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# Fish and Fisheries Report

## Eramurra Solar Salt Project

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## Version Register

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| A | Draft | M Wellington | D Hanf | | |
| B | Draft | B Campbell | D Hanf<br>D Ryan | Revision following discussions with DPIRD and WAFIC | |
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# Executive Summary

Leichhardt Salt Pty Ltd (LS) propose to construct and operate the Eramurra Solar Salt Project (ESSP), a solar salt project to extract up to 4.2 million tonnes per annum (Mtpa) of high-grade salt (sodium chloride (NaCl)) from seawater, using a series of concentration and crystalliser ponds and processing plant, transport corridor, stockpiling and export from the Cape Preston East Port (the Proposal). The concentration and crystalliser ponds will be located on Mining Leases.

This report presents the outcomes of a fish and fisheries desktop review that will be used to inform environmental impact assessment (EIA) and the formulation of related management measures.

State aquatic resources include the ecosystems and their constituent habitats, captured species and listed species. This report focusses on species of socio-economic importance, with conservation significant species covered in the Eramurra Solar Salt Project Conservation Significant Marine Fauna Desktop. The objectives of this report were to:

- Identify the aquatic resources, fisheries, and key fish species relevant to the Proposal; and
- Identify relevant biological and ecological information for key species (i.e., important habitat, nursery areas, critical stages in lifecycles).

Key species were identified so that the correct level of information is considered when assessing the nature and risk of potentially significant impacts. Key species were defined as:

- Key Indicator species for multi-species fishery resources;
- Additional species of recreational fishing importance; and
- Additional species of customary fishing importance.

The aquatic resources and their respective fisheries that operate within the vicinity of the Proposal have been identified as:

- Northern Demersal Scalefish Resource: Pilbara Fish Trawl (Interim) Managed Fishery, Pilbara Line Fishery and Pilbara Trap Managed Fishery;
- Northern Invertebrates Resource: Onslow Prawn Managed Fishery;
- North Coast Crab Resource: Pilbara Crab Managed Fishery;
- Statewide Large Pelagic Scalefish Resource: Mackerel Managed Fishery;
- Statewide Hand Collection Resource: Western Australian Sea Cucumber Fishery;
- Statewide Marine Aquarium Fish and Hermit Crab Resource: Hermit Crab Fishery and Marine Aquarium Fish Managed Fishery;
- Pearl Oyster (*Pinctada maxima*) Resource: Pearl Oyster Wildstock Fishery; and
- Statewide Specimen Shell Resource: Specimen Shell Managed Fishery.

Within each fishery indicator species are selected to undertake assessments of the fisheries stocks and to determine the status of the resource. Indicator species are selected based on their inherent vulnerability, management importance and overall risk to sustainability. The indicator species have been identified as:

- Bluespotted emperor (*Lethrinus punctulatus*);
- Red emperor (*Lutjanus sebae);*
- Rankin cod (*Epinephelus multinotatus*);

- Narrow-barred Spanish mackerel (*Scomberomorus commerson*);
- Grey mackerel (*Scomberomorus semifasciatus*);
- Western king prawn (*Penaeus latisulcatus*);
- Brown tiger prawn (*Penaeus esculentus*);
- Silver-lipped pearl oyster (*Pinctada maxima*);
- Blue swimmer crab (*Portunus armatus*);
- Australian land hermit crab (*Coenobita variabilis*);
- Sandfish (sea cucumber) (*Holothuria scabra*); and
- Redfish (sea cucumber) (*Actinopyga echinites*).

### Aquatic Resources

State aquatic resources are defined for each marine bioregion (i.e., a region defined by common oceanographic characteristics. The aquatic resources in the vicinity of the Proposal are utilised by many different stakeholders within the commercial, recreational, and customary fisheries sectors.

A summary of the aquatic resources are:

- The Northern Demersal Scalefish Resource has three fisheries, the PFTIMF, PTMF and PLF that occur within the vicinity of the proposal, with a total estimated value of $10-20 million. These are monitored through the indicator species bluespotted emperor, red emperor, and Rankin cod, which are taken both recreationally and commercially.
- The Statewide Large Pelagic Scalefish Resource is also of high commercial and recreational value within the vicinity of the Proposal. The key species for this fishery is the Spanish mackerel, which has an estimated value of $2.5-3 million locally (various other finfish are also targeted).
- The OPMF overlaps with the Proposal area and takes a variety of invertebrate species.
- The PCMF Fishery targets blue swimmer crabs in the vicinity of the Project area, both commercially and recreationally. This fishery is considered to be relatively small.
- Fisheries such as the WASCF, MAFMF, SSMF, Pearl Oyster Wild stock Fishery and the HCF are thought to be minor in the area, however Customary fishing may occur, particularly for Silver-lipped pearl oyster.

Although fisheries within the Northern Demersal Scalefish Resource operate offshore of the Proposal, there is some spatial overlap between the Proposal inshore Development Envelope (DE) and important nursey grounds for several fish species targeted by commercial and recreational fisheries. The Northern Demersal Scalefish Resource also has a fishery operating in the Kimberley region that is reliant on the Pilbara regions bluespotted emperor population.

### Indicator and Key species

Of the indicator species, bluespotted emperor, red emperor, Spanish mackerel, and prawns have been identified as the key socio-economically important species which are at the highest risk of potential impact from the Proposal. These high-value species have important habitats that may be directly impacted by the Proposal, most notably seagrass beds, macroalgal and subtidal habitats and mangrove areas. The key habitats for these species are detailed below:

- Bluespotted emperor: juveniles inhabit shallow macroalgal beds and may be vulnerable to their loss;

- Blue swimmer crabs: juveniles rely on high shoot density seagrass beds;
- Grey mackerel larvae: require inshore lower salinity areas; and
- Tiger prawns: juveniles inhabit shallow areas immediately adjacent to mangroves.

### Key Environmental Considerations

This report highlights the following key environmental considerations for subsequent impact assessment and management planning.

- The ecological integrity of mangrove dominated intertidal environments is vital for the sustainment ecosystem health and services (i.e., fisheries and associated fish species).
- Shallow macroalgal and subtidal environments are an important habitat for juvenile bluespotted emperor, tiger prawns and also provide a significant food source for sea cucumbers.
- The discharge of brine has the potential to impact various juvenile and adult species. The tolerances and likely exposure to brine should be considered in the impact assessment.
- Various juvenile and larval stages are present in the nearshore environment and could be entrained via seawater intake.
- The timing of sensitive ecological windows for key species should inform the construction dredging schedule.

# Acronyms and Abbreviations

| Acronyms and Abbreviations | Description |
|---|---|
| AFMA | Australian Fisheries Management Authority |
| ARMA | *Aquatic Resource Management Act 2016* |
| BC Act | *Biodiversity Conservation Act 2016* |
| BCH | Benthic Communities and Habitat |
| CAMBA | China-Australia Migratory Bird Agreement |
| CITES | Convention on International Trade in Endangered Species |
| CL | Carapace length |
| Cth | Commonwealth |
| CW | Carapace width |
| DCCEEW | Department of Climate Change, Energy, the Environment and Water |
| DBCA | Department of Biodiversity, Conservation and Attractions |
| DEs | Development Envelopes |
| DoE | Department of Environment |
| DPIRD | Department of Primary Industry and Regional Development |
| DWER | Department of Water and Environmental Regulation |
| EBFM | Ecosystem Based Fisheries Management |
| EIA | Environmental Impact Assessment |
| EP Act | *Environmental Protection Act 1986* |
| EPA | Environmental Protection Authority |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* |
| ESD | Environmental Scoping Document |
| FL | Fork Length |
| FRM Act | *Fish Resources Management Act 1994* |
| ha | Hectare |
| HCF | Hermit Crab Fishery |
| IMCRA | Interim Marine and Coastal Regionalisation |
| IMMA | Important Marine Mammal Area |
| IMS | Invasive Marine Species |

| Acronyms and Abbreviations | Description |
|---|---|
| ITQs | Individual Transferable Quotas |
| JAMBA | Japan-Australia Migratory Bird Agreement |
| KEFs | Key Ecological Features |
| Km | Kilometre |
| LAT | Lowest Astronomical Tide |
| m | metre |
| MAC | Management Advisory Committee |
| MAFMF | Marine Aquarium Fish Managed Fishery |
| mm | Millimetres |
| MMF | Mackerel Managed Fishery |
| MNES | Matters of National Environmental Significance |
| MSC | Marine Stewardship Council |
| NDSMF | Northern Demersal Scalefish Managed Fishery |
| nm | Nautical mile |
| NWA | North-west Australia |
| NT | Northern Territory |
| OPMF | Onslow Prawn Managed Fishery |
| PCMF | Pilbara Crab Managed Fishery |
| PDSF | Pilbara Demersal Scalefish Fisheries |
| PFTIMF | Pilbara Fish Trawl (Interim) Managed Fishery |
| PIN | Pilbara Nearshore |
| PLF | Pilbara Line Fishery |
| PON | Pilbara offshore |
| PTMF | Pilbara Trap Managed Fishery |
| SA | South Australia |
| SSMF | Specimen Shell Managed Fishery |
| t | tonne |
| TAC | Total Allowable Commercial Catch |
| TFC | Targeted fisheries closure |
| TL | Total length |

| Acronyms and Abbreviations | Description |
|---|---|
| WA | Western Australia |
| WAFIC | Western Australian Fishing Industry Council |
| WASCF | Western Australian Sea Cucumber Fishery |
| WCDSCMF | West Coast Deep Sea Crustacean Managed Fishery |

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## Figures

## Tables

# 1. Introduction

Leichhardt Salt Pty Ltd (Leichhardt) is seeking to develop the Eramurra Solar Salt Project (ESSP), a solar salt project east of Cape Preston, approximately 55 km west-south-west of Karratha in the Pilbara region of WA (Figure 1). The Proposal will be implemented (with necessary connecting infrastructure) within three Development Envelopes shown in Figure 2. The Proposal will utilise seawater and natural solar evaporation processes to produce a concentrated salt product. An average production rate of 5.2 Million tonnes per annum (Mtpa) is being targeted with up to 6.8 Mt of salt deposited in a low rainfall year. The following infrastructure will be developed:

- Seawater intake, pump station and pipeline
- Concentration ponds totalling approximately 10,060 hectares (ha) (6,930 ha West ponds and 2,110 ha East ponds)
- Crystallisers, totalling approximately 1,840 ha
- Drainage channels and bunds
- Process plant and product dewatering facilities
- Water supply (desalination plant)
- Bitterns disposal pipeline and outfall
- Power supply and power lines
- Pumps, pipelines, roads, and support buildings including offices and communications facilities
- Workshops and laydown areas
- Landfill, and
- Other associated infrastructure.

Table 1 Short Summary of the Proposal

| | |
|---|---|
| **Project Title** | **Eramurra Solar Salt Project** |
| **Proponent Name** | **Leichhardt Salt Pty Ltd** |
| **Short Description** | Leichhardt Salt Pty Ltd (Leichhardt) is seeking to develop a solar salt project in the Cape Preston East area, approximately 55 kilometres (km) west-south-west of Karratha in Western Australia (WA) (the Proposal). The Proposal will utilise seawater and evaporation to produce a concentrated salt product for export.<br><br>The Proposal includes the development of a series of concentration ponds, crystallisers and processing plant. Supporting infrastructure includes bitterns outfall, drainage channels, product dewatering facilities, desalination plant, pumps, pipelines, power supply, access roads, administration buildings, workshops, laydown areas, landfill facility, communications facilities and other associated infrastructure. The Proposal also includes dredging at the Cape Preston East Port and both offshore and onshore disposal of dredge spoil material. |

The export of salt is proposed to be via a trestle jetty. The jetty and associated stockpiles will be located at the Cape Preston East Port approved by Ministerial Statement (MS) 949. Dredging will be undertaken as part of

this Proposal to remove high points at the Cape Preston East Port. Dredged material will either be disposed of at an offshore disposal location, or onshore within the Ponds and Infrastructure Development Envelope. The Cape Preston East Port jetty and associated stockpiles are excluded from the ESSP. The ESSP will produce a salt concentrate according to the following processes:

- Seawater will be pumped into the first concentration pond and commence progressive concentration by solar evaporation as it flows through successive concentration ponds
- Salt is deposited onto a pre-formed base of salt in the crystallisers
- Salt will be removed from the drained crystallisers by mechanical harvesters and stockpiled adjacent to the processing facilities
- Salt concentrate will be trucked to the trestle jetty approved by MS 949 for export, and
- A maximum of 5.9 GL of bitterns (at 410ppt salinity) will be generated in any given year and up to 0.65 GL (at 410ppt salinity) in a peak summer month. The bitterns will be diluted 1:1 mass ratio with local seawater prior to discharge via ocean outfall diffuser within the Marine Development Envelope.

The Proposal may be developed in its entirety, or the East concentration ponds may be developed at a later stage.

O2 Marine was engaged by the proponent to undertake marine environmental investigations to help identify environmental risks of the ESSP, establish baseline conditions, help facilitate the environmental approvals process, and guide appropriate monitoring and management to minimise potential impacts to the marine environment during construction and operations.

Table 2 outlines the extent of the physical and operational elements of the ESSP.

Table 2 Location and proposed extent of physical and operational elements

| Element | Location | Proposed Extent |
|---|---|---|
| **Physical Elements** | | |
| **Pond and Infrastructure Development Envelope** – Concentration ponds and crystallisers. Process plant, desalination plant, administration, water supply, intake, associated works (access roads, laydown, water supply and other services). | Figure 2 | Disturbance of no more than 12,201 ha within the 20,160 ha Ponds Development Envelope. |
| **Marine Development Envelope** – Seawater intake and pipeline, dredge channel, bitterns pipeline, outfall diffuser and mixing zone. | Figure 2 | Disturbance of no more than 53 ha within the 703 ha Marine Development Envelope. |
| **Dredge Spoil Disposal Development Envelope** – Disposal location for dredge spoil. | Figure 2 | Disturbance of no more than 100 ha within the 285 ha Dredge Spoil Disposal Development Envelope. |
| **Operational Elements** | | |
| **Bitterns discharge** | Figure 2 | Discharge of up to 5.9 Gigalitres per annum (GL pa) of bitterns within a dedicated offshore mixing zone within the Marine Development Envelope |
| **Dredge Volume** | Figure 2 | Approximately 400,000 $m^3$ |

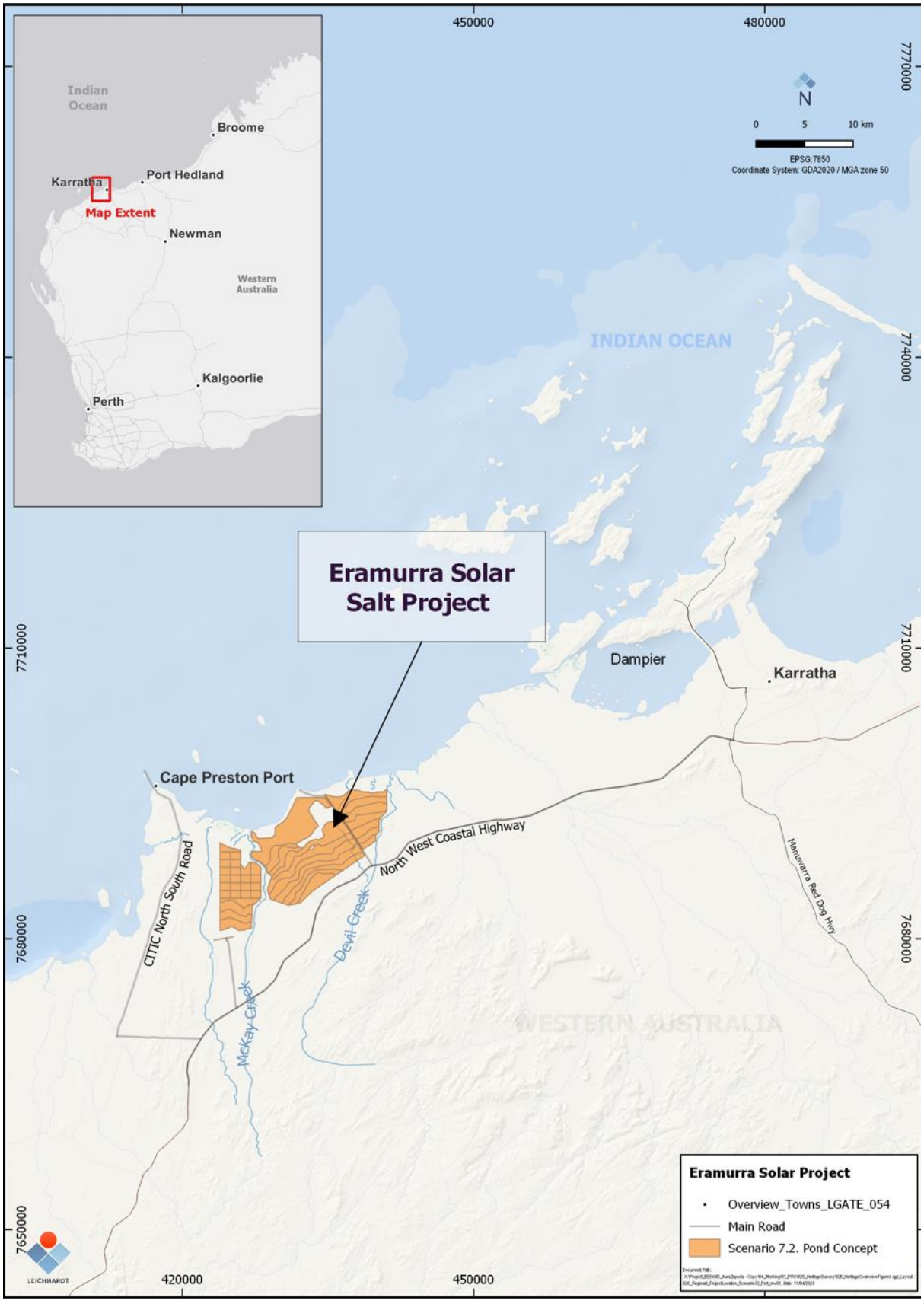


Figure 1 Project location and marine elements

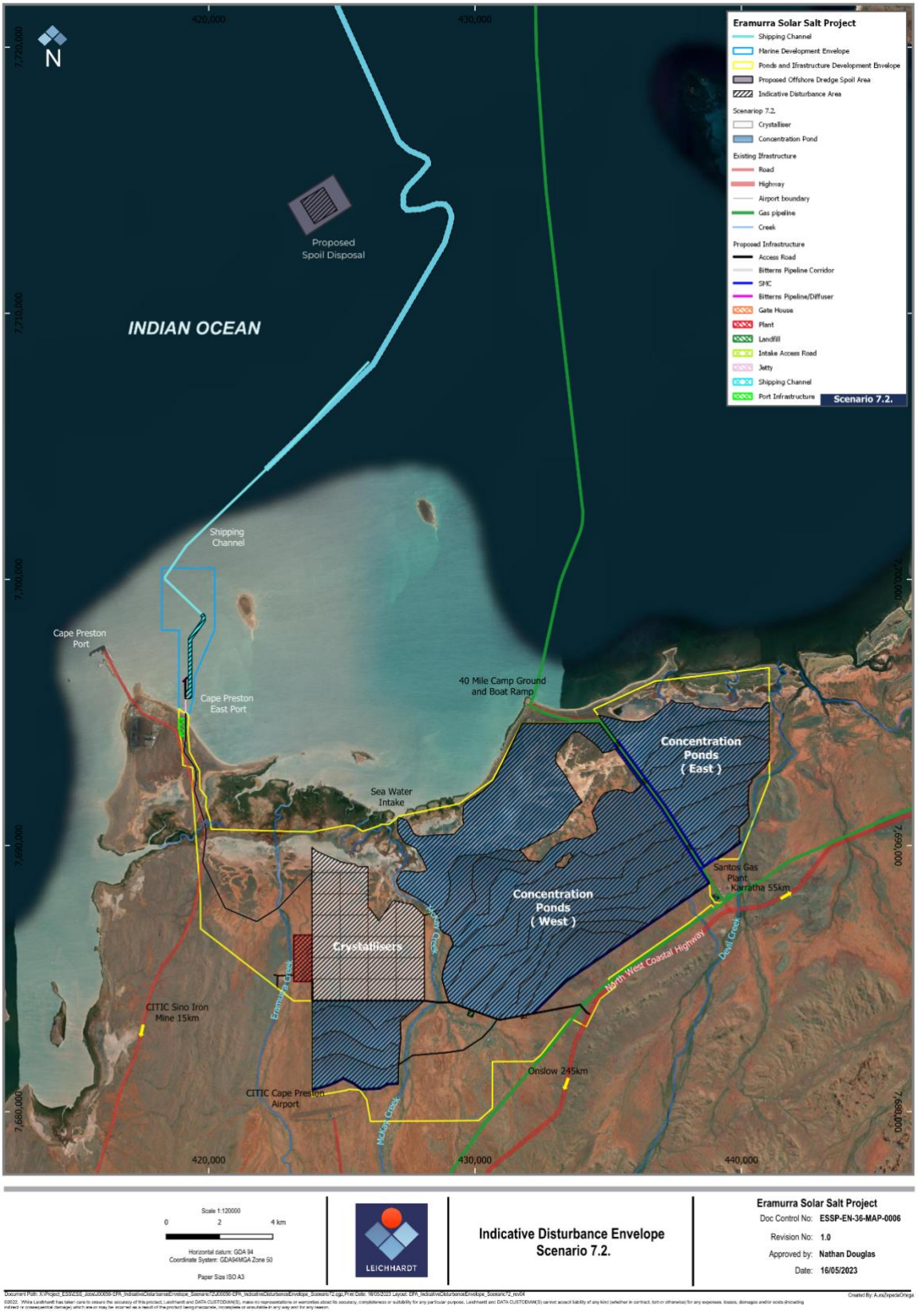


Figure 2 Proposed development envelopes and indicative layout.

## 1.1. Objectives

This report presents the outcomes of a fish and fisheries desktop study that will be used to inform the Fish and Fisheries Impact Assessment (O2 Marine 2023a) and development of management measures which will be open for stakeholder engagement. The objectives of this report were to:

- Identify the aquatic resources, fisheries, and key fish species relevant to the Proposal; and
- Identify relevant biological and ecological information for key species (i.e., important habitat, nursery areas, critical stages in lifecycles).

Key species were identified so that the correct level of attention is paid to those at greatest potential risk from the Proposal during impact assessment and management planning. The key species were identified as:

- Indicator species of aquatic resources; and
- Species of commercial, recreational and/or customary importance.

In doing so, this report addressed ESD items 69 and 70 outline by Preston Consulting (2022) (Table 3). This report addressed the commercially and recreationally important fish species noted in item 69, other marine species are discussed in the Conservation Significant Marine Fauna Desktop Study (O2 Marine 2023b), sawfish are discussed separately in the Eramurra – Sawfish Risk Assessment Workshop (O2 Marine 2022).

Table 3 ESD items and requirements (Preston Consulting 2022)

| ESD Items | Requirements |
|---|---|
| 69 | 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; |
| 70 | Identify any known critical periods for key environmental/life cycle events for marine fauna. |

## 1.2. Scope

The scope of this report covers the following:

- Identification of aquatic resources, fisheries, and habitats (including macroalgae habitat) relevant to the Proposal;
- Identify fisheries and species are greatest risk from the Proposal to inform the Fisheries Impact Assessment;
- Preparation of a preliminary report of background data which will inform targeted stakeholder engagement; and
- Liaison with Western Australian Fishing Industry Council (WAFIC), Department of Primary Industry and Regional Development (DPIRD) fish scientists and Recfishwest to gather background data and stakeholder information (including through FishCube).

## 1.3. Approach

Relevant legislation and key features of the existing environment surrounding the Proposal are summarised herein. In particular, a description of benthic communities and habitat available in the area provides context for an outline of finfish and invertebrate populations known to inhabit the area.

The EPA's objective for the factor Marine Fauna is: *'To protect marine fauna so that biological diversity and ecological integrity are maintained'* (EPA 2016). In the context of this objective: Ecological integrity is the composition, structure, function and processes of ecosystems, and the natural variation of these elements.

This report focusses on commercially and recreationally important fish species, which are of social, cultural and/or economic significance to Western Australians, relevant to the Proposal. Conservation significant species covered in the Eramurra Solar Salt Project Conservation Significant Marine Fauna Desktop (O2 Marine 2023b).

State aquatic resources, fisheries and indicator fish species that are of relevance to the Proposal were identified through spatial analysis and desktop review of existing datasets and reports (Table 4). Aquatic resources include the ecosystems and their constituent habitats, captured species and listed species and have been defined for each marine bioregion (i.e., a region defined by common oceanographic characteristics) (Newman et al. 2021a). For each aquatic resource that overlaps with the Proposal, the relevance of the various fisheries was determined using existing datasets and reports, and for each of these fisheries the species of value were identified. Key sources of information are presented below in Table 4.

The information presented in this report regarding recreational and customary fishing has not been verified by stakeholder engagement, and as such should be treated as preliminary in nature.

Table 4 Key information inputs used in this report

| Category | Sub-category | Key Inputs |
|---|---|---|
| **Fisheries** | Commercial | Fish cube data (DPRID 2021)<br>Stakeholder engagement (DPIRD, WAFIC)<br>2020/21 State of the Fisheries Report |
| | Tourism/Charter | Recfishwest<br>2020/21 State of the Fisheries Report |
| | Recreational | |
| | Customary | 2020/21 State of the Fisheries Report |
| **Fish species** | Commercial | Peer-reviewed journal articles<br>2020/21 State of the Fisheries Report |
| | Tourism/Charter | Status of Australian Fish Stock Reports 2020 |
| | Recreational | Boat-based recreational fishing in Western Australia 2020/21<br>Statewide survey of boat-based recreational fishing in WA 2017/18<br>Peer-reviewed journal articles |
| **Fish habitat** | Subtidal | BCH Report (O2 Marine 2023c)<br>Peer-reviewed journal articles<br>2020/21 State of the Fisheries Report<br>Stakeholder engagement (DPIRD, WAFIC) |
| | Intertidal | BCH Report (O2 Marine 2023d)<br>Peer-reviewed journal articles<br>2020/21 State of the Fisheries Report<br>Stakeholder engagement (DPIRD, WAFIC)<br>BCH Report (O2 Marine 2023c) |

# 2. Relevant Legislation

Key legislation governing the protection of fish and fisheries in WA are:

- WA *Environmental Protection Act 1986* (EP Act) (WA);
- WA *Fish Resources Management Act 1994* (FRM Act);
- WA *Pearling Act 1990;* and
- *Aquatic Resources Management Act 2016* (ARMA) (WA)

## 2.1. EP Act (WA)

Governed by the EP Act, the EPA uses environmental principles, factors and associated objectives as the basis for assessing whether a proposal's impact on the environment is acceptable. These principles, factors and objectives therefore underpin the EIA process.

The EP Act's objective is to protect WA's environment and identifies five environmental principles. The third principle of the conservation of biological diversity and ecological integrity is directly relevant to marine fauna. Marine Fauna are defined as 'Animals that live in the ocean or rely on the ocean for all or part of their lives' (EPA 2018). The EPA's objective for Marine Fauna is: 'To protect marine fauna so that biological diversity and ecological integrity are maintained'. Within an EIA, the EPA gives special attention to species that are iconic or of social, cultural, economic or ecosystem value. Animals such as sponges and corals that are attached to the seabed are typically considered under the environmental factor of Benthic Communities and Habitats.

## 2.2. FRM Act (WA)

The FRM Act (WA) is the principal act that regulates the management, utilisation, and conservation of fish (i.e., all aquatic organisms except reptiles, birds, mammals, amphibians) and their habitat in WA. This includes the management of biosecurity risks from the introduction and/or spread of invasive marine species (IMS). The Act is administered by the Department of Primary Industries and Regional Development (DPIRD). The department provides advice to the EPA and DCCEEW on the potential for proposed actions to have significant impact on fish or fish habitat in WA. Projects likely to have a significant impact on fish or fish habitat in WA State waters must be assessed by the EPA; and by DCCEEW in Commonwealth waters (between three and 200 nautical miles off the WA coast). Published guidance is currently available for seismic activities, with plans for guidance on drilling activities, dredging programs, and oil spill impacts and monitoring yet to be published.

## 2.3. Pearling Act (WA)

The Pearling Act (WA) is the legislation for management of the silver-lipped pearl oyster (*Pinctada maxima*) commercial fishing industry.

## 2.4. ARMA (WA)

The ARMA is expected to replace the FRM Act (WA) and the Pearling Act (WA) on the 1st November 2023 and will become the primary legislation used to manage WA fisheries and aquatic resources. The ARMA will replace the

FRM Act and the Pearling Act (WA) to become the primary legislation for managing fishing, aquaculture, pearling, and aquatic resources. The ARMA will be based on aquatic resources, rather than focusing on fisheries or fishing activities. The core objects of the Act are to ensure ecological sustainability of WA's aquatic resources and aquatic ecosystems for present and future generations, and that WA's aquatic resources are managed, developed, and used with consideration given to the economic, social, and other benefits they may provide. The Act will legally recognise fishing access rights for each sector, while also giving priority resource use to public benefit (e.g., for research purposes to ensure ongoing sustainability for the resource) and customary fishing. The ARMA will increase access rights for both commercial and recreational fishers. The *Pinctada maxima* pearl oyster resource will be the first resource to implement the new Act.

# 3. Existing Environment

## 3.1. Overview

The Proposal is situated on the Pilbara coastline and is located ~55 km west-south-west of Karratha within the North-west Bioregion. Marine elements of the Proposal and DEs are located on the coast and within the relatively flat and shallow waters of the Pilbara (Inshore) WA (PIN) IMCRA meso-scale region (IMCRA 1998), within the broader North-west Marine Region (DSEWPaC 2012). Habitats of the Proposal area are widespread and typical of the broader region (IMCRA 1998).

The Pilbara coastline is characterised by mangrove communities, supratidal flats behind the mangroves, intertidal creeks and mudflats and sandy flat habitats (IMCRA 1998). Climatic conditions and oceanographic features influence marine faunas ranges, and seasonal, and interannual distribution. Additionally nearshore and coastal environments provide habitat for a range of fauna species and may be utilised year-round or seasonally, depending on the species.

In WA, aquatic resources and fisheries are grouped into their respective bioregions under an Ecosystem Based Fisheries Management (EBFM) approach. The Proposal is located within the North Coast Bioregion, which extends from 114°50'E (east of Exmouth Gulf, West of Onslow) to the State border, thereby incorporating both the Pilbara and Kimberley regions. There are several diverse resources within the North Coast Bioregion that support a variety of different commercial, recreational, and customary fisheries within the region. The major commercial fisheries within the bioregion target tropical finfish species, with high-value emperors, snappers and cod caught by the Pilbara trap, line and trawl fisheries and the Norther Demersal Scalefish Fishery (trap and line). The typical catch is up to 3,000 to 4,000 t annually, making these fisheries the most valuable finfish sector in the State, with an estimated annual value of more than $20 million (Newman et al. 2021a). Invertebrate and Pearl Oyster fisheries make up a smaller proportion of the commercial fisheries in the bioregion. The prawn fisheries within the bioregion are relatively small compared to other parts of WA, and Pearl Oyster fisheries are significant within this bioregion.

## 3.2. Climate and oceanography

The Pilbara is characterised as an arid region, with pronounced wet (November to April) and dry (May to October) seasons and experiences an average annual rainfall of only 315 mm (which is dominated by wet season tropical storms). Maximum daily temperatures at nearby Mardie reach a monthly average of 37.9°C in January, falling to 28.3°C in July (O2 Metocean 2021). Winds range from easterly to south-easterly in the dry season to west and south-westerly in the wet season, when the area is also exposed to intense tropical storms and cyclones (with an average of 1 cyclone landfall every 2 years). Sea temperature varies from 18°C in the cooler months to a maximum of 31.5°C during the wet season, and inshore salinities may reach levels around 37 ppt (CALM 2005). Ocean temperatures are also strongly influenced by El Niño and La Niña events.

Wave energy in the area is typically relatively low, except during cyclones, with typical directions of west to south-west from May to July, and east to north-east between September and February (O2 Metocean 2021). Various currents operate in the vicinity of the study area and are typically dominated by tides on the inner

shelf. At the Proposal site, tides are semidiurnal with a mean spring tidal range of approximately 3 m, and a maximum range of 4.5 m (IMCRA 1998).

### 3.2.1. The marine heat wave

During the Austral summer of 2010/11, the WA coastline experienced a Marine Heat Wave, comprising an extending period of elevated sea temperature, which peaked at 3°C above the long-term mean (Pearce and Feng 2013). This extended period of elevated temperature had abrupt and long-lasting impacts on WA's marine ecosystem and fisheries recruitment. Following the Marine Heat Wave, commercial fisheries in the affected areas experienced severe decline, due to disrupted recruitment in target species. During this time, blue swimmer crabs' recruitment reached a record low level (Feng et al. 2021). Since the Marine Heat Wave, the affected fisheries stocks have been slowly recovering, with Marine Cold-Spells helping to encourage higher levels of recruitment, particularly during the 2015/16 and subsequent El Niño event.

## 3.3. Physical environment

The Pilbara region comprises a very broad and shallow continental shelf, which ranges from around 100 km wide in the west to 300 km wide in the east. According to James et al. (2004), shallower (continental shelf) deposits comprise mixed sediments, including both modern terrigenous (river derived) and carbonate (biogenic) materials. Marine sediments are mobilised and deposited through the action of wave and tides, whereas terrigenous sediments are delivered to the coast episodically through flood plains and river deltas - the largest river within Regnard Bay being the Maitland River to the east of the proposed site.

Between North-West Cape and the Dampier Archipelago, numerous small bedrock islands lie in shallow water and introduce heterogeneity in the ambient hydrodynamic conditions (O2 Metocean 2021) along the coastline, which in turn promotes heterogeneity in marine habitats. The Pilbara continental shelf is strongly influenced by the presence of limestone features that have been deposited during lower stages of sea-level and remain on the modern seabed as partially buried (reef veneer) or completely exposed rocky reef systems (LeBrec et al. 2022). These often-complex features vary greatly in morphology, state of weathering and bathymetric profile. LeBrec et al. (2022) identified that the seabed in the vicinity of the Regnard Islands to the 20 m isobath features a series of submerged ancient strandplains.

## 3.4. Intertidal benthic community and habitat

The intertidal zone typically extends ~5 km north to south within each local assessment unit (LAU) of the Proposal area. It encompasses foreshore mudflats of the lowest astronomical tidal level (LAT) to the intertidal habitats of highest astronomical tidal level (HAT). Certain species of mobile marine fauna are known to move between these habitats and nearshore coastal waters. Shorelines are comprised of both rocky and sandy shores (O2 Marine 2023d). An assessment of intertidal BCH at the site (Figure 3; O2 Marine 2023d) was mapped with the following habitat classes:

- Mudflat;
- Mudflat (inclusive of agal mat);
- Mangroves;

- Beach/Sand/Sand shoal;
- Samphire shrubland;
- Tidal creek;
- Intertidal rock platform.

Mudflat communities constitute the greatest BCH type by area followed by samphire shrubland, mangroves and algal mats, whilst sandy beach and rocky shore comprises the lowest BCH type by extent (O2 Marine 2023d). Across the study area decreasing trends in the relative abundance of algal mat and mudflats are evident north to south, corresponding with increasing areas of mangrove and samphire/samphire mudflats. Foreshore mudflats and tidal creeks and mangrove communities were identified only in coastal areas.

The intertidal mud and sand flat burrowing invertebrate fauna is abundant and species-rich, which is extremely important as a food source for migratory birds. The benthic fauna is typical of the coastal habitats of the Northern Australian region with a number of endemic coastal species being well represented.

### 3.4.1. Mangroves

Six species of mangrove occur in the region and mangroves are generally considered to be in pristine condition. Mangroves are known to cater for many ecosystem services that include providing substantial nurseries for juvenile fish, including sawfish, and foraging grounds and general habitat for turtles and other marine species. For this reason, mangrove areas are afforded a high conservation value and the EPA (2001) recommends that the impacts of development on mangrove habitat and on the ecological function of the mangroves should be reduced to the minimum practicable level.

The Proposal is situated within the EPA designated regionally significant mangrove management Area 9: Cape Preston Area. Guideline 3 as indicated in the *Guidance Statement for Protection of Tropical Arid Zone Mangroves Along the Pilbara Coastline* (EPA 2001) is appropriate for the Project Area as the mangrove areas are inside the designated industrial and port areas.

The mangrove communities in this area are of significant ecological and economic importance, supporting a large number of organisms such as snails, crabs, shrimps, oysters, barnacles, fish and birds and are highly productive nursery areas for many species including fish, sawfish, marine turtles and crustaceans (DSEWPaC 2012; DBCA 2020). An assemblage of fishes and invertebrates utilise the food resources of mangals (mangrove environments) on a temporary basis. There are also some fish and invertebrate taxa whose adult populations are restricted to mangrove habitats, referred to as “mangal obligates”. These mangrove habitats play a major role in supporting coastal food webs and nutrient cycles in the coastal zone and they are often an efficient sink for nitrogen, phosphorus, and silicon (O2 Marine 2023d).

Mangroves occurring within the study area were typically associated with tidal creeks, distribution patterns for mangroves are consistent with mapped extents of tidal creeks. Mangrove assemblages, in particular the closed canopy functional group, represent the most productive, structurally complex, and ecologically diverse BCH within the study area. They are deemed the most ecologically significant BCH across the study area. Mangrove communities were typically healthy with no signs of stress or anthropogenetic impacts (O2 Marine 2023d). Six species of mangroves are known to occur within the Pilbara region (EPA 2001). Of these, three species representing two families were identified during surveys undertaken by O2 Marine:

- White mangrove (*Avicennia marina*);
- Smooth-fruited yellow mangrove (*Ceriops australis*); and
- Red mangrove (*Rhizophora stylosa*).

### 3.4.2. Mudflat/Tidal Creeks

The intertidal BCH study conducted by O2 Marine identified mudflats as the dominant intertidal habitat class present in the study area (O2 Marine 2023d). The most continuous and extensive mudflat areas within the study area were located seaward of mangrove or beach/foredunes, extending out towards the intertidal macroalgae/seagrass/rock platform communities. Mudflats across the study area ranged from the spring low tide mark, landward to the spring high tide mark. Mudflats were typically located immediately adjacent (both seaward and landward) of mangal communities and generally had 'Terrestrial Vegetation' as the landward limit. Mudflat soils, on the landward side of the mangal were found to contain less sand and have more clay properties, shells and organic debris were commonly interspersed on the surface. These areas (particularly towards the Terrestrial Vegetation edge) have longer atmospheric exposure periods, with inundation only occurring at spring high tides. Whilst these areas may not have the highest primary productivity, they are known to support a wide array of secondary productivity and have been identified as important foraging areas for migratory birds (Phoenix 2022).

Tidal creeks are considered critical feeding and reproduction habitats for marine species such as fish, crustaceans, turtles, rays, and sawfish (DBCA 2020). Tidal creeks form the base environment for mangrove communities and all the associated fauna that utilise this vegetated habitat (insects, birds etc). In each location where tidal creeks were observed, mudflats and mangrove communities were also adjacently located (O2 Marine 2023d).

### 3.4.3. Algal Mats

Within the study area surveyed by O2 Marine, algal mats were observed to typically occur adjacent to samphire shrublands and be centralised between mudflat areas on both the seaward and landward side. mudflats/samphire mudflats occurred on the seaward edge and mudflat/salt flats on the landward edge. Algal mat microscopic examination identified six taxa recorded across the study area, dominated by filamentous cyanobacteria *Lyngbya* sp. then *Coleofasciculus chthonoplastes* and *Schizothrix* spp. Algal mats surveyed for this project are considered representative of other algal mat habitats within the Pilbara region, including the Mardie coastline (O2 Marine 2020), Exmouth Gulf (Biota 2005) and south of Onslow (Paling 1990; URS 2010). Algal mats are known to play an important role in nutrient and carbon cycling, however their overall significance on the surrounding intertidal BCH is not well documented (O2 Marine 2023d).

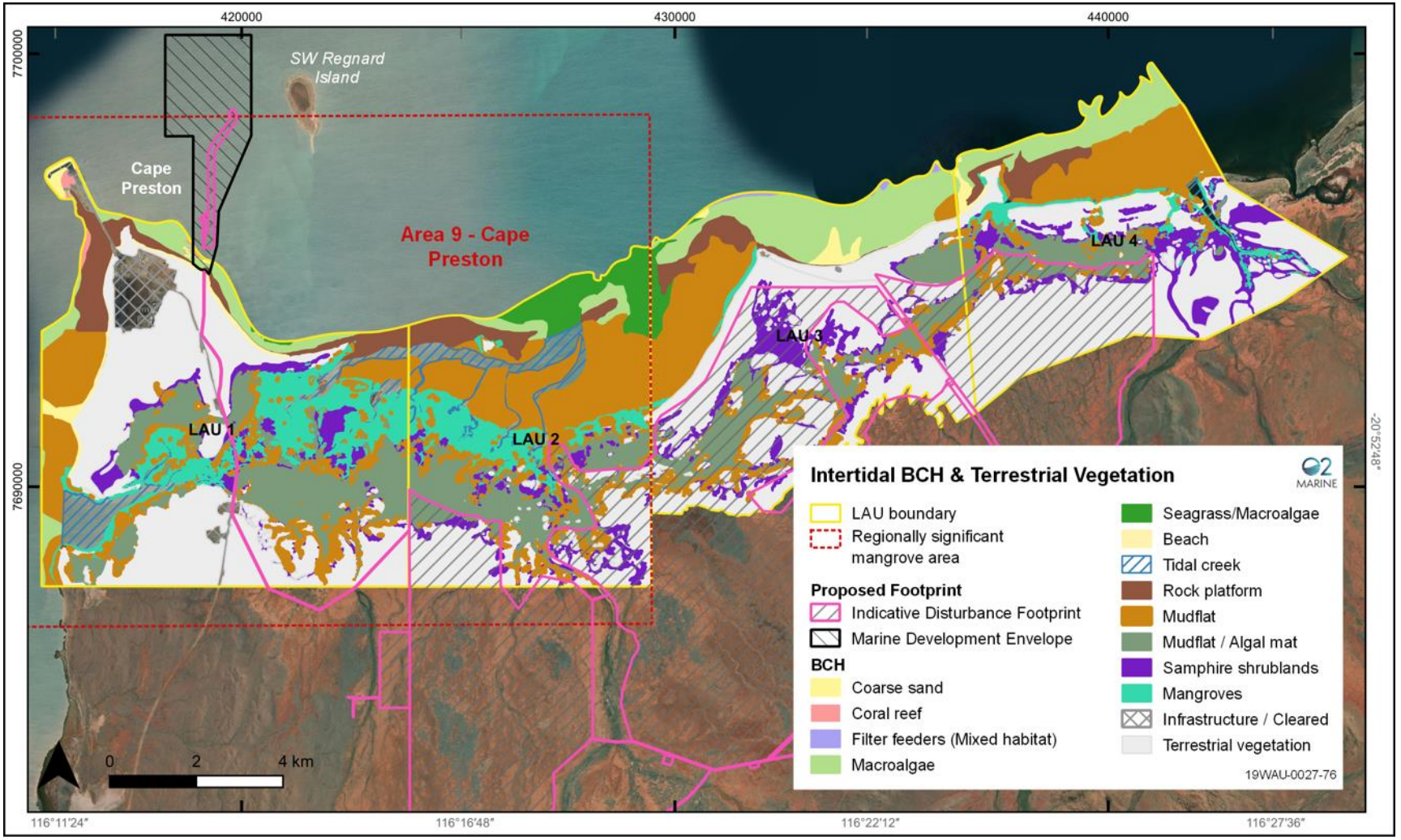


Figure 3 Intertidal BCH and Terrestrial Vegetation Classification within Proposed LAUs

## 3.5. Subtidal benthic community and habitat

A subtidal BCH assessment conducted by O2 Marine (2023c) identified eight benthic habitat classes within the subtidal zone of the Proposal area surveyed (Figure 4). The following benthic habitat classes were identified:

- Coarse sand;
- Coral reef (subtidal);
- Filter feeder (mixed habitat);
- Macroalgae (subtidal);
- Mudflat;
- Sand shoal;
- Seagrass/macroalgae; and
- Silt

Three associated substrate types were also identified:

- Coarse Sand;
- Rubble and 'Vegetated' areas; and
- Rock/Reef.

The PIN meso-scale region has a high diversity of in-fauna from intertidal mudflats and sandflats associated with fringing mangals in bays and lagoons (IMCRA 1998). The waters are highly turbid, especially during periods of spring tides, and associated with a large tidal range up to 6 m (IMCRA 1998). Fringing coral reefs exist around some of the islands (IMCRA 1998). The sea floor is gently sloping, and the 10 m bathymetric contour is generally between 1 and 2 nautical miles offshore (IMCRA 1998). Along the mainland, barrier islands and associated lagoons, embayments and deltas predominate, and the coast is either open or partly protected by chains and clusters of small, nearshore, shelly limestone islands (IMCRA 1998).

The subtidal nearshore zone extends from the intertidal foreshore mudflats of the Cape Preston East coast to approximately the 20 m isobath and includes several small coastal islands (O2 Marine 2023c). The Proposal area surveyed identified areas predominately consisting of coarse sand and subtidal macroalgae, subtidal coral reef, mixed filter feeders, seagrass and silt habitat types were also identified (O2 Marine 2023c). Silt typically does not contain any vegetation (O2 Marine 2023c).

### 3.5.1. Corals

Subtidal coral reef surveyed by O2 Marine was present within the BCH survey area (O2 Marine 2023c). Coral plays an important role in adding complexity to benthic communities and habitats. Coral reefs are often important recreational fishing areas. Inshore coral reefs tend to harbour fewer genera of coral compared to more speciose offshore reefs (Gilmour et al. 2006; Richards and Rosser 2012).

### 3.5.2. Seagrass/Macroalgae

Seagrass/macroalgae present within the BCH survey area was typically distributed inshore and around Southern Regnard. The coverage generally consisted of sparse to low seagrass cover (*Halophila sp.*), with low to moderate brown macroalgae cover.

Seagrass communities in the Pilbara are known to vary in response to changes in light availability, temperature, substrate movement, physical disturbance from cyclones, and flash flooding during heavy rainfall events. These conditions are seasonal, leading to altered exposure and inundation of hard substrates, which could support more or less complex BCH at different times.

### 3.5.3. Macroalgae

O2 Marine (2023c) survey found that subtidal macroalgae present within the subtidal BCH survey area generally formed high to dense coverage typically found adjacent to Cape Preston and in the mid to outer bay area near islands.

Macroalgae are photosynthetic primary producers and functionally contribute to the productivity of marine ecosystems. They are an important food source, and source of decomposition products (Olsen et al. 2019). Some macroalgae species are known to be short-lived (*Sargassum* sp. and *Sporochnus* sp.) and may increase in abundance during the summer months in the south-west Pilbara (Kendrick and Olsen 2017).

Functionally, macroalgae contribute to the productivity of marine ecosystems as they are a photosynthetic primary producer, which provide an important habitat for invertebrates, fish, and birds, and an important source of food and of decomposition products (Olsen et al. 2019). However, macroalgae differ from other marine plants such as seagrasses and mangroves in that macroalgae lack differentiated tissues such as roots, leafy shoots, flowers, and vascular tissues. Additionally, some algae (such as *Halimeda sp.* and other Rhodophytes) are important sediment producers and contribute towards the cementation and binding of materials with calcium carbonate, thereby creating hard substrate habitats for other organisms (Jones and Desrochers 1992).

### 3.5.4. Offshore

There are no physical elements of the Project that overlap with the offshore subtidal environment. However, marine fauna species can be highly mobile and move between offshore and nearshore subtidal environments, where operational vessels could potentially interact with mobile marine fauna.

The waters of the Pilbara (offshore) WA (PON) IMCRA meso-scale region are generally clear but may become turbid during periods of spring tide (IMCRA 1998). The continental shelf is wide in this vicinity of the Proposal, with a change to a steeper slope at about the 20 m bathymetric contour (IMCRA 1998). Just inside this contour there is a series of limestone islands (IMCRA 1998). Fringing coral reefs are well developed on the seaward sides of most of these islands (IMCRA 1998). Wide intertidal sandflats occur on the leeward sides of most of these islands, often with the sand forming thin sheets over a rock pavement (IMCRA 1998). The seabed substrate is mainly terrigenous mud but there is sand and gravel in tidal scours of some areas (IMCRA 1998). The fringing coral reefs of this sector are extensive and species rich (IMCRA 1998). Many of the Pilbara Islands are important nesting sites for turtles and seabirds (IMCRA 1998).

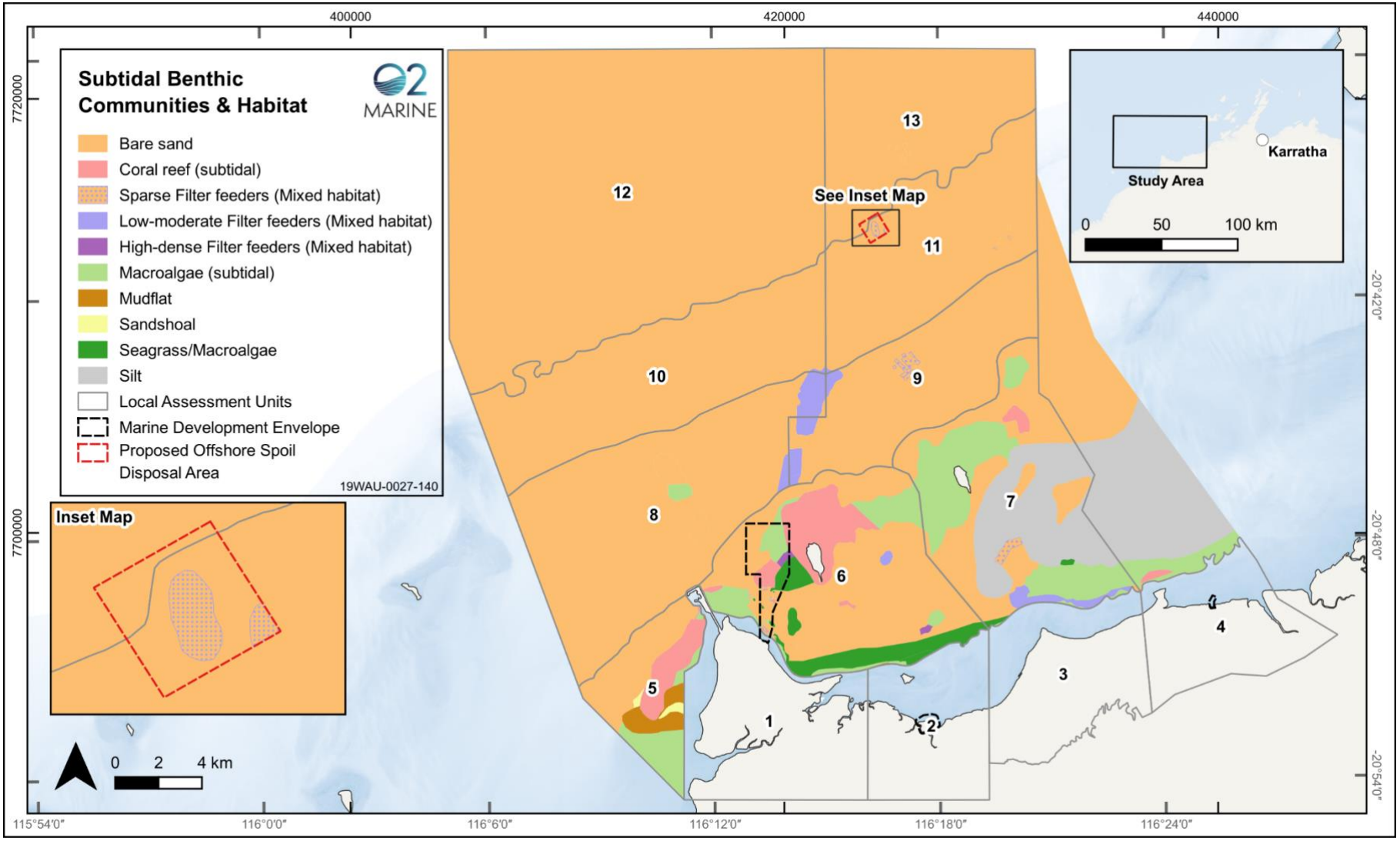


Figure 4 Subtidal BCH Classifications within Proposed LAUs.

## 3.6. Key Ecological Features

Key ecological features (KEFs) are elements of the Commonwealth marine environment in the North-west Marine Region that, based on current scientific understanding, are considered to be of regional importance for either the region's biodiversity or ecosystem function and integrity (DSEWPaC 2012). Figure 5 shows that there are no project elements that overlap with KEFS. The nearest KEF to the study area is the 'ancient coastline which occurs at the 125 m depth contour', a region which is located approximately 100 km to the north-west of the Proposal and is beyond the scope of this literature survey.

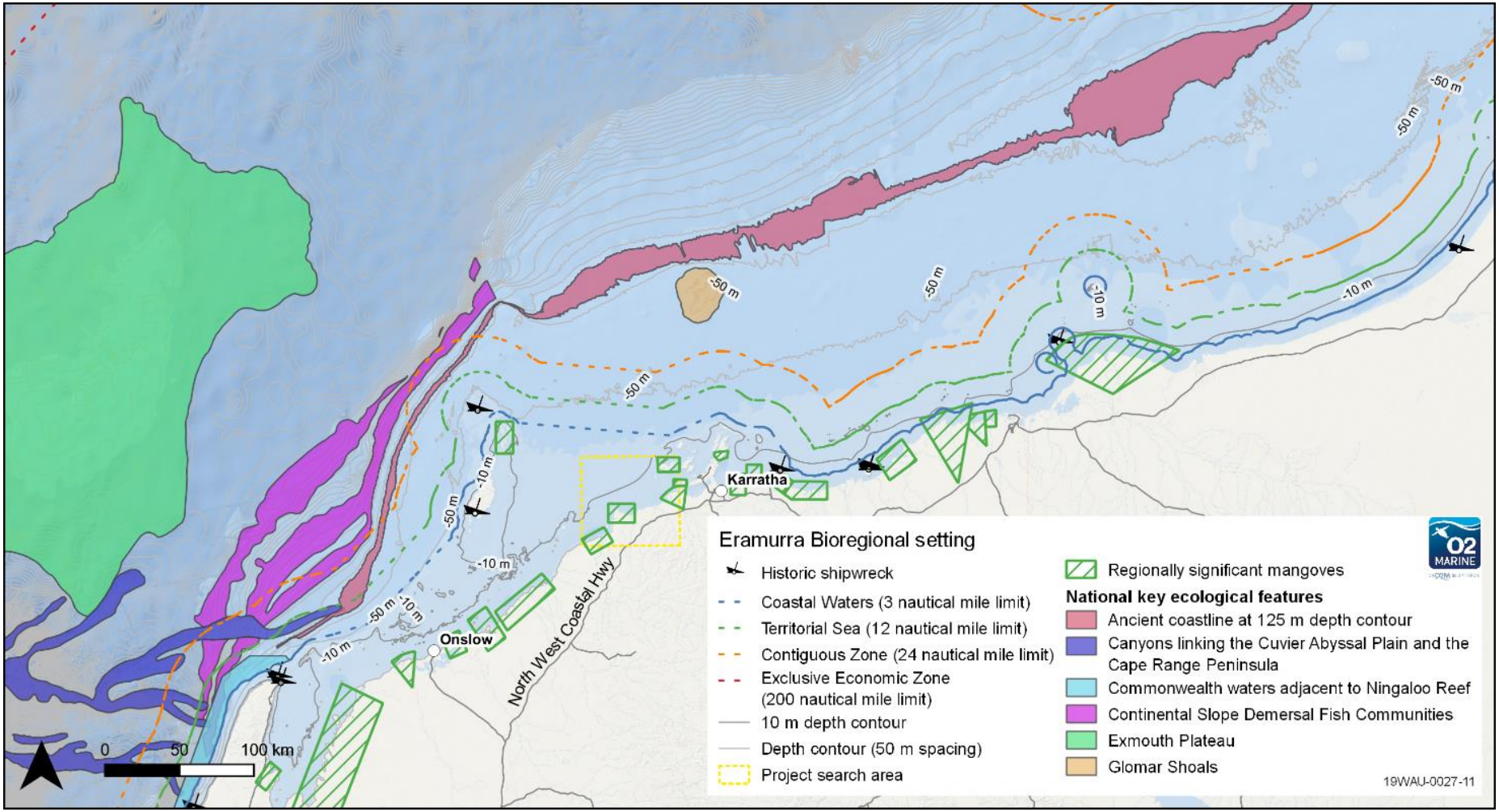


Figure 5 Bioregional setting

## 3.7. Finfish

Finfish include all fish and shark species, with records from the WA Museum showing there are more than 3,000 finfish species identified in the WA marine waters. DPIRD carries out research on finfish species within the four main bioregions of WA. Finfish assemblage and composition is predominately influenced by latitude, depth, and salinity. The primary use of commercially caught finfish within WA is for domestic consumption, with the preference to consume locally caught seafood. Demersal finfish are extensive within the nearshore (<30 m depth) and offshore (>50 m depth) environments in the Pilbara and Kimberley region, with species extending across the 3,000 km of the northern-western Australian coastline. The nearshore species are targeted by commercial line fishers, shoreline gill-net fishers, and recreational fishers (Newman et al. 2004). The offshore species within the Pilbara and Kimberley region are targeted by the trawl and trap fishers (Newman et al. 2004). A Newman et al. (2004) investigation into the nearshore finfish species of the Pilbara and Kimberley identified 170 species which represented 66 families. Of these species 53 were fished by both commercially and recreationally, and 17 were exclusively fished recreationally. Finfish species that were caught in the nearshore shallow water were dominated by juveniles, with 60 of the 70 shallow water caught species being juveniles. These juveniles are species that contribute to commercial and/or recreational fisheries. Less than half (24 out of 60) of the juvenile species were caught as adults within the nearshore environment (Newman et al. 2004). This demonstrates that as these species approach adulthood they emigrate from nearshore, shallow waters into the deeper offshore waters where they spawn and are targeted by trawl and trap fisheries (Newman et al. 2004). The nearshore shallow waters, often in water less than 2 m deep act as a nursey are for some species found in tropical waters (Newman et al. 2004). The nearshore environment of the Pilbara and Kimberley coast are nursey areas for certain elasmobranch species such as the lemon shark (*Negaprion acutidens*) and the green sawfish (*Pristis zijsron*).

A recent study along the WA coastline found a decline in species richness with increasing latitudes for deep-water fish species. Meso-predator fish species are most dominant in the depth range 300 to 399 m (Wellington et al. 2021). Finfish composition, species richness and density differ across different habitat types e.g., between reefs and soft substrata, and between unvegetated substrata and seagrass meadows (Travers et al. 2012). Within the North Coast bioregion finfish species richness and density is influenced by the wet and dry seasons. In the Pilbara region provides an environment, which is more productive and beneficial for a range of demersal fish species than the Canning region immediately to its north (Travers et al. 2012).

Marine species within the nearshore area are predominantly tropical and are short lived with high productivity, resulting in life-history traits of high fecundity and high productivity and high input into reproduction during their relatively short life spans. Most species are locally and regionally widespread with dominant species comprising a high proportion (i.e., ~80-90%) of marine fauna present. Dominant fishes typically recorded are those known to inhabit muddy sediment habitats which include ponyfish, goatfish and flathead or crabs and prawns, and the mantis shrimp. However, some dominant fish also inhabit reef and weed environments (Kangas et al. 2006).

Anecdotal information suggests larger fish may have been caught in higher numbers early in the development of these fisheries as well as prior to high levels of recreational fishing activity (Kangas et al. 2006). Some general observations can be made that many common species and the target species are short lived and highly

productive. This however does not dismiss the likelihood that long-lived species have contributed to the food webs and productivity within these regions in the past but are now in lower numbers and consequently play a lesser role.

Baseline data on the biodiversity and variability of trawl bycatch from the OPMF trawl grounds was reported in Kangas et al. (2006). The study examined the seasonal and annual variation in abundance and diversity measures and trawl efficiency in capture of bycatch species. Sites sampled within Area A of the OPMF recorded a low to moderate abundance of fish and invertebrates, with species richness ranging from low close nearshore to high further offshore. The moderate abundances and low species richness at nearshore sites are likely because of the Ashburton River, which flows heavily in summer after cyclone rains, resulting in extreme seasonal fluctuations in salinity, temperature, turbidity, and silt loading. These conditions can only be tolerated by a limited number of species, or by species that are quick to recolonise an area after a cyclone has passed. These extremes of environmental conditions are slightly moderated further offshore (Kangas et al. 2006). A site not subjected to trawling located further offshore of Onslow close to the 10 m isobath and near rich fish populations of the Mackerel Islands (Hutchins 2001) contained the greatest species richness of all sites (including Exmouth Gulf).

The abundance of fish recorded from all three surveys (March, June/July, November) from seven sites during 2004 ranged from 235 to 730 per nautical mile and the species richness ranged from 38 to 80 species. The most abundant 10 to 20 species of fish at most of the survey sites in Onslow represent a high proportion (i.e., ~80%) of the total catch. Except for the reference (not previously trawled sites) located slightly further offshore near the 10 m isobath, the common fish species occurring in Onslow samples differentiated the Onslow fish community as a separate assemblage from assemblages recorded in Exmouth Gulf (Kangas et al. 2006).

## 3.8. Invertebrates

The abundance of invertebrates recorded from all three surveys (March, June/July, November) undertaken by Kangas et al. (2006) from seven sites during 2004 ranged from 280 to 685 per nautical mile and the species richness ranged from 22 to 54 species. The most abundant 20 species of invertebrates for most of the survey sites in Onslow represent a high proportion (i.e., ~90%) of the total catch. These sites were dominated in abundance by crabs and prawns, and the mantis shrimp (*Carinosquilla australiensis*) was also among the most abundant species for Onslow sites. The nearshore sites in Onslow generally reflect the assemblages found towards Exmouth Gulf mainly due to a lack of Western king prawn species in these samples. The abundance of the Western king prawn species increased in samples with proximity from shore whilst the abundance of the Brown tiger prawn decreased. Sediments within Onslow sites were variable indicating the physical sediment particle distribution was not the primary determinate for the differences in invertebrate species assemblages (Kangas et al. 2006).

# 4. Aquatic resources

In WA DPIRD is responsible for the conservation, sustainable development, and allocation of WAs aquatic resources. This is achieved through the management of fisheries and aquatic ecosystems, assessments and monitoring of fish stocks, biosecurity management, enforcement and education, and licencing of both commercial and recreational fishing.

In WA, aquatic resources are managed using a risk-based Ecosystem Based Fisheries Management (EBFM) framework. This framework incorporates all fisheries-related activities within an ecosystem or bioregion. It considers the impacts fishing has on ecological assets (e.g., habitats and ecosystems), and the social and economic impacts (Newman et al. 2018). In WA the aquatic resources are managed by the five marine bioregions:

- North Coast;
- Gascoyne Coast;
- West Coast;
- South Coast; and
- Statewide.

Within each bioregion the resources are further separated into four/five ecological suites:

- Estuarine;
- Nearshore;
- Inshore demersal;
- Offshore demersal; and
- Pelagic.

Aquatic resources are multi-sector often, having fisheries operating within the commercial, recreational, charter, and customary fisheries.

## Commercial Fisheries

Commercial fisheries are managed by DPIRD who work closely with WAFIC and other stakeholders to ensure that WA's commercial fisheries are sustainably managed. The commercial fishing industry is an important part of the regional and coastal communities in WA. The WA commercial fisheries are known for producing high-value products with most of WA's seafood exported to China, Hong Kong, Japan, the United States of America, Taiwan, and Singapore, as well as providing seafood to Australia and WA (DPIRD 2020).

## Recreational Fisheries

Recreational fisheries are managed by DPIRD who work closely with Recfishwest and the WA recreational fishing community. Recfishwest is the peak recreation fishing body in WA, which works to represent the 750,000 recreational fishers in WA. Recreational fishing is managed through area specific rules and regulations, which relate to species and different fishing activities. The proportion of WA residents that engage in recreational fishing is above the national average, with an estimated 25.4% (95% CI 32-28.7%) participation rate in 2020/21 (Ryan et al. 2022). Recreational fishing within WA is estimated to contribute $2.4 billion yearly (McLeod and

Lindner 2018). Within the North Coast Bioregion recreational fishing has a distinct seasonal peak occurring in winter (Newman et al. 2021a). There are significant social benefits gained from recreational fishing, with recreational fishers stating their primary motives for fishing is to relax and unwind, to be outdoors, for solitude or to be with family and friends (Ryan et al. 2019; Ryan et al. 2022). Recreational fishers are more likely to consume seafood at least once per week, with a 70% of the WA recreational fishers surveyed consuming seafood once a week, compared to 25% of the population estimate (Hunt and McManus 2015). Recreational fishing has an important role in the fisher's health and well-being, with results from a recreational fishing survey in WA finding 79.5% of the respondents indicating that recreational fishing plays an important to very important role in their health and wellbeing (Hunt and McManus 2015). The results from this survey also found that 84% of the recreational fishers in WA had lower levels of overweight and obesity than the general population (Hunt and McManus 2015).

Charter services have been operating since 1990 providing fishing, whale watching, diving or other aquatic ecotourism service charters. Charter operations have the potential to increase the recreational exploitation of fish stocks.

### Customary Fisheries

Customary fishing applies to any person who is of Aboriginal descent who has traditional connections to the area that is being fished, who is fishing for personal, domestic, ceremonial, educational or non-commercial needs. Customary fishing is based on cultural needs and values. Customary fishing is separate from the other forms of fishing within an aquatic resource, and the fisheries legislation and policy for customary fishing is to allow for the development of appropriate management practices that reflect the customary fishing access rights, practices, and sustainability requirements. The Customary Fishing Policy ensures that our laws acknowledge Aboriginal people's rights to fish and hunt in accordance with their tradition and culture (DPIRD 2015).

## 4.1. Overview

Table 5 identifies the aquatic resources that occur within the vicinity of the Proposal. Within each aquatic resource the fisheries that utilise the resources have also been identified. Not all the commercial fisheries within the aquatic resource overlap with the Proposal, therefore only the fisheries that relate to the Proposal will be discussed in the following sections.

Table 5 Aquatic resources within the Proposal (Newman et al. 2021a)

| Aquatic Resource | Fisheries | Key Species |
|---|---|---|
| Northern Demersal Scalefish | Commercial<br>• Northern Demersal Scalefish Managed Fishery (NDSMF)<br>• Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF)<br>• Pilbara Demersal Trap Managed Fishery (PTMF)<br>• Pilbara Line Fishery (PLF)<br>Recreational | • Bluespotted emperor<br>• Rankin cod<br>• Red emperor<br>• Goldband snapper |
| Northern Invertebrates | Commercial<br>• Onslow Prawn Managed Fishery (OPMF)<br>• Nickol Bay Prawn Managed Fishery<br>• Broome Prawn Managed Fishery<br>• Kimberley Managed Fishery<br>• Exmouth Gulf Prawn Managed Fishery (MSC*) | • Western king prawn<br>• Brown tiger prawn<br>• Banana prawns |
| North Coast Crab | Commercial<br>• Pilbara Crab Managed Fishery (PCMF)<br>Recreational | • Blue swimmer crab |
| Statewide Large Pelagic Scalefish | Commercial<br>• Mackerel Managed Fishery (MMF)<br>Recreational | • Spanish mackerel<br>• Grey mackerel<br>• Samson fish<br>• |
| Statewide Hand Collection | Commercial<br>• Western Australian Sea Cucumber Fishery (WASCF) (MSC*)<br>Customary | • Sandfish<br>• Red Fish<br>• |
| Statewide Marine Aquarium Fish and Hermit Crab | Commercial<br>• Marine Aquarium Fish Managed Fishery (MAFMF)<br>• Hermit Crab Fishery (HCF) | • Syngnathids<br>• Invertebrates<br>• Hard corals<br>• Soft coral<br>• Living rock & living sand<br>• Sponges<br>• Algae/Seagrasses<br>• Hermit Crabs |
| Pearl Oyster (*Pinctada maxima*) | Commercial<br>• Pearl Oyster Wildstock Fishery (MSC*)<br>Customary | • Silver lipped pearl oyster |
| Statewide Specimen Shell | Commercial<br>• Specimen Shell Managed Fishery (SSMF) | |
| Statewide Abalone | Commercial<br>• Abalone (Roe's) Managed Fishery<br>• Abalone (Greenlip/Brownlip) (MSC*) Managed Fishery (MSC*)<br>Recreational | • Roe's abalone<br>• Greenlip abalone<br>• Brownlip abalone |
| South Coast and West Coast Crustacean | Commercial<br>• West Coast Deep Sea Crustacean Managed Fishery (MSC*) | • Crystal crab |

*Some fisheries within the aquatic resources are also certified fisheries by the Marine Stewardship Council (MSC), which means the fisheries have been independently certified as being sustainable.

The Statewide Abalone Resource has two fisheries that operate within WA waters; Abalone (Roe's) Managed Fishery and Abalone (Greenlip/Brownlip) Managed Fisheries. These fisheries extend across the entire waters of WA, with abalone mostly occurring in the West Coast Bioregion and the South Coast Bioregion (Hart et al. 2017). In relation to the Proposal area, the Statewide Abalone Resource fisheries, the Proposal overlaps with management Area 4 (Busselton Jetty to NT/WA border) of the fishery. Management Area 4 has no quota allocated and does not form part of the functional fishery (Hart et al. 2017). The Statewide Abalone Resource is not functional within the Proposal and will not be discussed further in this report.

The South Coast and West Coast Crustacean Resource manage the West Coast Deep Sea Crustacean Managed Fishery, which operate off the west coast of WA. The fishery is operational on the seaward side of the 150 m isobath and extends out to the Australian Exclusive Economic Zone (200 nm boundary) (How et al. 2015). The fishery targets the crystal crab (deep-water species), occurring in water depths of 300 to 1200 m (How et al. 2015). This fishery does not operate within the vicinity of the Proposal and will not be discussed further in this report.

The aquatic resources and their fisheries that overlap with the Proposal are discussed below. Key indicator species relevant to each aquatic resource are discussed in Section 5.

## 4.2. Northern Demersal Scalefish Resource

The North Coast Demersal Scalefish Resource operates in the Pilbara and Kimberley region, comprising of ecological suites of tropical fish species. Fishing activities within this resource predominantly occur inshore in water depths from 20 to 250 m (DPIRD Draft Report, *unpublished*). The resource includes high-value demersal species such as emperors (Lethrinidae), snappers (Lutjanidae), and cods/groupers (Epinephelidae) (DPIRD Draft Report, *unpublished*).

### 4.2.1. Commercial fisheries

The North Coast Demersal Scalefish Resource manages the Northern Demersal Scalefish Managed Fishery (NDSMF) in the Kimberley subregion and the Pilbara Demersal Scalefish Fisheries (PDSF) in the Pilbara subregion. The Pilbara Demersal Scalefish Fisheries includes:

- Pilbara Trap Managed Fishery (PTMF);
- Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF); and
- Pilbara Line Fishery (PLF).

The NDSMF does not overlap with the Proposal so will not be discussed in detail. However, it is important to note that a range of demersal fish species are fished and distributed throughout the aquatic resource, in both Kimberley and Pilbara Fisheries. Fish species which, may be affected by the Proposal, may have impacts across the resource, especially for the bluespotted emperor. Bluespotted emperor in the Pilbara region is thought to be the distribution point for the species into the Kimberley (Newman et al. 2020), therefore depletion of juveniles in the Pilbara could have impacts on the Kimberley fishery. The three Pilbara subregion fisheries will be the focus of discussion for the commercial fisheries within the North Coast Demersal Scalefish Resource (Figure 6). The fisheries within the North Coast Demersal Scalefish Resource are the most valuable finfish sector

in WA, with typically annual catch of 3,000 to 4,000 t with an estimated annual value greater than $20 million (Newman et al. 2021b).

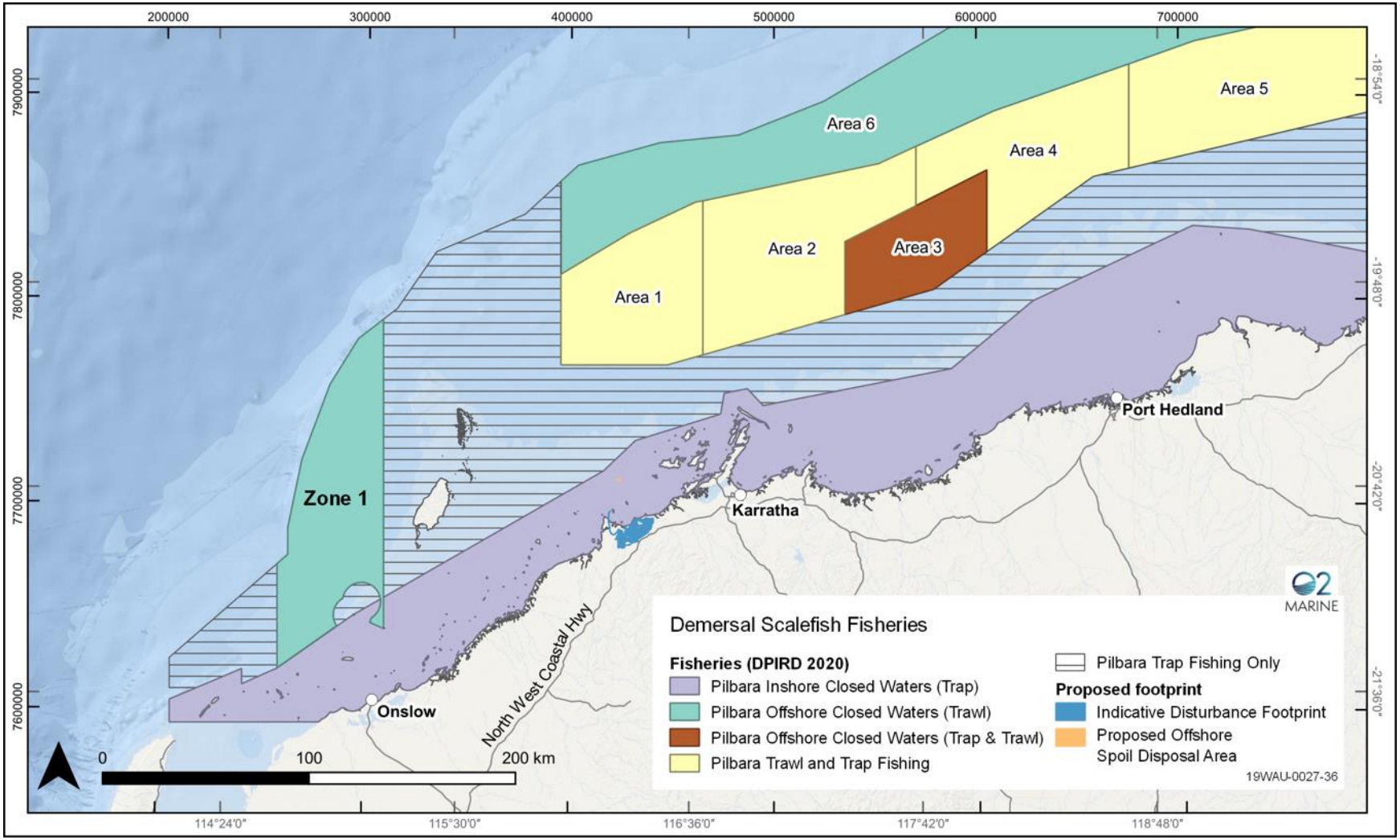


Figure 6 Northern Demersal Scalefish Resource fisheries zones in the Pilbara

## Species

The Northern Demersal Scalefish Resource comprises of tropical demersal fish species which are found in inshore waters (20 – 250 m deep) and offshore waters (>250 m deep). Within the three Pilbara fisheries a range of demersal fish species are routinely targeted and captured. The main species landed by the fisheries in the Pilbara subregion are red emperor (*Lutjanus sebae*), crimson snapper (*Lutjanus erythropterus*), goldband snapper (*Pristipomoides multidens*), rosy threadfin bream (*Nemipterus furcosus*) bluespotted emperor (*Lutjanus punctulatus*) and Rankin cod (*Epinephelus multinotatus*) (Newman et al. 2021b). Due to the Northern Demersal Scalefish Resource comprising of a wide range of species, a number of indicator species have been identified to assess the resource. The species are selected based on their inherent vulnerability and risk to sustainability. For the Pilbara region the indicator species are the red emperor (*L. sebae*), bluespotted emperor (*L. punctulatus*) and Rankin cod (*E. multinotatus*). The ruby snapper (*Etelis* sp.) is also used as an indicator for the offshore demersal scalefish resources (targeted by the PLF) (Newman et al. 2021b), however this species is a deep-water species often found in depths greater than 250 m (Wellington et al. 2021) and therefore are unlikely to be present within the Proposal area.

The PFTIMF has the largest number of species caught compared to the PLF and PTMF. Typically, the PFTIMF lands ~53 species, compared to the ~49 from the PTMF and ~47 from the PLF (Newman et al. 2018). The PDSF catches make up 67% of the total demersal catches occurring within the North Coast Bioregion. These fisheries are highly reliant on the three indicator species, with 90% of the total bluespotted emperors caught by the PDSF, 59% for the red emperor and 70% for the Rankin cod. The PDSF are also responsible for 100% of the commercial catches of the frypan snapper and rosy threadfin bream within the resource (Newman et al. 2021b).

## Area

The Pilbara Demersal Scalefish Fisheries span a large area, with coastal waters adjacent to the Proposal being within the designated trap fishing boundary. However, despite the large size of the fisheries and distance offshore of some of the fishing grounds from the Proposal, inshore areas in the vicinity of the Proposal are known to provide important nursery grounds for target species in these fisheries (DPIRD Draft Report, *unpublished*). The PTMF extends from the North-West Cape to 120° East. The fishing efforts for the PTMF concentrated between the 30 m and 100 m isobath (Looby 1997).

## Socio-economic value

The total estimated economic value of the PDSF is $10-20 million. The PFTIMF has an estimated value of $5-10 million (Level 3) and the PTMF and PLF has an estimated value of $1-5 million (Level 2). During 2020, the PDSF directly employed at least 33 people (3-4 per vessel). The estimates for 2020 for the three fisheries within the PDSF were two vessels (~10 fishers) for the PFTIMF, three vessels (~8 fishers) for the PTMF and five vessels (~15 fishers) for the PLF (Newman et al. 2021b).

The fisheries within the Northern Demersal Resource have high economic value to other regions in WA. The fish caught from these Pilbara fisheries dominate the Perth fishing markets and support the local fish-processing sector (WAFIC n.d.)

## Catch/Effort

The total commercial catch for the PDSF in 2020 was 2,854 t. Of the total catch, 74% (2,103 t) was from the PFTIMF, 20% (584 t) from the PTMF and 6% (167 t) from the PLF. All three of the fisheries exceeded their acceptable catch tolerance for 2020, despite having the same annual effort allocation. This suggests effort reductions since 2008 have resulted in increased fish abundance and stocks rebuilding (Newman et al. 2021b). Within the vicinity of the Proposal the PFTIMF operates offshore, with recorded catch captured by DPRID is presented in Figure 7 (DPRID 2021).

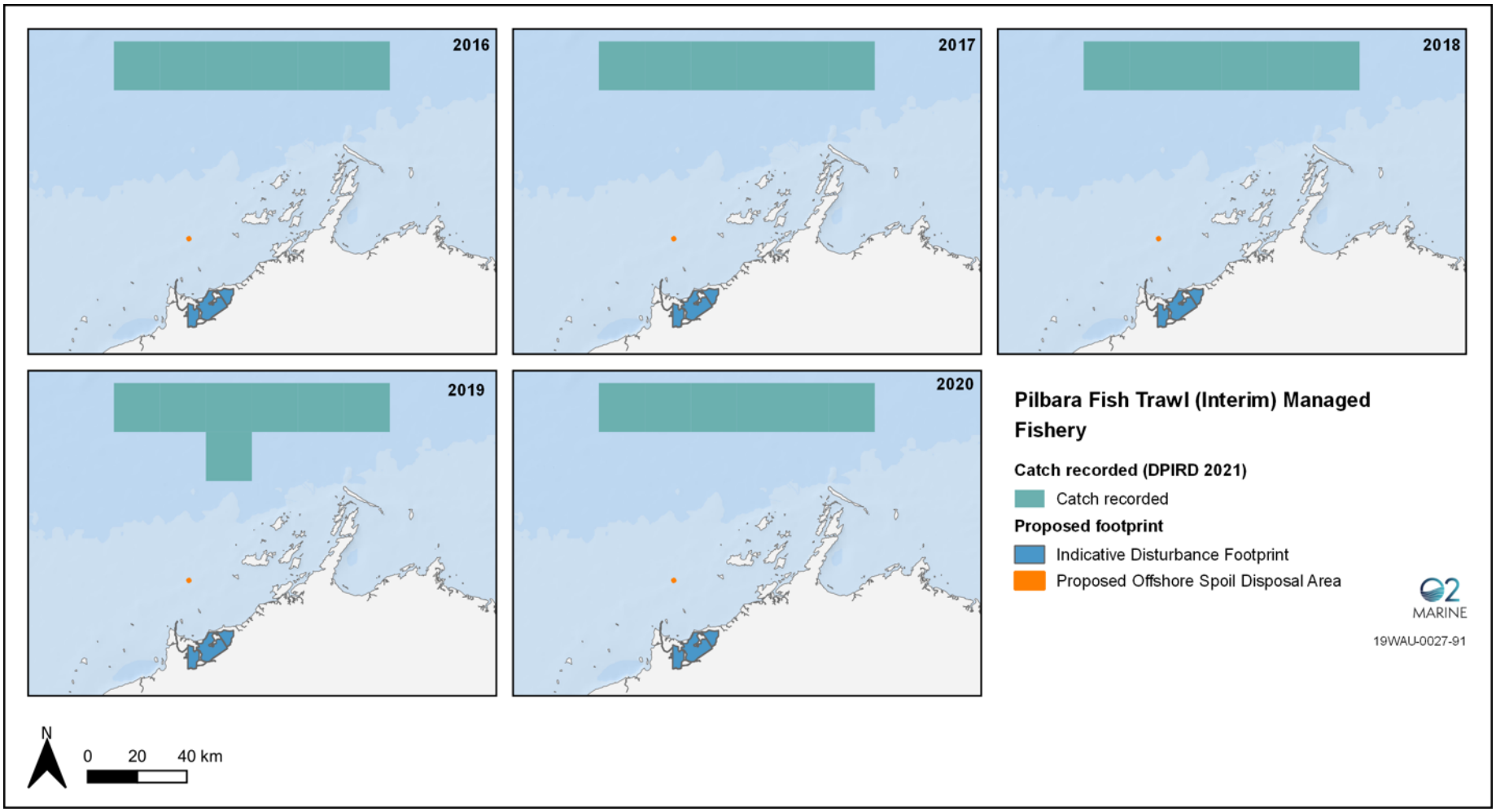


Figure 7 PFTIMF recorded catch in the vicinity of the Proposal

### 4.2.2. Recreational

#### Catch

Recreational use of the Northern Demersal Scalefish Resource is predominantly line fishing from private boats or charter vessels. To manage the recreational use of the resource, recreational fishers are managed through controlling both inputs (e.g., recreational licences) and outputs (e.g., bag and/or boat limits, size limits). The recreational take of the Northern Demersal Scalefish Resource status is acceptable (Newman et al. 2021b), with the recreational catch from the 2020/21 boat-based survey of 41 to 63 t (Ryan et al. 2022). The Pilbara regions recreational catch accounts for 2.7% of the total statewide catch (Ryan et al. 2019). Recreational fishing within the Northern Demersal Scalefish Resource is concentrated to the nearshore areas of Dampier, Karratha, Port Hedland, and Broome. Charter fishing of the Resource operates at offshore islands and reefs (i.e., the Montebello Islands and the Rowley Shoals) (DPRID 2017). Recreational fishing within the Northern Demersal Scalefish Resource peaks during the dry season, April to October (DPRID 2017).

#### Socio-economic value

Recreational and charter fishing for demersal finfish species is popular in the North Coast Bioregion. The species most commonly caught by recreational fishers aligns with the species commonly harvested by the commercial fisheries. Demersal fishing in the North Coast bioregion brings many visitors to the inshore fishing areas during the dry season, from April to October. Recreational and charter fishing of demersal finfish supports various local charter fishing companies and fishing tackle shops (Newman et al. 2021a)

## 4.3. Northern Invertebrates Resource

There are four commercial fisheries managed under the Northern Invertebrates Resource: the Onslow Prawn Managed Fishery (OPMF), the Nickol Bay Prawn Managed Fishery, the Broome Prawn Managed Fishery and Kimberley Prawn Managed Fishery.

### 4.3.1. Commercial fisheries

The prawn fisheries operating within the Northern Invertebrates Resource have limited entries and relatively small catch biomass in comparison with other prawn fisheries in WA (Kangas et al. 2021). Of the four commercial fisheries managed within the Northern Invertebrates Resource, the OPMF is the only one which overlaps with the Proposal (Figure 8), and therefore will be the fishery discussed in more detail.

#### Species

The OPMF targets western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*), blue endeavour prawns (*Metapenaeus endeavouri*) and banana prawns (*Penaeus merguiensis*). Minor species in the fishery include Moreton Bay bugs, squid, blue swimmer crabs, cuttlefish, other prawn species (i.e., coral prawns), and some finfish species. Indicator species for the OPMF are brown tiger prawns and western king prawns (Kangas et al. 2021).

#### Area

The OPMF encompasses an area of 39,748 km$^2$. The waters adjacent to the Proposal are not designated as nursery areas (unlike the Fortescue Nursery area West of Cape Preston). Juvenile species of prawn utilise

nearshore habitat and mangrove areas found within the Proposal area. Post-larval stages of prawns settle in the upper reaches of small creek systems and the success of juvenile populations emigrating from the creeks correlates positively with rainfall during the wet season (Vance et al. 1998).

## Socio-economic value

According to the 2020/21 fisheries report, the North Coast Prawn Resource (inclusive of the Kimberley, Broome, Nickol Bay and OPMF), was estimated to employ 30 to 60 commercial crew, with a total estimated value of $4.9 million (excluding by-product) (Kangas et al. 2021).

## Catch/Effort

The total landings for the OPMF in 2020 was less than the target catch range (60 t) with only 13 days of fishing taking place by one boat (Kangas et al. 2021). The reduce fishing effort within the OPMF in 2020 was attributed to the fishing operators choosing to fish elsewhere where catches are more likely to be more profitable (Kangas et al. 2021). Total catches vary substantially between years, the average catch of 96.8 t is dominated by tiger prawns (*P. esculentus*) and king prawns (*P. latisulcatus*), with significant contributions from endeavour prawns (*M. endeavouri*) and banana prawns (*P. merguiensis*). The OPMF operates in nearshore, within and adjacent to the Proposal, with recorded catch reported to DPRID from 2016 to 2020 presented in Figure 9 (DPRID 2021).

Historically the OPMF has experienced years of reduced fishing efforts, including in 2012 when restricted access and habitat disturbance resulted in no commercial fishing (Sporer et al. 2013). Construction of a gas pipeline, wharf construction and general boat movement restricted fishing operations (Sporer et al. 2013). Dredging for the wharf facility and inshore disturbances were likely to cause short term loss of some nursey habitat with some loss of seagrass/algal habitats and potentially to have impacted juvenile tiger prawns in the short term (Sporer et al. 2013). Disturbances within Area 1 of the OPMF were also noted in 2014, where trawling efforts were restricted due to a pipeline on the seabed and general boat movements within the fishing area (Sporer et al. 2015).

Reduced catch rate for the OPMF has historically occurred, with minimum fishing reported in 2014 (Sporer et al. 2015), 2015 (Fletcher et al. 2017), 2016 (Gaughan and Santoro 2018), 2017 (Gaughan et al. 2019), 2018 (Gaughan and Santoro 2020), and 2019 (Gaughan and Santoro 2021); in 2018 and 2019 only one boat was operating within the fishery (Gaughan and Santoro 2020, 2021).

The marine heat wave caused loss of seagrass/algae habitat within tiger prawn nursey areas, which resulted in low level of recruitment in 2012 and slow recovery in subsequent years (2013 and 2014) (Caputi et al. 2016). Similar reduced tiger prawn recruitment was observed following the 1999 cyclone, damaging inshore seagrass/algae (Loneragan et al. 2013) and resulting in slow tiger prawn recovery from 2000 to 2004 (Caputi et al. 2016). Increased water temperatures in recent years have also had a negative effect western king prawn, which may be affecting the northern prawn fisheries (Kangas et al. 2021). The brown tiger prawn has been identified as having a high risk to climate change and the western king prawn as moderate/high (Kangas et al. 2021).

The historical reduced fishing effort and catch rate could be due to loss of habitat and recruitment, either from the marine heat wave impacting nursey habitat, or from disturbances by infrastructure development within the fishing grounds. Or it could be an accumulation of both impacting the OPMF.

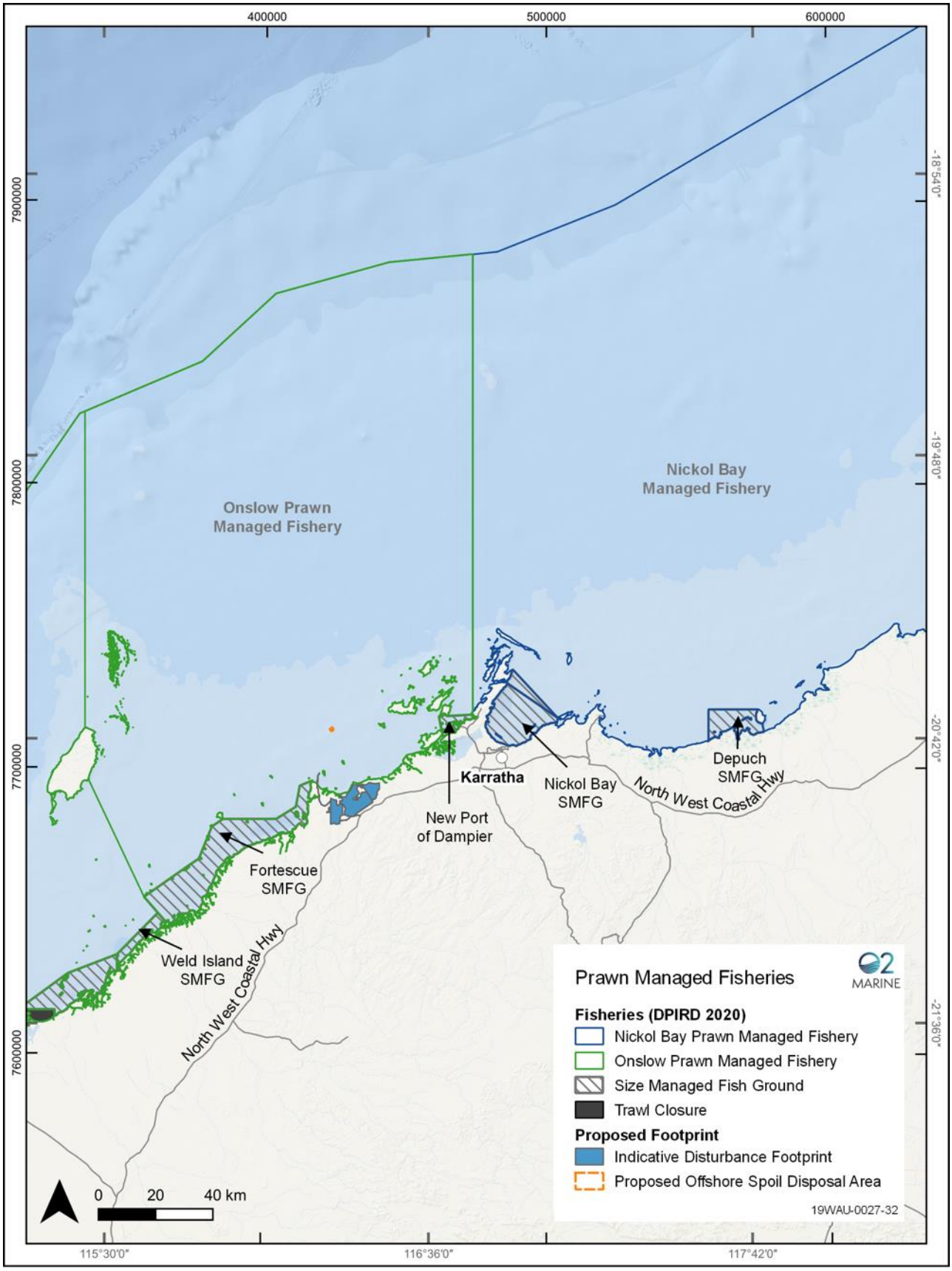


Figure 8 Prawn Managed Fisheries in the Pilbara

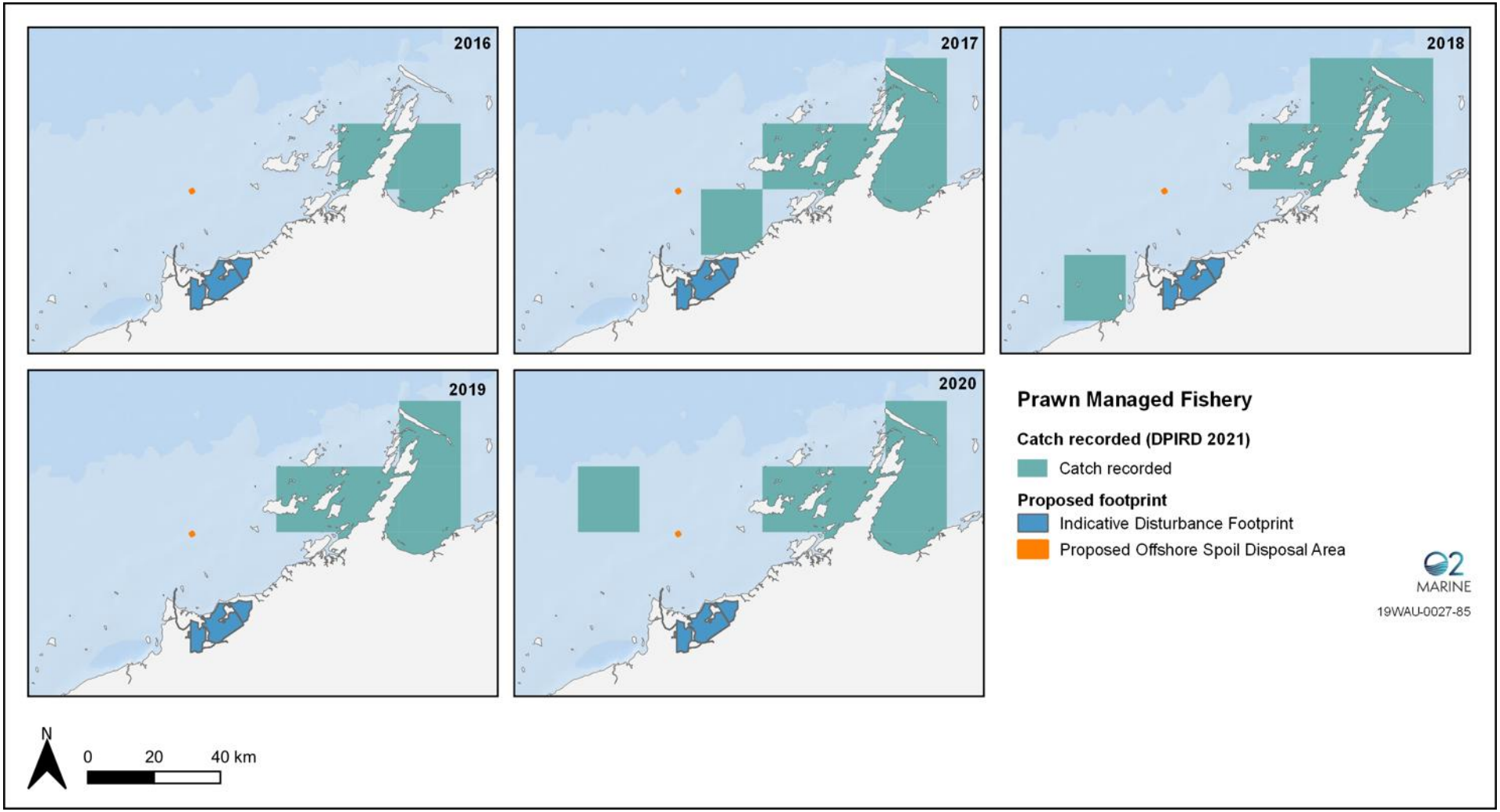


Figure 9 Prawn Managed Fishery catch in the vicinity of the Proposal (DPIRD 2021)

## 4.4. North Coast Crab Resource

There are two commercial fisheries which are managed within the North Coast Crab Resource, they are the Pilbara Crab Managed Fishery (PCMF) and the Kimberley Crab managed Fishery (KCMF).

### 4.4.1. Commercial fisheries

Of the two fisheries managed within the North Coast Crab Resource, the PCMF is the only one which overlaps with the Proposal (Figure 10), and therefore will be discussed in more detail. The PCMF targets blue swimmer crabs (*Portunus armatus*) using hourglass traps, primarily within the inshore waters of Nickol Bay. The PCMF blue swimmer crab catch makes up a relatively small proportion of the State's total catch of this species (Johnston et al. 2021a).

#### Species

Blue swimmer crabs are the target species of the PCMF, however, the singular commercial fisher operating in the PCMF is also authorised to retain the coral crab (*Charybdis ferriata*) and three spot sand crab (*Portunus sanguinolentus*), which reside in similar habitats to the blue swimmer crab. However, catches of these by-product species to date have been negligible (Johnston et al. 2021a).

#### Area

The PCMF is generally focused on inshore and estuarine areas, <20 m depth, and extends to the 200 m isobath between longitudes 115° 5' 60" E and 120°0' 0" E (approximately Onslow to Port Hedland). The majority of catch and effort is historically from the Nickol Bay region (Johnston et al. 2021a). Historical commercial fishing suggests that commercially viable stocks exist along much of the coastline from the Exmouth Gulf to Port Hedland. These stocks are a substantial distance from the nearest port, which makes them economically unviable to fish while the need to get fresh catch to market within a day or two of being caught remains (Johnston et al. 2020). There has been discussion to catch and freeze the crab onboard the vessel to open up areas currently too far from market to supply live product, however frozen crab is less attractive to the market (Johnston et al. 2020).

#### Socio-economic value

The estimated gross value of product for the crab fishery within the North Coast Bioregion for 2020 was approximately $5,000 for blue swimmer crabs, due to the low catch rate of 0.6 t. If annual catches reach the tolerance of 73 t, the value of the PCMF could exceed $600,000 (based on the average beach price paid to fishers in 2019/20 of $8.40/kg). The crab catch from the Pilbara region is sold through local and interstate markets (Johnston et al. 2021a).

North Coast blue swimmer crab fisheries provide a high social amenity to recreational fishers and consumers via commercial crab supply. During 2020, two people were employed as skippers and crew on vessels fishing for the PCMF, although minimal fishing effort occurred. Additional employment for several workers has been created in Point Samson through the development of a post-harvest processing facility for the crab catch (Johnston et al. 2021a).

### Catch/Effort

The PCMF generally operates from March to November each year due to the harsh climatic condition in the Pilbara over the summer months (Johnston et al. 2020). Currently there is only one commercial licence for blue swimmer crabs, coral and three spot sand crabs. In 2016 the number of traps was increased by 200, to a total of 600 and the traps are allowed to be used across two vessels. In 2020 the commercial catch for the PCMF was considerably low, with only 0.6 t reported. This catch was well below the 20 t catch tolerance level. The PCMF catch only accounts for <0.1% of the total WA commercial catch of 713.5 t (Johnston et al. 2021a). The 2020/21 Status report attributed this low catch to reduced fishing efforts during the COVID-19 pandemic, with fishing only occurring for one month of the year in 2020 (Johnston et al. 2021b).

## 4.4.2. Recreational

Recreational fishing of the PCMF is allowed to occur all year round. The total recreational boat-based catch of blue swimmer crab in 2020/21 was estimated to be 0.8 t (Ryan et al. 2022) and mud crabs estimated to be 3 t (Ryan et al. 2020). The North Coast recreational catch is relatively small compared to the other bioregions, only representing 3% of the WA boat-based recreational catch (Johnston et al. 2021b).

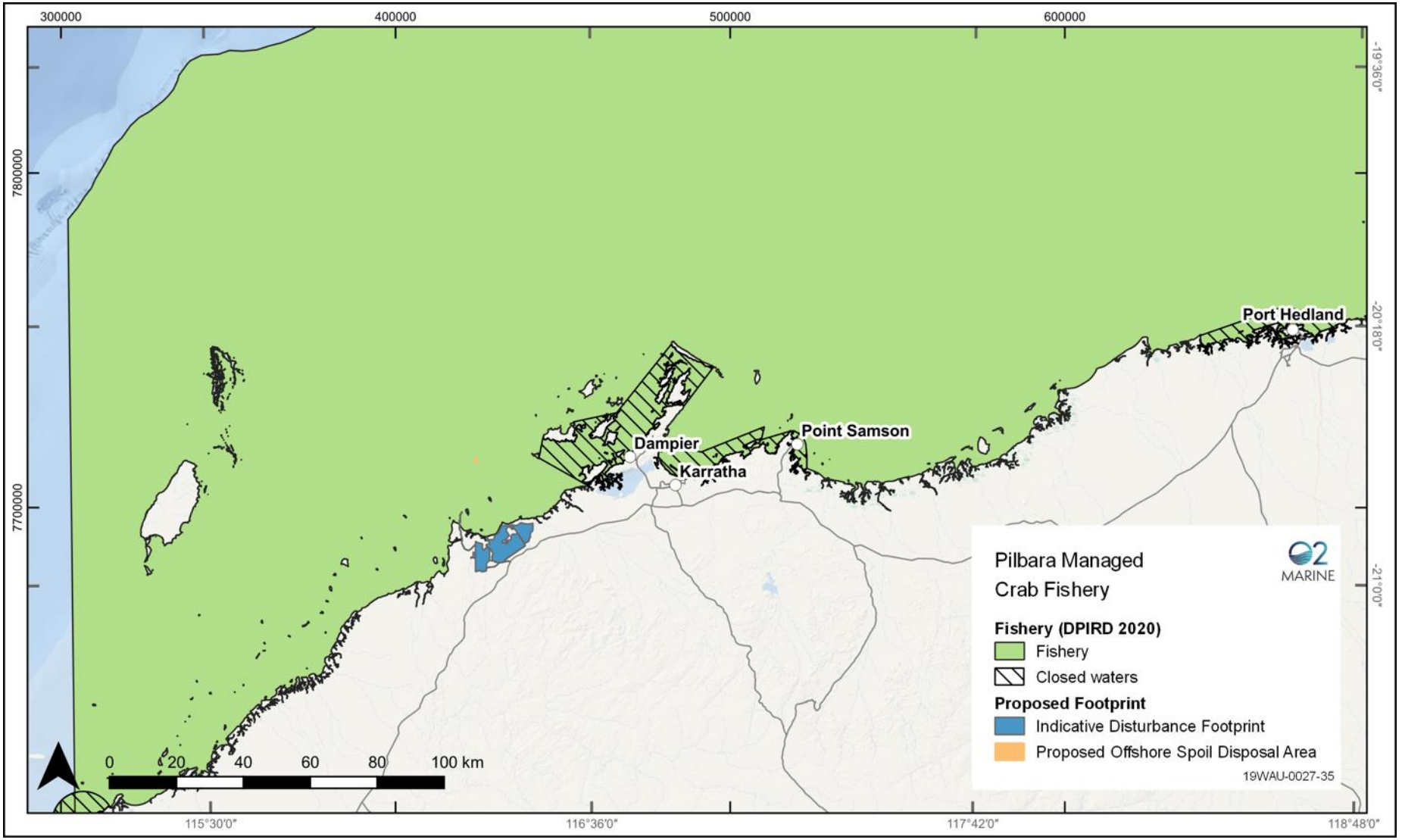


Figure 10 Pilbara Crab Managed Fishery zones and fishing areas

## 4.5. Statewide Large Pelagic Scalefish Resource

Within the Statewide Large Pelagic Scalefish Resource, the Mackerel Managed Fishery is separated into three areas: Kimberley, Pilbara, and Gascoyne/West Coast. This resource is also important to the charter fishing and recreational sectors.

### 4.5.1. Commercial Fisheries

The Mackerel Managed Fishery (MMF) forms a part of the Statewide Large Pelagic Finfish Resource which includes a range of bioregions and tropical and temperate pelagic fish species. The MMF is comprised of several licences and vessels which troll fishing lines in the North Coast and Gascoyne Coast Bioregion, bringing in up to 80% of WAs commercial catch of large pelagic finfish (Lewis and Watt 2021).

#### Species

The Statewide Large Pelagic Scalefish Resource is distributed throughout WA and includes a range of 21 tropical and 4 temperate pelagic finfish species in the families of *Carangidae* (large trevallies), *Coryphaenidae* (mahi mahi), *Istiophoridae* (billfishes), *Scombridae* (mackerels and tunas), *Sphyraenidae* (barracuda), and *Rachycentridae* (cobia). The two indicator species for tropical finfish in the MMF are the Spanish mackerel (*Scomberomorus commerson*) and grey mackerel (*Scomberomorus semifasciatus*) (Lewis and Watt 2021), which are relevant to the North Coast Bioregion.

#### Area

The MMF extends from the West Coast Bioregion to the WA/Northern Territory (NT) border, with most effort and catches recorded north of Geraldton, especially from the Kimberley and Pilbara coasts. The MMF catches are reported separately for three areas; Kimberley, Pilbara (114° E to 121° E) and Gascoyne/West Coast (Lewis and Watt 2021).

#### Socio-economic Value

During the 2020 season, the MMF had sixteen boats operating primarily from May to November. This resulted in the direct employment of 35 to 40 people. The Spanish mackerel has the highest economic value of the target species, with an estimated value in 2020 of $2.5-4 million, with the other large pelagic finfish estimated value of less than $500,000 (Lewis and Watt 2021).

#### Catch/Effort

The main commercial catch within the MMF is the Spanish mackerel, the species catch has ranged from 270-330 t since quotas were introduced in 2006. In 2020 the MMF landed 288 t of Spanish mackerel. The commercial catch of the grey mackerel in 2020 was 11 t. The total catch of grey mackerel in the MMF has been consistently below 20 t since 2006. The commercial landings of other tropical large pelagic species in the North Coast and Gascoyne bioregion such as amberjack (*Seriola dumerili*), cobia (*Rachycentron canadum*) and golden trevally (*Gnathanodon speciosus*) were 11.7 t, 18.3 t, and 22.3 t, respectively, with remaining species <10 t in 2020 (Lewis and Watt 2021). The MMF operates within and adjacent to the Proposal area, with recorded catch reported to DPRID from 2016 to 2020 presented in Figure 11 (DPRID 2021).

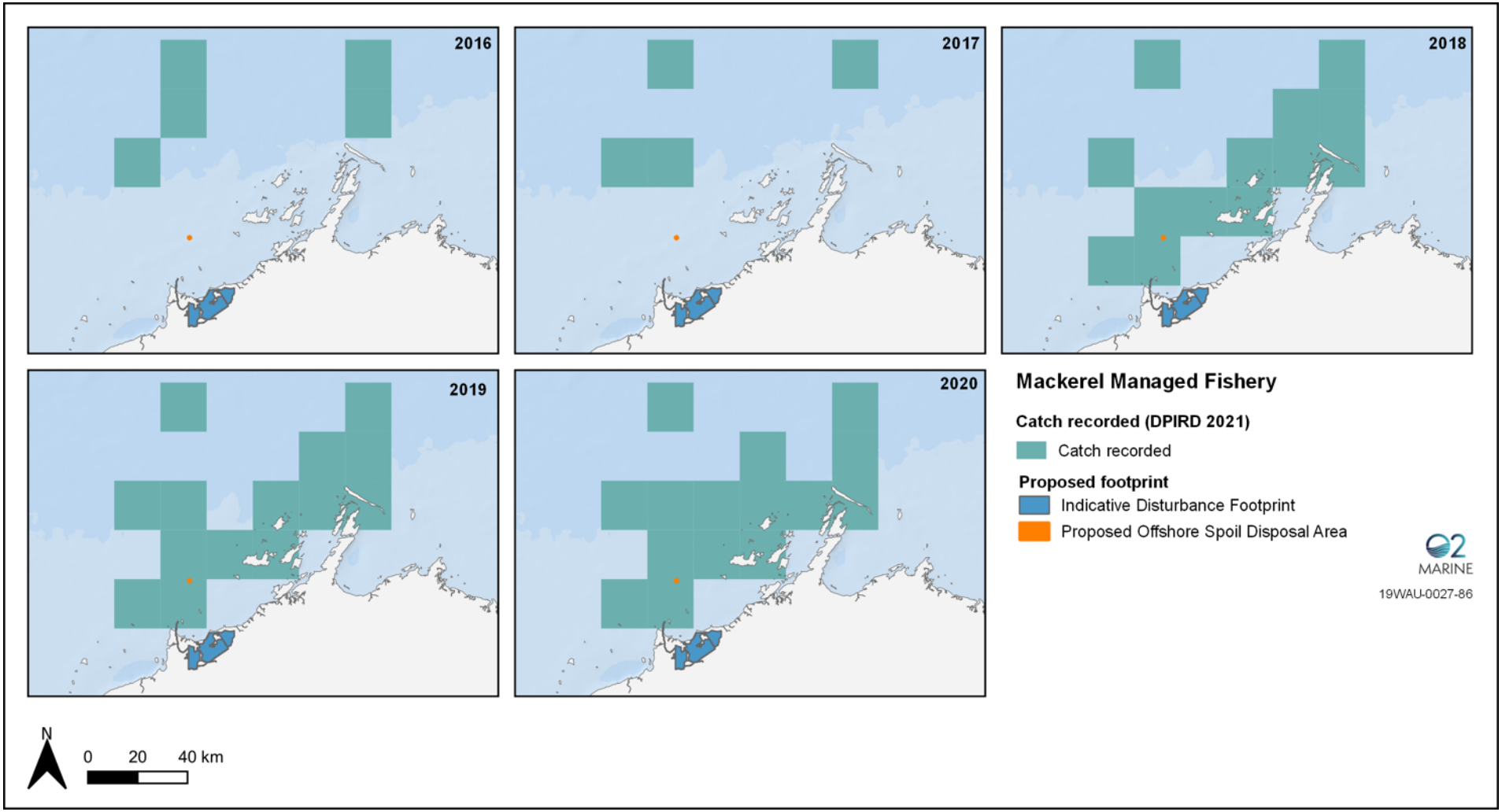


Figure 11 MMF recorded catch in the vicinity of the Proposal from 2016–2020 (DPIRD 2021).

### 4.5.2. Recreational

#### Catch

The Statewide Large Pelagic Scalefish Resource had a recreational take of 114 t (CI 95% 89-138) in 2020/21, which is consistent with previous results from the previous surveys (Ryan et al. 2020). Recreational fishing and charter fishing target a range of large pelagic finfish species, particularly Spanish Mackerel. The sportfishing value of large pelagic fish to the recreational sector is much higher than for other species. Recreational surveys indicate that Spanish mackerel is the 5$^{th}$ highest retained finfish species and the 4th highest retained by charter/fishing tour operator in 2019/20 (catch-by-weight) (Lewis and Watt 2021). For most other large pelagic species, the majority of catches are released (Ryan et al. 2019; Ryan et al. 2022). Over the last 10 years (2009/18) charter boats combined annual retained catch has ranged from 15 to 25 t. Spanish mackerel dominate the retained recreational and charter catches, at over 75% of the resource (Lewis and Watt 2021).

#### Socio-economic value

The Statewide Large Pelagic Scalefish Resource has a high species abundance throughout WA waters, the species, especially Spanish mackerel, are targeted by charter operations and recreational fishers, and have high eating qualities and the species are deemed to have high social value (Lewis 2020).

The Statewide Large Pelagic Scalefish Resource provides moderate to high social amenity value to recreational fishers (Lewis and Watt 2021). The MMF is important to the WA economy and majorly supports regional coastal towns. Statewide Finfish Pelagic recreational catch has an estimated food value of $8,413 to $73,222 (McLeod and Lindner 2018). The Statewide Large Pelagic Scalefish Resources has an estimate sport value of $243,750 to $1,001,500 (McLeod and Lindner 2018).

## 4.6. Statewide Hand Collection Resource

The Statewide Hand Collection Resource manages the Western Australian Sea Cucumber Fishery (WASCF). There are no recreational fisheries for the Statewide Hand Collection Resource.

### 4.6.1. Commercial fisheries

#### Species

In the North Coat Bioregion, the WASCF targets two main species of sea cucumber; the Sandfish (*Holothuria scabra*) and deep-water Redfish (*Actinopyga echinites*). However, six other species are also permitted to be taken (Hart and Murphy 2021):

- White teat fish (*Holothuria fuscogilva*);
- Black teat fish (*Holothuria whitmaei*);
- Prickly red fish (*Thelenota aranas*);
- Lolly fish (*Holothuria atra*);
- Brown curry fish (*Stichopus vastus*); and
- Curry fish (*Stichopus hermanni*).

#### Area

Fishing occurs mostly in the northern half of the State, from Exmouth Gulf to the NT border, however Shark Bay was fished for the first time in 2020. Fishing mainly occurs within shallow, low energy environments sheltered by fringing reefs or within bays (Hart and Murphy 2021). The commercially viable WASCFs are located east of the Proposal area, however the target species known distribution overlaps with the Proposal area.

#### Socio-economic value

Generally, four to six crew are employed on a vessel, comprising of a master, deckhand, and divers. Additional individuals are employed for the processing of the products. The estimated annual value for 2020 was <$100,000, based on a total live weight of 3.7 t at $4.25 per kg. Sea cucumbers are primarily exported to Asian markets as a dried product termed “beche-de-mer” (Hart and Murphy 2021).

#### Catch/Effort

Six licence holders are permitted to operate within the WASCF under a Ministerial exemption. The commercial industry has adopted a rotational fishing strategy for the main harvest species. In 2020, 3.7 t of sea cucumbers were harvested. This catch comprised 3.6 t of deep-water Redfish (*A. echinites*) and 0.1 t of black teatfish (*H. whitmaei*). The total annual catch of sea cucumbers in the WASCF has ranged between 0 and 252 t live weight from 2009 to 2018 (Hart and Murphy 2021). Customary fishing for sea cucumber is permitted, although catches are considered to be negligible. Reported catch for the WASCF from 2016 to 2020 in the vicinity of the Proposal is presented in Figure 12 (DPIRD 2021)

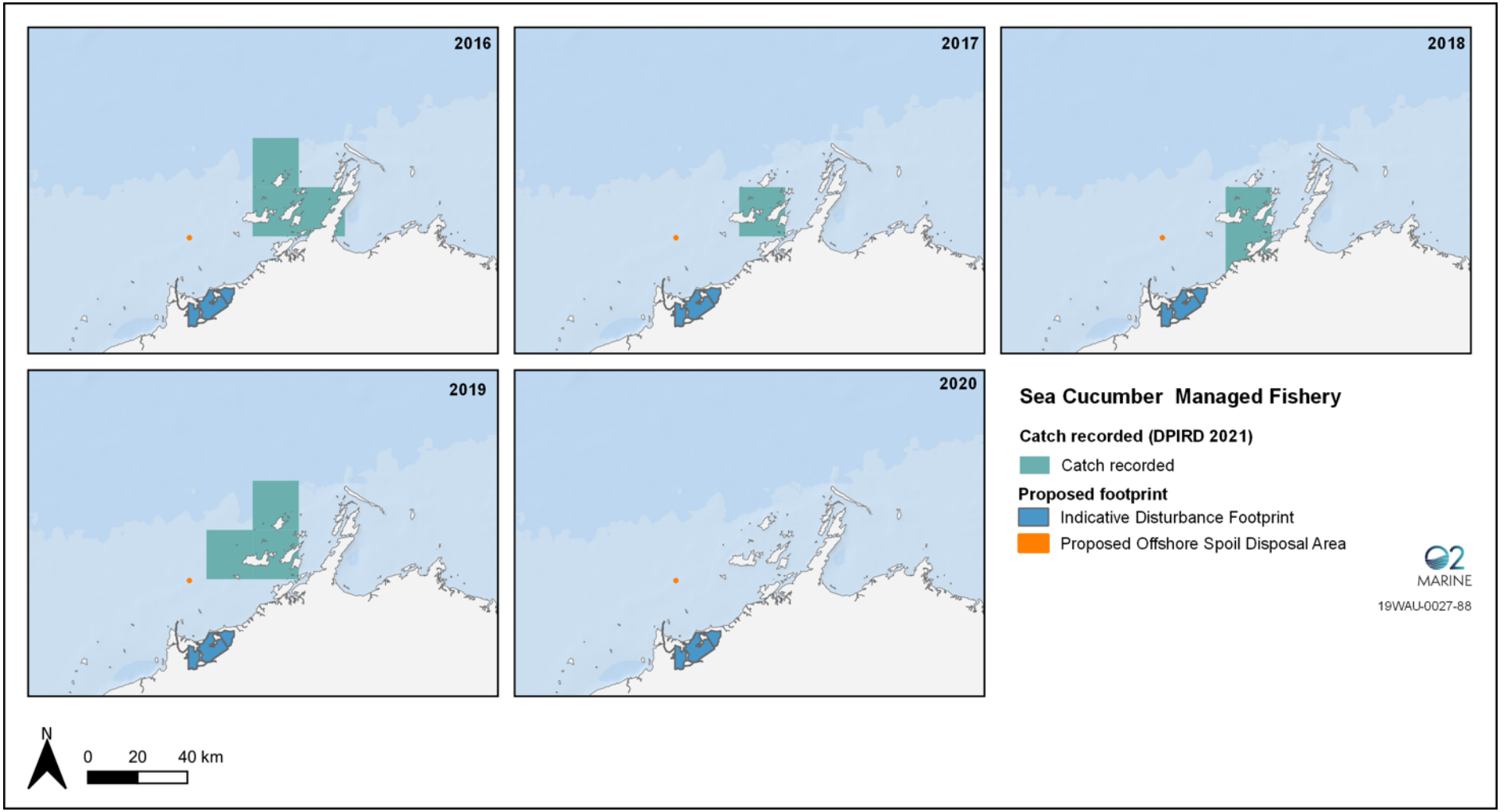


Figure 12 WASCF reported catch in the vicinity of the Proposal from 2016–2020 (DPIRD 2021).

## 4.7. Statewide Marine Aquarium Fish and Hermit Crab

The Statewide Marine Aquarium Fish and Hermit Crab Resource has two fisheries that operate within WA waters; the Marine Aquarium Fish Managed Fishery (MAFMF), and the Hermit Crab Fishery (HCF).

### 4.7.1. Commercial fisheries

The MAFMF and HCF supply the domestic and international markets with aquarium species, and the live pet trade. The MAFMF is State-wide, while the HCF is spread along the North Coast of WA. The HCF is one of only two-land based commercial fisheries in WA, with remote beaches typically accessed by four-wheel drive vehicle and on foot, and collections being made by hand only (Newman et al. 2021c).

#### Species

The MAFMF Resource potentially includes more than 1,500 species of marine aquarium fishes as well as coral, live rock, algae, seagrass, and invertebrates. In 2020, MAFMF fish catches were dominated by Vachell's Glassfish (*Ambassis vachellii*), Scribbled Angelfish (*Chaetodontoplus duboulayi*), Blue and Yellow Wrasse (*Anampses lennardi*), Margined Coralfish (*Chelmon marginalis*), Green Chromis (*Chromis cinerascens*) and Allen's Glidergoby (*Valenciennea alleni*), with nearly 250 other fish species and over 100 invertebrate species also reported. The HCF exclusively targets the Australian land hermit crab (*Coenobita variabilis*). Collection is by hand and other species are not taken (Newman et al. 2021c).

#### Area

The HCF operates under Ministerial Exemptions and is currently permitted to fish WA waters north of, and including, Exmouth Gulf (22°30'S,Figure 13).

The MAFMF operates in all State waters between the NT border and South Australian border. However, the fishery is more active in some areas than others, with waters surrounding Dampier being among the areas which experience higher reported catch (Figure 15).

#### Socio-economic value

The annual economic value of both the MAFMF and the HCF combined, is estimated to be between $1-5 million (Newman et al. 2021c).

#### Catch/Effort

In 2020 the MAFMF and the HCF combined had thirteen active licences. Twelve of the licences are acquired within the MAFMF. In 2020 the total catch was 89,925 fishes, 32.12 t of coral, live rock and living sand, and <20 L of marine plants and live feed. The HCF total catch was >75,000 crabs, which is within the range caught over the previous 10 years (58,000-106,000 crabs) (Newman et al. 2021c). The reported catch within the HCF from 2016 to 2020 are presented Figure 14 and for the MAFMF is presented in Figure 15 (DPRID 2021).

#### Stock status

Traditional stock assessments are not undertaken for the MAFMF due to the large number of species captured and the relatively low numbers per species. The level of harvest of the Australian land hermit crab in the HCF is low relative to the large area in which this species is distributed in WA. While a typical stock assessment has

not been conducted for this fishery, the breeding stocks of the Australian land hermit crab in the HCF are classified as sustainable-adequate (Newman et al. 2021c).

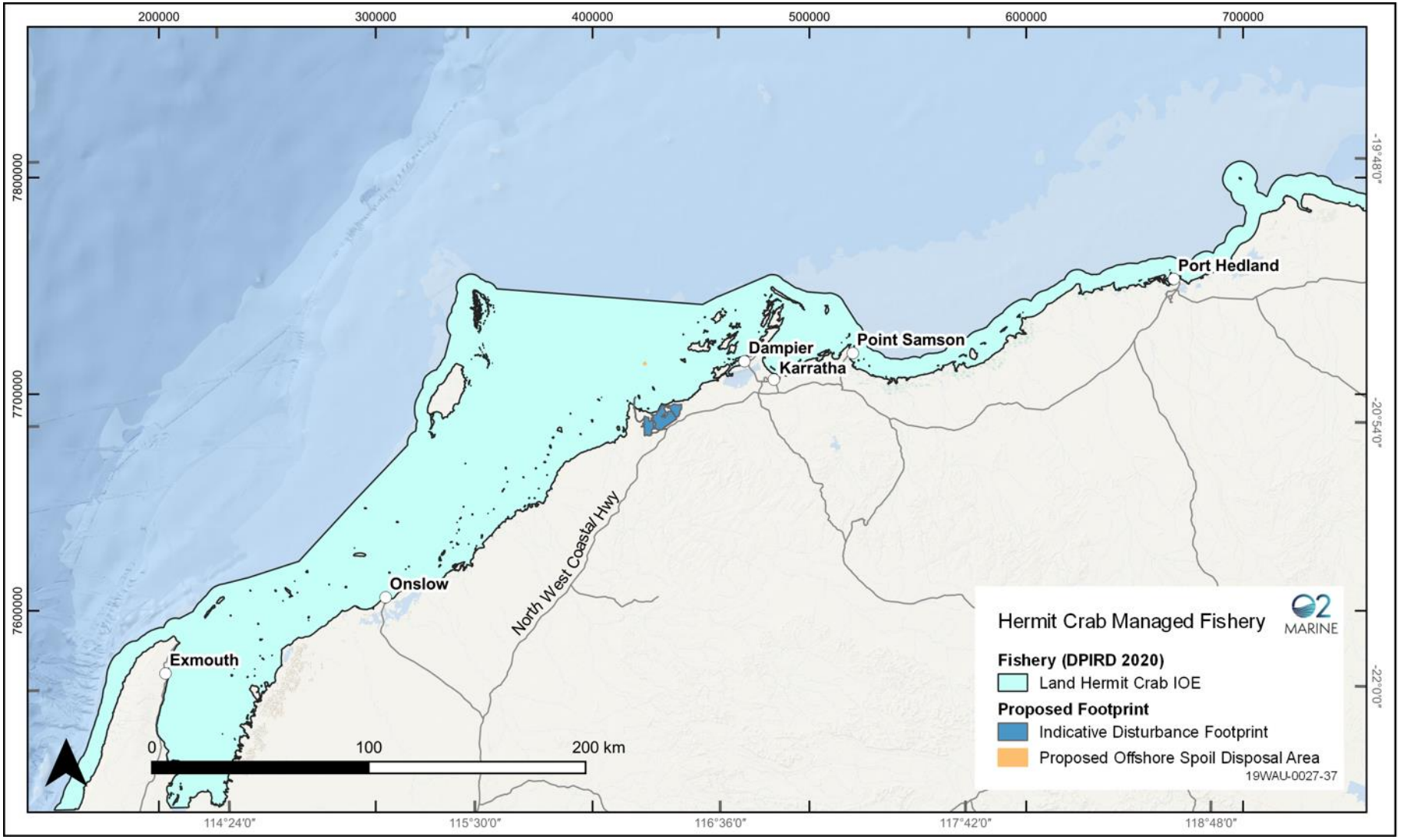


Figure 13 Hermit Crab Managed Fishery zones and fishing area.

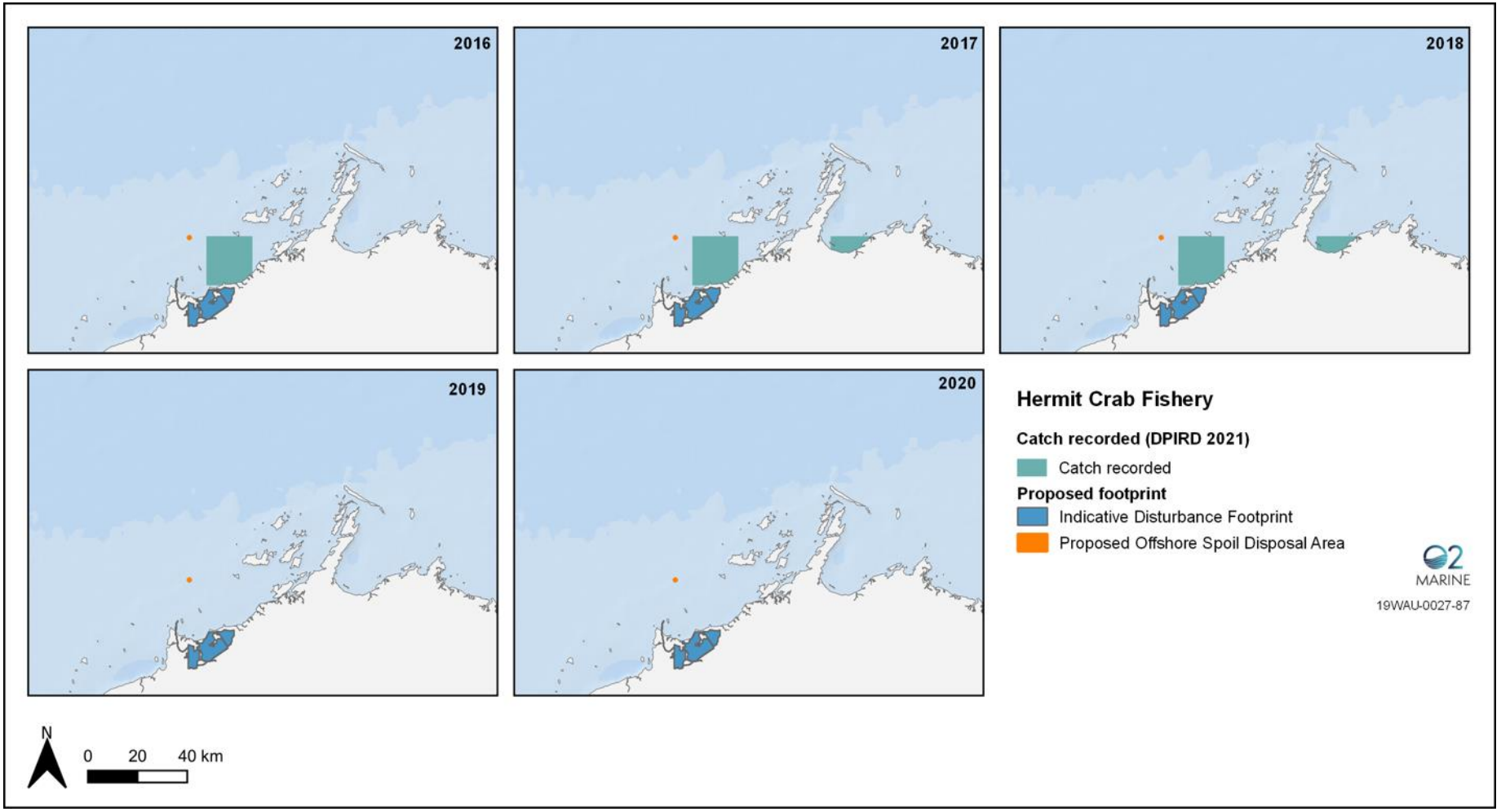


Figure 14 HCF reported catch in the vicinity of the Proposal from 2016–2020 (DPIRD 2021).

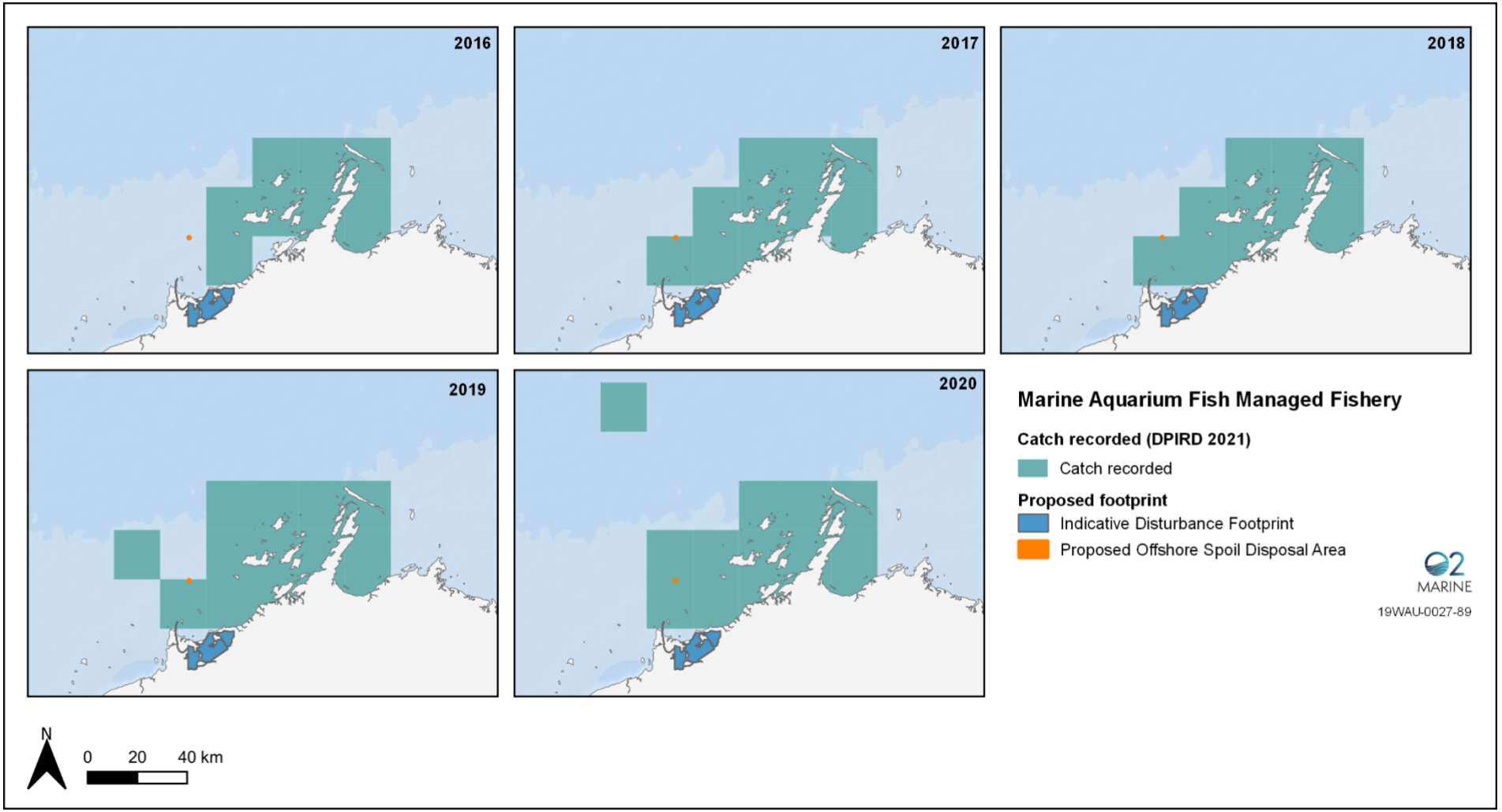


Figure 15 MAFMF reported catch in the vicinity of the Proposal from 2016–2020 (DPIRD 2021).

## 4.8. Pearl Oyster (*Pinctada. maxima*) Resource

The Pearl Oyster (*Pinctada maxima*) Resource manages the Pearl Oyster Wildstock Fishery (MSC). The WA pearl oyster fishery is the only remaining significant wild-stock fishery for pearl oysters in the world (Hart et al. 2021a).

### 4.8.1. Commercial fisheries

The WA pearl oyster fishery operates in shallow coastal waters along the North Coast Bioregion and targets the silver lipped oyster (*P. maxima*). The dive-based fishery is divided into three management zones, with the Proposal falling within Zone 1. No fishing occurred in Zone 1 from 2017 to 2020, and relatively low catches were reported in 2016 (Figure 16). Collection of wild-stock pearl oysters has reduced over the years, with an increased reliance on hatchery-produced pearl oysters (Hart et al. 2021a).

#### Species

The target and indicator species of the fishery is the silver-lipped pearl oyster. As the principal and only harvest strategy is collection by divers, no other species are caught or retained (Hart et al. 2021a). The present-day fishery focusses on the collection of smaller pearl oysters (100 to 175 mm shell length) that are optimal for pearl culture. In addition to the collection of pearl oysters for culture purposes, the harvest of a specific number of pearl oysters larger than 175 mm shell length was permitted following an exceptional settlement event in 2005. This has allowed the industry to increase the production efficiency of Mother of Pearl and pearl oyster meat (Hart et al. 2016).

#### Area

The pearl oyster fishery boundaries encompass the northern coastal waters from North West Cape (114° 10' E longitude), including Exmouth Gulf, north-east to the NT border. Three management zones exist within this area where harvesting of wild stock is permitted (Hart et al. 2021a). The Proposal falls within Zone 1, which extends from the Cape Range to a location 45 km west of Port Hedland (Figure 16).

#### Socio-economic value

The number of vessels in the fishing fleet has been slowly reducing from the peak of sixteen in 1997. In 2020, five vessels operated across all zones. Most vessels presently operate 10 to 14 crew for the fishing of pearl oysters between March and August each year. These vessels also support pearl oyster operations and several other pearl oyster farm functions throughout the year. Personnel employed in the pearling industry and current full-time employees is estimated to be around three hundred. Fishing for pearl oyster in WA has been occurring since 1850 and it comprises an important part of the maritime history of many coastal towns in the north-west of WA. By 1910 there were nearly 400 luggers and 3500 people in the pearling industry. At its peak, around 2000 tonnes (approximately 2 million pearl oysters) were harvested annually, supplying up to 75% of global mother of pearl demand (Hart et al. 2021a).

A large proportion of pearls are sold to overseas markets. Fluctuations in the value of the Australian dollar and other macroeconomic factors can have a large influence on the industry. For example, the pearling industry suffered a major economic downturn from the Global Financial Crisis in 2008, which had an impact on luxury goods including pearls (Hart et al. 2021a).

### Catch/Effort

The fishery is managed primarily through output controls in the form of a Total Allowable Commercial Catch (TAC) that is divided into Individual Transferable Quotas (ITQs). There are 572 total quota units, across management Zones 1 to 3 (Hart et al. 2021a). One quota unit equates to a particular number of pearl oysters and varies from year to year. Operators must hold a licence, and Pearling (wild stock) licence holders are required to hold a minimum of 15 quota units. Most of the fishing effort is focussed in Zones 2 and 3, away from the Proposal area (Figure 16). While catch does vary year-to-year, in 2020 the total catch across all zones was 455,980 shells harvested across 7,942 dive hours. In Zone 1, no pearl oysters were taken from 2017 to 2020, with only 4,594 culture shells taken in 2016. Both the catch and effort levels were determined to be acceptable. The reduced catch and effort were due to COVID-19 related issues (Hart et al. 2021a).

### Stock status

The TAC is set annually through a consultative process with DPIRD and is generally proportionate to overall stock abundance. In 2020, the overall TAC for all zones was 786,170 pearl oysters, with 455,980 harvested overall. The stock status of the resource is determined individually for each zone, with Zone 1 determined to be sustainable-adequate. The Zone 1 TAC is 54,970 pearl oysters, with none harvested overall from 2017 to 2020 (Hart et al. 2021a).

## 4.8.2. Recreational

There is no authorised recreational fishing of the South Sea pearl oyster under the *Pearling Act 1990* (DPIRD 2022).

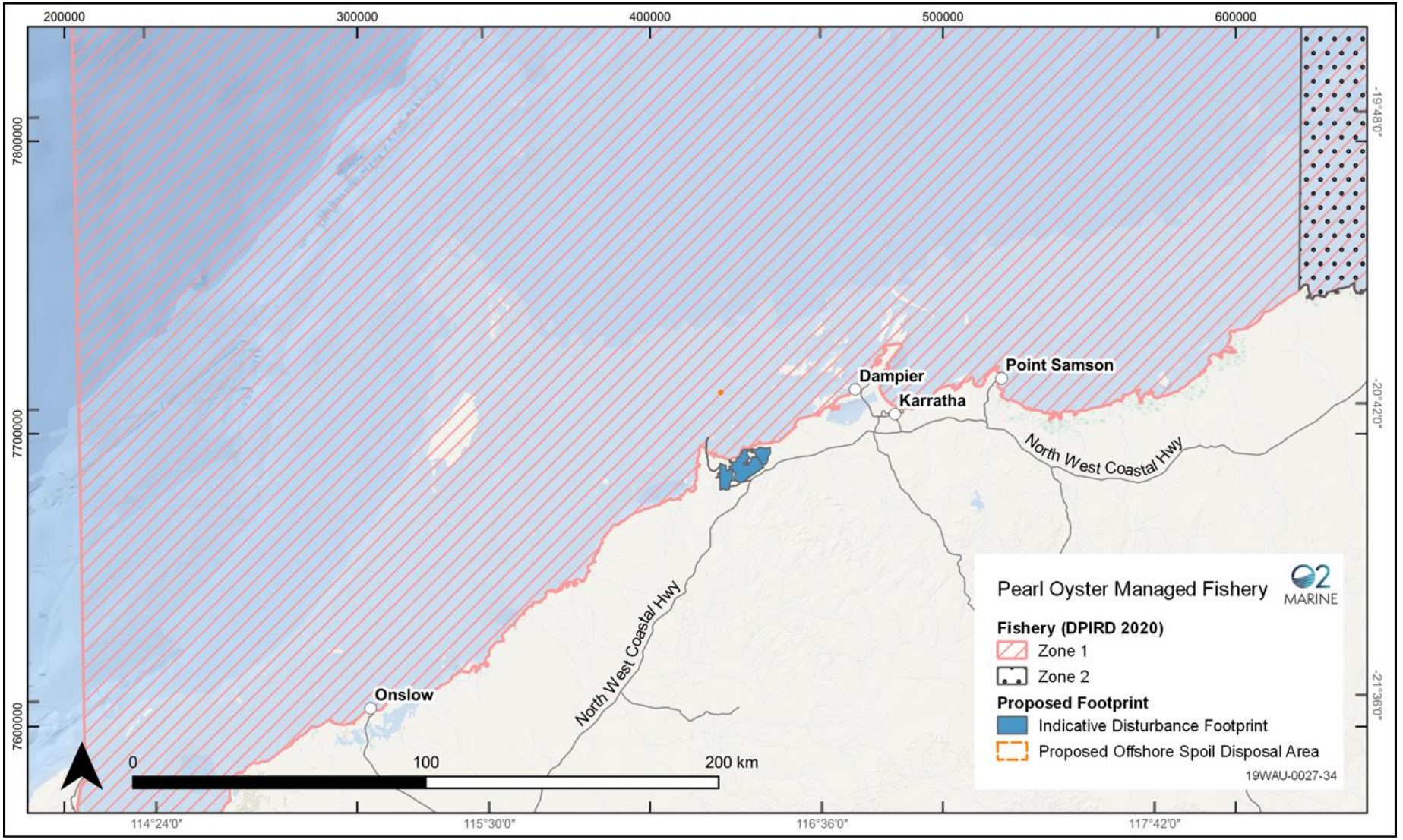


Figure 16 Pearl Oyster Managed Fishery zones and fishing areas.

## 4.9. Statewide Specimen Shell Resource

The Statewide Specimen Shell Resource manages the commercial Specimen Shell Managed Fishery (SSMF).

### 4.9.1. Commercial fisheries

The SSMF is based on the collection of individual shells for the purposes of display, collection, cataloguing, classification, and sale. The main methods are via hand collection by small groups of divers operating from small boats in shallow coastal waters, by wading along coastal beaches below the high-water mark, and using remotely operated underwater vehicles (Hart et al. 2021b).

#### Species

About 200 species of specimen shells are collected each year, although, in the past 5 years, more than 430 different species of molluscs have been collected. There is some focus of effort on mollusc families that are the most popular with shell collectors, such as cowries, cones, murexes, and volutes. Cypraeidae or cowries are known for their localised variations in both shape and colour, making them attractive to collectors (Hart et al. 2021b).

#### Area

While the fishery covers the entire WA coastline, there are areas of concentrated effort adjacent to population centres such as Broome, Exmouth, Shark Bay, Geraldton, Perth, Mandurah, the Capes area, Albany, and Esperance (Hart et al. 2021b). Figure 17 shows the area where commercial catch has been recorded for the SSMF from 2016 to 2020 in the vicinity of the Proposal (DPIRD 2021).

#### Socio-economic value

In 2020, only ~5 licences recorded consistent fishing activity, and ~16 people operated occasionally in the fishery. There are approximately 12 people are employed through the SSMF. Estimated annual economic value of this fishery is currently not assessed (Hart et al. 2021b).

#### Catch/Effort

The SSMF allows for a maximum of 30 active licences, which allows for 4 divers in the water at any time. Shell specimens are only allowed to be collected by hand or by the use of remotely operated underwater vehicles. In 2020, the total number of specimen shells collected was 4,258 distributed over 206 species. Of the 30 licences in the fishery, 15 fished in 2020. The total number of fished days in 2020 was 375, which is 85 days less than 2019, and below the annual average of ~546 days (Hart et al. 2021b).

#### Stock status

While some species have been determined to be vulnerable to over-exploitation, the breeding stocks of landed species are classified as sustainable-adequate (Hart et al. 2021b).

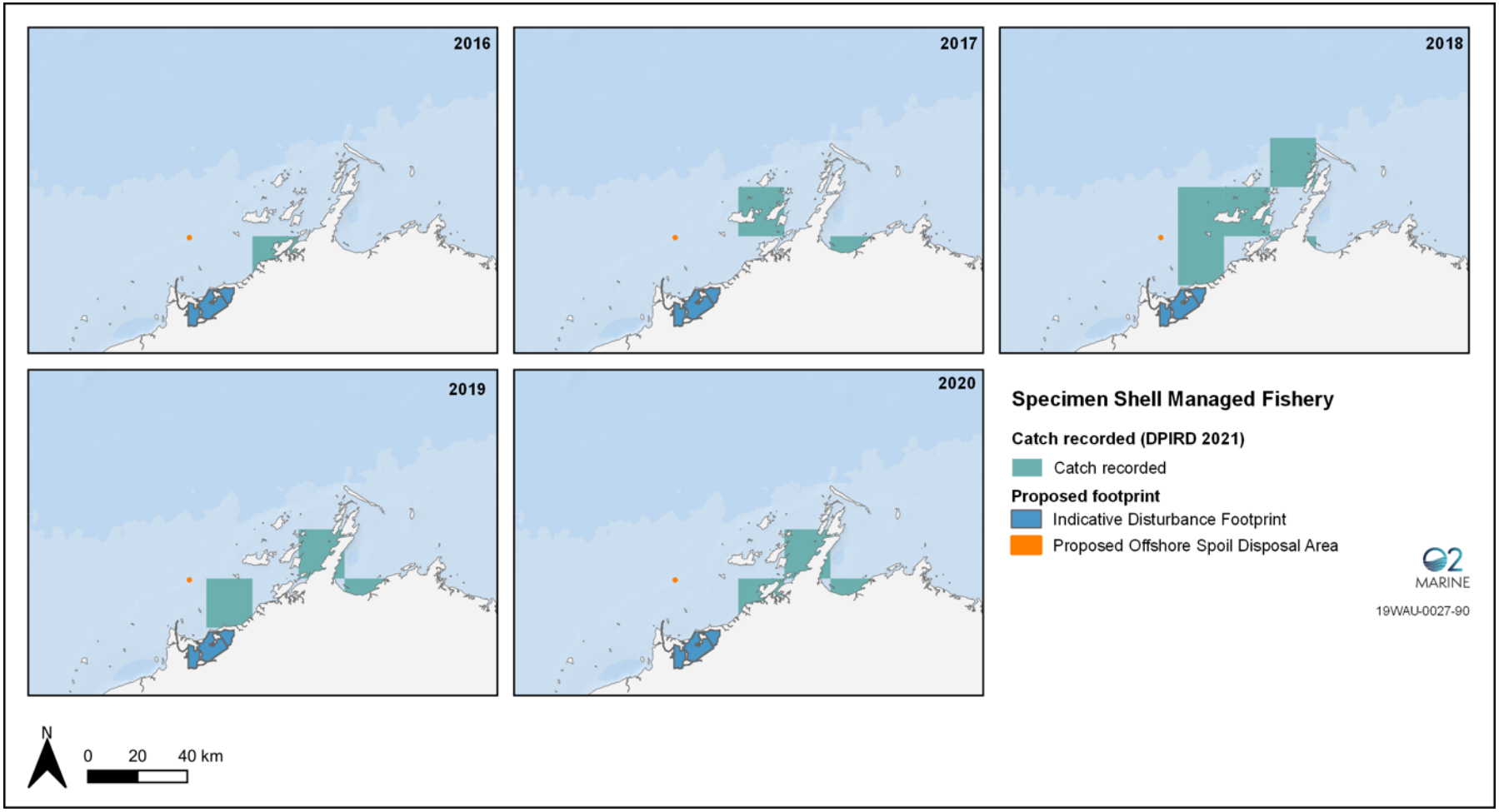


Figure 17 SSMF reported catch in the vicinity of the Proposal from 2016–2020 (DPIRD 2021).

## 4.10. Federal fisheries

The following Federally managed fisheries have fishing grounds (legally permitted to fish) in offshore waters adjacent to the Proposal, however, fishing effort is spread across a large area. The area adjacent to the Proposal is not known to be particularly important for these fisheries, as these fisheries predominantly target species in the continental shelf waters out to 200 nautical miles offshore. The Federal fisheries present in the broader area include:

- North West Slope Trawl Fishery;
- Western Skipjack Tuna Fishery;
- Southern Bluefin Tuna Fishery; and
- Western Tuna and Billfish Fishery.

The North West Slope Trawl Fishery operates from 114°E to about 125°E off the Western Australian coast between the 200 m isobath and the outer limit of the Australian Fishing Zone (AFZ) (AFMA 2012). Therefore, this fishery operates outside the Proposal area.

The Western Skipjack Fishery covers all waters around WA out to 200 nm from the coast. The fishery is currently not active and has not been fished since 2008/09, with no Australian boats currently fishing in WA or Australian waters (AFMA n.d. a).

The Southern Bluefin Tuna Fishery covers all waters around Australia out to 200 nm from the coast. The target species of this fishery is the southern bluefin tuna, which is caught in southern and eastern Australia, and is not targeted within WA waters. There is no fishing of the southern bluefin tuna as part of the Southern Bluefin Tuna Fishery in WA waters (AFMA n.d. b). The WA waters are the migratory pathway for the species, which is discussed in the Conservation Significant Marine Fauna Desktop Study (O2 Marine 2023b) and has been deemed to have a 'low' likelihood of occurrence within the Proposal area.

The Western Tuna and Billfish Fishery operates west from the tip of Cape York in QLD, around WA, to the border between Victoria and South Australia (SA) (AFMA n.d. c). The fishery targets the bigeye tuna (*Thunnus obesus*), yellowfin tuna (*Thunnus albacares*), broadbill swordfish (*Xiphias gladius*), and the striped marlin (*Tetrapturus audux*). These target species are pelagic, found in depths greater than 250 m. Commercial fishing of these species does not occur within the Proposal area (Figure 18; Figure 19; Figure 20). The fisheries predominantly use pelagic longline gear to catch the target species; this fishing method would not occur within the Proposal area as the waters are too shallow.

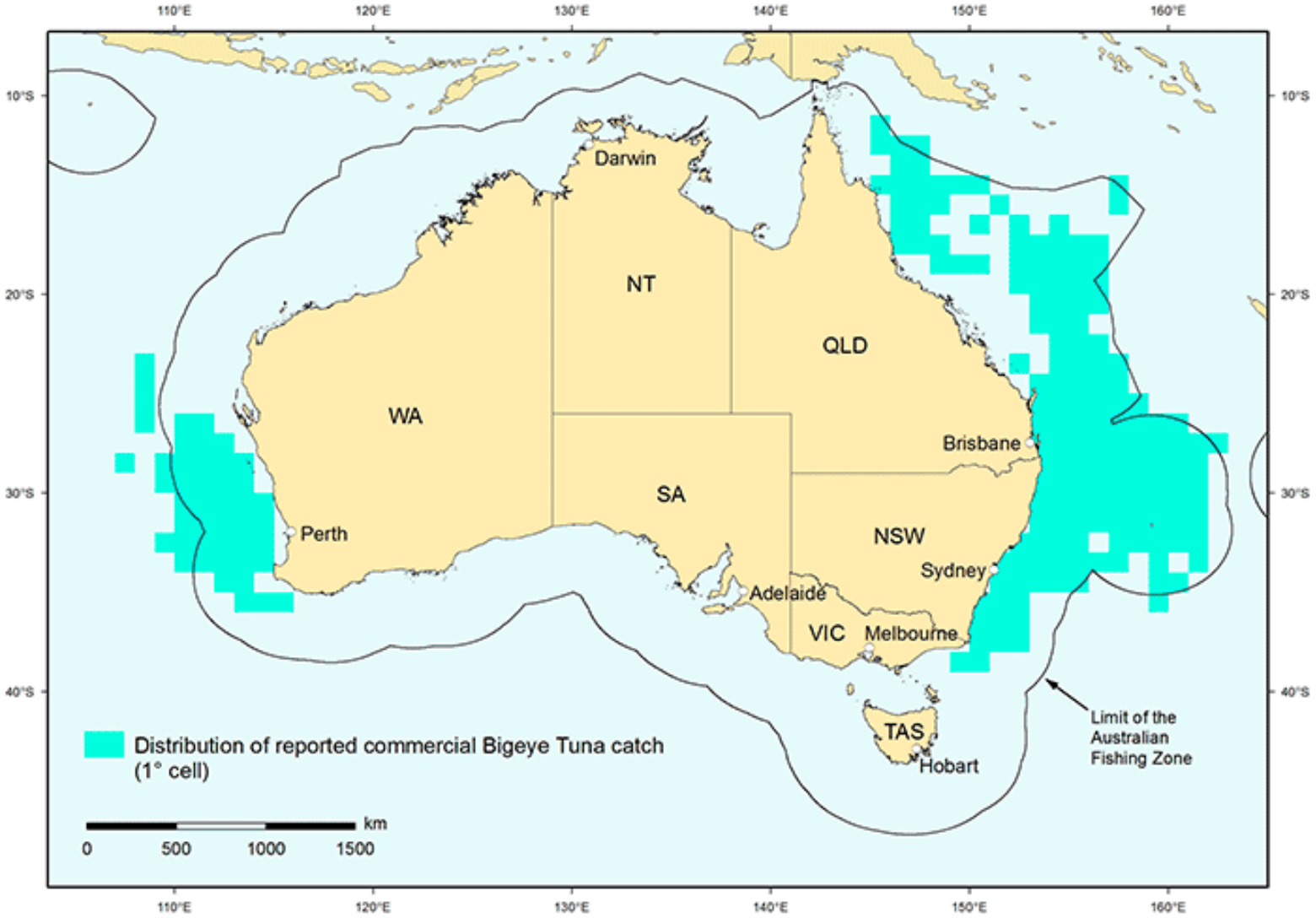


Figure 18 Reported commercial catch for bigeye tuna (AFMA n.d. c)

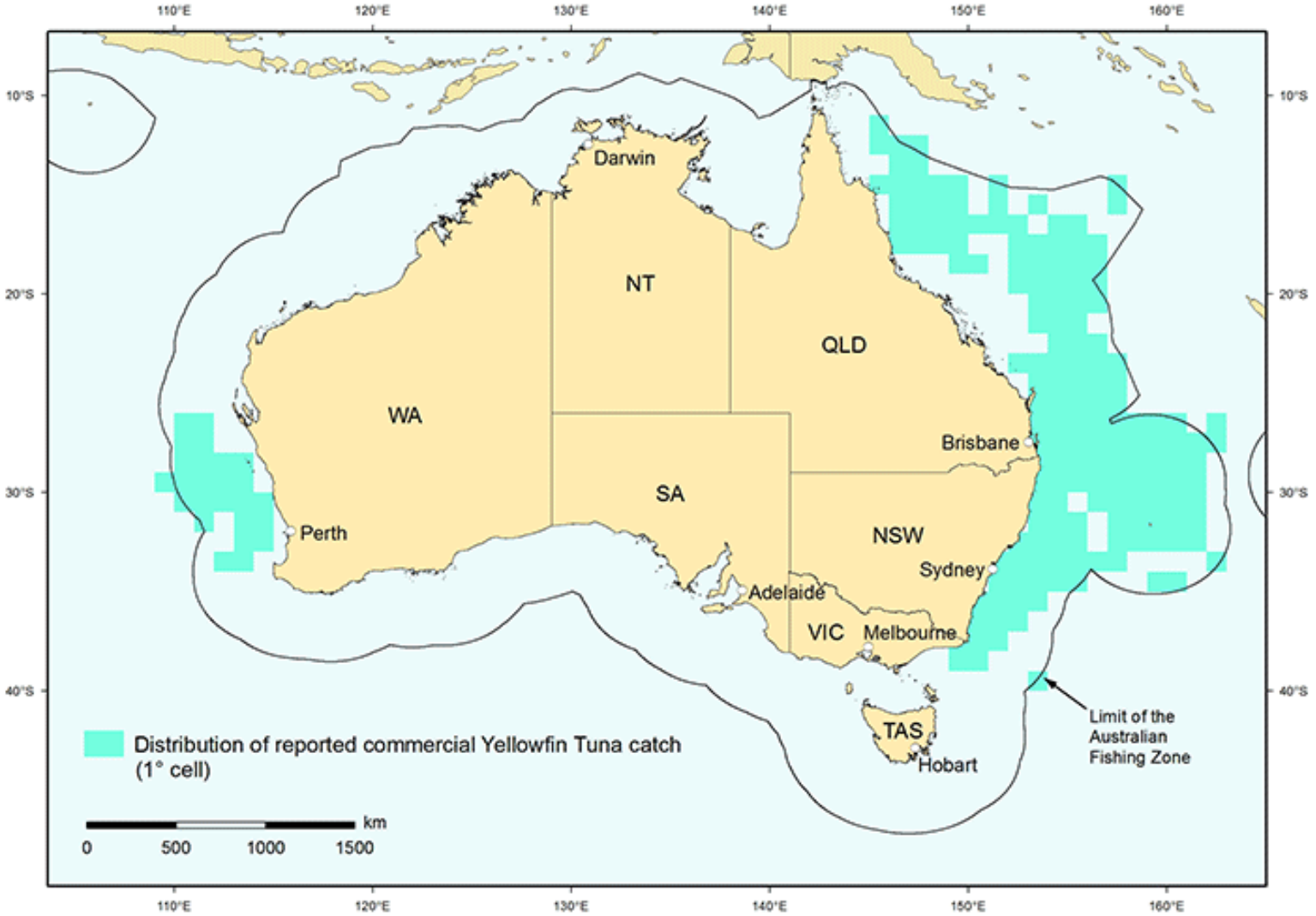


Figure 19 Reported commercial catch for yellowfin tuna (AFMA n.d. d)

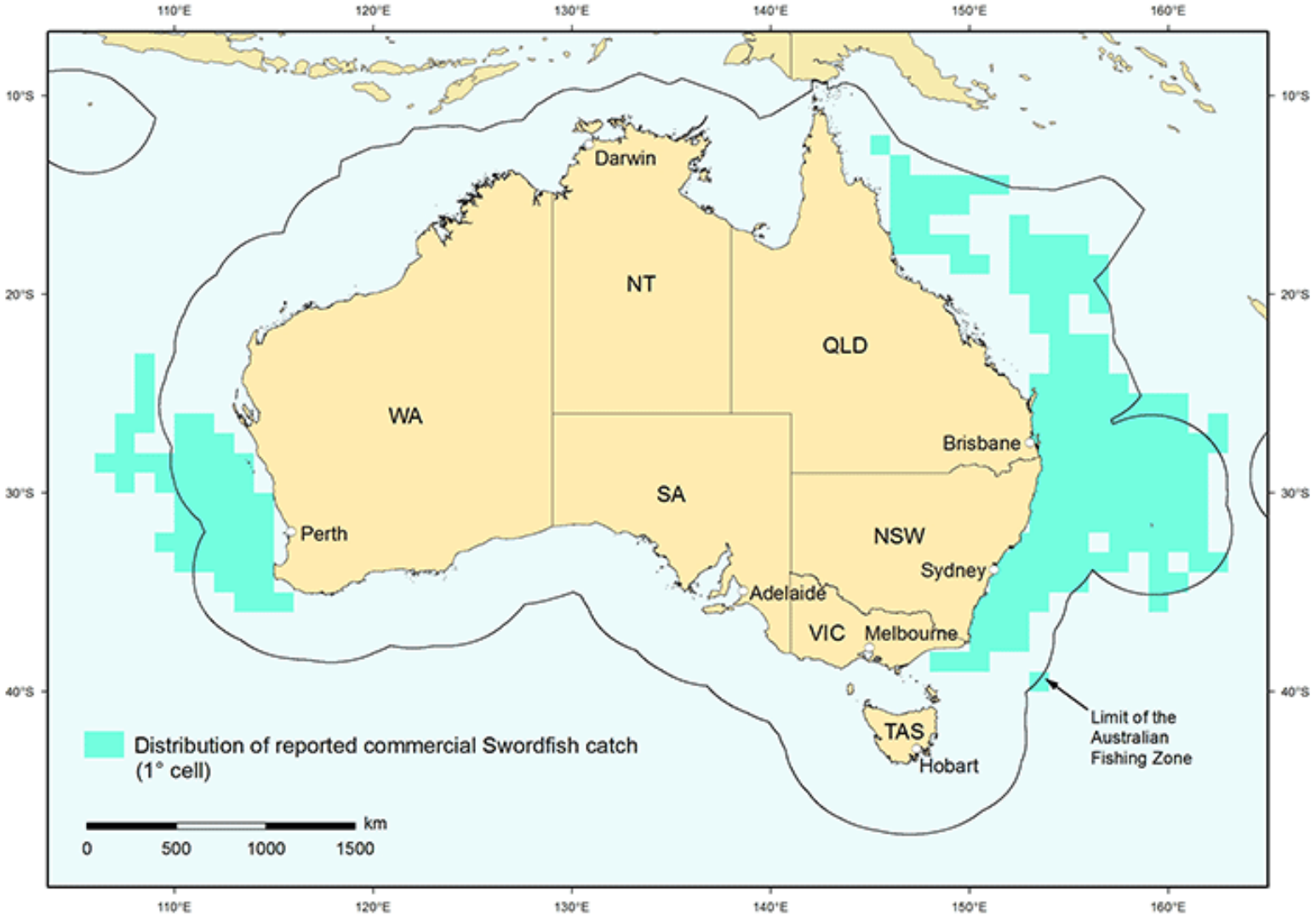


Figure 20 Reported commercial catch for swordfish (AFMA n.d e)

# 5. Indicator and key species

Within each aquatic resource, the fisheries stock assessments are challenging due to multi-species targeted within the Resource. To assess the stock of the fishery indicator species have been identified (Table 6) and are used to assess the status of the entire fishery. Indicator species are selected by DPIRD based on their vulnerability to over-fishing, whether they are target species for major fisheries, their value to the community, and their overall economic, recreational, and cultural value (Newman et al. 2021a). The indicator species are used by DPIRD to evaluate the status of the aquatic resource. Each year DPIRD assesses the indicator species annual catch and/or catch rate trends (Strain et al. 2021). This approach allows a proportional management response to be implemented for any predicted impacts. Furthermore, the identified key species are also effectively 'umbrella' species – when they are protected, others will be indirectly protected. The aquatic resources outlined in Table 5 include twelve indicator species that occur within the vicinity of the Proposal, namely:

- Bluespotted emperor (*Lethrinus punctulatus*);
- Red emperor (*Lutjanus sebae*);
- Rankin cod (*Epinephelus multinotatus*);
- Narrow-barred Spanish mackerel (*Scomberomorus commerson*);
- Grey mackerel (*Scomberomorus semifasciatus*);
- Western king prawn (*Penaeus latisulcatus*);
- Brown tiger prawn (*Penaeus esculentus*);
- Silver-lipped pearl oyster (*Pinctada maxima*);
- Blue swimmer crab (*Portunus armatus*);
- Australian land hermit crab (*Coenobita variabilis*);
- Sandfish (sea cucumber) (*Holothuria scabra*); and
- Redfish (sea cucumber) (*Actinopyga echinites*).

The ruby snapper has been excluded from the relevant indicator species list as it is found further offshore in depths greater than 150 m. The crystal crab also is found and fished further offshore from the Proposal area at depths of >150 m. Goldband snapper, Banana prawn and Samson fish are all indicator species for fisheries, which occur well outside the Proposal area.

Details on each of the above key species population/stock status, distribution, habitat, and life history are provided below. Table  shows the fisheries (commercial, recreational, and customary) that overlap with the Proposal area, and the indicator species selected for each fishery.

Table 6 Key Indicator species and fisheries that occur within the vicinity of the Proposal.

Blue=commercial, Green= customary fishing of species, Orange= recreational fishing of species

| Species | Pilbara Fish Trawl (Interim) Managed Fishery | Pilbara Demersal Trap Managed Fishery | Pilbara Line Fishery | Mackerel Managed Fishery | Onslow Prawn Managed Fishery | Pilbara Crab Managed Fishery (PCMF) | Pearl Oyster Wildstock Fishery (MSC) | Hermit Crab Fishery (HCF) | Western Australian Sea Cucumber Fishery (MSC) |
|---|---|---|---|---|---|---|---|---|---|
| Bluespotted emperor | | | | | | | | | |
| Red emperor | | | | | | | | | |
| Rankin cod | | | | | | | | | |
| Narrow-barred Spanish mackerel | | | | | | | | | |
| Grey mackerel | | | | | | | | | |
| Western king prawn | | | | | | | | | |
| Brown tiger prawn | | | | | | | | | |
| South Sea pearl oyster | | | | | | | | | |
| Blue swimmer crab | | | | | | | | | |

| Species | Pilbara Fish Trawl (Interim) Managed Fishery | Pilbara Demersal Trap Managed Fishery | Pilbara Line Fishery | Mackerel Managed Fishery | Onslow Prawn Managed Fishery | Pilbara Crab Managed Fishery (PCMF) | Pearl Oyster Wildstock Fishery (MSC) | Hermit Crab Fishery (HCF) | Western Australian Sea Cucumber Fishery (MSC) |
|---|---|---|---|---|---|---|---|---|---|
| Australian land hermit crab | | | | | | | | | |
| Sandfish | | | | | | | | | |
| Redfish | | | | | | | | | |

## 5.1. Bluespotted emperor

### Population

The bluespotted emperor (*L. punctulatus*) is endemic to north-western Australia (NWA). There is little genetic variation between the bluespotted emperor along the NWA coastline, suggesting connectivity between the populations. Although the juvenile and adult bluespotted emperors display restricted movements, the larvae have the ability to disperse long distances, allowing gene flow throughout the NWA population (Johnson et al. 1993).

### Distribution

Bluespotted emperors are, found in the waters off WA from Geraldton to the Kimberley region, with some occurrences in the NT. The species is predominantly distributed within the waters of WA. The Pilbara region of NWA has the highest relative abundance of the bluespotted emperor, with commercial catch of this species concentrated across the continental shelf from 115°E to 120°E, being a major component of the catch of the Pilbara Fish Trawl Fishery (Newman et al. 2004).

Spawning and nursery areas are thought to be restricted to the west Pilbara, being the area from which species disperse more widely (Newman et al. 2020). No differences in biomass or abundance were found between the targeted fisheries closure (TFC) areas and the broader NWA shelf, which is high overall (Langlois et al. 2021).

### Habitat and life history

Juvenile bluespotted emperors are found to be intimately associated with inshore macroalgae beds, often in water depths less than 10 m (DPIRD Draft Report, *unpublished*). Two cohorts per year are recruited in the inshore macroalgae beds in the Dampier Archipelago, with the biannual recruitment corresponding with the biannual peaks in spawning. The bluespotted emperor's juvenile habitat is extensive across the intertidal BCH extending from Dampier to Cape Preston. The juvenile phase of the bluespotted emperor is directly associated with macroalgae. As the juveniles increase in size and age, they undergo an ontogenetic shift and move further offshore across the shelf. Adults are typically found in depths of 80 to 150 m. Adult bluespotted emperors in the western Pilbara have high abundance in the continental shelf waters adjacent to large expanses of inshore macroalgae beds. The adults are also found in coral reef or lagoon habitats, over hard coral, gravel, or rubble substrates. Stereo-BRUV surveys of the bluespotted emperor have shown that adult abundance is highest during daylight hours and decreases e with increasing depths (Harvey et al. 2021). The species are generally carnivorous bottom feeders, they feed on other finfish species and invertebrates.

Bluespotted emperors are functional gonochoric broadcast spawners, therefore the eggs and larval stages of the species are pelagic. Spawning occurs through the Pilbara from June to April, with peak spawning occurring from July to October and March (DPIRD Draft Report, *unpublished*). Bluespotted emperors are a relatively short-lived species, reaching sexual maturity at 206 mm fork length (FL) for females and 223 mm FL for males, which generally takes 18 months. They can grow up to 384 mm FL and live up to 16 years (Newman et al. 2021d; DPIRD Draft Report, *unpublished*).

### 5.1.1. Commercial catch

The bluespotted emperor is an indicator species within the Northern Demersal Scalefish Resource and is an indicator for the four fisheries that operate within the resource: NDSMF, PFTIMF, PTMF and PLF. Of these fisheries, the PFTIMF, PTMF and PLF operate within the vicinity of the Proposal. The bluespotted emperor is predominately fished by the PFTIMF and PTMF (Newman et al. 2021b). Section 4.2 discusses in more detail the fisheries within the Northern Demersal Scalefish Resource.

The commercial catch for the bluespotted emperor for the 2018/19 financial year was 463.22 t (Newman et al. 2021d). The commercial fisheries that target the bluespotted emperor operate offshore of the Proposal, but there is some overlap between important nursery habitat and the nearshore development envelope. The presence of the bluespotted emperor caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 21. The current stock status for the bluespotted emperor in the Pilbara is currently considered to be sustainable.

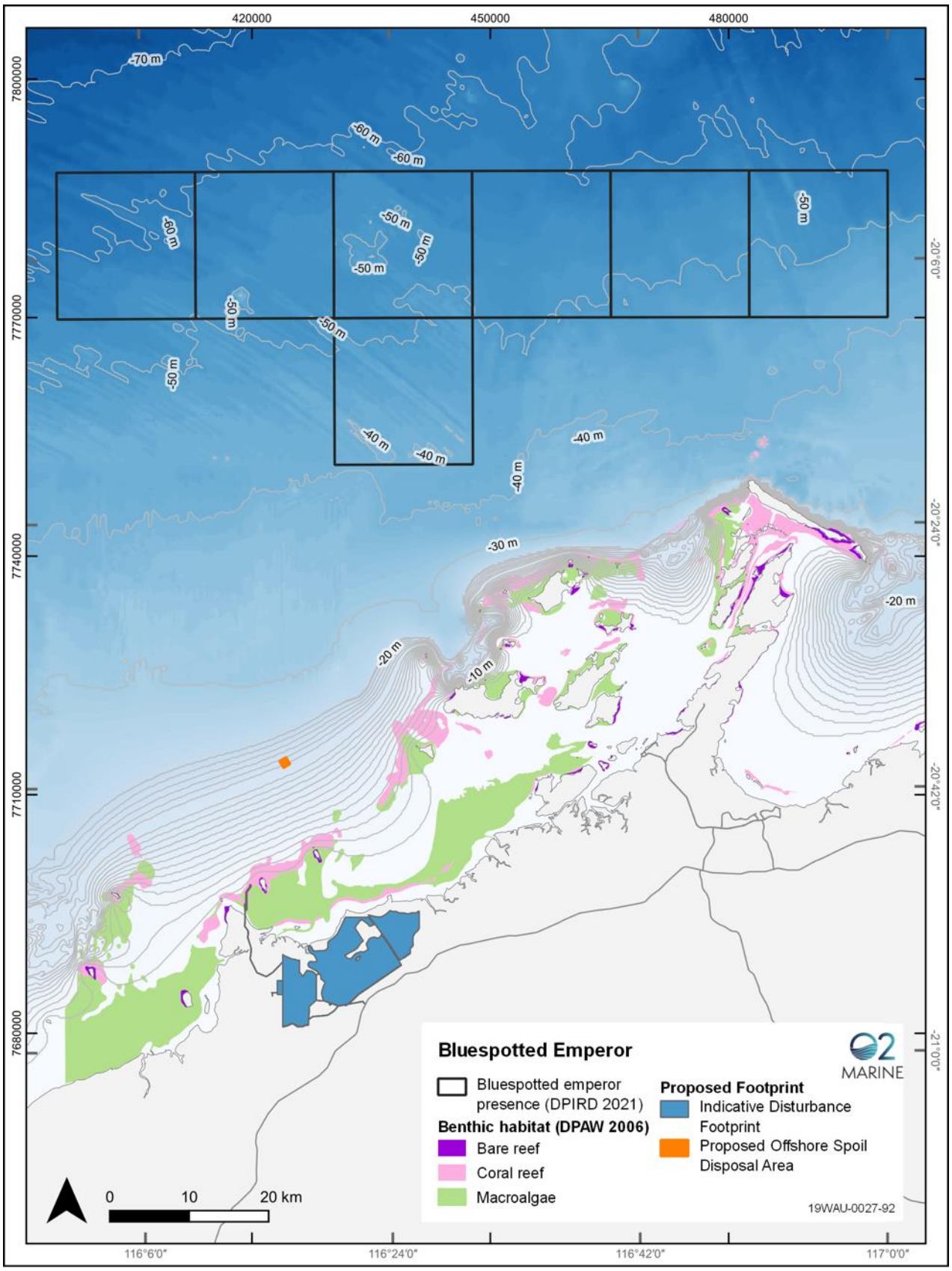


Figure 21 Bluespotted emperor presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021).

### 5.1.2. Recreational catch

The bluespotted emperor is caught by recreational fishers throughout the North Coast and Gascoyne bioregions, with nearly all recreational catches being released (74%, from the 2020/21 survey). Recreational catch survey results showed bluespotted emperors caught by recreational fishing were mainly taken from the inshore and nearshore areas using line fishing methods. Bluespotted emperors are harvested by recreational fishers throughout the year, the highest number of catches in spring months for 2020/21 (Ryan et al. 2022), which varied from the 2018/19 results where peak catches were reported in winter months (Ryan et al. 2019). The results from the 2020/21 survey found that the estimated recreational kept and released catches were similar to the previous recreational surveys. The recreational catch estimate for the bluespotted emperor has high uncertainty (Ryan et al. 2019). There was insufficient data to assess the total recreational catchweight of the bluespotted emperor for the financial year (Newman et al. 2021d).

### 5.1.3. Charter catch

The charter catches for the bluespotted emperor for the 2018/19 finical year was < 0.5 t (Newman et al. 2021d).

## 5.2. Red emperor

#### Population

The red emperor (*L. sebae*) populations along the NWA coastline display little genetic variation, with no clear evidence for different geographical populations (Johnson et al. 1993). However, stable isotope analysis results from individuals at Shark Bay, Ningaloo, Pilbara and Broome were significantly different, which suggests separate stocks along the NWA coastline with limited mixing of juvenile and adult populations (Stephenson et al. 2001). The genetic homogeneity of the species is suggested to be maintained by the dispersal of pelagic eggs and larvae stages along the NWA coastline (DPIRD Draft Report, *unpublished*).

#### Distribution

Red emperors are widely distributed throughout the Western Pacific and Indian Ocean. Throughout Australia they range from Sydney in NSW around the north coast to Cape Naturaliste in WA (DPIRD Draft Report, *unpublished*). Red emperors were found to have greater abundance within the TFC compared to other areas of the NWA coast (Langlois et al. 2021).

#### Habitat and life history

Juvenile red emperors (<20 cm) inhabit nearshore environments, typically in turbid waters, and have also been found further offshore in reef structures. As the juveniles mature and grow, they disperse into deeper waters across the continental shelf. Sub-adult red emperors (20–40 cm) are distributed across the continental shelf (DPIRD Draft Report, *unpublished*). Adult red emperors are found in water depths of up to 180 m, generally found across the shelf in mid-shelf depths (50–110 m depth), and are often associated with reefs, limestone, and gravel substrates, and also rarely can be found within lagoons (DPIRD Draft Report, *unpublished*). Adult red emperors can be found either solitary or in schools.

Red emperors are long-lived and slow-growing, with a lifespan of up 40 years and a maximum length of 80.4 cm. Sexual maturity for females can take 8 to10 years, when they reach a FL of 43 cm, males take 8 years and reach sexual maturity when they reach 46 cm FL. The species is a broadcast spawning fish, spawning is opportunistic with spawning occurring for 10 months of the year, with peaks observed in October and March (DPIRD Draft Report, *unpublished*). Stereo-BRUV analysis of the species found that the highest abundance was during daylight hours (Harvey et al. 2021). The red emperor diet comprises mainly bottom-dwelling fish, benthic crustaceans, and cephalopods, which are typically consumed at night (Allen 1985).

### 5.2.1. Commercial catch

The red emperor is an indicator species within the Northern Demersal Scalefish Resource, including the NDSMF, PFTIMF, PTMF and the PLF. Of these fisheries, only the PFTIMF, PTMF and the PLF operate within the vicinity of the Proposal. Section 4.2 discusses the Northern Demersal Scalefish Resource in more detail. In the 2018/19 financial year the total commercial catch of red emperor in the Pilbara was 223.31 t, and for all of WA was 415.50 t (Newman et al. 2021b, e). The fisheries that target the red emperor operate offshore of the Proposal. The presence of the red emperor caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 22.

The major performance measures for the red emperor as an indicator species for the Pilbara fisheries are the species' spawning stock levels, and fishing mortality estimates. The spawning threshold level is 40% spawning in the unfished biomass. The assessment model indicates that the spawning biomass for the red emperor is above the threshold. In the 2015 assessment, it was found that fishing was impacting the age structure of the red emperor population in some management areas. The PFTIMF trawl effort was reduced in 2008 as a result of relatively high levels of red emperor fishing mortality and declining catch rates. The current fishing levels in the Pilbara are unlikely to impair recruitment, and therefore the red emperor Pilbara stock management unit is considered to be stable (Newman et al. 2021e).

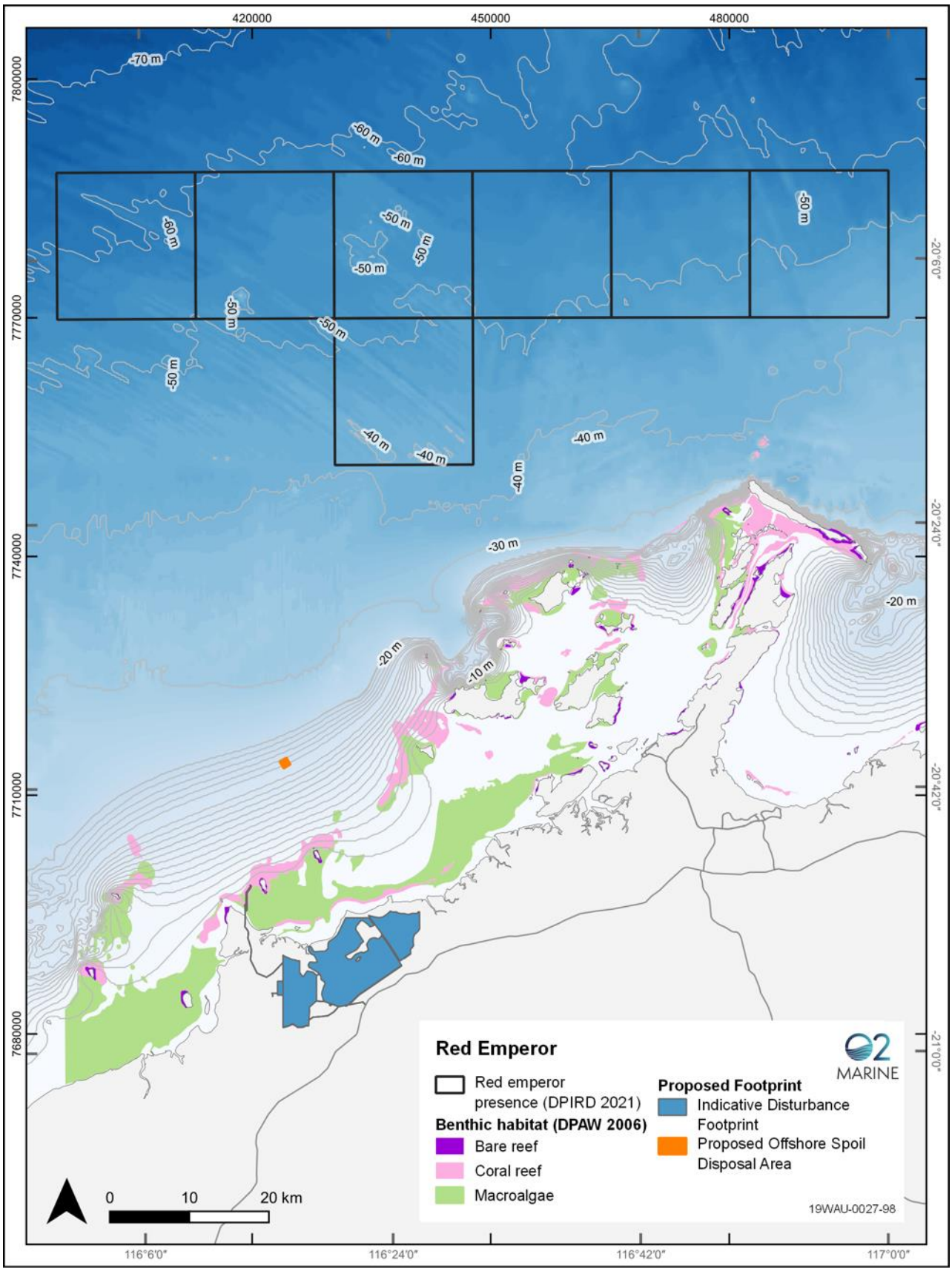


Figure 22 Red emperor presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021).

### 5.2.2. Recreational catch

Most of the recreational catches for the red emperor occur throughout the North Coast and Gascoyne bioregions, with small amounts of recreational fishing recorded in the West Coast bioregion. Majority of the recreational catches occurred inshore or nearshore, with a small amount recorded in the pelagic and offshore environments (Ryan et al. 2022). Line fishing was the dominant method to catch red emperor, with a small amount caught via diving. Results from the DPIRD survey show winter had the highest catch rates for the red emperor, but catches were recorded year-round. Similar proportions of the recreational catch were kept and released numbers for the red emperor across the five recreational surveys DPIRD has completed. The 2020/21 survey results for amount kept and released were similar with 46% released (Ryan et al. 2022). In the 2017/18 financial year the total recreational catch for the red emperor was 28 t (Ryan et al. 2019), and the recreational catch for 2020/21 noted harvest rates were steady compared with the previous years (Ryan et al. 2022). Within the Pilbara region the red emperor accounted for 3% of the total recreation catch within the region (Ryan et al. 2022). The recreational economic value for the red emperors kept for food is estimated to be $26,911 and the sport value is estimated to be $64,600 (McLeod and Lindner 2018).

### 5.2.3. Charter catch

The charter catch for the red emperor for the 2018/19 financial year in WA was 9 t (Newman et al. 2021e).

## 5.3. Rankin cod

#### Population

Rankin cod (*E. multinotatus*) populations are found throughout the Indian Ocean, the population that occurs in WA water is distinct from the others found in the Indian Ocean (Heemstra and Randall 1993). The Rankin cod population in the NWA comprises only one genetic population, with little genetic diversity observed within individuals across the shelf. Stable isotope analysis indicates that there is little mixing between the adult populations along the NWA coastline, such as between Onslow and Broome (Stephenson et al. 2001). The genetic similarity is thought to be a result of spawning in pelagic waters and dispersal of eggs and larvae (Newman et al. 2018). The Pilbara management unit for the Rankin cod is considered to be a sustainable stock (Newman et al. 2021f).

#### Distribution

Rankin cods are found throughout the Indian Ocean, from the Persian Gulf south to Madagascar and east to Australia. Along the WA coastline, they are found from the lower west coast up to the NT border (Newman et al. 2021a). Adult Rankin cods have very limited movement between different geographical locations. In the North West Shelf, the Rankin cod has highest abundance within the areas of the TFC. It is generally associated with areas with greater habitat relief (soft coral) within the TFC (Langlois et al. 2021).

#### Habitat and life history

Juvenile Rankin cods are predominately found in inshore shallow reef systems but can also be found throughout the shelf waters in similar habitat to adults. Adult Rankin cods are found offshore across the shelf waters, often in areas with sandy substrates or rocky reefs. The species abundance is however patchy across

the shelf waters, with a slight increase in abundance with depths. The maximum depth the species is found in the water off WA is up to 120 m (DPRID Draft Report, *unpublished*).

Rankin cods are protogynous hermaphrodites, changing from female to male, with the larger older individuals within the population being predominately male. The females reach sexual maturity at 2.2 years of age, when they reach 391 mm FL. Once they have reached 626 mm FL, half the females will have changed sex to male. They can live up to 24 years and grow to a maximum length of 776 mm FL (DPIRD Draft Report, *unpublished*). The Rankin cod have pelagic eggs, with spawning predominately occurring from June to December (Gaughan et al. 2018; DPIRD Draft Report, *unpublished*). Rankin cod diet predominately consists of fish and crustaceans.

### 5.3.1. Commercial catch

The Rankin cod is an indicator species within the Northern Demersal Scalefish Resource and is an indicator for the four fisheries, NDSMF, PFTIMF, PTMF and PLF, that operate within the resource. Of these fisheries PFTIMF, PTMF and PLF are relevant within the vicinity of the Proposal (Newman et al. 2021). Section 4.2 discusses in more detail the fisheries within the Northern Demersal Scalefish Resource. The fisheries that target the Rankin cod operate offshore of the Proposal. The presence of Rankin cod caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 23. The current stock status of the Rankin cod in the Pilbara is sustainable, with spawning biomass unlikely to be depleted and recruitment unimpaired (Newman et al. 2021f). For the 2018/19 finical year the total commercial catch of the Rankin cod in WA was 240.42 t.

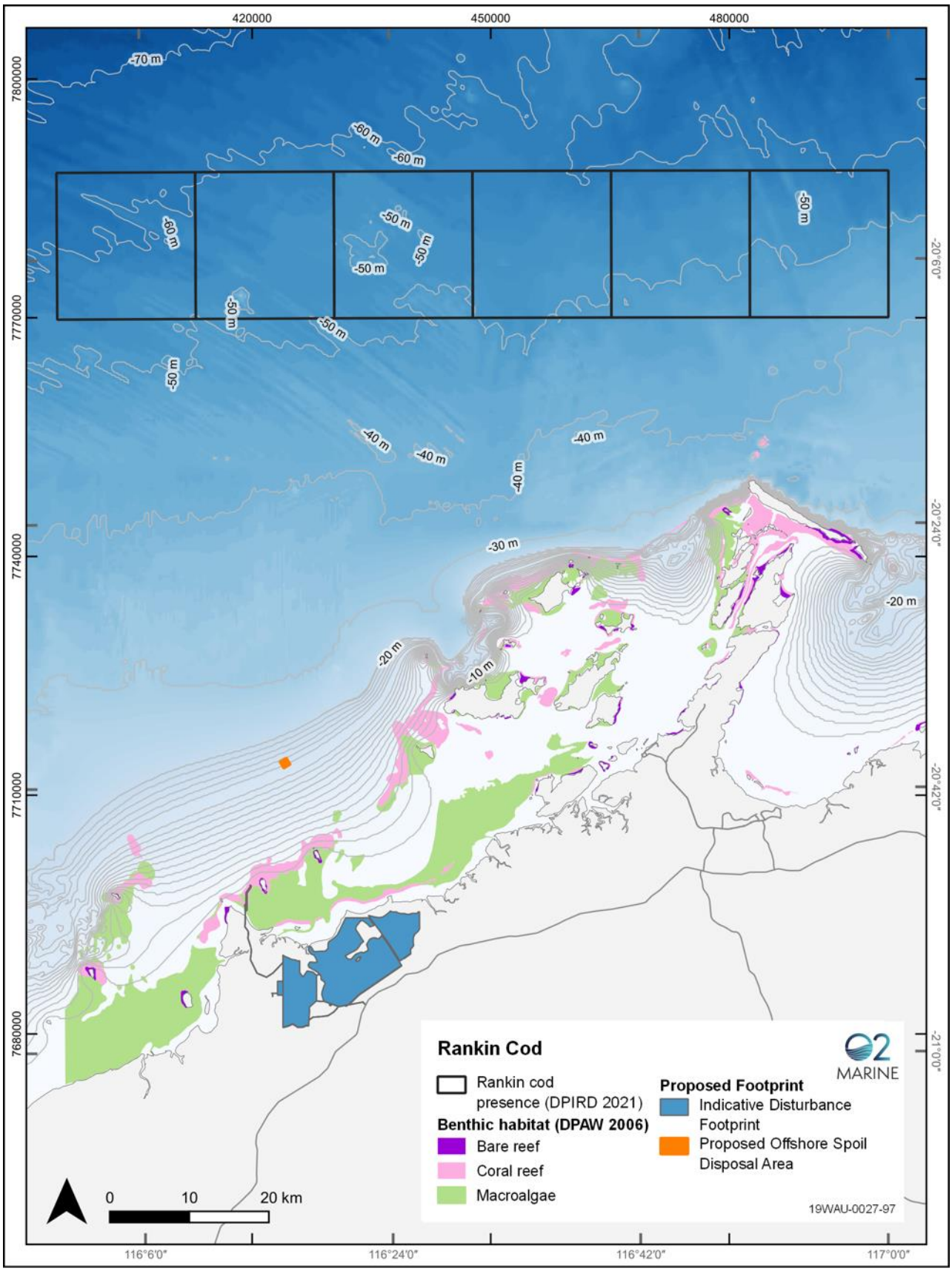


Figure 23 Rankin cod presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021).

### 5.3.2. Recreational catch

Majority of recreational catches occur throughout the North Coast and Gascoyne bioregion, with small amounts being caught within the West Coast bioregion. The recreational catch data shows that most Rankin cod catches are kept, with a release rate of 29% during the 2020/21 period. Rankin cod are predominately caught by recreational fishers within the inshore and nearshore environments with small amounts of recreational catches occurring in the estuarine, offshore and pelagic environments. Almost all recreational catches are obtained using fishing line methods, with a small amount caught through diving. The majority of Rankin cod catches occur during the autumn and winter months but are caught by recreational fishers throughout the year. Within the North Coast bioregion, the Rankin rod accounted for 2% of the total recreational catch during the 2020/21 period (Ryan et al. 2022). The estimated recreational catch of Rankin cod in 2017/18 was 27 t (Ryan et al. 2019) and the recreational catch for 2020/21 noted harvest rates were steady compared with the previous years (Ryan et al. 2022).

### 5.3.3. Charter catch

The WA charter catch for the Rankin cod in the 2018/19 finical year was 18 t (Newman et al. 2021f).

## 5.4. Western king prawn

#### Population

Electrophoretic studies on western king prawns have demonstrated genetic differences among populations sampled in WA, the Gulf of Carpentaria and SA (Richardson, 1982). This species generally only forms large stocks in areas associated with the hypersaline waters of marine embayments (Kailola et al. 1993). The populations of western king prawns in Shark Bay and Exmouth Gulf thus function as independent, self-sustaining stocks.

#### Distribution

Western king prawns are distributed throughout the temperate, subtropical, and tropical waters of Australia. The species occurs from SA, WA, NT, Queensland (QLD) and northern New South Wales (NSW) (Grey et al. 1983).

#### Habitat and life history

The life history of western king prawns closely resembles that of brown tiger prawns. As in other penaeid prawns, they undertake a migration from nursery areas to deeper, more offshore waters, to spawn. Post-larval and juvenile western king prawns are found in shallow waters, in shallow tidal flats with sand or mud substrate. They are generally associated with mangrove habitats and seagrass beds. Juveniles can inhabit areas with higher salinity. In Shark Bay, juveniles are found in extensive hypersaline shallow banks (Penn 1975). Juvenile western king prawns spend about three to six months in the nursery grounds before they reach maturity and migrate offshore, entering the trawl fishing grounds (Penn and Stalker 1979). This migration takes place in April/May of each year. Spawning occurs from August to May, with juveniles present in shallow embayments from September to April, with peak abundance in January. Once grown to 20 to 25 mm carapace length (CL) they begin to migrate further offshore into deeper waters.

Western king prawns reach sexual maturity when they reach 23-27 mm CL, which takes 6 to 9 months. The lifespan for western king prawns is generally between 2 to 3 years, with a maximum life span of 4 years (Noell et al. 2021).

### 5.4.1. Commercial catch

The western king prawn is an indicator species for the Northern Invertebrate Resource, which includes the following fisheries: OPMF, Nickol Bay Prawn Managed Fishery, Broome Prawn Managed Fishery and Kimberley Prawn Managed Fishery. The OPMF operates within the vicinity of the Proposal. Section 4.3 discusses in more detail the fisheries within the Northern Invertebrate Resource. Commercial fisheries that target the western king prawn operate within the vicinity of the Proposal. The presences of western king prawns caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 24.

The total commercial catch for the 2018/19 financial year for WA was 1010 t, however the Northern Invertebrate Resource makes up a very small amount of the total WA catch, with only 5.5 t coming from the fisheries within the resource (Noell et al. 2021). For the fisheries within the Northern Invertebrate Resource, western king prawn stocks are considered sustainable.

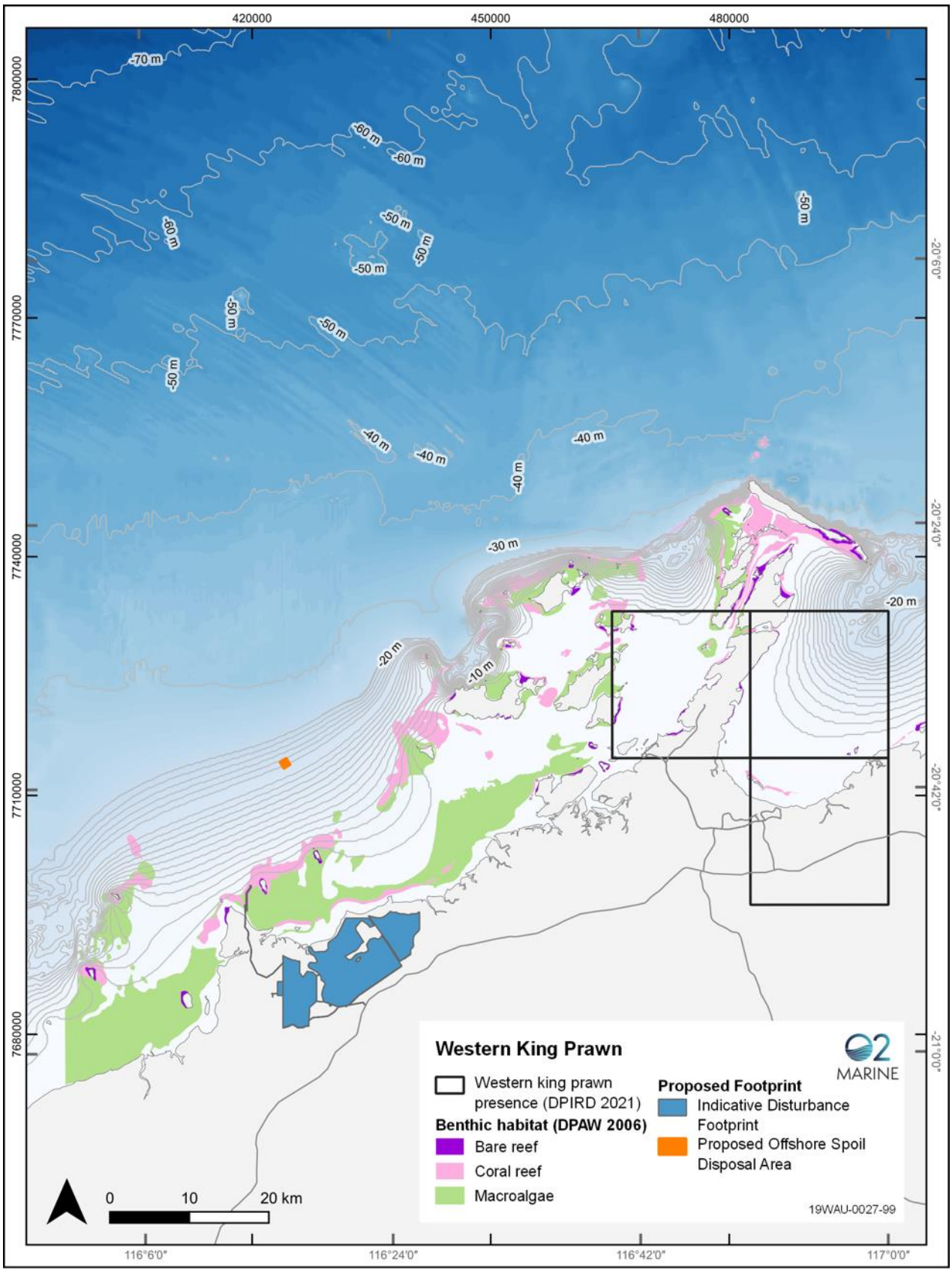


Figure 24 Western king prawn presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021).

## 5.5. Brown tiger prawn

### Population

The population of brown tiger prawns (*P. esculentus*) across Australia is not genetically homogenous, with Ward et al. (2006) showing a genetic break and small differences occurring between the populations of Shark Bay and Exmouth Gulf.

### Distribution

Brown tiger prawns are generally regarded as endemic to Australia and are distributed around the northern coast, from central NSW in the east to Shark Bay in WA. They are found in tropical and subtropical waters (Ward et al. 2006).

### Habitat and life history

Brown tiger prawns can live for 2–3 years and mature at 6-7 months of age, reaching sexual maturity when they reach 32-39 mm CL, at which time they undertake a migration into more offshore waters to spawn. Once eggs hatch, larvae metamorphose through various nauplii stages. If larvae have drifted to a suitable nursery area, they will settle as post larvae on beds of seagrass and algae, two to four weeks after the eggs are released from the females. If settlement occurs in unsuitable habitats, they are likely to perish.

Post-larval brown tiger prawns occupy shallow seagrass and algal communities, generally in water less than 2 m deep (Ovenden et al. 2007). Juvenile brown tiger prawns are generally found in dense patches of seagrass, with higher densities of juveniles found in seagrass beds that are in close proximity to mangroves. Cyclones have historically damaged critical inshore nursery habitats. In Exmouth Gulf, a loss of <2% of macroalgal/seagrass bed cover was linked to a subsequent reduction of prawn recruitment. Loneragan et al. (2013) found that tiger prawn recruitment and landings are significantly correlated with macroalgae and seagrass bed cover. Larger juveniles and adult brown tiger prawns are less dependent on seagrass and macroalgal beds, with larger juveniles moving further offshore into deeper waters, and adults often being found over mud or sand substrates in waters less than 30 m depth. Most spawning females are found in water 13 to 20 m deep (Kangas and Sporer 2015).

### 5.5.1. Commercial catch

The brown tiger prawns are an indicator species for the Northern Invertebrate Resource, which includes the following fisheries: OPMF, Nickol Bay Prawn Managed Fishery, Broome Prawn Managed Fishery and Kimberley Prawn Managed Fishery. The OPMF operates within the vicinity of the Proposal. Section 4.3 discusses in more detail the fisheries within the Northern Invertebrate Resource.

The commercially fished ‘tiger prawn’ includes both the brown tiger prawn (*P. esculentus*) and the grooved tiger prawn (*P. semisulcatus*), however the grooved tiger prawn is not found in WA. The total WA commercial catch for tiger prawns for the 2018/19 financial year was 815.29 t (Butler et al. 2021). Only 34 t of the WA catch came from the Northern Invertebrate Resource. The commercial fisheries that target the brown tiger prawn operate within the vicinity of the proposal. The presences of brown tiger prawns caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 25. The stock status of the Northern Invertebrate Resources is considered to be sustainable.

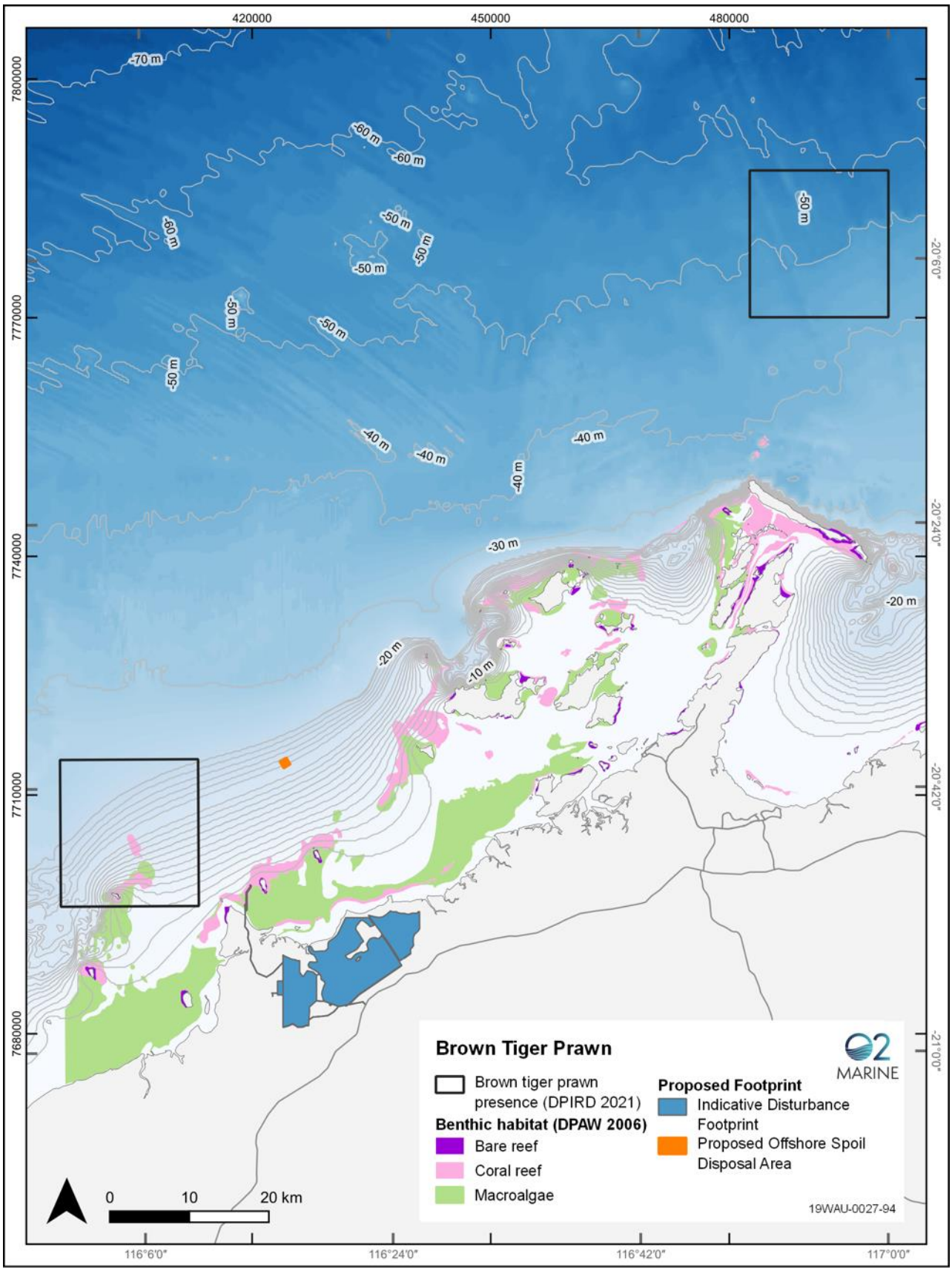


Figure 25 Brown tiger prawn presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021)

## 5.6. Blue swimmer crab

### Population

Chaplin et al. (2001) reported that assemblages of blue swimmer crabs throughout WA become increasingly genetically distinct as the geographic distance between the assemblages increases. The Exmouth Gulf and Shark Bay populations are therefore considered to be genetically separate from one another.

### Distribution

The blue swimmer crab has a wide distribution throughout the Indo-West Pacific region. In WA, the distribution of the blue swimmer crab occurs along 2500 km of the coastline, where the species range from cool temperate waters through to warm tropical waters (Johnston et al. 2021c).

### Habitat and life history

Blue swimmer crabs can spawn all year round. In the Pilbara, the crabs exhibit a similar life cycle to those in Shark Bay, with peak spawning occurring from July to September (Johnston et al. 2020). Mating generally occurs during the warmer months. Females will generally move offshore when spawning, but in some cases, they will spawn near the mouths of estuaries (Kangas 2000). Juvenile crabs with <100 mm carapace width (CW) inhabit shallow habitats (often seagrass beds), preferably in protected bay environments. The structural integrity, shoot density and size of the seagrass beds are important for the survival of juvenile blue swimmer crabs (Hovel and Lipcius 2001; Hovel and Lipcius 2002). The juvenile crabs remain in the shallower habitats during the spring to summer months while they grow and mature (Chandrapavan et al. 2019).

Adult blue swimmer crabs move further offshore into deeper waters at the autumn and during winter, this movement is thought to be influenced by temperature and salinity. Adult blue swimmer crabs inhabit a wide range of inshore and continental shelf ecosystems, from the intertidal zone to at least 50 m in depth (Kangas 2000). However, they are most abundant in sandy, muddy or macroalgal and seagrass benthic habitats of shallow (≤ 20 m) nearshore and estuarine ecosystems (Johnston et al. 2020).

Blue swimmer crabs are fast growing and short-lived. Females reach sexual maturity at 10 to 12 months of age or ~110 mm CW, and 105 mm carapace width (CW) for males (Chandravapan et al. 2017). Both sexes attain a commercial size of 135 mm CW at about 15 months. Fishing is normally restricted to between March and November each year (Johnston et al. 2020).

### 5.6.1. Commercial catch

The blue swimmer crab is the indicator species for the North Coast Crab Resource, which includes two fisheries: PCMF and the Kimberley Crab managed Fishery. The PCMF is the only fishery that operates within the vicinity of the Proposal. Section 4.4 discusses in more detail the fisheries within the North Coast Crab Resource. The blue swimmer crab is also an indicator species within other aquatic resources within WA, with fisheries occurring along 2500 km of the WA coastline. (Johnston et al. 2021a) Commercial fisheries that target the blue swimmer crab operate within the vicinity of the Proposal. The presence of blue swimmer crabs caught by commercial fisheries within 10 x 10 nm blocks in relation (Figure 26). Environmental variables such a temperature have a significant influence on the fisheries catch per unit of effort, with increased catch rates during the warmer months (Johnston et al. 2021c).

The total commercial catch for the blue swimmer crabs in WA was 688.27 t, The PCMF contributes only a small amount to the total commercial catch, with only 28.3 t of blue swimmer crab caught from the PCMF, the Exmouth Gulf Developing Crab Fishery and as a by-product from the Northern Invertebrate Resources fisheries (Johnston et al. 2021b).

### 5.6.2. Recreational catch

Blue swimmer crabs are a very common recreational catch, with almost all the recreational catches occurring in the West Coast bioregion, with a very small amount of recreational catch occurring throughout the Gascoyne (3%) and North Coast (1%) bioregions (Ryan et al. 2022). The North Coast bioregion had an estimated recreational catch of 1.5 t of blue swimmer crabs for the 2017/18 period (Ryan et al. 2019). In the Pilbara region the blue swimmer is the most commonly caught recreational invertebrate, accounting for 7% of the recreational catch within the region for the 2020/21 period. In the North Coast Bioregion blue swimmer crabs only present 3% of the recreational catch (Ryan et al. 2022). The estimated recreational catch for blue swimmer crabs in WA was 63 t, with most of this coming from the West Coast bioregion.

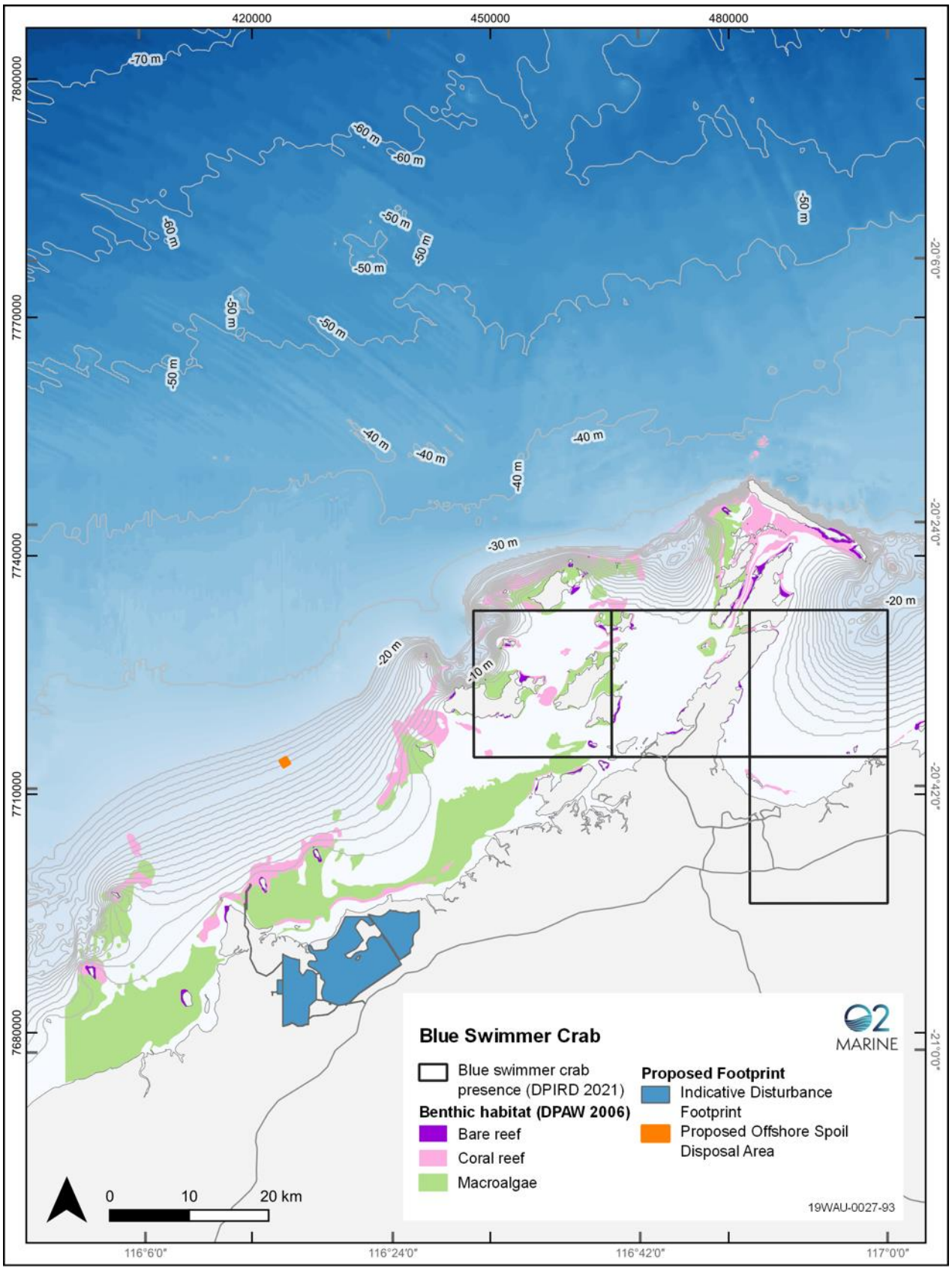


Figure 26 Blue swimmer crab presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021)

## 5.7. Narrow-barred Spanish mackerel

The narrow-barred Spanish mackerel is an important commercial, recreational and fishing charter species throughout the Indo-pacific, especially off the coast of Northern Australia (Newman et al. 2012). The species *S. commerson* is often referred to as either the Spanish mackerel or the narrow-barred Spanish mackerel.

### Population

Several distinct genetic stocks of Spanish mackerel are found across the Indo-Pacific region. Genetic and microsatellite analysis of Spanish mackerel have found that there are three distinct Australian stocks (Buckworth et al. 2007), including:

- Northern/Western Australian;
- Torres Strait; and
- East coast Australian.

Within the Northern/Western Australian Spanish mackerel genetic metapopulation, regionally specific population structures also occur, with evidence of little dispersal of adults between groups. These groups have been termed the Gascoyne/West Coast, Pilbara, and Kimberley (Buckworth et al. 2007; Newman et al. 2012). Populations within these management zones show differences in demography, age structure, otolith opaque zone formation, and growth trends (Newman et al. 2012).

### Distribution

The Spanish mackerel is widely distributed along the WA coastline from 13-29° (Newman et al. 2012). The species is targeted by both commercial and recreational fisheries in WA, NT, QLD and NSW (Roelofs et al. 2021a).

### Habitat and life history

Juvenile Spanish mackerel inhabit inshore shallow waters and are often associated with mangroves and reef structures (Newman et al. 2012). The rate of growth of juveniles is extremely rapid within the first 80 days, when they reach approximately 300 mm FL. After this the growth rate slows down due to the decreased water temperatures in the winter months when the juveniles have reached this growth stage (Newman et al. 2012).

Adult Spanish mackerel are found in coastal waters with depths ranging from 15 to 200 m, often around reef systems. Critical habitat for the Spanish mackerel is oceanographic features such as reefs and islands located within the inshore and offshore pelagic zone (Lewis 2020). They form seasonal aggregations in shallow coastal waters, which are generally associated with foraging and gonad development prior to spawning. In the Pilbara, Spanish mackerel spawn during October to January (Lewis 2020). The fishing season in WA is from May to October (Mackie et al. 2003; Lewis 2020).

Spanish mackerel can live for over 22 years. Growth curves demonstrate that this species grows very rapidly early in life (attaining about 800 mm FL around the end of the first year of life). The fishery (MMF) is based on 2 to 4 year old individuals (Lewis 2020). Females reach sexual maturity at the age of 2 years.

Spanish mackerel begin to form schools early in their juvenile stage (Mackie et al. 2003), and this schooling behaviour continues throughout their adult life. Spanish mackerel feed on fish, squid, prawns and mantis shrimp.

### 5.7.1. Commercial catch

The Spanish mackerel is an indicator species for the Statewide Large Pelagic Scalefish Resource, which manages the MMF. The MMF is separated into the three population areas: Kimberley, Pilbara and Gascoyne/West Coast. Section 4.5 discusses in more detail the Statewide Large Pelagic Scalefish Resource. Commercial fisheries that target the narrow-barred Spanish mackerel operate within the vicinity of the Proposal. The presence of Spanish mackerel caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 27.

The total WA catch of Spanish mackerel for 2020 was 288 t and the commercial status of species was deemed as acceptable (Lewis and Watt 2021). The minimum size limit of the Spanish mackerel is 900 mm TL in WA. The status of the MMF in WA is considered to be sustainable (Roelofs et al. 2021a).

The life-history traits, which include rapid initial rate of growth and low age of sexual maturity, give the species a high production potential. However, in WA, the productivity of the species is relatively low, compared to other mackerel fisheries in the Indo-pacific. This is a result of the low levels of primary and secondary production within the Kimberley and Pilbara region, with the low-nutrient current limiting production within the shelf waters. The low productivity of the Spanish mackerel in WA waters means that the species has low levels of sustainable catch and does not have the capacity for the fishery to undergo any large-scale development (Newman et al. 2012).

### 5.7.2. Recreational catch

Spanish mackerel is the most popular recreationally caught pelagic species, making up 50% of the top 15 pelagic species caught recreationally from 2020 to 2021 (Ryan et al. 2022). Spanish mackerel are mostly caught recreationally through boat-based fishing, with the highest number of catches recorded in the North Coast and Gascoyne bioregions, with some catches recorded in the West Coast bioregion. These catches are predominately in the inshore, nearshore, and pelagic but a small amount are also caught offshore. Spanish mackerel are caught predominately by fishing line, with smaller amounts caught by diving and nets. Spanish mackerel are caught recreationally throughout the year, but have lower recreational catch in the summer months (Ryan et al. 2022). The total estimated recreational catch of Spanish mackerel for 2020/22 was 56 t (Ryan et al. 2022).

Recreational fishing of the Spanish mackerel occurs at one of the highest rates for large pelagic fish and is the fifth most kept finfish species. Large numbers of Spanish mackerel recreational catches are released due to being undersize, with 41% of the recreational catches being release (Ryan et al. 2022). There is high post-release mortality for Spanish mackerel, this may be due to not having a swim bladder (Lewis 2020).

### 5.7.3. Charter catch

The Spanish mackerel is a popular charter fish species. The total WA charter catch for the 2018/19 financial year was 14 t. The species is the fourth highest kept for charter/fishing tour operations. The charter catch of Spanish mackerel has been stable since 2008, with catch levels of 14 to 20 t per year (Roelofs et al. 2021a).

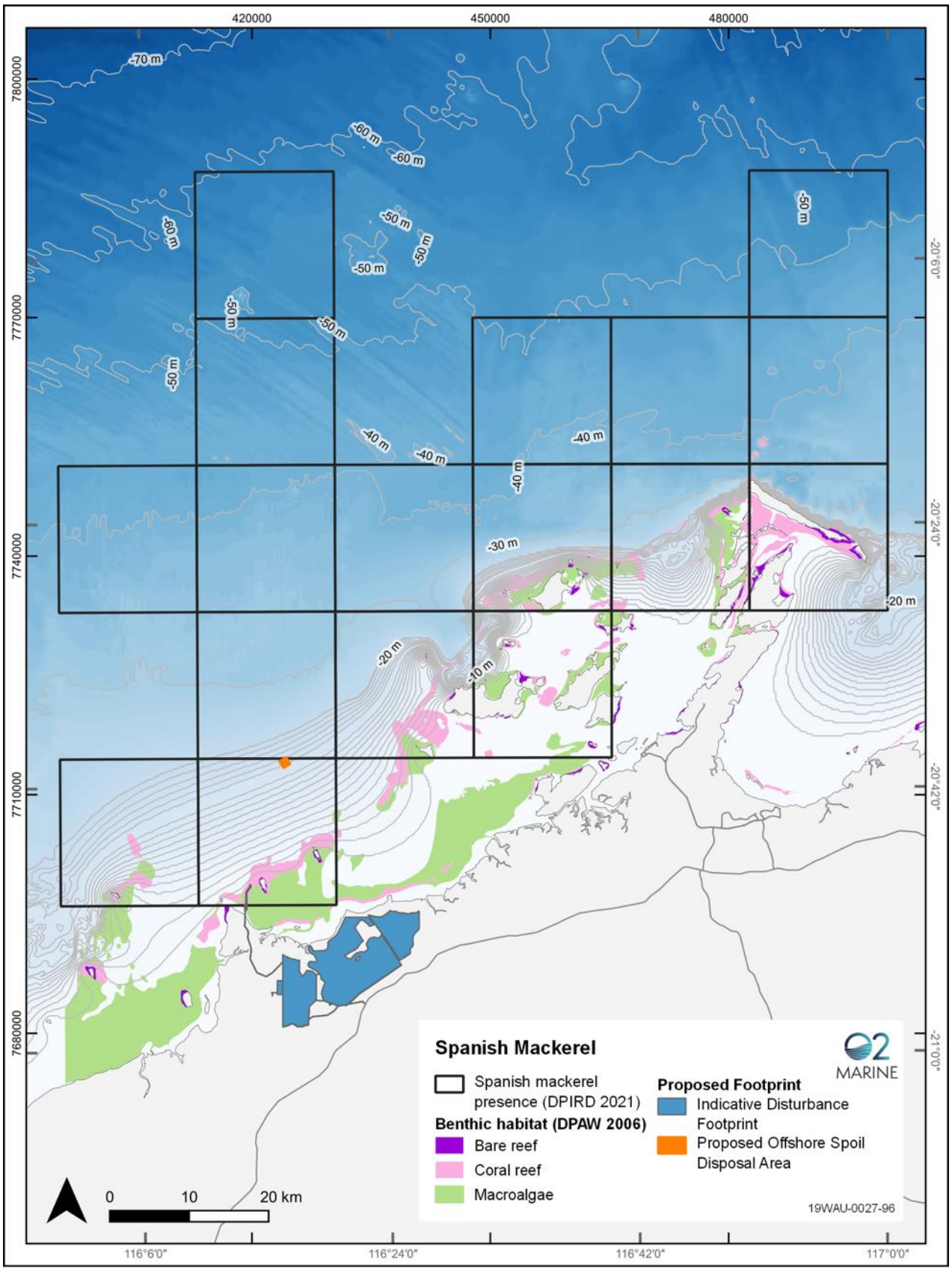


Figure 27 Spanish mackerel presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021)

## 5.8. Grey mackerel

### Population

The WA population of grey mackerel (*S. semifasciatus*) are a different genetic stock to those found throughout the NT and the east coast of QLD. There is little genetic flow and connectivity between the WA population and the eastern populations, which is thought to be a result of unsuitable habitat along the Kimberley coastline (Broderick et al. 2011). All WA Grey mackerel belong to the same genetic stock.

### Distribution

Grey mackerel have restricted distribution throughout the southern waters of Papua New Guinea and northern Australia from Shark Bay to NSW (Roelofs et al. 2021b). The grey mackerel has a nearshore distribution and is the largest inshore mackerel species. The WA population of grey mackerel have a high degree of spatial separation from the other populations and seem to be restricted to the waters off the WA coastline (Newman et al. 2010).

### Habitat and life history

The larvae and juveniles of this species inhabit coastal bays, the inner margins of lagoons, estuarine environments, and nearshore areas that are typically influenced by freshwater run-off and low salinity surface waters (Newman et al. 2010). Adult grey mackerel are known to commonly occur in turbid tropical and sub-tropical waters of approximately 3 to 30 m depth. This is usually found in the vicinity of bottom structures, near rocky headlands and reefs (where pelagic baitfish such as tropical sardines and herrings are concentrated) and over sandy mud and muddy sand substrates. They rarely occur at the edge of the continental shelf, to depths of 100 m. Grey mackerel also inhabit nearshore areas such as river mouths and estuaries, due to their ability to tolerate low salinity waters (Neman et al. 2010).

Grey mackerel are known to live up to 14 years (Roelofs et al. 2021b). Grey mackerel are a fast-growing species, reaching sexual maturity in less than 2 years. Females reach sexual maturity when they reach 700 mm total length, males when they reach 660 mm TL.

The species forms large schools in June to September, during which the short fishing season takes place. It is not known where they reside outside of this period, however it is thought that they disperse in coastal waters. In WA, this period of schooling does not coincide with the spawning season of December to March (Lewis 2020).

### 5.8.1. Commercial catch

The grey mackerel is an indicator species for the Statewide Large Pelagic Scalefish Resource, which manages the MMF. The MMF is separated into three areas: Kimberley, Pilbara and Gascoyne/West Coast. Section 4.5 discusses in more detail the Statewide Large Pelagic Scalefish Resource. Commercial fisheries that target the grey mackerel operate within the vicinity of the Proposal. The presences of grey mackerel caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 28.

The total WA commercial catch of grey mackerel in 2020 was 11 t (Lewis and Watt 2021), and its status was assessed to be acceptable and sustainable. The commercial catch in WA is considerably smaller than the NT and QLD and is thought to be a reflection of low deemed and limited targeted commercial fishing (Roelofs et al. 2021b).

### 5.8.2. Recreational Catch

Grey mackerel is a popular recreational species and was the eleventh most recreationally caught pelagic species in the 2020/21 survey period (Ryan et al. 2022). Most recreational catches of grey mackerel during the 2020/21 were recorded in the North Coast and Gascoyne Bioregions. The 2020/21 recreational survey results showed that the recreational catches of grey mackerel for this period was lower than the 2018/19 survey but higher than in the previous three State-wide surveys (2011/12, 2013/14 and 2015/16), but had a high level of uncertainty. Most of the recreational catches are through line fishing, with a small number of caught via diving. Spanish mackerel were mostly caught in the pelagic environment, followed by nearshore and inshore environments. Recreational catches were recorded year-round with high amount caught in autumn and spring (Ryan et al. 2022).

### 5.8.3. Charter Catch

The total WA charter catch four tour operations within WA grey mackerel generally account for <1 t of the annual large pelagic indicator species (Lewis and Watt 2021). For the 2018/19 financial year the charter catch was <0.5 t (Roelofs et al. 2021b).

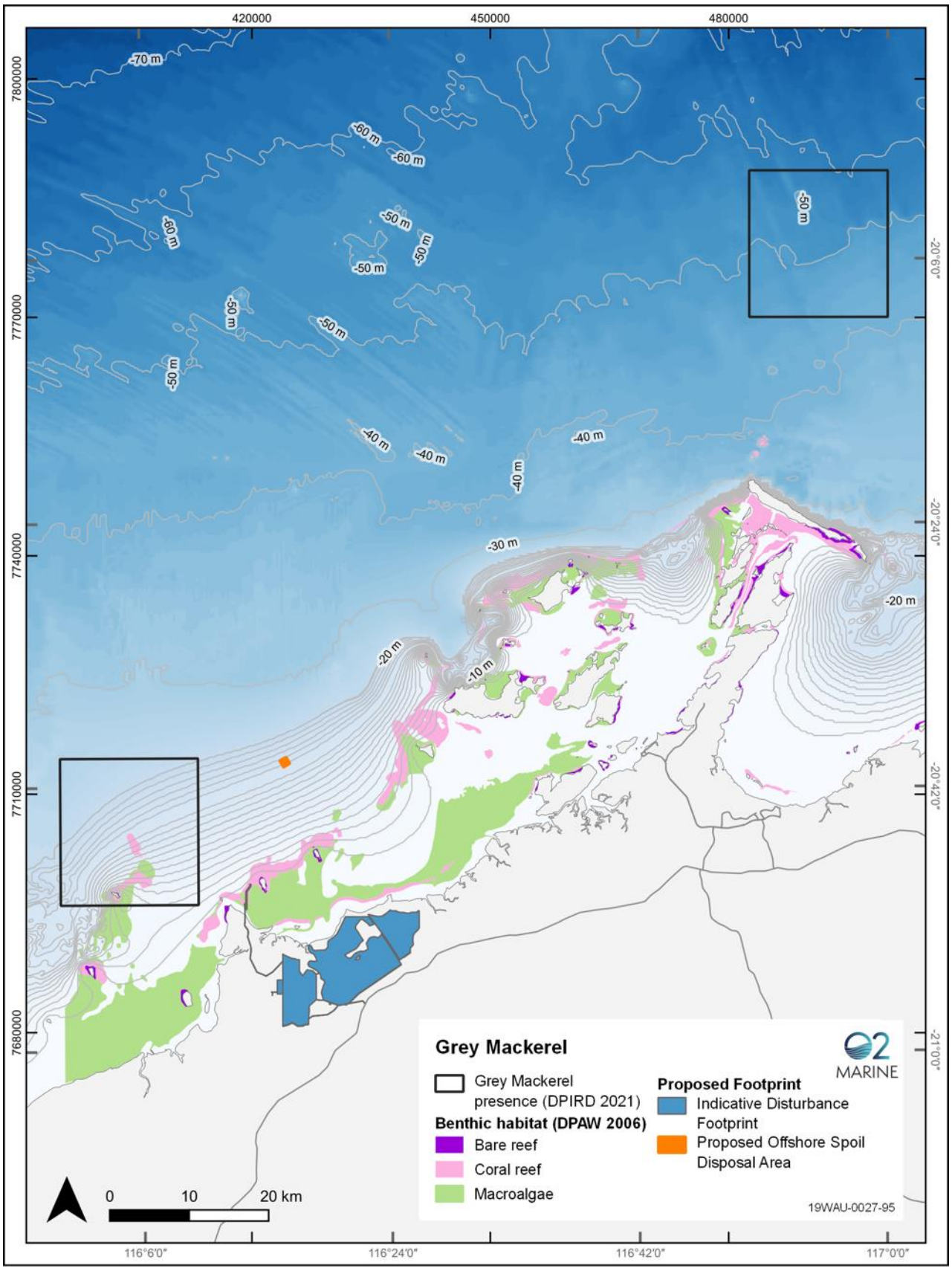


Figure 28 Grey mackerel presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021)

## 5.9. Sea Cucumbers (Redfish and Sandfish)

Sea cucumbers are soft-bodied, elongated animals of the Phylum Echinodermata (Class Holothuroidea) that grow to around 400 mm in length (DPIRD 2018). The two indicator species for the WA Sea Cucumber fishery are the sandfish (*H. scabra*) and redfish (*A. echinites*). They are also key indicator species for the customary fisheries.

### Population

The genetic stock of both the sandfish and redfish have not yet been determined and is a gap within the knowledge of the fishery. There have been genetic studies on the sandfish found in the NT and QLD, which indicated that there are genetic differences between the stocks in NT and QLD. Therefore, it is plausible that within WA there may be different genetic stocks in the Kimberley and Pilbara (DPIRD 2018).

### Distribution

Sandfish and redfish are distributed throughout the Indo-Pacific tropical waters. Within WA, they are found in the waters along the Kimberley and Pilbara coastline (DPIRD 2018).

### Habitat and life history

Sea cucumbers are generally found in shallow waters with soft sediment, usually within protected bays or behind fringing reef systems. Juvenile sandfish (~9 mm) inhabit seagrass beds, where they stay until they mature and then move onto soft sediments away from seagrass beds. The species exhibits diel burying behaviour, where they will bury into the sand during the day and come out at night. This behaviour is more common during the juvenile stage. The main component of sea cucumber diet is macroalgae (Sinsona and Juinio-Menez 2018). The peak spawning period in WA is from September to November, but they can spawn all year round. Sexual maturity is reached at 2 years of age or 140 mm length for sandfish (as determined outside of WA; DPIRD 2018). Sandfish larvae are planktonic, and then live on seagrass until they reach ~9 mm in length (Hamel et al. 2013).

Adult redfish are generally found in shallow waters, in depths up to 30 m, but are most abundant in waters around 12 m depth (Conand et al. 2013; DPIRD 2018). They are often found on fringing reefs, rubble, lagoons and reef flats. The size at maturity of redfish is approximately 120 mm or 2 years of age (DPIRD 2018). Spawning times within WA are not known, however across its global distribution the species is known reproduce sexually during the warmer months of the year, with spawning in New Caledonia in January and February, and in December in Papua New Guinea (Conand et al. 2013).

### 5.9.1. Commercial catch

The redfish and sandfish are both indicator species of the WASCF, which is the only fishery within the Statewide Hand Collection Resource in WA. It is a small, low value commercial fishery, with animals caught principally by diving, and a smaller amount by wading. Section 4.6 describes in further detail the Statewide Hand Collection Resource socio-economic value. Commercial fisheries that target sea cucumbers operate within the vicinity of the Proposal. The presences of redfish and sandfish caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is presented in Figure 29.

Based on the information and analyses available, the current risk level for Pilbara sandfish was estimated to be sustainable – adequate.

### 5.9.2. Customary catch

For the 2020 season, Aboriginal native title holders were granted permission to collect from the Shark Bay Statewide Hand Collection stock, as part of the WASCF. This involved collection of both redfish and sandfish (Hart and Murphy 2021).

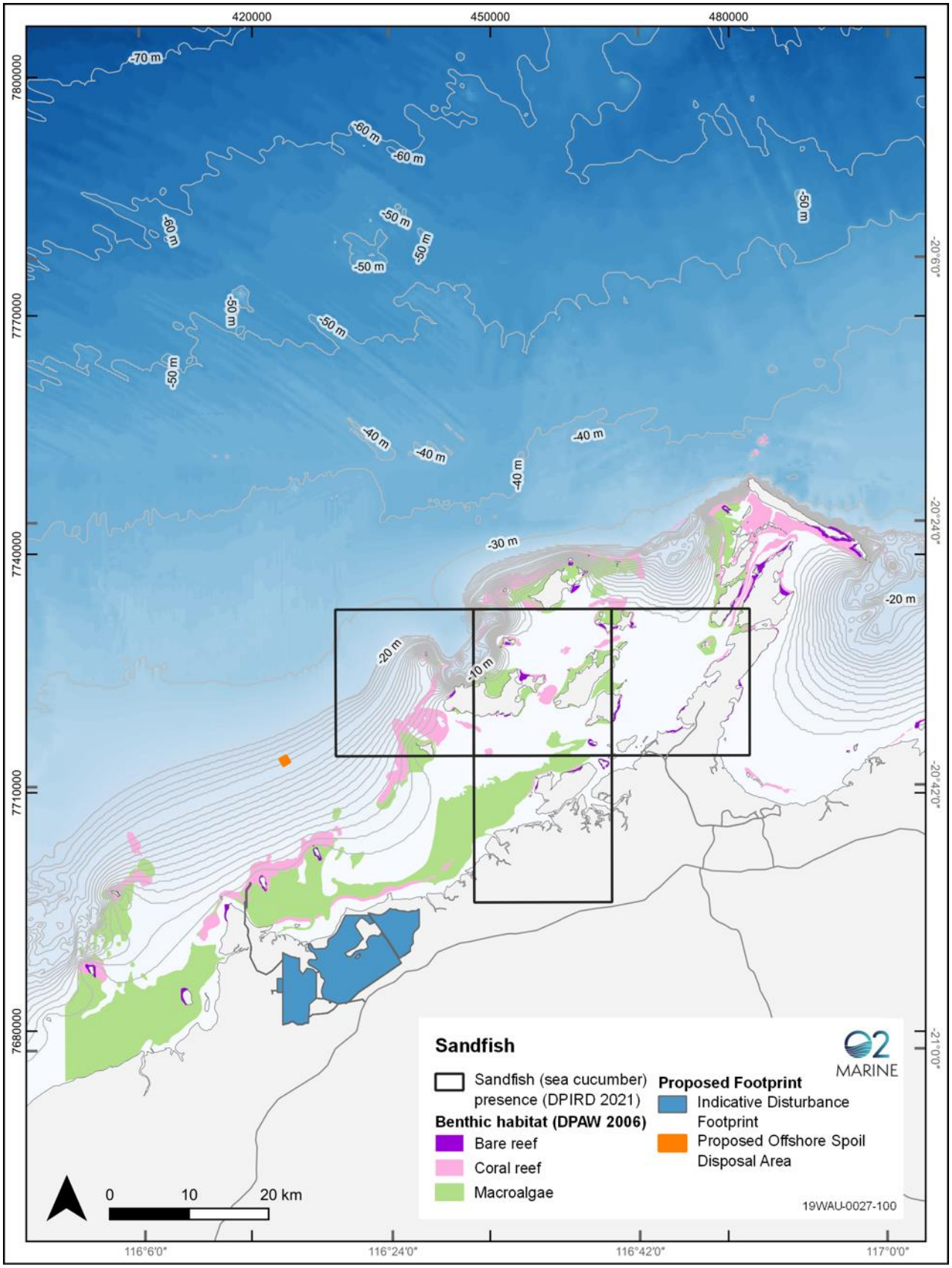


Figure 29 Sea cucumber presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021)

## 5.10. Australian land hermit crab

### Population

The scale and genetic connectivity of the Australian land hermit crab (*C. variabilis*) population in the NCB is not known to have been investigated, although they are relatively abundant.

### Distribution

This species is endemic to northern Australia including northern WA, the NT and northern QLD. Recent hermit crab catches have been concentrated on beaches in Broome and Karratha/Dampier (Newman et al. 2021c).

### Habitat and life history

This species has a terrestrial life stage; however, females must move to the ocean to release eggs, which hatch as planktonic larvae. The Australian land hermit crab reproductive season occurs from November to March. The larval stage lasts for 6 days, they then return to the beach where they undergo metamorphosis in the sand (van Dam et al. 2018). For the Australian land hermit crab to grow, they must exchange their shell for a larger sized one. This species occurs intertidally and supra-tidally, up to 100 m or so from the beach. These crabs are most common near mangroves, but they also occur on sand and rocky beaches. This species is nocturnal and during the day can be found amongst mangroves, sheltering under rocks and logs from the heat. They are omnivorous and scavenge on beaches and creek beds during the night (van Dam et al. 2018).

### 5.10.1. Commercial catch

The Australian land hermit crab is the indicator species for the Statewide Marine Aquarium Fish and Hermit Crab Resource, which have two fisheries that operate within WA waters: MAFMF and HCF. Further discussion on the socio-economic value can be found in Section 4.7. Commercial fisheries that target the Australian land hermit crabs operate within the vicinity of the Proposal. The presences of the Australian land hermit crab caught by commercial fisheries within 10 x 10 nm blocks in relation to the Proposal area is present in Figure 30.

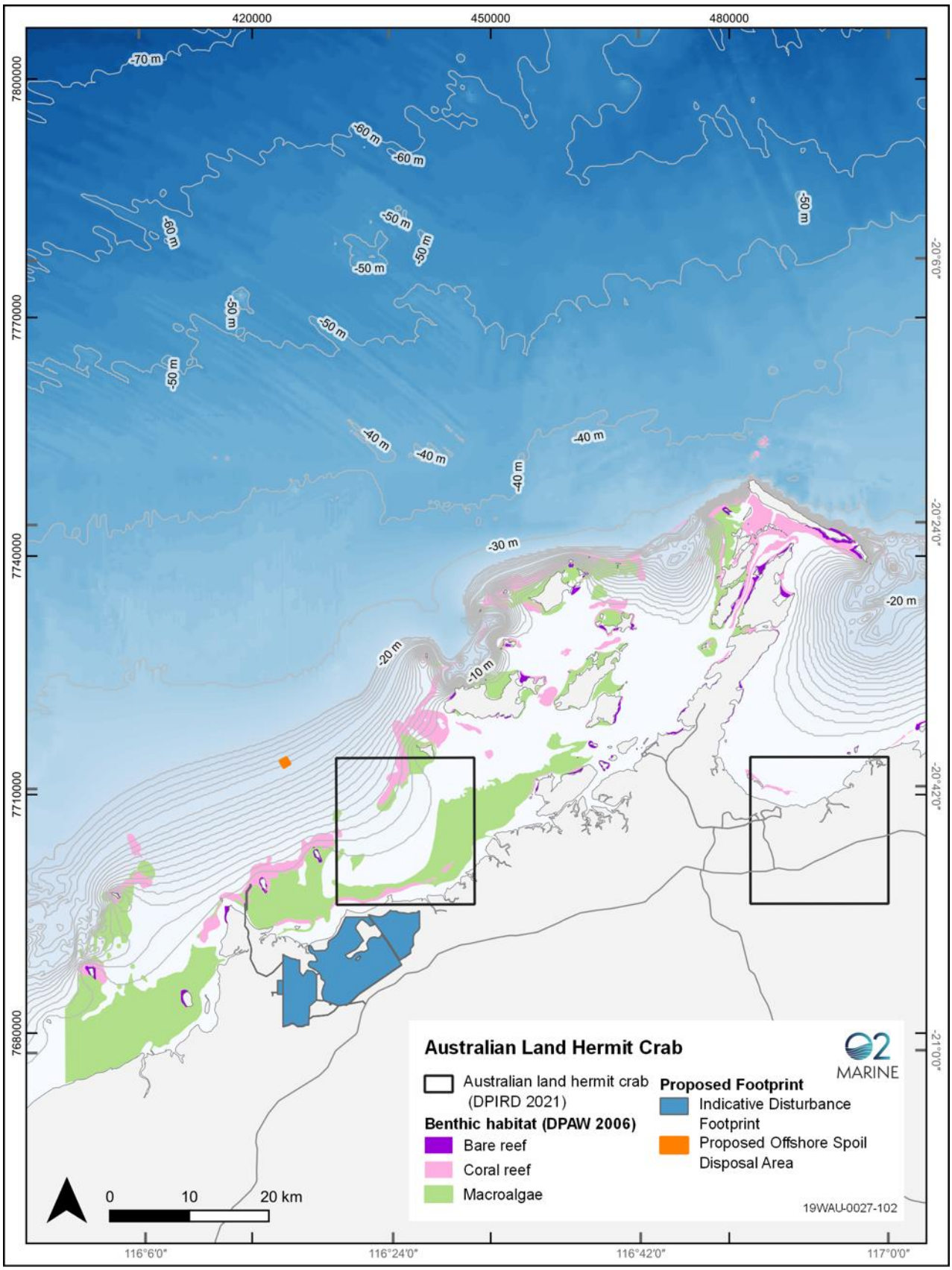


Figure 30 Hermit crab presence (10 x 10 nm blocks) within the Proposal area from commercial catch data from 2016-2020 (DPIRD 2021)

## 5.11. Silver-lipped pearl oyster

The South Sea, or silver-lipped, pearl oyster, *P. maxima*, is a filter-feeding bivalve mollusc and is the largest of four *Pinctada* species found in WA (DPIRD 2022).

### Population

The WA silver-lipped pearl oysters are considered to be one single management stock, with their broadcast spawning techniques allowing for connectivity between geographical locations. Recent microsatellite analysis found little difference between the Exmouth Gulf and Kimberley region oysters, and therefore they can be considered a single population comprising several thousands of individuals (Benzie and Smith-Keune 2006).

### Distribution

The silver-lipped pearl oyster can be found throughout the Indo-Pacific, and ranges from north of Exmouth, WA to Cooktown, QLD. Eighty Mile Beach along the WA coastline is the key harvest area for the silver-lipped pearl oyster (Whalan et al. 2021).

### Habitat and life history

Silver-lipped pearl oysters are broadcast spawners, with a larval period that lasts 2 to 3 weeks before they must attach to an area of hard substrate (Whalan et al. 2021; DPIRD 2022). This generally occurs in protected areas of seabed such as crevices. They are found in a variety of benthic habitats such as mud, sand, and gravel (DPIRD 2022). Silver-lipped oysters are most often found in water depths less than 40 m, with less than 2% of oysters at Eighty Mile Beach found in depths greater than 50 m (Whalan et al. 2021). However, they have been reported in depths up to 120 m elsewhere.

Silver-lipped pearl oyster are hermaphrodites, beginning as males for the first 3 to 4 years of life (reaching 110-120 mm shell length), then becoming females. Individuals can spawn annually, with juvenile recruitment being driven by sea surface temperature, rainfall, and wind. Spawning is observed throughout September to May, with peak spawning observed between October to December. A small secondary spawning event can also occur in February and March (DPIRD 2022). The reproduction rate of the species is high, with female gonads containing from 20 to 50 million eggs (DPIRD 2022). The oysters have a low natural mortality rate with only 10 to 16.5% annual mortality, individuals >200 mm shell length have an estimated age of 15 to 20 years (Rose and Baker 1994; Hart et al. 2016).

### 5.11.1. Commercial catch

The silver-lipped pearl oyster is the indicator species of the Pearl Oyster (*P. maxima*) Resource, which manages the Pearl Oyster Wildstock Fishery. The WA Pearl Oyster Managed Fishery is the last remaining significant wild stock in the world (Hart et al. 2021b). The WA silver-lipped pearl oyster stock is considered to be sustainable. Further information regarding Pearl Oyster (*P. maxima*) Resource can be found in Section 4.8.

The total WA commercial catch for the silver-lipped pearl oyster in the 2018/19 finical year was 201.22 t, which is considerably larger than the NT and QLD commercial take (Hart et al. 2021b).

### 5.11.2. Recreational catch

Under the *Pearling Act 1990*, there is no recreational fishing of the silver lipped pearl-oyster (DPIRD 2022).

### 5.11.3. Customary catch

Pearl oyster shell is an important resource of cultural significance to the Indigenous people of Australia and has been harvested for at least 20,000 years (DPIRD 2022). Aboriginal Australians of the West Kimberley harvested pearl oyster shells from shallow waters and had well established traditional trading networks that extended throughout Australia (Akerman and Stanton 1994). The *P. maxima* pearling industry was initiated in 1861 through trade between early explorers and Aboriginal Australians (DPRID 2022). Pearl oysters have been recognised under Native Title. The total customary catch for the silver-lipped pearl oyster is unknown by DPIRD, as customary catch records are not maintained.

# 6. Key species, habitat associations and ecological windows

The benthic community habitats found in the Proposal area are typical of the Pilbara area, comprising offshore sponge-dominated habitats, ephemeral macroalgal beds, mostly sparse seagrass beds, rocky reef, significant inshore coral reef areas, mangrove lined tidal creeks, intertidal mudflats, sandy beaches and supratidal saltmarshes and salt flats. Most notably, the area does comprise a broad, shallow embayment with significant intertidal features and large offshore rocky islands that provide a variety of sheltered habitats. Across all the Aquatic Resources identified within the proposal, there are a total of 12 key indicator species for commercial fisheries. Table 7 summarises the key habitat associations and seasonal occurrences for these species during their various life phases, with relevance for the Proposal area.

Table 7 Summary of key habitats and ecological timings for key fish species

| Species | Population | Range | Juvenile Habitat | Adult Habitat | Spawning/ Critical Period | Food source | Turbidity Tolerance | Salinity Tolerance | Fishing Effort (in Project area) | Stock Status | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bluespotted emperor** | One genetic population with separate adult stocks (broadcast spawning); relatively short lived | Endemic from Geraldton to NT. Highest abundance in Pilbara. | -Reach sexual maturity 1.6 years<br>-Macroalgae beds, shallow inshore water <10m depth<br>-Mangroves | -Coral reefs, rubble/sand substrate, and seagrass beds<br>-Found offshore<br>-Depths up to 150m | June – April<br>Peak spawning July-October and March | Carnivorous species feeding on bottom dwelling fish, other finfish and invertebrates | - | - | -Rec. fished throughout the year, peak in winter and autumn occurring inshore<br>-Commercial fishing occurs offshore | Stable (sustainable) | DPIRD Draft Report, *unpublished*;<br>Ryan et al. (2019) |
| **Red emperor** | One genetic population with separate adult stocks (broadcast spawning); Long lived | Throughout northern Australia and Tropical Indo-Pacific | Turbid inshore environments including reefs and mangroves | Mid-shelf- reefs, lagoons, limestone sand/gravel in depths up to 180 m | Opportunistic spawners (10 months of the year)<br>Peak Oct-March | Bottom-dwelling fish, benthic crustaceans and cephalopods | High (juveniles) | - | -Rec. fished throughout the year, peak in winter and autumn occurring inshore<br>-Commercial fishing occurs offshore | Stable (sustainable) | Ryan et al. (2019);<br>DPIRD Draft Report, *unpublished.* |
| **Rankin cod** | One genetic population with separate adult stocks (broadcast spawning); Long lived | Throughout northern Australia and Tropical Indo-Pacific | Inshore to shelf reef systems | -Offshore deeper rocky reefs and sand habitats<br>-Depths up to 120m | Spawning June–Dec | Fish and crustaceans | - | - | -Rec. fished throughout the year, peak in winter and autumn occurring inshore<br>-Commercial fishing occurs offshore | Stable (sustainable) | Gaughan et al. (2018);<br>Ryan et al. (2019) |
| **Narrow-barred Spanish mackerel** | Three genetic stocks across northern Australia. in WA the northern/western Australia stock is considered a metapopulation, with little movement between regions. High production potential but within WA has low productivity. | Within WA range from latitudes 13 – 29 ° and they extend across three management regions; Kimberley, Pilbara and Gascoyne/West Coast | -Inshore habitats as nursey areas<br>-Inshore waters with mangrove systems and reef structures | Coral reefs, shoals and headland<br>-Critical habitat reefs and islands within inshore and offshore pelagic zone<br>-Water depths 15 to 200m | Spawning Oct-Jan | Piscivorous, small pelagic and reef species | High | Observed in salinity levels 0-31%. | Inshore Rec. fishing, Pilbara Mackerel Managed Fishery Fishing season May – October | Stable (sustainable) | Mackie et al. (2003);<br>Schrandt et al. (2015);<br>Newman et al. (2012) |
| **Grey mackerel** | One genetic stock in WA (little connectivity through Kimberley), Short lived | Shark Bay to NSW | Larvae- coastal bays, nearshore areas that are typically influenced by freshwater run-off and low salinity surface waters<br>Juveniles- Inshore coastal bays, lagoons, and estuarine environments influenced by low salinity surface waters. | -Rocky headlands, reefs, and muddy sandy substrates<br>-Turbid tropical and sub-tropical waters of approximately 3– 30 m depth | Spawning Dec-March | Pelagic predators feeding on baitfish e.g., sardines, anchovies and herring | High | Juveniles can inhabit low salinity surface water habitats | Inshore Rec. fishing, June-Sept Pilbara Mackerel Managed Fishery fishing season June-September | Stable (sustainable) | Lewis (2020);<br>Newman et al. (2010) |
| **Western king prawn** | Independent, self-sustaining stocks, short lived | Throughout the temperate, subtropical, and tropical waters of Australia | Shallow tidal flats, embayments with sand or mud substrate, mangroves and seabeds, from September to April, with peak abundance in January | Near shore habitats | Spawning offshore from Aug-May. Migrates from nursery grounds April/May annually | Adults feed on benthic fauna and organic debris.<br>Juveniles feed on copepods, decapods ostracods, gastropods, diatoms, filamentous algae and small protozoa | High | High<br>Salinity is negatively correlated with recruitment | Onslow Prawn Managed Fishery operates within vicinity of the Proposal | Stable (sustainable) | Noell et al. (2021);<br>Kangas and Sporer (2015) |
| **Brown tiger prawn** | Independent, self-sustaining stocks, short lived | Central NSW in the east to Shark Bay in WA; endemic. | -Shallow seagrass/algae generally in <2 m<br>-Often associated with mangroves | Offshore <30m depth, muddy or sandy substrates | Spawning offshore depths 13-20 m | Feed predominately at night on molluscs, crustaceans and polychaete worms | High | Extreme salinities and temperatures are lethal on juveniles. | Onslow Prawn Managed Fishery operates within the vicinity of the Proposal | Stable (sustainable) | Loneragan et al. (2013);<br>Kangas and Sporer (2015) |
| **Silver lipped pearl oyster** | One genetic population (broadcast spawning); | North of Exmouth, WA to Cooktown, QLD (Indo-Pacific) | Juveniles settle into protected environments with crevices | Mud, sand, and gravel substrate, in water depths up to 50 m | Spawning Sept–May (peak Oct–Dec) | Filter feeders | - | High<br>Better tolerance to high salinity than low salinity | WA Pearl Oyster Managed Fishery. | Stable (sustainable) | DPIRD (2022);<br>Hart et al. (2011);<br>Wie et al. (2022) |

| Species | Population | Range | Juvenile Habitat | Adult Habitat | Spawning/ Critical Period | Food source | Turbidity Tolerance | Salinity Tolerance | Fishing Effort (in Project area) | Stock Status | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue swimmer crab | Genetic distinctness increases with geographic distance | Throughout cool temperate to tropical waters | Seagrass beds (high density), protected bays | Sandy, muddy, or algal substrates, seagrasses normally <20 m, max 50 m | Spawning Year round, peak July-Oct. Moves offshore autumn- winter | Predominately consists of molluscs, crustaceans, polychaetes and brittle stars. Opportunistic feeders | Increased turbidity in shallow waters will results in crabs migrating away into deeper waters (away from turbid waters). | Can withstand wide salinity range 11-53%<br>Salinity levels significantly affect survival and growth of juveniles. Salinity for juveniles 20-35ppt. | Recreational year-round.<br>Commercial usually operates March-November. | Stable (sustainable) | Kangas (2000);<br>Chandrapavan et al. (2019);<br>Hovel and Lipcius (2001; 2002);<br>Romano and Zeng (2006) |
| Australian land hermit crab | Unknown/Short Lived. Highly abundant. | Endemic to northern Australia | Juveniles bury in sand onshore to undergo metamorphosis | Mangroves, sandy, rocky beaches, under rocks and logs during the day. Intertidal to supratidal, up to 100 m from the beach. | Releases eggs into the ocean Nov-March | Scavengers, predominately feeding on crabs and other live prey. | - | - | Hermit Crab Fishery | | van Dam et al. (2018) |
| Sandfish | Unknown/Short Lived | Pilbara-Kimberley (Indo-Pacific wide) | Seagrass beds near mangroves, <2 m water depths | Seagrass beds, adjacent to mangroves, inner reefs and lagoons | Year round<br>Peak Sept-Nov | Macroalgae | - | Have greater tolerance than other sea cucumbers<br>Salinity >47ppt causes death | WA Sea Cucumber fishery (minor) | Sustainable-Adequate | Sinsona and Juinio-Menez, (2018);<br>Hamel et al. (2013);<br>Tuwo et al. (2021) |
| Redfish | Unknown/Short Lived | Pilbara-Kimberley (Indo-Pacific wide) | Seagrass beds | Reef flats, estuaries, lagoons, seagrass, rubble, depths <20 m. | Unknown (summer months) | Macroalgae | - | - | WA Sea Cucumber fishery (minor) | Sustainable-Adequate | Conand et al. (2013) |

# 7. Summary and conclusions

## 7.1. Aquatic resources

Aquatic resources encapsulate the commercial, recreational, and customary use of the species they manage across a geographical region. The Northern Demersal Scalefish Resource has three fisheries that occur near the vicinity of the proposal, which provides sustainable commercial and recreational fishing value to the region, estimated to be $10-20 million. The fisheries within the resources are currently listed as adequate and sustainable. The aquatic resource in the Pilbara makes up a high percentage of the total catch, with 67% of the North Coast Bioregion demersal catches occurring in the three Pilbara fisheries. These fisheries are highly reliant on the three indicator species, with 90% of the total bluespotted emperor commercially caught by the PDSF, 59% for the red emperor and 70% for the Rankin cod are caught within the Pilbara commercial fisheries (Newman et al. 2021a). Although the Northern Demersal Scalefish Managed Fishery operates in the Kimberley subregion and does not overlap with the Proposal area, depletion of juvenile bluespotted emperor in the Pilbara could impact the catch within the Kimberley, as the Pilbara is thought to be the distribution point for the species into the Kimberley.

The Statewide Large Pelagic Scalefish Resource is another aquatic resource which is of high commercial and recreational value within the vicinity of the Proposal. The resource is highly reliant on its indicator species for both commercial and recreational value, especially the Spanish mackerel. The Spanish mackerel is the 5th highest finfish species caught by recreational fisheries and the 4$^{th}$ highest caught by tour and charter companies. The species is also highly economically valuable for the commercial fisheries, with an estimated value of $2.5-3 million. The recreational use of the resource is also estimated to generate an estimated $2.4 billion into the WA economy yearly (Lewis and Watt 2021) and is likely to occur within the Proposal area.

Although there are four commercial fisheries managed under the Northern Invertebrates Resource, including the OPMF, the Nickol Bay Prawn Managed Fishery, the Broome Prawn Managed Fishery and Kimberley Prawn Managed Fishery, only the OPMF overlaps with the Proposal area. This fishery relies on the key prawn species and also takes a variety of other non-target species.

The impact assessment will need to assess the impact to individual fisheries, especially with respect to their occurrence and habitat reliance during different life phases. The aquatic resource is utilised by many different stakeholders and these Resources are not restricted to the Proposal area. In particular, the Northern Demersal Scalefish Resource, including the key species bluespotted emperor, has a Pilbara population which is also important to the fishery in the Kimberley area.

- The Northern Demersal Scalefish Resource has three fisheries, the PFTIMF, PTMF and PLF that occur within the vicinity of the proposal, with a total estimated value of $10-20 million. These are monitored through the indicator species bluespotted emperor, red emperor and Rankin cod, which are taken both recreationally and commercially;
- The Statewide Large Pelagic Scalefish Resource is also of high commercial and recreational value within the vicinity of the Proposal. The key species for this fishery is the Spanish mackerel, which has an estimated value of $2.5-3 million locally (various other finfish are also targeted);

- The OPMF overlaps with the Proposal area and takes a variety of invertebrate species;
- The PCMF Fishery targets blue swimmer crabs in the vicinity of the Project area, both commercially and recreationally. This fishery is considered to be relatively small;
- Fisheries such as the WASCF, MAFMF, SSMF, Pearl Oyster Wild stock Fishery and the HCF are thought to be minor in the area, however Customary fishing may occur, particularly for silver-lipped pearl oyster; and
- Federally managed fisheries have fishing grounds in offshore waters adjacent to the Proposal area but are largely unrelated with the Proposal area as discussed in Section 4.10.

## 7.2. Indicator and key species

Species present and relevant to the Proposal area include the bluespotted emperor (*L. punctulatus),* red emperor (*L. sebae*), Rankin cod (*E. multinotatus*), narrow-barred Spanish mackerel (*S. commerson*), grey mackerel (*S. semifasciatus*), western king prawn (*P. latisulcatus*), brown tiger prawn (*P. esculentus*), silver-lipped/south sea pearl oyster (*P. maxima*), blue swimmer crab (*P. armatus*), Australian land hermit crab (*C. variabilis*), sandfish (sea cucumber) (*H. scabra*), and the redfish (sea cucumber) (*A. echinites*).

Of these, bluespotted emperor, red emperor, Spanish mackerel and prawns have been identified as the key socio-economically important species which are at the highest risk of potential impact from the Proposal. These high-value species have important habitats that may be directly impacted by the Proposal, most notably seagrass beds, macroalgal habitats and mangrove areas.

- Bluespotted emperor: juvenile phase is directly associated with inshore shallow macroalgal beds and may be vulnerable to their loss;
- Blue swimmer crabs: juveniles rely on high shoot density seagrass beds;
- Grey mackerel larvae: require inshore lower salinity areas; and
- Tiger prawns: juveniles inhabit shallow areas immediately adjacent to mangroves.

Macroalgae is a critically important nursery habitat for bluespotted emperors, with juveniles being reliant on nearshore macroalgae beds. Spawning and nursery areas are thought to be restricted to the west Pilbara. The western Pilbara region has the highest relative abundance of the bluespotted emperor and is the distribution point for the species across other regions.

Red emperors are long-lived slow growing species, and adults have restricted movements, which makes them inherently vulnerable to localised depletion. Juvenile red emperors are found inshore in turbid waters, while adults are found further offshore away from the Project activities. The species is commercially important within the Pilbara fisheries but is also a key species for the Kimberley demersal fisheries and other parts of WA. As this species relies on broadcast spawning, depletion in one area may affect other fisheries elsewhere. Impact assessment of the species will need to consider both the juvenile and adult habitat, and also its commercial and recreational impact.

Grey mackerel and Spanish mackerel should also be considered species of importance for the impact assessment, particularly due to their importance to recreational fishing and due to the fact that the grey mackerel juveniles may be sensitive to higher salinity water discharges.

Various prawn species as well as blue swimmer crabs typically show a high reliance on protected, muddy inshore areas, adjacent to either mangrove or dense seagrass beds (or both). Removal or damage to estuarine mangroves is likely to result in high sediment loads smothering the habitat on which they depend (Robertson and Alongi, 1995).

Other species of relevance include the banana prawn (*P. merguiensis*). Although not a key species, it is known to be present in the area and has a lifecycle that includes a post-larval and juvenile phase, which is restricted to mangrove lined estuaries. Additionally, some lesser commercially caught demersal species such as fingermark bream, estuarine rockcod, and mangrove jack are known to use the shallow nearshore waters of the Pilbara as nursery areas (Newman et al. 2004).

## 7.3. Important environmental aspects

- Mangrove-dominated intertidal environments are key to a variety of marine communities with relevance to fish and fisheries and should therefore be adequately considered in the impact assessment;
- Shallow macroalgal environments similarly are an important habitat and provide a significant food source;
- The discharge of brine has the potential to impact various juvenile and adult species. The tolerances and likely exposure to brine should be considered in the impact assessment; and
- Various juvenile and larval stages are present in the nearshore environment and may be impacted by seawater entrainment. The potential effects of this should be considered in the impact assessment.

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