoxicity is recommended (Commonwealth of Australia, 2009).

2.2 Bitterns

Bitterns is a hypersaline solution of concentrated seawater, formed as a result of solar salt operations. Bitterns solutions generally have a salinity of around 300 parts per thousand (ppt). The solar salt evaporation process does not lead to chemical reactions that produce substances that do not commonly occur in seawater because it is essentially an evaporation/crystallisation process for removal of sodium chloride. This process leaves behind only naturally occurring elements within the bitterns (predominantly magnesium sulphate).

The key impact that bitterns can have on biota within the receiving environment is physico-chemical stress due to the high salinity which has osmotic effects on the cells of living organisms. The salinity component of bitterns is classified as a Physical Chemical (PC) stressor and is not a "toxicant". Given no additives are introduced during the solar salt production process, the only toxicants that exist in the bitterns are naturally occurring elements of seawater (specifically metals) which may be concentrated by the solar evaporation process.

ANZG (2018) provides DGVs for assessing a range of toxicants in marine waters. The use of the ANZG DGVs for toxicants is recommended by the WA EPA in its *Technical Guidance – Protecting the Quality of Western Australia's Marine Environment* which recommends that 99% species protection levels are adopted for a high Level of Environmental Protection (LEP) with the exception of cobalt where 95% species protection levels are recommended (EPA, 2016a).

It should be noted that the ANZG (2018) and EPA (2016a) approaches for developing guideline values for PC stressors (such as salinity) use reference data. In other words, the recommended approach to derive guideline values for salinity (which is not considered to be a toxicant) is to calculate an appropriate percentile of measured reference site water quality data. Given salinity is not a toxicant, it is not the focus of this Ecotoxicology Assessment.

3.0 Approach taken for the Ashburton Salt Project

3.1 Dredged Material

With regards to assessing the potential toxicity of dredged material:

- GHD (2021) conducted a geochemical investigation of the seabed materials to be dredged from the berthing pocket.
- K+S has proposed that the dredged material will not be disposed of within the ocean (i.e. land disposal is proposed).
- Although the NAGD (CoA, 2009) are considered relevant to ocean disposal of dredged material (rather than land disposal), the ANZG (2018) *toxicant DGVs for sediment quality* still provide useful "Screening Levels" for potential toxicants within dredged material. Therefore, AECOM has reviewed the GHD (2021) test results against these Screening Levels.

3.2 Bitterns

For the Ashburton Salt Project, Environmental Quality Criteria (EQC) have been proposed as recommended by ANZG (2018) and EPA (2016a) as follows:

- For the PC stressor salinity, a referential approach has been followed, involving the collection of 20 months of baseline data at the proposed bitterns discharge location (Locker Point). This has enabled the development of a baseline salinity dataset, enabling the calculation of percentiles of the dataset. Given salinity is not considered a toxicant, it is not discussed in detail within this report.
- For toxicants (metals), ANZG (2018) DGVs for appropriate species protection levels have been proposed. This is consistent with EPA (2016a) which recommends that for a High LEP, ANZG (2018) 99% species protection levels should be adopted, with the exception of cobalt where 95% species protection levels are appropriate.

It should be noted that given the high salinity of the bitterns (typically around 300 ppt), it is not feasible to conduct whole effluent toxicity (WET) testing of bitterns on test species. This is because mortality of ecotoxicology test species due to the high salinity levels would obscure any mortality due to toxic effects from the other bitterns constituents. In other words, organisms would suffer mortality due to physio-chemical stress (osmotic effects of salinity) well before any toxic effects of metals would occur.

WET testing is not an approach used for the derivation of DGVs by ANZG (2018), which uses single-toxicant, single-species laboratory testing as the preferred approach in order to avoid such confounding factors, as these confounding factors would make it impossible to set appropriate guideline values.

4.0 Methods

4.1 Dredged Materials

GHD (2021) undertook sampling of sediment representative of proposed dredged material, via mobilisation of a vibracore system mounted on a marine vessel to collect sediment samples at 12 locations. The sampling program and methodology were undertaken in accordance with NAGD (CoA, 2009). Sediment samples were collected using a 450 vibracore, which retrieved an undisturbed core (as far as practically possible) within a de-contaminated polycarbonate liner with a nominal diameter of 50 mm. Sub-samples were obtained from the core at discrete intervals based on the sediment conditions encountered. Composite samples were also obtained in order to preserve sufficient volumes of sample for analysis. Samples were then sent for analysis at a NATA accredited laboratory and the toxicant concentrations were compared to the sediment DGVs in ANZG (2018).

4.2 Bitterns

As the concentration of various naturally occurring metals within seawater varies according to geographic location, the metals constituents of bitterns can vary significantly with the location of the source seawater. Therefore, to provide a prediction of the toxicity of metals within the bitterns to be generated from the proposed Ashburton Salt Project, the following approach was adopted:

- A 30 L sample of local seawater (from the location of the proposed seawater intake in Urala Creek South) was collected by AECOM.
- This sample was provided to NATA-accredited Analytical Reference Laboratory (ARL) to concentrate the sample using evaporation, to mimic the bitterns creation process.
- Sodium chloride was precipitated (crystallised) and removed, and the evaporation process was continued until the solution remaining reached a density typical of bitterns (1.248 g/cm^3).
- The bitterns sample was then tested for levels of expected macro level chemical composition to confirm it was representative of bitterns constituents at expected levels (based on known main constituent levels of bitterns analysed for other salt projects such as salinity and density).
- Laboratory testing was then undertaken by ARL on the laboratory generated bitterns sample for the following analytical suite (Table 1) to identify and assess toxicants within the proposed Ashburton Salt Project bitterns discharge.

Table 1. Analytical suite (bitterns sample)

All Analytes			
pH	Nitrite-N	Aluminium - Total	Lead - Total
Conductivity	Bromide	Manganese - Total	Lead - Dissolved
Total Dissolved Solids	Total Nitrogen	Manganese - Dissolved	Nickel - Total
Alkalinity	Total Kjeldahl Nitrogen	Tin - Total	Nickel - Dissolved
Bicarbonate	Total Phosphorus	Tin - Dissolved	Cadmium - Total
Carbonate	Sodium - Total	Vanadium - Total	Mercury - Total
Hydroxide	Sodium - Dissolved	Zinc - Total	Mercury - Dissolved
Chloride	Calcium - Total	Arsenic - Total	Selenium - Total
Sulfate	Calcium - Dissolved	Chromium - Total	
Filterable Reactive Phosphorus	Magnesium - Total	Cobalt - Total	
Ammonia-N	Magnesium - Dissolved	Cobalt - Dissolved	
Nitrate-N	Potassium - Total	Copper - Total	
NOx-N	Potassium - Dissolved	Copper - Dissolved	

5.0 Results

5.1 Dredged Material

GHD (2021) did not detect any toxicants for which the 95% Upper Confidence Limit (UCL) concentrations exceeded the ANZG (2018) sediment DGVs (which are equivalent to the NAGD Screening Levels [CoA, 2009]) (Table 2). Therefore, there is no indication that any further assessments of ecotoxicology or bioaccumulation are warranted for dredged material and this has not been considered further within this ecotoxicology assessment.

Table 2. Summary of Toxicant Results for Dredged Material (GHD, 2021)

Analyte	Practical Quantitation Limit	ANZG (2018) DGV	Max	Min	Mean	Median	95% UCL
	mg/kg						
Antimony	10	2	<10	<10	-	-	-
Arsenic	2	20	23	9.2	13.1	12	14.75
Cadmium	0.4	1.5	0	0	-	-	-
Chromium (III+VI)	5	80	73	37	46.5	44	51.02
Copper	5	65	22	8.7	13.7	13	15.51
Lead	5	50	8	5.2	6.4	6.4	6.77
Mercury	0.1	0.15	0	0	-	-	-
Nickel	5	21	21	12	15.0	13	16.31
Selenium	2	NA	0	0	-	-	-
Zinc	5	200	25	13	20.3	23	22.31

5.2 Bitterns

5.2.1 Bitterns Composition

The results of the laboratory testing of the bitterns sample prepared using local seawater (from the location of the proposed seawater intake) are summarised in Table 3.

Table 3. Summary of toxicant results for bitterns sample

Parameter	Unit	PQL	Result	Parameter	Unit	PQL	Result
pH	pH units	0.1	6.8	Aluminium - Total	mg/L	0.01	0.06
Conductivity	mS/cm	0.01	190	Manganese - Total	mg/L	0.01	0.04
Total Dissolved Solids	mg/L	5	450,000	Manganese - Dissolved	mg/L	0.01	0.04
Alkalinity	mg $CaCO_3$/L	5	490	Tin - Total	mg/L	0.01	<0.01
Bicarbonate	mg $CaCO_3$/L	5	490	Tin - Dissolved	mg/L	0.01	<0.01
Carbonate	mg $CaCO_3$/L	5	<5	Vanadium - Total	mg/L	0.01	0.01
Hydroxide	mg $CaCO_3$/L	5	<5	Zinc - Total	mg/L	0.005	0.024
Chloride	mg/L	5	220,000	Arsenic - Total	mg/L	0.001	0.009
Sulfate	mg/L	1	44,000	Chromium - Total	mg/L	0.001	0.001

Parameter	Unit	PQL	Result	Parameter	Unit	PQL	Result
Filterable Reactive Phosphorus	mg/L	0.01	0.01	Cobalt - Total	mg/L	0.001	<0.001
Ammonia-N	mg/L	0.02	0.17	Cobalt - Dissolved	mg/L	0.001	<0.001
Nitrate-N	mg/L	0.01	0.4	Copper - Total	mg/L	0.001	0.015
NOx-N	mg/L	0.01	0.44	Copper - Dissolved	mg/L	0.001	0.015
Nitrite-N	mg/L	0.01	0.24	Lead - Total	mg/L	0.001	<0.001
Bromide	mg/L	0.1	3,600	Lead - Dissolved	mg/L	0.001	<0.001
Total Nitrogen	mg/L	0.2	0.6	Nickel - Total	mg/L	0.001	0.007
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	Nickel - Dissolved	mg/L	0.001	0.005
Total Phosphorus	mg/L	0.01	0.16	Cadmium - Total	mg/L	0.0001	0.0005
Sodium - Total	mg/L	0.1	91,000	Mercury - Total	mg/L	0.0001	<0.0001
Sodium - Dissolved	mg/L	0.1	91,000	Mercury - Dissolved	mg/L	0.0001	<0.0001
Calcium - Total	mg/L	0.1	210	Selenium - Total	mg/L	0.001	<0.001
Calcium - Dissolved	mg/L	0.1	210				
Magnesium - Total	mg/L	0.1	37,000				
Magnesium - Dissolved	mg/L	0.1	37,000				
Potassium - Total	mg/L	0.1	8,800				
Potassium - Dissolved	mg/L	0.1	8,800				

Note: PQL = Practical Quantitation Limit

5.2.2 ANZG (2018) Default Guidelines

ANZG (2018) provides DGVs for assessing a range of toxicants (including metals) in marine waters. Specifically, for metals in marine waters ANZG (2018) DGVs are provided for Aluminium, Antimony, Arsenic, Boron, Cadmium, Chromium, Cobalt, Copper, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium, Silver, Thallium, Tributyltin, Uranium, Vanadium and Zinc.

Laboratory effects data from single-toxicant and single-species ecotoxicity laboratory tests underpin most of the information used by ANZG (2018) to derive toxicant water quality DGVs. Species sensitivity distributions (SSDs) of chronic laboratory ecotoxicity data for a number of species and life stages have been used by ANZG (2018) to derive DGVs that will protect 80, 90, 95 or 99% of species. Therefore, it is reasonable to consider that these DGV's have relevance to local indicator species including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages. The percent level of protection adopted is then applied according to the current or desired ecosystem condition and associated level of protection (ANZG, 2018).

The use of these of the ANZG DGVs is recommended by the WA EPA (2016a) which states that for a:

- High LEP: 99% species protection levels are adopted with the exception of cobalt where 95% species protection levels are recommended.
- Moderate LEP: 90% species protection levels are adopted.

5.2.3 Toxicants (Metals) below 99% Species Protection Levels

The laboratory analysis showed that concentration of the following metals within the raw bitterns sample was already lower than the ANZG (2018) 99% species protection DGVs:

- Manganese
- Vanadium
- Cobalt
- Lead
- Nickel
- Cadmium
- Mercury
- Selenium.

Therefore, these metals within the bitterns discharge present very low risk of ecotoxicity or bioaccumulation in the marine environment and the bitterns will meet a High LEP at the discharge point for these metals.

5.2.4 Toxicants (Metals) exceeding 99% Species Protection Levels

The laboratory analysis showed that concentration of the following metals within the raw bitterns sample exceeded the ANZG (2018) 99% species protection DGVs:

- Aluminium
- Zinc
- Arsenic
- Chromium
- Copper.

Therefore, Environmental Quality Criteria (EQC) have been formulated using ANZG (2018) DGVs for these metals as outlined in the following sub-sections.

5.2.4.1 Zinc, Arsenic and Chromium

For zinc, arsenic and chromium, it is proposed that the ANZG (2018) 99% species protection DGVs are met by the bitterns discharge at the boundary of an appropriate Level of Environmental Protection "mixing zone" around the discharge point (via appropriate dilution and mixing of the discharged plume).

5.2.4.2 Aluminium

At present there is no DGV specified for aluminium in ANZG (2018). A low reliability value of 0.0005 mg/L is presented in Wenziker et al (2006); however, it is noted that this is not based on sufficient data such that it should be considered a trigger level. Recent research acknowledges that current water quality guidelines fail to accurately assess the environmental risk associated with aluminium in marine waters (van Dam et al, 2018). A recent publication presents a study combining chronic biological effects data generated over several years with toxicity data from the open literature to construct SSDs which enabled the computation of revised water quality guidelines for aluminium (van Dam et al, 2018). A guideline concentration of 0.002 mg/L was derived for a 99% species protection level in tropical waters. Therefore, it is proposed that this guideline level (0.002 mg/L) is met by the bitterns discharge at the boundary of an appropriate Level of Environmental Protection "mixing zone" around the discharge point (via appropriate dilution and mixing of the discharged plume).

5.2.4.3 Copper

The background water quality data collected from the proposed bitterns discharge location (Locker Point) has shown that the ANZG (2018) 99% species protection DGV of 0.0003 mg/L is regularly exceeded naturally in background seawater at Locker Point (Water Technology, 2021). Therefore, it is proposed that the ANZG (2018) 95% species protection level of 0.0013 mg/L is met by the bitterns discharge at the boundary of an appropriate Level of Environmental Protection "mixing zone" around the discharge point (via appropriate dilution and mixing of the discharged plume).

5.2.5 Proposed Metals Environmental Quality Criteria

Based on the above information, the EQC for toxicants (metals) outlined in Table 4 are proposed.

The required dilution of the bitterns plume in order to achieve these EQC, based on pre-dilution with seawater at a ratio of 1 to 1 (planned by the Project) and the measured metals levels within the bitterns sample as outlined in Table 3, are presented in Table 4.

The distances from the bitterns discharge diffuser at which these dilutions are predicted to be met have been modelled by Water Technology (2021) and are presented in their report.

Potential impacts on benthic communities and habitat and marine fauna have been assessed based on the Water Technology (2021) model outputs in additional reports by AECOM (2021a and 2021b).

Once the metals within the bitterns plume are diluted such that they meet the 99% or 95% species protection level assigned in Table 4 below, they present very low risk of ecotoxicity or bioaccumulation in the marine environment.

Table 4. Proposed metals Environmental Quality Criteria (EQC) and dilutions required to meet EQCs

Metal	Proposed EQC (mg/L)	% Species Protection Level (DGV)	Dilution Required in Plume	Notes
Aluminium	0.002	99	17.7	Based on van Dam et. al. (2018)
Manganese	0.08	99	0*	Bitterns concentration < DGV
Vanadium	0.05	99	0*	Bitterns concentration < DGV
Zinc	0.007	99	2.3	Bitterns concentration < DGV
Arsenic	0.0023	99	6.7	Lower DGV for As III applied
Chromium	0.0001	99	38	Lower DGV for Cr VI applied
Cobalt	0.001	95	0*	Bitterns concentration < DGV
Copper	0.0013	95	19.7	Background water Exceeds 99% DGV
Lead	0.0022	99	0*	Bitterns concentration < DGV
Nickel	0.007	99	0*	Bitterns concentration < DGV
Cadmium	0.0007	99	0*	Bitterns concentration < DGV
Mercury	0.0001	99	0*	Bitterns concentration < DGV
Selenium	0.003	99	0*	Bitterns concentration < DGV

Table Notes:

DGV = Default Guideline Value from ANZG (2018), except aluminium which is a protection level proposed by van Dam et al (2018)

* = the expected bitterns concentration is below the DGV upon discharge therefore no dilution is required to meet the DGV.

6.0 Summary and Outcomes

The ESD (EnviroWorks Consulting 2017) for the Ashburton Salt project indicated that a Marine Ecotoxicology Assessment would be undertaken in relation to:

- Sediment mobilisation due to dredging.
- Discharge of bitterns.

The methodologies adopted to undertake the assessment, and the outcomes, are detailed in this report. The way in which each requirement of the ESD has been addressed within this report is outlined in Table 5.

Table 5. How the requirements of the ESD have been met.

<table>
<tr><th>Requirement</th><th>How Met</th><th>Section</th></tr>
<tr><td>5. Determine the likely toxicity of the bitterns to be discharged and use in combination with bitterns plume modelling to determine the potential impacts of the discharge on benthic communities and habitats. Specifically, undertake a marine biota ecotoxicology assessment of local marine indicator species for proposed marine discharges (bitterns, dredging sediment mobilisation).</td><td>The toxicity of dredged material has been determined by testing of representative sediment samples against NAGD (CoA, 2009) and ANZG (2018) screening criteria. Given none of the screening criteria were exceeded and land disposal of dredged material is proposed, no further assessment was warranted.

The toxicity of bitterns has been determined by:
• Creation of a bitterns sample using source seawater from the proposed intake location.
• Comprehensive laboratory testing of the bitterns sample.
• Comparison to DGVs for species protection from ANZG (2018).
• Calculation of dilution required to meet appropriate ANZG (2018) DGVs.
• Modelling the distances from the bitterns discharge diffuser at which these dilutions are predicted to be met (Water Technology, 2021).</td><td>5.2</td></tr>
<tr><td>a. Identify appropriate local indicator species (including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages);</td><td rowspan="2">ANZG 2018 DGVs are based on SSDs of chronic laboratory ecotoxicity data for a range of species and species life stages to derive DGVs that will protect 95% or 99% of species.

Therefore, these DGVs have relevance to local indicator species including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages.

Given the high salinity of the bitterns (typically around 300 ppt), it is not feasible to conduct WET testing of bitterns to assess the potential effects of toxicants (metals). The mortality of ecotoxicology test species due to the high salinity levels would obscure any mortality due to toxic effects from the other bitterns constituents. Organisms would suffer mortality due to physico-chemical stress (osmotic effects of salinity) well before any toxic effects of metals would occur.</td><td>3.2 and 5.2</td></tr>
<tr><td>b. Test the tolerance of indicator species to predicted bitterns discharge and turbidity (under usual operation and extreme events), with consideration given to fertilisation, embryo and larval development, growth, and chronic and acute toxicity.</td><td>3.2 and 5.2</td></tr>
</table>

Requirement	How Met	Section
c. Establish trigger thresholds, below which discharge concentrations may be considered safe.	EQC have been formulated based on ANZG (2018) DGVs. Dilutions of the bitterns plume required in order to achieve these EQC have also been calculated based on a bitterns sample generated from locally sourced intake water. The distances from the bitterns discharge diffuser at which these dilutions are predicted to be met have been modelled by Water Technology (2021). Once the metals within the bitterns plume are diluted such that they meet the 99% or 95% species protection level assigned in ANZG (2018), they will present a very low risk of ecotoxicity or bioaccumulation in the marine environment.	5.2
d. Use the results of the biota ecotoxicology assessment to inform the marine hydrodynamic modelling and design process to determine the likely impact of the discharges modelled on marine biota sensitive receptors.	The distances from the bitterns discharge diffuser at which these dilutions are predicted to be met have been modelled by Water Technology (2021). Impacts on Benthic Communities and Habitat and Marine Fauna have been assessed based on the Water Technology (2021) model outputs in additional reports by AECOM (2021a and 2021b).	5.2

7.0 References

AECOM 2021a. *Assessment of Benthic Communities and Habitats*. Perth: Unpublished report prepared for K+S Salt Australia.

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ANZG 2018*. Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines.

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EnviroWorks Consulting. 2017. *Environmental Scoping Document, Ashburton Salt Project*. Unpublished report prepared for K+S Salt Australia.

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Water Technology 2021. Suite of Reports Prepared for the Ashburton Salt Project. Reports prepared for K+S:

- Data Collection Report
- Marine, Coastal and Surface Water Existing Environment
- Surface Water Assessment and Modelling
- Marine and Coastal Assessment and Modelling
- Nutrient Pathways Assessment and Modelling

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Appendix H

Phase 2 Ecotox Report

Prepared for
K plus S Salt Australia Pty Ltd
ABN: 55607033447

Technical Memorandum – Phase 2 Ecotoxicology Assessment

Ashburton Salt Project

26-Oct-2022
Ashburton Salt Project
Doc No. 60692046_0

Technical Memorandum – Phase 2 Ecotoxicology Assessment

Ashburton Salt Project

Client: K plus S Salt Australia Pty Ltd

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1.0 Background

K+S Salt Australia Pty Ltd (K+S) is developing the Ashburton Salt Project (the Project), a solar salt production facility on the Pilbara Coast adjacent to Tubridgi Point. Several plants for the extraction of sea salt have been, or are currently being, established in the coastal region of this area, including the Onslow and Mardie salt operations, as indicated in **Plate 1** below.

Plate 1 Approximate Locations of K+S, Onslow and Mardie Salt Operations (adapted from Google Maps)

The Ashburton Salt Project (the Project) proposal includes the construction of solar salt evaporation and crystallisation ponds and associated infrastructure/activities. The Project will produce a hypersaline wastewater stream (bitterns), which is essentially the components of natural seawater left-over after removal of water and sodium chloride. The bitterns are proposed to be diluted with seawater in a dilution pond prior to disposal via discharge offshore (K+S, 2021).

K+S has submitted the *Ashburton Salt Project: Draft Environmental Review Document* [ERD, (K+S, 2021)] to the Western Australian (WA) Environmental Protection Authority (EPA), to report on potential ecotoxicity of bitterns. AECOM (2021) identified that once the metals within the bitterns plume are diluted such that they meet the appropriate species protection levels, the bitterns present very low risk of ecotoxicity or bioaccumulation in the marine environment. EPA advised further information was required to determine the potential toxicity of the bitterns.

Since the time of submission of the K+S (2021) ERD, a similar salt and potash operation – the Mardie Project – proposed by Mardie Minerals Pty Ltd (Mardie), which proposed to utilise seawater and evaporation to produce concentrated sulfate of potash (and other associated products), and includes a bitterns disposal pipeline and outfall, received EPA-recommendation that the proposal may be implemented (EPA, 2021). It is noted that the ecotoxicology assessment for the Mardie project was based on a whole effluent toxicity (WET) analysis surrogate prototype sample (sourced from the Onslow operation), in the absence of Project-specific bittern samples.

The purpose of this Technical Memorandum (memo) is to respond to the EPA request for further bitterns toxicity information during the current stage of the K+S Project. In the absence of WET results for Project-specific bitterns samples – and considering similar project proposals (Mardie Project) within the bioregion which have received approval – this memo will present surrogate WET analysis information from the Onslow operation in support of the Project proposal.

1.1 Environmental Scoping Document (ESD) Requirements

The requirement for a marine ecotoxicology assessment was outlined within the requirements of an Environmental Scoping Document (ESD), specifically *Task Number 5*, as follows, as presented in K+S (2021) ERD and AECOM (2021):

Task 5. "*Determine the likely toxicity of the bitterns to be discharged and use in combination with bitterns plume modelling to determine the potential impacts of the discharge on benthic communities and habitats. Specifically, undertake a marine biota ecotoxicology assessment of local marine indicator species for proposed marine discharges (bitterns, dredging sediment mobilisation). This assessment will:*

a. Identify appropriate local indicator species (including benthic and pelagic species, prawn larvae and juveniles, and the most vulnerable pearl oyster life stages);

b. Test the tolerance of indicator species to predicted bitterns discharge and turbidity (under usual operation and extreme events), with consideration given to fertilisation, embryo and larval development, growth, and chronic and acute toxicity.

c. Establish trigger thresholds, below which discharge concentrations may be considered safe.

d. *Use the results of the biota ecotoxicology assessment to inform the marine hydrodynamic modelling and design process to determine the likely impact of the discharges modelled on marine biota sensitive receptors*."

1.2 K + S Ashburton Salt Project – Previous Ecotoxicology Assessments

The previous bitterns water quality and toxicity information considered by the EPA is summarised as follows. This information will be supplemented by the surrogate WET analysis presented in this memo.

1.2.1 Bitterns Generation and Discharge Assessment – EnviroWorks Consulting (2020)

In November 2020, in the absence of project-specific bitterns, a laboratory-generated bitterns sample was prepared using a 30 L sample of local seawater (collected by AECOM from the location of the proposed Ashburton Salt project seawater intake), which was provided to Analytical Reference Laboratory (ARL), to concentrate via evaporation, to mimic the process of formation of bitterns (EnviroWorks, 2020). Salt was precipitated (crystallised) and removed, and the evaporation process was continued until the solution remaining reached a density typical of bitterns.

The bitterns sample was then analysed to confirm it was representative of bitterns constituents at expected levels (based on known constituent levels of bitterns analysed for other salt projects). The Analytical results are summarised in **Table 2.** Based on the chemical composition, Enviroworks (2020) determined that the bitterns sample generated was representative of the expected constituents of bitterns.

EnviroWorks (2020) assessed the potential toxicity of the proposed bitterns to be discharged in accordance with the regulatory framework contained within:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
- Technical Guidance – Protecting the Quality of Western Australia's Marine Environment (EPA, 2016).

Based on the composition of the bitterns sample, EnviroWorks (2020) identified two key water quality parameters which need to be assessed and regulated:

- Salinity (a physical / chemical (PC) stressor), to be assessed using on a referential approach based on baseline salinity data; and

- Metals (toxicants), to be assessed based on ANZG (2018) default guideline values for appropriate species protection levels.

Laboratory ecotoxicity testing on selected species from exposure to the whole of effluent bitterns stream was not undertaken by EnviroWorks on the basis of the following:

- WET testing for the entire bitterns effluent would introduce confounding factors because organisms would be exposed to a combination of PC stress from salinity and cumulative toxicant (metals) exposure. ANZG (2018), uses single toxicant, single-species testing as the preferred approach in order to avoid such confounding factors.
- WA EPA (2016) recommends approaches consistent with ANZG (2018).

The data generated in this report were presented in AECOM (2021) which reported an analysis of water quality parameters against ANZG (2018) criteria, and an evaluation of the level of dilution required for environmentally protective discharge of the bitterns (see **Section 1.2.3**).

1.2.2 Water Technology (2021, as cited in AECOM, 2021)

Water Technology (2021) modelled the distances from the bitterns discharge diffuser at which environmentally protective dilutions are predicted to be met. These results are reported in AECOM (2021, see **Section 1.2.3**), and the dilution levels ranged from 0 (for manganese, vanadium, cobalt, lead, nickel, cadmium, mercury and selenium) to 38 (for chromium).

1.2.3 Ecotoxicology Assessment – AECOM (2021)

In July 2021, AECOM undertook a marine ecotoxicology assessment for the Ashburton Salt Project to address the requirements of the ESD (refer to **Section 1.1**). The assessment identified the key impact bitterns can have on biota within the receiving environment is physico-chemical stress due to the high salinity which has osmotic effects on the cells of living organisms. Salinity is classified as a ‘PC stressor’ and is not a ‘toxicant’. The only toxicants identified in the bitterns are naturally occurring metals in seawater which may be concentrated by the solar evaporation process. AECOM (2021) concluded that once the metals within the bitterns plume are diluted such that they meet the appropriate species protection level (99% or 95%), they present very low risk of ecotoxicity or bioaccumulation in the marine environment. The distances from the discharge point at which these dilutions are predicted to be met have been modelled by Water Technology (2021).

It is noted that no WET testing was undertaken as requested in the ESD Requirements, given the high salinity of the bitterns would result in mortality of ecotoxicology test species and obscure any mortality due to toxic effects from other bitterns’ constituents, i.e., test organisms would suffer mortality due to PC stress well before any toxic effects of metals would occur. Furthermore, WET testing is not an approach used for the derivation of DGVs by ANZG (2018), which uses single-toxicant, single-species laboratory testing as the preferred approach in order to avoid confounding factors from multiple toxicants.

1.3 Ecotoxicology analysis Phase 2: Mardie Salt Project surrogate data

As discussed in **Section 2.1**, other facilities for the extraction of sea salt, including the Onslow and Mardie salt operations are located along the WA coast in the vicinity of the K+S facility.

Since the time of submission of the K+S ERD, the Mardie Project, which proposed to utilise seawater and evaporation to produce a concentrated salt, sulfate of potash (and other associated products) and includes bitterns disposal pipeline and outfall, has received EPA-recommendation that the proposal may be implemented (EPA, 2021).

In order to address EPA comments requesting further ecotoxicity information, the following Sections present additional EPA-approved (EPA, 2021) ecotoxicology and water quality data from comparable operations sourced from publicly-available sources.

1.3.1 Mardie WET Testing

As part of the Mardie Project investigations, WET testing was undertaken to determine potential toxicity of bitterns discharge. The basis and outcomes of the testing was reported in O2 Marine (2019). In the absence of a project-specific bitterns sample, a prototype bitterns effluent sample from the Onslow salt processing facility was used as the sample for WET testing. The composition of the prototype Onslow sample was analysed along with two seawater samples collected from the site for a control comparison with the bitterns sample for characterisation. Analytical results are summarised in **Table 2**, alongside the K+S bitterns sample for comparison, and discussed further in **Section 2.3**.

1.3.1.1 Acceptability of data from other bitterns

The Mardie approach involving the use of a prototype bitterns effluent from a different operation [the Onslow facility (O2 Marine, 2019)] was determined by the EPA (2021, Section 2.5.2 in that report) as "adequate to inform the EPA's assessment of the proposal", and recommended that the proposal may be implemented subject to conditions.

1.3.1.2 Species Selection and Test Method

Mardie WET analysis was undertaken by ESA on six marine organism groups (microalgae, echinoderm, crustacean, cnidarian, mollusc and fish) to represent local marine indicator species.

The test species were considered representative for local ecosystems several bases, including:

all test species are found in tropical/subtropical Australia
the test milky oyster *Saccostrea echinata* was considered representative of Pilbara milky oyster molluscs (e.g. *Saccostrea cucullata*) and pearl oysters (e.g. *Pinctada* spp.)
the test sea urchin *Heliocidaris tuberculata* is commonly found in the Pilbara
the test barramundi *Lates calcarifer* represents a common tropical fish species
the test diatom *Nitzchia Closterium* is commonly found in Pilbara waters.

This suite of test species also satisfies the ESD requirements for the K+S SAshburton Salt proposal as described in Task 5a in **Section 1.1**.

1.3.1.3 Levels of ecological protection (LEP)

The Mardie proposal (O2 Marine, 2019) involved an assessment of the levels of ecological protection (LEPs) applicable to the receiving environment for the operation. This assessment involved the spatial designation of the area around the outfall into three LEPs, in accordance with EPA (2016) guidelines: High, Moderate and Low:

- the Low LEP extends 70 m around the outfall
- the Moderate LEP extends 250 m from the Mardie project infrastructure
- the area beyond the 250 m boundary is designated as High LEP.

The rationale and results of LEP designation for the Mardie operation is presented in **Table 1**, along with a comparison with the derivation for the K+S LEPs (AECOM, 2021; K+S, 2021).

Table 1 Levels of Ecological Protection as Designated for Mardie (O2 Marine, 2019) and K+S (AECOM, 2021) Proposals

Operation	LEP	Species Protection Level (%)[2]	Designation	EPA Guideline	Dilutions Required[5]	% Effluent (95% Confidence Interval)[5]
Mardie	Low	80	70 m around outfall	≤70 m from diffuser	417	0.44 (0.38 – 0.65)
	Moderate	90	250 from project infrastructure	≤250 m from operation	263	0.38 (0.33 – 0.60)
	High[4]	99	>250m from 250m project boundary	Boundary of the area allocated to the	227	0.44 (0.38 – 0.65)

Operation	LEP	Species Protection Level (%)[2]	Designation	EPA Guideline	Dilutions Required[5]	% Effluent (95% Confidence Interval)[5]
				identified purpose		
	Maximum[4]	No detectable biological or chemical changes (from background)	Zones within the High LEP	A high conservation zone not within 5 km of large commercial or population centres	NR	NR
K+S	Low	80	20 m around outfall	≤70 m[3]	NA	NA
	Moderate	90	180 m from project infrastructure	≤250 m[3]	NA	NA
	High[4]	99	> 180 m from project boundary	Boundary of the area allocated to the identified purpose[3]	NA	NA
	Maximum[4]	No detectable biological or chemical changes (from background)	Zones within the High LEP	A high conservation zone not within 5 km of large commercial or population centres	NA	NA

NR = not reported, NA = not available
1 – See AECOM (2021) for further information
2 – EPA (2016)
3 – Represents a worst-case scenario (K+S, 2021). Best case scenario distances are 1/3 these reported values
4 – Informed by the Pilbara Coastal Water Quality Consultation Outcomes — Environmental Values and Environmental Quality Objectives, Department of Environment, Government of Western Australia, Marine Series Report No. 1 (Department of Environment, 2006)
5 – Based on WET analysis results

The LEPs adopted for both operations are consistent with the EPA (2016) guidelines, being informed by modelled water quality of discharges, and are within the maximum advised spatial extents. The High and Maximum LEPs for both operations are mapped based on the same resource (Department of the Environment, 2006) as both proposed operations occur in the Pilbara Coastal Waters.

1.3.1.4 WET Testing Outcomes

The WET testing undertaken using the prototype sample indicated salinity [which is expected to reach 325 parts per thousand (ppt)], was the primary causative agent for the toxic effects observed. It is proposed that the bitterns will be diluted with seawater prior to discharge to bring its salinity closer to that of the receiving environment (O2 Marine, 2019).

Modelling carried out for the proposal indicated that the proposed discharge of bitterns would result in the criteria for High Level of Ecological Protection Area (HEPA) no longer being achieved in an area around the discharge diffuser. Mardie proposed that the areas around the diffuser be re-designated as Low Level of Ecological Protection Area (LEPA) and Moderate Level of Ecological Protection Area (MEPA) based on modelling of bitterns disposal (EPA, 2021).

1.3.2 EPA's Assessment

The EPA's assessment – considering WET analysis data from an Onslow bitterns prototype – determined the impacts to marine water quality from bitterns disposal are likely to be consistent with the

EPA's objectives for marine environmental quality, subject to management of bitterns in accordance with the Mardie MEQMMP, and EPA considers the proposal can be implemented (EPA, 2021).

2.0 Comparative Lines of Evidence

2.1 Location and Bioregion

K+S, Onslow and Mardie are operations considered to be comparable based on geography, bioregion and comparable receiving environment.

The K+S Ashburton Salt Project is located in the north of Western Australia, about 40 km southwest of Onslow. The coastal region in this vicinity is becoming established with several plants for the extraction of sea salt, including the Onslow (operational) and Mardie (not yet operational) salt operations. The K+S, Onslow and Mardie salt operations are all located within a coastal stretch of approximately 160 km, as indicated on **Plate 1**. The K+S facility is in closer proximity to the Onslow facility, compared to the Mardie facility, which is located approximately 100 km northeast of Onslow.

Based on the Integrated Marine and Coastal Regionalisation of Australia (IMCRA)[1], which is a spatial framework for classifying Australia's coasts and near-shore marine environment into bioregions, the three salt operations are located within the Pilbara bioregion. The IMCRA mesoscale bioregions are derived by jurisdictions at a finer scale than Australia's marine planning regions, and are based on biological and physical data, including the distribution of demersal fish, marine plants and invertebrates, sea floor geomorphology and sediments, and oceanographic data (ANZG, 2018).

Based on their location within the same bioregion, i.e., the Pilbara bioregion, K+S, Onslow and Mardie salt operations are expected to have similar or comparable diversity of marine ecosystems within and surrounding their operational facilities, including their respective receiving environments.

2.2 Operations

Both the K+S and the Onslow projects' operations involve salt production, whereas the Mardie project's' operations involves both salt and potash production. Differences in operations and types of salts extracted are expected to generate a greater difference in the composition of bitterns. In this regard, the similarities between the K+S and Onslow operations are considered to be greater than the similarities between the Mardie and Onslow operations. EPA (2021) determined the Onslow bittern sample to be a suitable surrogate for the Mardie operations. The composition of Onslow bitterns are likely to represent K+S bitterns more closely than Mardie bitterns.

It should also be noted that, while the current report considers potential ecotoxicology of undiluted K+S bitterns, the operation itself may ultimately involve a 1:1 "pre-dilution" prior to discharge (K+S, 2021). If this is the case, then this provides an additional level of conservatism to the dilution factors proposed in **Table 4**, which do not consider this potential "pre-dilution" factor.

2.3 Bitterns Composition – Data Comparison

Analytical results characterising the K+S laboratory-generated bitterns sample as well as the Onslow prototype used by the Marie Project are summarised in Table 2.

[1] IMCRA mesoscale bioregions of Australia, as accessed via the Australian and New Zealand Guidelines for Fresh and Marine Water Quality website, on 23 September 2022, at https://www.waterquality.gov.au/anz-guidelines/your-location/australia-marine-IMCRA

Table 2 Comparison of Chemical Composition of Bittern Samples

Analyte	Unit	PQL / LOR	K+S Bitterns Sample[1]	*Onslow Bitterns Sample[1]	**K+S Sample ÷ Onslow Sample	99% Ecosystem Guidelines[2]
pH	pH units	-	6.8	7.2		8-8.4
Electrical Conductivity	mS/cm	0.01 / 0.001	190	170	0.94	-
Total Dissolved Solids	mg/L	5	450,000	420,000	1.12	-
Specific gravity	g/mL	-	-	1.25	1.07	-
Total Alkalinity	mg $CaCO_3$/L	5	490	820		-
Bicarbonate Alkalinity	mg $CaCO_3$/L	5	490	820	0.60	-
Carbonate Alkalinity	mg $CaCO_3$/L	5	<5	<5	0.60	-
Hydroxide Alkalinity	mg $CaCO_3$/L	5	<5	<5		-
Chloride	mg/L	5 / 1	220,000	180,000		-
Sulfate	mg/L	1	44,000	56,000	1.22	-
Ionic balance	%	-	-	2.2	0.79	-
Total Hardness as $CaCO_3$	mg/L	3	-	160,000		-
Filterable Reactive Phosphorus	mg/L	0.01	0.01	-		-
Ammonia-N	mg/L	0.02	0.17	-		0.5
Nitrate-N	mg/L	0.01	0.4	-		-
NO_x-N	mg/L	0.01	0.44	-		-
Nitrite-N	mg/L	0.01	0.24	-		-
Bromide	mg/L	0.1	3,600	-		-
Total Nitrogen	mg/L	0.2	0.6	-		-
Total Kjeldahl Nitrogen	mg/L	0.2	<0.2	-	-	-
Total Phosphorus	mg/L	0.01	0.16	-	-	-
Sodium - Total	mg/L	0.1	91,000	-	-	-
Sodium - Dissolved	mg/L	0.1	91,000	69,000	-	-
Calcium - Total	mg/L	0.1	210	-	1.32	-

Analyte	Unit	PQL / LOR	K+S Bitterns Sample[1]	*Onslow Bitterns Sample[1]	**K+S Sample ÷ Onslow Sample	99% Ecosystem Guidelines[2]
Calcium - Dissolved	mg/L	0.1	210	230		-
Magnesium - Total	mg/L	0.1	37,000	-	0.91	-
Magnesium - Dissolved	mg/L	0.1	37,000	38,000	-	-
Potassium - Total	mg/L	0.1	8,800	-	0.97	-
Potassium - Dissolved	mg/L	0.1	8,800	12,000	-	-
Aluminium - Total	mg/L	0.01	0.06	-	0.73	-
Manganese - Total	mg/L	0.01	0.04	-	-	-
Manganese - Dissolved	mg/L	0.01	0.04	-	-	-
Tin - Total	mg/L	0.01	<0.01	-	-	-
Tin - Dissolved	mg/L	0.01	<0.01	-	-	-
Vanadium - Total	mg/L	0.01	0.01	-	-	0.05
Zinc - Total	mg/L	0.005	**0.024**	**0.018**	-	0.0033
Arsenic - Total	mg/L	0.001	**0.009**	**0.012**	1.33	0.0008[3]
Chromium - Total	mg/L	0.001	**0.001**	**<0.005**	0.75	0.001
Cobalt - Total	mg/L	0.001	<0.001	-	0.2	-
Cobalt - Dissolved	mg/L	0.001	<0.001	-	-	-
Copper - Total	mg/L	0.001	0.015	-	-	-
Copper - Dissolved	mg/L	0.001	**0.015**	**<0.005**	-	0.0003
Lead - Total	mg/L	0.001	<0.001	-	3	-
Lead - Dissolved	mg/L	0.001	<0.001	**<0.005**		0.0022
Nickel - Total	mg/L	0.001	0.007	-	0.2	-
Nickel - Dissolved	mg/L	0.001	**0.005**	**<0.005**	-	0.0007
Cadmium - Total	mg/L	0.0001	**0.0005**	**<0.0005**	-	0.0007
Mercury - Total	mg/L	0.0001	<0.0001	-	-	-

Analyte	Unit	PQL / LOR	K+S Bitterns Sample[1]	*Onslow Bitterns Sample[1]	**K+S Sample ÷ Onslow Sample	99% Ecosystem Guidelines[2]
Mercury - Dissolved	mg/L	0.0001	**<0.0001**	**<0.00005**	-	0.0001
Selenium - Total	mg/L	0.001	<0.001	-	-	-

*Notes: * – It is not specified in the O2 Marine (2021) report whether the concentrations of metals and ions reported as part of the Mardie Project composition analysis are total concentrations or dissolved concentrations. K+S analysis includes reporting of a combination of dissolved and total concentrations for certain analytes. It is noted that ecological guidelines generally apply to dissolved concentrations rather than total concentrations. It has thus been conservatively assumed herein that the Onslow concentrations reported by O2 Marine (2021) are dissolved concentrations, representative of bioavailable fractions, except in cases where dissolved concentrations have not been reported for the K+S sample.*

*** - where values are >0.1 and <10, the results are within an order of magnitude of each other*

*LOR – Limit of reporting, PQL – Practical quantitation limit*1 – **Bold and green** – exceeds 99% DGV (compared for parameters reported for both bitterns samples). For <LOR values, the LOR was adopted as the concentration (ANZG, 2018)
2 – Default guideline values (DGVs) from ANZG (2018)
3 – DGV for arsenic(V), which is the most conservative of arsenic(V) and arsenic(III) (ANZG, 2018)
4 – DGV for chromium(VI), which is the most conservative of chromium(VI)and chromium(III) (ANZG, 2018)

2.4 Receiving environment – Data Comparison

To compare the similarity of water quality for the respective receiving environments, data were compared between the Mardie and K+S (which proposes to discharge at Locker Point) receiving environments. Comparison of results (for common parameters measured between both operations) are presented in **Table 3**.

Table 3 Comparison of Mardie and K+S receiving environments

Analyte	Unit	Maximum value for K+S RE[2,3,4,6]	Maximum value for Mardie RE[1,3,4,6]	99% Ecosystem Guidelines	K+S value ÷ Mardie value[4,5]
Zinc	mg/L	**0.016**	0.003	0.0033	5.33
Arsenic	mg/L	0.002	0.002	0.0008	1.00
Chromium	mg/L	**<0.001**	**<0.002**	0.00014	0.50
Copper	mg/L	**0.0008**	**<0.002**	0.0003	0.40
Cadmium	mg/L	<0.0001	<0.0002	0.0007	0.50
Mercury	mg/L	<0.0001	<0.00002	0.0001	5.00

Notes
1 – RE = Receiving Environment. Maximum value from the two samples reported in Appendix A of O2 Marine (2021)
2 – Maximum value for 2019 – 2021 monitoring program for K+S RE (Locker Point) reported in K+S (2021)
3 – It is not known whether Mardie values are for dissolved or total metals. K+S results are for total metals. For comparisons purposes, it is assumed Mardie results are dissolved metals. This is a conservative approach, as it presents a "worst case scenario" for the Mardie receiving environment
4 – Non-detect values are substituted with LOR for this comparison (ANZG, 2018)
5 – Where values are >0.1 and <10, the results are within an order of magnitude of each other
6 – **Bold and green** – exceeds 99% DGV

Table 3 provides some indication that the receiving environments for K+S and Mardie operations are chemically similar. For the parameters commonly available for both environments, all values are within an order of magnitude of each other. The receiving environment for K+S may have a slightly higher contamination status than that for Mardie, as Locker Point shows an exceedance of the DGV for zinc that Mardie's receiving environment does not. This suggests a less pristine condition for the K+S receiving environment relative to the Mardie receiving environment, and hence discharge dilution levels protective for Mardie would also be expected to be protective of K+S's receiving environment.

2.5 Water quality data comparisons – Summary

The following is noted regarding the comparability of K+S and Onslow bittern samples:

- The composition of the K+S bittern sample is comparable to that of the Onslow sample (used as a surrogate in the EPA-approved Mardie Project), with concentrations of cations, anions and metals being reported within the same order of magnitude.
- A comparison of concentrations of metals in the bitterns samples compared against the 99% species protection level marine water quality ANZG (2018) guideline values (GV) determined the following, noting that where data were reported below the limits of reporting (LOR) as 'below detection limit' the numerical value of the detection limit was used for comparison (in accordance with ANZG 2018 guidance):
  - Concentrations of zinc, arsenic, chromium and copper in both K+S and Onslow samples exceeded GV.
  - Concentrations of nickel, cadmium and mercury did not exceed the GV in either of the two samples.
  - Concentration of lead exceeded the guideline in the Onslow sample, but not in the K+S sample.
- This indicates similar exceedances were noted in both K+S and Onslow samples. The exceedance of lead for the Onslow, but not K+S, sample indicates that Onslow has a higher-likelihood of metals-influenced toxicity, and WET results from this analysis might therefore actually be slightly overprotective for K+S bitterns. The water quality of the Mardie receiving environment K+S bittern sample is comparable to that for the Mardie receiving environment, with concentrations of metals being reported within the same order of magnitude.
- A comparison of concentrations of metals in the receiving environment samples compared against the 99% species protection level marine water quality ANZG (2018) guideline values (GV) determined the following, noting that where data were reported below the limits of reporting (LOR) as 'below detection limit' the numerical value of the detection limit was used for comparison (in accordance with ANZG 2018 guidance):
  - Concentrations of chromium and copper for both K+S and Mardie receiving environments exceeded GV.
  - Concentration of zinc exceeded the guideline in the K+S receiving environment, but not in the Mardie receiving environment.

  This indicates similar exceedances were noted in both K+S and Mardie receiving environments. The exceedance of zinc for the K+S, but not Mardie, receiving environments indicates that K+S receiving environment has a higher metals contamination status than that for Mardie, and WET results from the Mardie analysis might therefore actually be slightly overprotective for K+S bitterns.

3.0 Conclusions and Recommendations

In the absence of a project-specific K+S bittern sample, the Onslow bittern sample is considered to be a suitable surrogate, sufficiently representative of K+S operations, on the basis of the following lines of evidence:

- Location and bioregion – K+S, Onslow and Mardie salt operations are all located within the same IMCRA bioregion, i.e., the Pilbara bioregion, and are expected to have similar or comparable diversity of marine ecosystems within and surrounding their operational facilities
- Operations – Both the K+S facility and the Onslow projects' operations involve salt production, whereas the Mardie project's' operations involves both salt and potash production. In this regard, the similarities between the K+S and Onslow operations are considered to be greater than the similarities between the Mardie and Onslow operations.

- Chemical Composition – The composition of the K+S bittern sample is comparable to that of the Onslow sample used as a surrogate in the Mardie Project, with concentrations of cations, anions and metals being reported within the same order of magnitude.
- Bitterns chemical exceedances – A comparison of concentrations of metals in the bitterns samples compared against the 99% species protection level marine water quality ANZG (2018) guideline values (GV) determined the similar exceedances were noted in both K+S and Onslow samples, however one exceedance for Onslow – lead – was not observed for K+S, suggesting K+S as of lower potential toxicity.
- Receiving environments metals levels – The metals levels in the K+S receiving environment are comparable to those for the Mardie receiving environment, suggesting a comparable receiving environment for both operations.
- Receiving environments metal exceedances – A comparison of concentrations of metals in the receiving environments for K_+S and Mardie compared against the 99% species protection level marine water quality ANZG (2018) guideline values (GV) determined the similar exceedances were noted in both K+S and Mardie samples, however one exceedance for K+S – zinc – was not observed for Mardie, suggesting K+S as in less pristine condition.
- Required dilutions – Given the comparability of water quality between the K+S and Mardie samples, the proposed dilution levels for Mardie bitterns (227 – 417×, or 0.44 – 0.24% effluent, in order to protect the requisite 80 – 99% species levels) are likely to be suitable for K+S bitterns. Mardie dilution levels may in fact be conservative given the slightly higher metal (lead) toxicity expected to be associated with Mardie bitterns.

It is noted that Mardie salt project proposal has received approval to use seawater to produce salt and dispose bitterns to the marine environment (EPA, 2021). The Onslow bitterns sample, that also formed the basis of the Mardie WET testing (O2 Marine, 2021), is considered to be adequately representative of K+S operations, and is in fact expected to be more similar to the K+S operations, compared to the Mardie operations.

Based on the above lines of evidence, it is proposed that WET testing undertaken for the Mardie Salt Project are considered suitable for application to the assessment of potential impacts associated with the K+S Ashburton Salt Project.

Based on this it is recommended that the percent effluent and dilution ratios identified by the Mardie Salt Project to define levels of environmental protection associated with Bitterns discharge are applied as set out in **Table 4**.

Table 4 Recommended Guideline Values (± 95% CI) for the Concentration of K+S Bitterns Effluent for each Species Protection Level and LEP

Species Protection Level (%)	LEP	Estimated Dilutions	Guideline (%)	Lower 95% Confidence Limit (%)	Upper 95% Confidence Limit (%)
99	High	417	0.24	0.20	0.46
95	-	-	0.33	0.28	0.55
90	Moderate	263	0.38	0.33	0.60
80	Low	227	0.44	0.38	0.65

4.0 References

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