LEICHHARDT SALT PTY LTD

Eramurra Solar Salt Production:

Identifying Potential Risks to Fisheries Values

Project: 0176 LEICHHARDT ESSP

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Acronyms and Abbreviations

BCH	Benthic Communities and Habitat
CC	Closed canopy
CIA	Cumulative Impact Assessment
CL	Carapace length
CPE	Cape Preston East
CW	Carapace width
DPIRD	Department of Primary Industries and Regional Development
DSDMMP	Dredge Spoil and Disposal Monitoring and Management Plan
EGPMF	Exmouth Gulf Prawn Managed Fishery
EIA	Environmental Impact Assessment
EPA	Environmental Protection Authority
ERA	Ecological Risk Assessment
ESSP	Eramurra Solar Salt Project
GL	Gigalitres
ha	Hectares
HEPAs	High ecological protection areas
HCF	Hermit Crab Fishery
ISO	International Organization for Standardization
Km	Kilometres
Kt	Thousand Tonnes
LAU	Local Assessment Units
LEP	Levels of ecological protection
LEPAs	Low ecological protection areas
L-M-C	Low – Medium Cover
LNG	Liquefied Natural Gas
L	Litres
l/s	Litres per second
LWC	Land & Water Consulting
m	Metre
m/s	Metres per second
m^2	Square metres
m^3	Cubic metres
MAMF	Marine Aquarium Managed Fishery
MEPAs	Medium ecological protection areas
MEQMMP	Marine Environmental Quality Monitoring and Management Plan
MD	Marine Development
MCEMP	Marine Construction Environmental Management Plan
MMF	Mackerel Managed Fishery
MSY	Maximum Sustainable Yield
Mt	Million tonnes

NaCl	Sodium Chloride
NBPMF	Nickol Bay Prawn Managed Fishery
NSW DPE	New South Wales Department of Planning & Environment
NT	Northern Territory
OPMF	Onslow Prawn Managed Fishery
PCMF	Pilbara Crab Managed Fishery
PDSF	Pilbara Demersal Scalefish Fishery
PID	Pond and infrastructure development
POMF	Pearl Oyster Managed Fishery
ppt	Parts per thousand
RFBL	Recreational Fishing from Boat Licence
SC	Scattered canopy
SCMF	Sea Cucumber Managed Fishery
SoP	Sulphate of Potash
SPL	Species protection levels
SSMF	Specimen Shell Managed Fishery
t	Tonnes
WA	Western Australia
WET	Whole of effluent toxicity
WPWSC	West Pilbara Water Supply Scheme
ZEPAs	Maximum ecological protection areas
ZoI	Zone of Influence
ZoHI	Zone of High Impact
ZoMI	Zone of Moderate Impact

1 Background

1.1 The Eramurra Solar Salt Project (ESSP)

Leichhardt Salt Pty Ltd (Leichhardt) proposes to construct and operate the Eramurra Solar Salt Project (ESSP), a solar salt production facility located 55 km west-south-west of Karratha in the West Pilbara Coast region of Western Australia (WA).

This facility will be used to extract up to 4.2 million tonnes (Mt) of high-grade salt (sodium chloride, NaCl) from seawater per year, using a series of evaporation and crystallisation ponds. This process involves:

- Pumping seawater into the first concentration pond, with progressive concentration by solar evaporation as the water flows through successive concentration ponds.
- Transferring the saturated brine into the pre-crystalliser and later, the crystalliser ponds, where further evaporation occurs. The resulting salt is deposited onto a pre-formed base in the crystallisers.
- Removing the salt from the drained crystallisers by mechanical harvesters, where it is stockpiled next to the processing facilities.
- Trucking the salt concentrate to the trestle jetty at Cape Preston East Port for export (by shipping).

One of the byproducts of the salt production process is bitterns, a highly concentrated brine that remains after the salt has crystallised. A maximum of 5.4 gigalitres (GL) of bitterns (at 360 ppt salinity) is expected to be produced each year. This will be pumped and discharged via an ocean outfall diffuser extending off the trestle jetty.

The ESSP proposal was referred to the WA Environmental Protection Authority (EPA) in June 2021 for assessment under part IV of the WA *Environmental Protection Act 1986*. Proposed project activities include the development of a series of concentrator and crystalliser ponds (approx.11,900 ha total area), a salt processing and dewatering plant, and associated infrastructure including:

- Seawater intake, pump station and pipeline
- Drainage channels and bunds
- Water supply (desalination plant)
- Bitterns disposal pipeline and outfall (via the trestle jetty)
- Utilities (power supply and lines)
- Pumps, pipelines, roads and support buildings
- Workshops and laydown areas
- Landfill

The proposal also includes dredging of a channel and berth pocket at the Cape Preston East Port, along with the disposal of dredged materials (onshore and offshore). Other shipping related impacts are considered separately under the Cape Preston East Port development proposal.

In 2022, the EPA approved Leichhardt's submitted Environmental Scoping Document. Since then, Leichhardt has commissioned several studies to establish baseline environmental conditions, identify environmental risks, and guide the development of mitigation strategies to alleviate project impacts where needed.

This process has included an evaluation of potential direct and indirect impacts to key fish species and fisheries from ESSP construction and operations. These reviews concluded that while many of the potential impacts to fish and fisheries had been adequately addressed through the proposed mitigation and management measures, there remain a few unresolved issues of concern that need to be considered. In particular, cumulative impacts to fish and fisheries from existing and proposed solar salt production facilities and other coastal developments along the West Pilbara Coast have yet to be adequately addressed. There is strong concern from commercial and recreational fishers that increasing solar salt production in the Pilbara will threaten the viability of important fish and invertebrate populations from the potential loss and disturbance of nearshore nursery habitats and related flow-on effects to offshore populations.

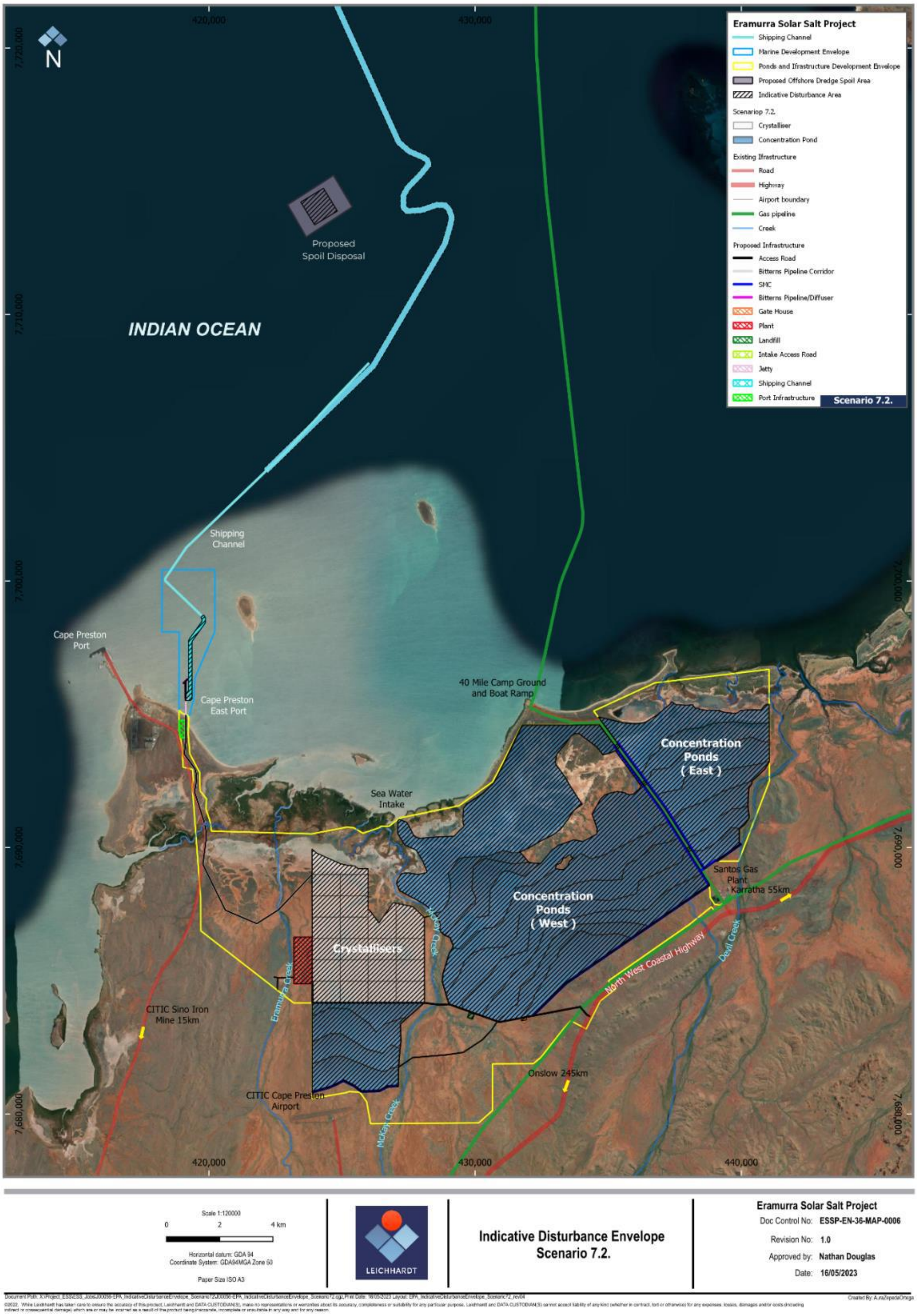

Figure 1–1: Proposed development envelope and indicative layout of the ESSP (O2 Marine, 2023a).

1.2 Purpose

This report provides background information to support a Cumulative Impact Assessment (CIA) of the ESSP on fisheries values, including important species and commercial, recreational and customary fisheries, within the ESSP vicinity and the broader West Pilbara Coast region. This includes:

- Review of previous fisheries impact assessments for the ESSP.
- Identification and characterisation of fisheries values within the ESSP vicinity.
- Collation of publicly available information on other relevant future projects within the West Pilbara Coast region to inform the CIA.
- Development of a risk-based approach that can be applied with scientists, managers and other stakeholders including fishers and Traditional Owners, to evaluate potential impacts at a project and regional level. Outcomes from this process will be used to identify and refine potential mitigation strategies for the ESSP to address high-risk issues and minimise the project's contribution to any unacceptable cumulative impacts.

1.3 Previous fisheries impact assessments

There have been multiple studies exploring the potential impacts of the ESSP on fish and fisheries in the project's vicinity:

- An initial desktop review identified key fisheries and species in the ESSP vicinity, along with their associated habitats and important ecological windows (O2 Marine, 2023a)
- Quantitative studies and modelling were used to estimate impacts to intertidal and subtidal benthic communities and habitats (BCH), including estimates of total habitat loss from combined project activities (O2 Marine, 2023b)
- A fisheries impact assessment considered the scale and significance of potential direct and indirect impacts on key fish species, critical habitats, and associated fisheries at a local and regional scale (O2 Marine, 2023c). This was accompanied by a qualitative evaluation integrating expert input from marine ecologist and fish biologists (Fishwell Consulting, 2023).

These studies concluded that proposed avoidance and mitigation measures—such as optimising the project footprint to avoid high value BCH areas (where possible), limiting dredging to April through July to avoid peak reproductive periods and key ecological windows (e.g., coral spawning), maintaining surface flows through McKay Creek, limiting seawater intake velocities to a maximum of 0.15 metres per second (m/s), and optimising bitterns outfall maximise mixing— adequately address many of the anticipated project impacts.

However, there were several unresolved issues that require further attention (Fishwell Consulting, 2023):

(1) Loss of important nursery habitats and flow-on effects to offshore fish and invertebrate populations

Potential impacts on critical nursery habitats, like mangroves, seagrasses, macroalgae and corals, could extent to offshore populations, due to their ecological connectivity. These areas serve as important nursery areas for species like prawns, blue swimmer crabs, and finfish (including indicator species for the demersal finfish suite), supporting juvenile stages before they move offshore and support local fisheries.

Key species, such as prawns, bluespotted emperor, red emperor and rankin cod may be particularly vulnerable, with potential repercussions for fisheries management and stock recovery efforts (e.g., for red emperor, goldband snapper).

(2) Entrainment and entrapment of early life stage fish and invertebrates

Many fisheries species rely on nearshore habitats like creeks, mangroves, seagrasses, and macroalgae for their early development stages (Arevalo et al. 2023; Plaganyi et al. 2023). Hydrodynamic processes, such as flood tides and longshore drift, also help concentrate larvae in nearshore areas (Penn, 1975; Condie et al. 1999), making them vulnerable to intake systems.

Entrainment occurs when small larvae and juvenile fish or invertebrates are directly drawn into intake pipes along with seawater, entering the concentrator pond system. In contrast, entrapment often affects larger individuals (e.g., adults or larger juveniles) that become physically trapped against the screens at the intake structure, potentially leading to injury or mortality if they cannot escape.

Studies elsewhere in WA have shown that species like prawns, mud crabs, blue swimmer crabs and various finfish are susceptible to these impacts (Molony and Parry, 2002), which may be significant given the high intake rate (6000 litres per second (l/s)) and substantial quantity of seawater extracted annually (~160 GL).

(3) Changed environment flows around McKay Creek that support ecosystem services.

Extracting approx. 160 GL of seawater annually from the tidal McKay Creek may disrupt natural environmental flows, with potential effects on ecosystem functions that support commercial and recreational species, such as snappers and groupers.

Pumping when the basin is above mean sea level is expected to delay natural upstream tidal flooding by around 10 minutes. This delay may alter local hydrodynamics and coastal processes, potentially impacting habitat conditions and species movement patterns.

Additionally, there is uncertainty regarding the seepage of hypersaline water from the ponds into groundwater systems, which could potentially impact nearby seagrasses and mangrove habitats.

(4) Implications for Indigenous communities

The ESSP is located within the Land and Sea Country of the Mardudhunera and Yaburara peoples. Given the importance of this area and fisheries resources for food and cultural practices, these considerations require thorough assessment to understand the project’s full impact on the Mardudhunera and Yaburara communities.

(5) Cumulative impacts from multiple solar salt projects across the West Pilbara region

The broader, cumulative impacts of multiple solar salt operations and other coastal development across the West Pilbara region are not yet fully understood. Given the region's extensive industrial development and the compounding effects of climate change, this uncertainty underscores the need for a comprehensive CIA.

2 Cumulative Impact Assessment (CIA)

The EPA has advised that all future salt proposals on the West Pilbara Coast must include an assessment of the cumulative impacts to benthic habitats and communities from their activities along with existing, approved and proposed projects.

Undertaking a CIA is inherently complex, due to uncertainties surrounding future projects, data limitations, and the challenge of integrating impacts from multiple activities. To inform our assessment approach, we reviewed existing assessment methods for fisheries values, as well as guidelines for cumulative impact assessments used elsewhere in Australia (e.g., NSW DPE, 2022).

This information was used to develop a fit for purpose framework to assess potential impacts of the ESSP project to the existing baseline conditions[1] of fisheries values within the ESSP area, as well as the cumulative impacts of the ESSP with other relevant future projects within the West Pilbara Coast region.

2.1 Assessment framework

This assessment uses a combination of incremental and cumulative impact assessments (CIAs) to evaluate potential impacts from the ESSP on fisheries values in the project vicinity, as well as potential cumulative impacts on fisheries values from multiple solar salt production facilities across the West Pilbara Coast region.

- **Incremental assessment** considers the additive effects of ESSP activities relative to baseline (current) conditions in the project vicinity over its lifetime. This assessment is conducted for each identified *issue*, which is the combination of an *activity* (e.g., dredging) and a specific *fisheries value* (e.g., the bluespotted emperor population), as well as the combined effects of all activities on fisheries values.
- **CIA** considers the cumulative impacts on fisheries values from the ESSP in combination with other relevant future projects in the West Pilbara Coast region.

By combining these approaches, we can assess potential changes to the baseline condition of each fisheries value resulting from the ESSP, alongside additional impacts that may arise due to interactions between the ESSP and other relevant future projects in the region. This includes changes to existing projects (e.g., expansion, closure) or the initiation of new projects.

Table 2-1: Assessment approaches used to evaluate cumulative impacts (adapted from NSW DPE, 2022).

Assessment types	Description
Incremental assessment	Impact of adding a specific ESSP activity on the baseline condition* of relevant fishery values.
Combined incremental assessment	Combined effect of different ESSP impacts on relevant fisheries values.
Issue-specific cumulative impact assessment (CIA)	Cumulative impacts from ESSP together with other future projects on specific fisheries issues. Extends beyond impacts to the existing baseline condition to consider additional impacts that may occur over time as a result of changes to existing projects or the introduction of new projects.
Combined CIA	Combined effects of different cumulative impacts of the ESSP and other future projects on relevant fisheries values.

[1] Baseline condition should include the existing impacts caused by historical and currently operating projects within the ESSP vicinity.

Assessment types	Description
** Baseline (current) condition includes the existing impacts caused by past projects, as well as currently operating projects within the ESSP area.*	

2.2 Assessment scope

This assessment aims to identify and address high-risk issues that may significantly impact fisheries values as a result of the ESSP and other relevant future projects, building on previous studies by O2 Marine (2023c) and Fishwell Consulting (2023).

This is done by evaluating changes to the baseline condition of each fisheries value as a result of ESSP activities and assessing how these changes compare to relevant criteria set out in EPA legislation, policies and guidelines.

2.2.1 Environmental objectives

As per EPA guidelines, most fish and invertebrates are addressed under the environmental factor of *marine fauna*; however, animals that are attached to the seabed, such as sponges and corals, are addressed under *BCH*. Commercial, recreational and customary fishing are considered within *social surroundings*.

Relevant objectives for these factors are (EPA, 2018):

- Marine fauna: to protect marine fauna so that biological diversity and ecological integrity are maintained.
- Benthic communities and habitats (BCH): to protect BCH so that biological diversity and ecological integrity are maintained.
- Social surrounds: to protect social surroundings from significant harm.

In this context, *ecological integrity* refers to the composition, structure, function and processes of ecosystems and the natural variation of these elements. *Social surroundings* refer to the cultural, aesthetic, economic and social factors in a person's environment, which are interconnected with their physical and natural surroundings.

The EPA focuses on significant impacts to marine fauna, including (EPA, 2016):

- Reduced populations of locally or regionally important species
- Impacts on species or groups that fulfil critical ecological functions within the ecosystem
- Loss or impact to critical habitat, including nursery areas and fish spawning aggregation areas
- Reduced species diversity in an area, possibly resulting from factors such as migration or range contraction due to declines in local environmental quality
- Introduction and/or spread of invasive marine species or diseases.

Given the inherent links exist been marine fauna and other environmental factors (e.g., BCH, marine environmental quality and coastal processes), impacts to marine fauna are assessed alongside these other factors to evaluate impacts on overall ecosystem integrity.

Under the EPA guidance, project specific impacts are also considered in terms of their potential to contribute to further changes in biological diversity and ecological integrity, in combination with climate change (EPA, 2016).

2.2.2 Spatial and temporal aspects

The study area for this assessment encompasses the geographical region surrounding the ESSP and relevant future projects, with a focus on areas that may be impacted by the proposed activities.

For the incremental assessment, we use the study area defined for the ESSP environmental impact assessment process, which covers the project footprint and potential impact area within the project vicinity. This area has been divided into 13 local assessment units (LAU) to help quantify impacts to BCH (Figure 2–1).

The CIA considers impacts across the West Pilbara Coast region, extending from Karratha through Exmouth Gulf. Given the wide spatial scale and diversity of issues being considered, the assessment scope will vary depending on the specific characteristics of the issues being addressed, as well as the scale and nature of potential impacts. For example, the assessment area for a specific fish species may be determined by that species' distribution, stock structure, and habitat use. Impacts to fisheries will be assessed along the West Pilbara Coast or within the local boundary of the fishery, whichever is smaller.

The assessment will cover the entire life of the ESSP, including construction (4 years) and operations (60 years), as well as other future projects expected to occur over this time period.

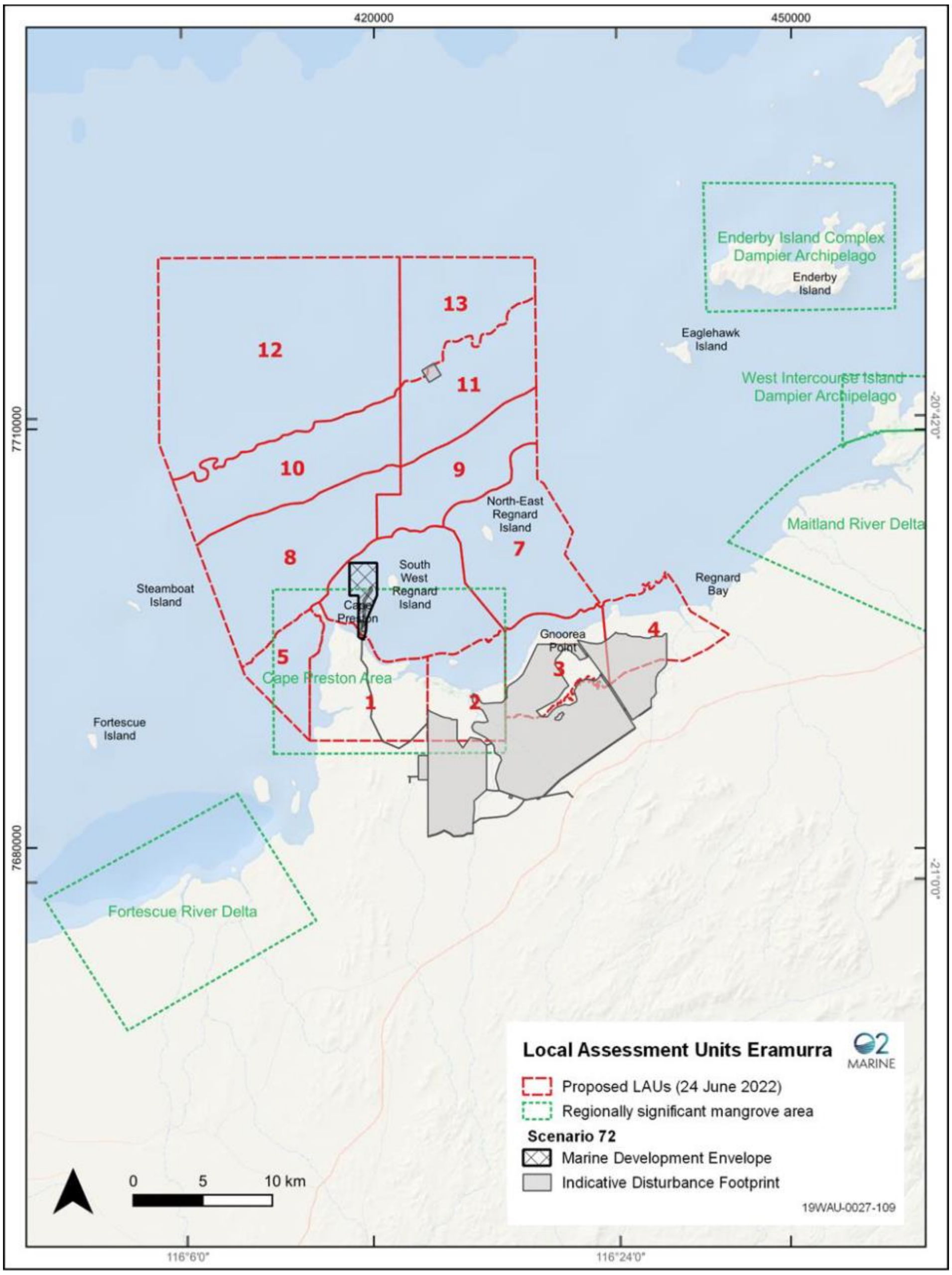

Figure 2–1: Study area and associated local assessment units (LAU) for the ESSP, along with regionally significant mangrove areas (O2 Marine, 2023b).

2.2.3 Other relevant projects

Other solar salt projects currently operating along the West Pilbara Coast include Onslow Salt, Dampier Salt, and Sino Iron Desalination Plant. Existing impacts from these projects are captured in the baseline condition used to inform the incremental assessments (as per O2 Marine, 2023b).

Table 2-2: Other solar salt project and coastal infrastructure currently operating/in place along the West Pilbara Coast region.

Project	Summary
Onslow Salt Shark Bay Salt Pty Ltd (subsidiary of Mitsui & Co. Ltd)	The Onslow salt field was built in the late 1990s near Onslow township. The salt field encompasses 220 km^2, of which 87 km^2 is occupied by six evaluation ponds and 15 crystalliser ponds. 6.0 GL of bitterns discharged per year. Onslow Salt has a salt-washing plant, a stockpile area and its own port. Onslow salt produces 2.7 Mt of salt per year.
Dampier Salt – Dampier Dampier Salt Ltd. (joint venture between Rio Tinto, Marubeni Corp. and Sojitz)	Dampier Salt was built in the late 1960s and is located midway between Dampier and Karratha. Produces approx. 4 Mt of salt per year. 3.86 million m^3 (3.86 GL) of bitterns discharged into Nickol Bay per year.
Sino Iron Desalination Plant and bulk loading facility CITIC Pacific Mining	Commissioned in 2013, the plant extracts seawater from the coastal waters off Cape Preston and uses reverse osmosis technology to produce up to 140 megalitres of potable water per day (51 GL per year) for the Sino Iron Project. The plant (54,000 m^2) incorporates an intake pump well with 2 stage screening, a 2.5 km intake pipeline, 4-stage pretreatment plant, reverse osmosis plant, energy recovery system, post treatment water stabilisation plant, and a 3 km outfall pipeline. 64 GL of bitterns discharged per year.

The CIA also considers impacts from other relevant future solar salt and coastal development projects in the region. This includes:

- Existing projects whose activities are expected to change, e.g., the intensity of operations is expected to change, the project is seeking approval for expansion, or the operation will close.
- Projects approved by the EPA but that have not yet started.
- Projects that are currently under assessment by the EPA.
- Development projects related to the ESSP that are subject to separate assessment (e.g. the Cape Preston East Port facility).

Eight relevant future projects were identified for inclusion in the ESSP CIA (Figure 2–2). These projects are in various stages of development and include two solar salt production projects, Mardie and Ashburton, desalination plants, and coastal infrastructure (e.g. port development/expansion). The desalination plants support various mining, industrial and municipal infrastructure along the coast. Some of the plants operate through independent infrastructure, while others utilise combined infrastructure and discharge through the Multi-User Brine Return Line on the Burrup Peninsula.

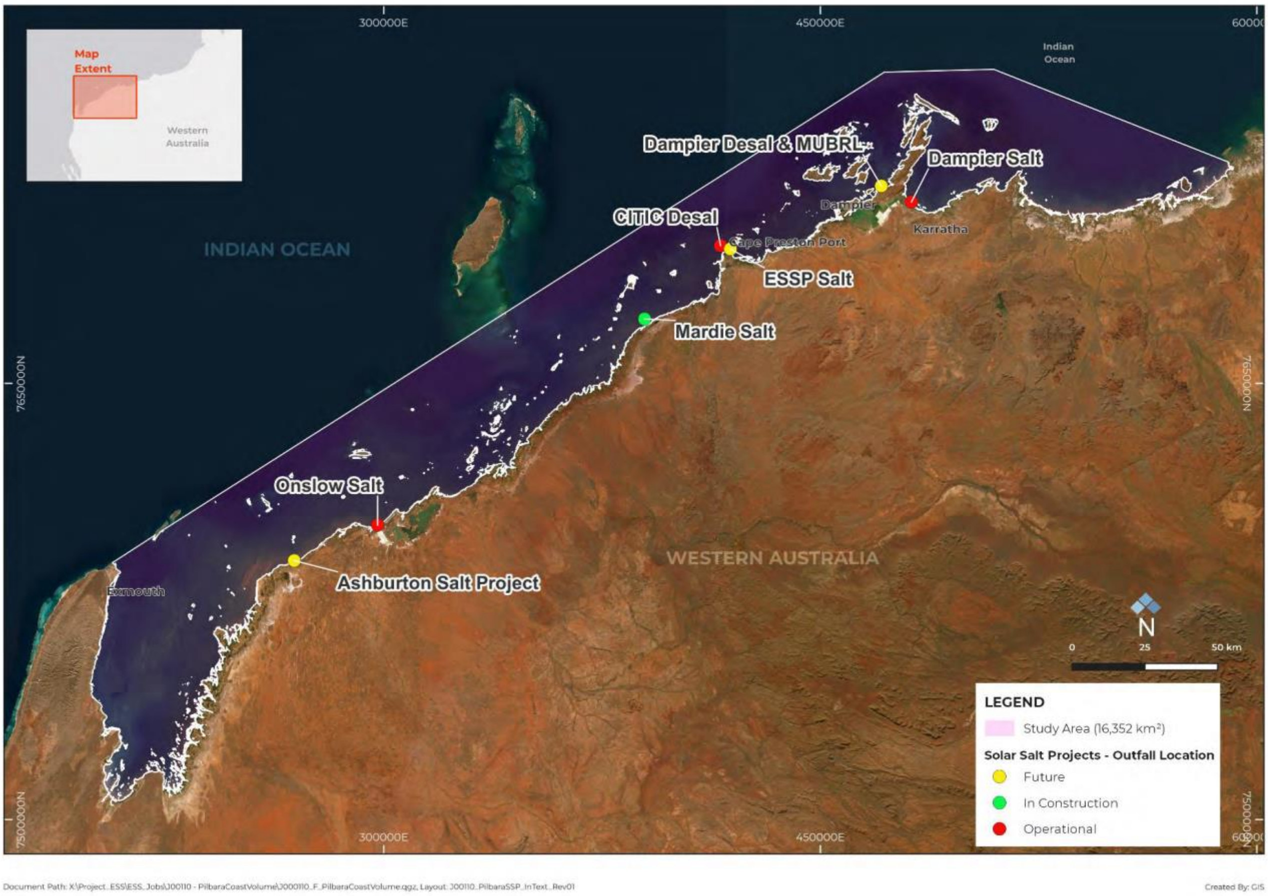

Figure 2–2: Other solar salt production and seawater processing projects in the West Pilbara Coast region. Note, CITIC represents the Sino Iron Project Desalination Plant (Preston Consulting, 2023a)

2.3 ESSP activities

Construction and development of ESSP is expected to take four years to complete. This process includes the construction of concentration ponds and related land-based infrastructure; installation of the seawater intake pipeline, bitterns' pipeline and outfall diffuser; and initial dredging of a shipping channel and berth pocket.

Once operational, the ESSP will produce up to 4.2 million tonnes (Mt) of high-grade salt (sodium chloride, NaCl) from seawater per year, using a series of evaporation and crystallisation ponds. This involves pumping seawater from McKay Creek into the first concentrator pond, with progressive concentration by solar evaporation as the water moves through successive ponds and finally, into the crystalliser for harvesting.

One of the byproducts of the salt production process is bitterns, a highly concentrated brine that remains after the salt has crystallised. A maximum of 5.4 GL of bitterns (at 360 ppt salinity) is expected to be produced each year. This will be pumped and discharged via an ocean outfall diffuser extending off the trestle jetty. Bitterns return are pumped into the port berth/shipping channel, reducing the overall area directly impacted by ESSP activities (Table 2-3**;** Figure 1–1).

Table 2-3: ESSP construction and development activities and proposed extent of disturbance from development process.

Activity	Proposed extent of disturbance
Construction and Development	
Pond and Infrastructure Development Development, construction and installation of concentrator ponds and crystallisers, process plant, desalination plant, administration and site offices, and associated works (e.g., access roads, laydown, water supply, other services)	No more than 12,210 ha footprint within the 20,160 ha Ponds Development Envelope
Marine Development Development and installation of infrastructure for seawater intake and pipeline, bitterns pipeline and outfall diffuser, and shipping channel (initial dredging). Dredging is scheduled to occur in winter months, avoiding peak storm water flow periods and associated increased inshore turbidity. Periodic maintenance dredging is anticipated every 5 – 10 years, depending on impacts from events like cyclones.	No more than 53 ha footprint within the 703 ha Marine Development Envelope
Dredge spoil disposal development Development of an offshore location for disposing of dredge spoil.	No more than 100 ha footprint within the 285 ha Dredge Spoil Disposal Development Envelope Approximately 400,000 m3 dredge material Dredge material disposed of offshore, 14 km north of the Marine Development Envelope.
Operations	
Seawater intake Seawater will be taken into the pond system each year from within the Marine Development Envelope, including the entrance to McKay Creek. The pump station will only operate when waters are above mean sea level (MSL), with staged energisation and the progress speed gradually increasing in line with natural flows.	160 GL of seawater intake per year Maximum intake flow rate of 0.15 m/sec, in line with global standards.
Concentration in ponds Sea water is stored and moved through concentration ponds to progressively increase salt concentration and into crystallisers to form precipitate (salt crystals).	Ponds and crystalliser will cover 12,201 ha and are located on a Mining Lease.
Bitterns discharge Bitterns will be discharged via ocean outfall diffuser off the trestle jetty at the port berth area within the Marine Development Envelope. Bitterns will be diluted to 1:1 volume ratio with local seawater prior to discharge and are expected to remain within the shipping channel until	Up to 5.4 GL of bitterns (360 ppt salinity) discharged each year, with maximum of 0.65 GL discharged in a peak summer month.

Activity	Proposed extent of disturbance
fully dissolved. Modelling indicates that seawater salinity will return to normal levels within several hundred metres of the discharge site.	

2.3.1 Pond construction and related infrastructure

The terrestrial development footprint includes the construction of concentration ponds and crystallisers, processing plant, desalination plant, administration, accommodation camp and associated works (access roads, laydown, etc.). These activities have an estimated maximum disturbance extent of 12,201 ha within the 20,160 ha Ponds and Infrastructure Development (PID) envelope. The concentration ponds cover approximately 10,060 ha, while the crystallisers cover approximately 1,840 ha. Construction and development activities (on- and off-shore) are managed through a dedicated Marine Construction Environmental Management Plan (MCEMP).

This construction is expected to result in the direct irreversible loss of 1,267 ha of intertidal BCH, including beach, rock platform, mangroves (including scattered and closed canopy mangroves), samphire shrublands, mudflats and algal mats. Most of the direct disturbance will occur in the central-eastern part of the intertidal area (LAU2 – LAU4). This area comprises predominantly terrestrial vegetation, inland mudflats, samphire shrubland and algal mats. The development envelope also includes a section of Regionally Significant Mangrove Area (in LAU1 and LAU2; O2 Marine, 2023b).

While significant changes to tidal inundation around the pond infrastructure are expected, mangrove inundation has been mostly maintained: ~ 99.9 % and 98.5 % of regionally significant mangroves in LAU1 and LAU2, respectively, will not be impacted by changes (O2 Marine, 2023b).

Pond construction and development activities (on- and off-shore) are managed through a dedicated MCEMP.

The three major freshwater flow paths in the area, McKay Creek, Eramurra Creek and Devil Creek, will be maintained (O2 Marine, 2023b). The pond layout has been designed to allow surface water drainage to continue through McKay Creek (the most significant creek) to the marine environment—an area that supports intertidal samphire shrubland and algal mat—effectively directing and concentrating flows along this drainage channel.

A surface water hydrology study by Land & Water Consulting (LWC) determined that the proposed ponds would reduce the area of land contributing freshwater runoff to the marine environment by approximately 17 %. This reduced catchment area means that during flooding events, the volume of fresh water available to flush intertidal areas downstream of the ponds would decrease significantly. This change could potentially affect the intertidal samphire shrubland and algal mat communities; however, the exact effects of this reduction on these ecosystems remain unknown (LWC, 2023).

Additionally, water levels around the perimeter of the ponds are expected to increase, but these increases would be confined to within 500 m of the pond embankments (LWC, 2023).

The total volume of fresh water typically available to flush the intertidal areas downstream of the ponds during a flooding event would be appreciably reduced due to the reduced catchment surface area (LWC, 2023). The overall reduction in surface water has the potential to adversely affect the intertidal samphire shrubland and algal mat BCH that occur downstream of the ponds by altering seasonal freshwater inundation patterns; however, the effects of this are unknown.

Leichhardt has committed to monitoring changes to hydrodynamics regime and potential impacts to mangroves, with management actions implemented should any impacts be detected.

2.3.2 Marine development

Development activities within the marine environment include the installation of the seawater intake and associated pipeline, installation of the bitterns pipeline and outfall diffuser, and channel dredging. The maximum extent of disturbance is proposed to be 53 ha, within the 703 ha Marine Development (MD) envelope. Marine construction and development activities (on- and offshore) are managed through a dedicated MCEMP.

Dredging will be done as part of the development process to remove high points at the Cape Preston East Port to create a berth pocket, turning basin and channel for the self-propelled, self-unloading transhippers that will transfer salt from the trestle jetty to ocean going vessels located at anchorages 10 – 15 km from the jetty (O2 Marine, 2023d). Periodic maintenance dredging is anticipated every 5 – 10 years, depending on local environmental conditions and disturbance events, such as cyclones.

Port design has been optimised to reduce overall dredging volumes and associated dredging duration (up to 105 days). Dredging will occur during winter months (May – September) to avoid peak periods of storm water flows, which increase coastal water turbidity, and minimise cumulative impacts on water quality. Up to 400,000 m^3 of sand and calcarenite will be dredged to form the berth pocket, turning basin and transit channel. The dredge spoil has been characterised as ‘generally fine to coarse sand, occasionally gravelly’, with a very low percentage of fine sediments (O2 Marine, 2023d).

Dredged materials will be disposed of onshore (within the Pond Development envelope) or at a single offshore location. Dredging and offshore spoil disposal areas are within the Marine Development envelope (O2 Marine, 2023d).

Most of the disturbance to subtidal areas is expected to occur in LAU6. This area includes filter feeder communities, macroalgae, and low-moderate cover coral habitat. Direct disturbance will result in irreversible loss of 24.6 ha of vegetated subtidal BCH including 3.1 ha (7.1 %) of filter feeders (high cover), 17.9 ha (1 %) of coral reef (low-moderate cover), and 3.6 ha (0.05 % of macroalgae, including 2.5 ha (0.1 %) of macroalgae (low-moderate cover) and 1.1 ha (0.1 %) of seagrass/macroalgae. An additional 125.3 ha (0.2 %) of bare ‘unvegetated’ substrate (e.g. coarse sand) will also be directly impacted.

As per EPA guidance, a dredge plume impact assessment was undertaken to predict the dredging Zone of Influence (ZoI), Zone of Moderate Impact (ZoMI) and Zone of High Impact (ZoHI) for BCH in the vicinity of dredging activities (O2 Marine, 2023b). Although dredging scenarios were modelled for both winter and summer seasons (O2 Marine, 2023b), dredging will only occur during April – June, to avoid environmentally sensitive windows and peak fish and coral spawning periods. Therefore, only the winter scenario was considered for impact assessment purposes.

Dredge plume modelling results for both coral and seagrass thresholds indicate that the ESSP will not result in any *indirect* irreversible loss impacts for either coral, seagrass or macroalgae BCH. The worst case ZoMI (winter scenario) for suspended sediment concentration was also used to determine the extent of predicted recoverable impacts to subtidal BCH as an indirect result of dredging. Results estimate recoverable impacts to 81 ha of coral reef (5 ha of high cover and 76 ha of low-moderate cover reef). There were no recoverable impacts to seagrass/macroalgae.

The Dredge Spoil and Disposal Monitoring and Management Plan (DSDMMP) includes a comprehensive set of management actions and environmental performance measures, as well as a tiered framework for minimising the extent of any impacts to important critical fish habitat (e.g. coral, seagrass or macroalgae).

2.3.3 Operations: seawater intake

Seawater intake will occur via a single intake system at McKay Creek. The intake system is designed to operate only when water levels are at baseline sea levels (0 m AHD) or higher, with progressive increase in extraction rates in line with tidal flows. At these levels, there is a larger volume of water flowing through the tidal zone, which reduces the likelihood of localised impacts from water extraction, such as water depletion or disruption of normal tidal flows.

The intake will be fitted with screens to enclose the intake pipe. Intakes will draw in water through all sides of the perimeter screen, resulting an even flow rate around the perimeter.

Seawater intake speeds are limited to a maximum of 0.15 metres per second (m/s). This is the maximum flow rate recommended by the United States EPA (USEPA, 2014), as it protects 96 % of fish species, including prawns. This flow rate has also been adopted for seawater intakes in nearby projects, including the Wheatstone Development and Mardie Salt Project (O2 Marine, 2023c).

2.3.4 Operations: salt concentration process

Seawater is stored and moved through concentration ponds, progressively increasing the salt concentration, and into crystallisers to form precipitate (salt crystals).

The pond walls have been designed in accordance with international standards, with details of the wall design provided in CMW Geosciences (2022). The CMW Geosciences (2022) geotechnical review found that the pond wall design includes a significant safety factor, which sufficiently mitigates the risk of pond wall failure.

2.3.5 Operations: bitterns discharge

The salt production process will produce a high-salinity bittern (360 ppt salinity) that will discharge up to 5.4 GL of bitterns each year into the marine environment.

Leichhardt has measured salinity within the project area, logging a mean salinity of 37 ppt across the study area (maximum salinity of 42 ppt), with increased salinity closer to shore and within the shallow bay area (Preston Consulting, 2023a).

Bitterns will be discharged into the ocean via a bitterns diffuser that extends beyond the end of the trestle jetty, within a dedicated offshore mixing zone (within the Marine Development envelope). Modelling indicates that bitterns will sink to the seafloor, as it has a higher specific gravity than seawater, and remain in the dredged berth/channel area until dissolved. Seawater salinity is expected to return to normal levels within several hundred metres of the discharge site, limiting the spatial extent of any impacts due to hypersalinity. The location of the diffuser approx. 1.5 km along the jetty avoids any high salinity discharges within inshore coastal bays, lagoons and estuarine environments that support seagrass and mangrove habitats.

Within the Environmental Quality Management Framework, different levels of ecological protection are applied to spatially defined areas to establish limits of acceptable change. This includes maximum ecological protection areas (XEPAs), high ecological protection areas (HEPAs), medium ecological protection areas (MEPAs) and low ecological protection areas (LEPAs).

Whole of effluent toxicity (WET) testing was conducted on bitterns (based on Mardie bitterns[2]), which determined that the bitterns' toxicity was primarily related to changes in salinity. Results were used to determine the dilutions needed to meet the required species protection levels (SPL) and levels of ecological protection (LEP).

The diffuser's design and location were developed to ensure adequate dilution of bitterns to ensure required marine water quality is achieved at the edge of the mixing zone and proposed LEPA. Based on bitterns dispersion modelling, an applied dilution factor of 509 resulted in a salinity increase of < 1 ppt above the background salinity at the high LEP boundary. This is similar to the existing mean salinity difference at the proposed diffuser location (1.5 km offshore) and 4.5 km out from the mouth of McKay Creek (within a shallow bay area).

All BCH within the LEPA (area immediately around the discharge zone) are conservatively assumed to be irreversibly impacted and permanently lost. This includes loss of coral reef (1.4 ha), macroalgae (2.5 ha), and seagrass (1.1 ha).

Beyond the LEPA mixing zone, a MEPA is proposed out to a 250 m radius (from ship turning basins and berths) to accommodate potential impacts on environmental quality. Dispersion modelling found that the extent of the moderate LEP stabilised at 1.29 km^2, and within the MEPA, the input of salts was balanced by its removal from the zone via mixing and convection processes. Beyond the MEPA, an HEPA will be maintained. There is an XEPA east of the proposal area (due to a proposed marine park), which will not be impacted (O2 Marine, 2023c).

Bitterns discharge will be managed through a Marine Environmental Quality Monitoring and Management Plan (MEQMMP) to validate predicted outcomes and ensure designated LEPs are achieved for the lifetime of the project.

This will ensure that background water and sediment quality beyond the designated LEPs is maintained and unacceptable impacts on marine species and habitats are prevented.

2.3.6 Benthic habitats and communities (BCH) in the ESSP vicinity

Extensive surveys of intertidal and subtidal BCH were undertaken within and adjacent to the ESSP area (O2 Marine, 2023e, O2 Marine, 2023f). Seventeen BCH classes were identified and mapped (Table 2-4; Figure 2–3)

ESSP construction and development activities are estimated to result in the direct irreversible loss of 1,267 ha of intertidal BCH within the Terrestrial Development envelope and 24.6 ha of vegetated substrate within the Marine Development envelope. A further 125.3 ha of bare (unvegetated) substrate, e.g. coarse sand, will also be directly impacted as a result of dredging and/or spoil disposal; however, as this area will remain classified as bare sand after dredging completion, these impacts are not considered habitat loss. Based in the immediate nature of proposed impacts and spatial accuracy of mapping, there is a high degree of certainty these impacts will occur (O2 Marine, 2023b).

Indirect impacts from ESSP construction/development and operations, including dredging/dredge plume disposal, bitterns discharge, changes to surface water flow, nutrient budget, coastal processes and groundwater seepage have also been assessed (see O2 Marine, 2023b for summary).

BCH in the ESSP area has been historically impacted by the development of the Cape Preston Port (in 2010) and construction of the road to Gnoorea Point. These developments resulted in the estimated

[2] Note, additional WET testing using bitterns that are likely to be characteristic of the ESSP is currently underway. These results may affect the SPLs and modelling results.

direct loss of BCH over an area of ~ 63 ha. A summary of estimated historical loss and predicted recoverable impact and irreversible loss from the ESSP, by habitat type, is provided in Table 2-4.

Table 2-4: Intertidal and subtidal habitats within the ESSP area and estimated extent of direct irreversible loss and recoverable impacts due to project activities (based on information presented in O2 Marine 2023b).

Habitat type	Description	Estimated disturbance from ESSP	
		Irreversible loss	Recoverable impact
Intertidal habitats			
Sandy beaches	Typically flat, low energy, low profile beaches backed by gently rising dunes.	Direct disturbance: 0.1 ha (< 0.1 %)	None
Tidal creeks	Traverse the intertidal zone between Gnoorea Point and Cape Preston East. Typically flat, with fine to coarse sand and mud, with occasional sparse macroalgae.	None	None
Fringing rock platform	Occasional very sparse turf algae cover. Occurs within wave zone along some of the beaches west of Regnard Bay and around Gnoorea Point.	Direct disturbance: 0.04 ha (< 0.1 %)	None
Mangroves	Closed canopy (CC) mangroves, which comprise greater structural complexity compared to scattered mangrove and typically have higher seaward mangrove associations. *Avicennia marina* is dominant species, with *Rhizophora stylosa* the sub-dominant species.	Direct disturbance: 1.8 ha (0.3 %) Indirect loss due to changes in coastal processes: 1.7 ha (adjacent to seawater intake at McKay Creek) (O2 Marine, 2023b)	None
	Scattered canopy (SC) mangroves, comprising less structural complexity compared to CC mangroves and have typically lower landward mangrove associations. Includes *Avicennia marina*, *Rhizophora stylosa*, with occasional *Ceriops australis*.	Direct disturbance: 6.1 ha (1 %)	None
Mudflat/ sandflats	Extremely low biodiversity, supporting little to no fauna or flora due to characteristic high salinity. Occurs on higher intertidal gradients and the landward extent of Samphire or algal mats.	Direct disturbance: 35.8 ha (1.4 %)	None
Algal mat/ mudflat	Typically, green to grey or black and either contiguous or fragmented. Typically, green to grey or black and either contiguous or fragmented. Vary greatly in desiccation status (largely dependent on frequency of inundation relative to timing of mapping surveys). Six species were identified in algal mats, dominated by filamentous cyanobacteria	Direct disturbance: 771.1 ha (23.4 %)	None

Habitat type	Description	Estimated disturbance from ESSP	
		Irreversible loss	Recoverable impact
	Lyngbya sp., *Coleofasciatus chthonoplastes* and *Schizothrix* spp.		
Samphire shrublands	Typically located on landward of mangroves, with several smaller communities located landward of algal mats and seaward of terrestrial vegetation. Also overlap areas where samphire shrublands extend into low lying algal mat areas, which rely on seasonal freshwater inundation.	Direct disturbance: 452 ha (31.6 %)	None
Subtidal habitats			
Bare substrate	Includes coarse sand and silt. Coarse sand may consist of very sparse patches of sandy veneer on limestone pavement, which may support patches of sparse (< 5 %) macroalgae/filter feeders/corals. Finer silt areas likely to be bioturbated with little macroalgae/filter feeders/corals.	Direct disturbance: 125.3 ha (0.2 %)	20.4 ha (<1 %)
Coral reef	Comprises a variety of hard/encrusting coral species (e.g. *Turbinaria*), interspersed with sparse/very sparse filter feeders. Classified as low-moderate (< 25 %) or high (> 25 %) cover.	Direct disturbance: 17.9 ha (1 %) low-moderate cover Includes indirect loss of 1.4 ha due to toxic effect of bitterns	Dredge plume[i]: 5 ha high cover (50 %); 76 ha low-moderate cover (7.1 %)
Filter feeders	Low-moderate (< 25 %) cover, dominated by macroalgae and filter feeders, interspersed with moderate hard coral cover on sandy veneer limestone pavement.	None	None
	Diverse high (> 25 %) cover habitat characterised by high/dense cover of sponges and corals on rock/reef, low/moderate macroalgae cover may also be present.	Direct disturbance: 3.1 ha (7.1 %)	None
Macroalgae	Low-moderate (< 25 %) cover of turf algae dominated shallow fringing rock platform just below intertidal zone.	Direct disturbance: 2.5 ha (0.1 %) Includes indirect loss of 2.5 ha due to toxic effect of bitterns	2.5 ha (0.1 %)
	High (> 25 %) cover habitat dominated by dense brown macroalgae species on rock/reef	None	None

Habitat type	Description	Estimated disturbance from ESSP	
		Irreversible loss	Recoverable impact
	and sandy veneer on limestone pavement, occasional sparse hard corals/filter feeders.		
Seagrass/ macroalgae	Low-moderate (< 25 %) cover, sparse to low seagrass (*Halophila* sp.) cover interspersed with low/moderate brown macroalgae occurring on predominantly sand substrate with patches of sandy veneer on limestone pavement.	Direct disturbance: 1.1 ha (0.1 %) Includes indirect loss of 1.1 ha due to toxic effect of bitterns	None
[I] Based on worst case (winter scenario) zone of moderate impact modelling result (O2 Marine, 2023b)			

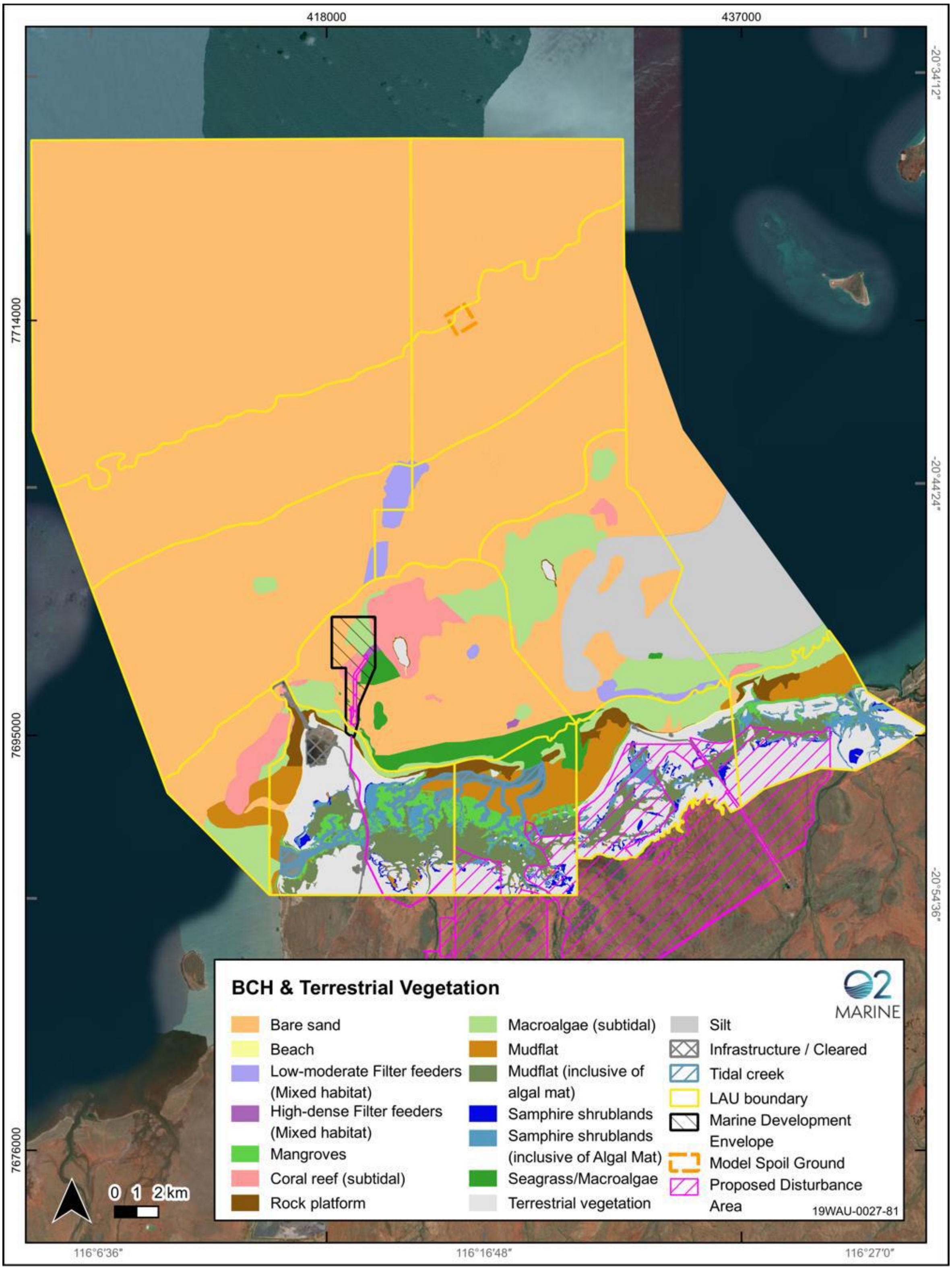

Figure 2–3: Distribution of mapped intertidal and subtidal BCH in the ESSP area (O2 Marine, 2023b).

2.4 Cumulative solar salt and coastal development activities

We have identified eight relevant future projects along the West Pilbara Coast (see **Error! Reference source not found.**), which will have an additional impact on marine BCH and fisheries values in the region. Information about these projects, including location, scale, activities and potential impacts, has been obtained from available records (publicly available and shared in confidence). The amount of information and data available varied across projects, resulting in a level of uncertainty in predicting cumulative impacts.

Compiled data regarding direct and indirect impacts to BCH are available in Appendix A.

Note: the summary values presented in Table 2-5 were obtained from published project documentation. Where figures were not explicitly provided, values were derived by summing the relevant data available.

Table 2-5. Identified relevant future projects for cumulative impact assessment on fisheries values.

Project	Summary

Ashburton Salt Project
 	
K+S Salt Australia Pty Ltd
	Development of a new solar salt project located approx. 40 km southwest of Onslow.
	
	Includes seawater intake (250 GL per year), evaporation and crystallisation ponds, bitterns discharge (10 GL per year), jetty, and supporting infrastructure (K+S, 2023).
	
	Footprint:
	• Development envelope: 20,990 ha
	• Combined (direct and indirect) disturbance footprint: 12,148.33 ha
	
	Estimated impacts:
	• Loss of 10,832.8 ha of intertidal BCH, and 8.68 ha of subtidal BCH (AECOM, 2022; K+S, 2023; Table 4-2).
	• Indirect impacts from seepage, creek blockage, dredge disposal and bitterns discharge estimated to affect:
	    ○ 5.52 ha of intertidal BCH including 0.34 ha mangroves and 0.24 ha of a tidal sub-creek, 3.94 ha of algal mat and 0.09 ha of samphire
	    ○ 223.7 ha of subtidal BCH including 217 ha of soft sediment, 0.18 ha of macroalgae and 2.2 ha of macroalgae and sparse coral habitat (K+S, 2023).
	
	Expected output: 4.5 Mt of salt per year
	
	Expected lifespan: 50 years
	
	Status: EPA Stage 3 (public review)

Mardie Project & Optimised Mardie Project Mardie Minerals Pty Ltd (subsidiary of BCI Minerals)	The Optimised Mardie Project expands the original Mardie Project (approved by the EPA in 2021) to develop a solar salt and sulphate of potash (SoP) project and export facility at Mardie, approx. 80 km southwest of Karratha. Includes 800,000 m^3 of dredging, two seawater intakes (180 GL per year), nine evaporation ponds, up to 60 crystalliser ponds, a salt wash plant,

Project	Summary
	bittern discharge (5.5 GL per year), processing plant, trestle jetty with associated dredge channel, and supporting infrastructure (EPA, 2023). Footprint: • Terrestrial development envelope: 19,645 ha • (Marine) Dredge development envelope: 307.5 ha Estimated impacts: • Intertidal BCH disturbance of 8,600 ha including 17 ha of direct disturbance to mangroves and 880 ha of algal mat. • Subtidal BCH disturbance of 183 ha including 35 ha of irreversible macroalgae/seagrass/filter feeder loss, 44 ha of coral/macroalgae loss, and 104 ha of bare bioturbated sand (O2 Marine, 2022; EPA, 2023) (Table 4-3). Expected output: 5.35 Mt of salt and 140 thousand tonnes (kt) SoP per year Expected lifespan: 3 years construction; 60 years operations Status: EPA Stage 5 Construction of the Mardie project commenced in February 2022 and is now more than halfway complete. Initial operations commenced in late 2024 with the filling of first three evaporation ponds. First salt exports are expected to occur in 2027 (WA Gov, 2024).
Cape Preston East – Multi-commodity export facility Leichhardt Port Pty Ltd	Development of Cape Preston East as a bulk export facility for salt, plus iron ore and other minerals. Terrestrial infrastructure includes a desalination plant, salt export shed and infrastructure, port and central services facilities, and access roads. Marine infrastructure includes desalination plant seawater intake (not to exceed 0.15 m/s) and bitterns discharge (3 GL per year) pipelines, a 200 m rock breakwater, a 1.5 km trestle jetty, navigation markers, cyclone mooring, and transhipment anchorage points (total clearing of 4.8 ha). Footprint: • Development envelope: 2,563 ha • Total disturbance of up to 413.3 ha (within the development envelope), including up to 4.8 ha of benthic intertidal and coastal areas (Leichhardt, 2021) Estimated impacts: • Indirect impacts to up to 5 ha of algae dominated limestone pavement habitat due to changes in coastal processes (west side of the breakwater) (Preston Consulting, 2013) (Table 4-4) Expected lifespan: 2 years construction; 62 years operations Status: Approved under MS949; however, not yet constructed (EPA, 2020)
Dampier Seawater Desalination Plant	Development of a seawater reverse osmosis desalination plant at Parker Point, Dampier. The proposal will provide a potable water supply for the Proponent's Dampier operations, the town of Dampier, and a connection to

Project	Summary
Hamersley Iron Pty Ltd	the West Pilbara Water Supply Scheme (WPWSS). Due to the proximity to Port of Dampier, commercial fishing activities are absent. Includes a seawater desalination plant, seawater intake (22 GL per year with an intake velocity of 0.1 – 0.15 m/s), water transfer pipelines, supporting infrastructure, and bitterns discharge (13 GL per year). Salinity of the discharge is 65.9 ppt in the summer, and 64.4 ppt in the winter and is < 2°C above ambient seawater temperature. Footprint: • Development envelope: 57.5 ha including 13.5 ha of native vegetation, 43.2 ha of already cleared or completely degraded land, and 0.8 ha of open water Estimated impacts: • Residual indirect impact of the loss of one hectare of sparse mixed assemblage community (< 5% cover), located 120 m south of the bitterns discharge. The community consists of turf algae and occasional small (< 30 cm) corals dominated by stony corals *Turbinaria* (Family: Dendrophylliidae) with sparse sponges and zoanthids on highly disturbed substrate (Table 4-5). Expected output: 8 GL of potable water per year (Rio Tinto, 2022). Expected lifespan: 1.5 years for construction; 50 years operations Status: EPA Stage 2
Dampier Cargo Wharf Extension Pilbara Ports Authority	Development of an extension to the Dampier Cargo Wharf at the Port of Dampier. Includes a new (adjoining) southern section of wharf and mooring dolphin, dredged berth pocket and vessel manoeuvring area. The proposal will enable larger vessels to access the terminal. Key construction elements of the project include 380,000 m^3 of capital dredging, approx. 100,000 m^3 of drilling and blasting, pile driving, stabilisation of the shoreline via construction of rock revetment or a retaining wall and construction of a concrete deck. Footprint: • Development envelope: 15.2 ha • Disturbance footprint: 10.79 ha • Dredging footprint of 8.4 ha, including drilling and blasting sites Estimated impacts: • Irreversible loss of 0.8 ha of coral habitat from dredging • Reversible disturbance of 0.17 ha of coral habitat from dredge plume (O2 Marine, 2023g) • Will result in an estimated cumulative loss of 14.6 ha coral habitat (building on previous historical loss within the area) (O2 Marine, 2022)

Project	Summary
	Expected lifespan: 1.5 – 2 years for construction; 50 years operations Status: EPA Stage 2
Perdaman Lateral Project DBNGP (WA) Nominees Pty Ltd	Development of a 550-meter pipeline and supporting infrastructure to transport natural gas from the Dampier to Bunbury Natural Gas Pipeline to the proposed Perdaman Urea Plant development. Includes lateral pipeline, inlet station, meter station, material laydown/storage areas, and rock causeway. Footprint: • Development envelope: 2.05 ha • Disturbance footprint: 2.05 ha Estimated impacts: • 1.22 ha of intertidal habitat loss (mudflat with no vegetation) Expected output: 150 TJ of natural gas per day Expected lifespan: 4 – 6 months of construction; 28 years operations (AGIG, 2024) Status: EPA Stage 2
Perdaman Urea Project Perdaman Chemicals and Fertilisers Pty Ltd	Development of a urea plant within the Burrup Strategic Industrial Aera (SIA) on the Burrup Peninsula. The development will be the largest urea plant in Australia. Includes brine discharge of approximately 20 GL per year (55 ML per day), resulting in a combined discharge quantity of 112 ML per day in King Bay. Water supply (25.2 GL per year) from existing sea water supply by Water Corporation. Footprint: • Development envelope: 106.7 ha • Disturbance footprint: 73.05 ha Expected output: 2 Mt of urea per year Expected lifespan: up to 80 years (initial approval for 40 years) Status: EPA Stage 5 (Approved); Construction started in 2023 with expected completion by mid-2027 (Cardno, 2020; EPA, 2021)
Downstream Processing Chemical Production Facility Wesfarmers Chemicals, Energy & Fertilisers	Development of a methanol plant on Site E of the Burrup Strategic Industrial Area (SIA), Burrup Peninsula. The proposal is adjacent to the Murujuga National Park. Includes a processing plant, natural gas supply pipeline, product export pipeline, seawater intake, and bitterns discharge pipelines (via the extension of a pre-existing pipeline system). Footprint: Disturbance of 75 ha Expected output: 5,000 t per day

Project	Summary
	Status: EPA Stage 2 (pre-feasibility stage) (EPA, 2018b).
Onslow Seawater Desalination Plant (OSDP)	Development of a seawater desalination plant to supply drinking water to Onslow. The plant will be built on the coastal side of Beadon Creek Road, between Bindi Bindi Aboriginal Community and Discovery Parks Onslow.
Water Corporation	Includes a reverse osmosis seawater desalination plant, intake (400 m long pipeline, 4.44 ML per day) and brine outfall (700 m long pipeline, 2.44 ML per day) 1 km seaward from the shoreline, water tank and pumping station, and 2.5 km of belowground (200mm diameter pipeline) to the existing Onslow tanks, where the water will be connected to the town's water supply. Footprint: • Desalination Plant: 3.5 ha • Intake head and pipeline: 0.02 ha Estimated Impacts: • Direct disturbance to 0.02 ha of intertidal and subtidal BCH from intake head and pipeline (O2 Marine, 2021; Table 4-8). • Brine Salinity of ≤ 75 ppt in the dry season and ≤ 77 ppt in the wet season, at a temperature of +4 °C (Fresh Water Thinking, 2021). Expected output: 0.7 GL of fresh water per year. Status: Water Corporation referred the desalination plant proposal to the EPA in January 2021. A public comment period occurred between 29 March and 7 April 2021. The regulator decided the proposal would not be assessed under Part IV of the EP Act (EPA, 2021b). Early sitework and bulk earthworks commenced in 2024, and the onshore processing plant and pipelines are under construction. Construction of marine pipelines is expected to start in mid-2025. The OSDP is schedule to produce water in 2026 (Water Corporation, 2025).

2.4.1 Construction and development

The identified relevant future projects have a combined development envelope of approx. 43,765 ha. The development envelopes for these projects include terrestrial, coastal/intertidal, and subtidal habitats including mangroves, algal mats, mudflats, macroalgae, seagrass, filter feeders, corals and bare (unvegetated) substrates.

Construction and development activities include direct habitat removal, e.g. through dredging or drilling/blasting, and indirect impacts resulting from construction and dredge plumes and related spoil disposal. A summary of estimated habitat impacts by project is available in Appendix A - Cumulative impacts on BCH from relevant future projects. Leichhardt has assessed cumulative impacts on intertidal BCH based on impact assessments and regional mapping conducted by Leichhardt and for the Mardie Project.

Within the region, mangroves remain at high (pre-European) levels, with an estimated total extent of 33,706 ha. Previous mangrove loss from older salt projects is estimated to be more than double the estimated losses by new/future projects, due to increased EPA requirements. A combined total of up to

29.5 ha of mangrove BCH is proposed to be disturbed by ESSP (7.9 ha), Mardie (17 ha) and Ashburton (4.6 ha) solar salt projects (Table 2-4).

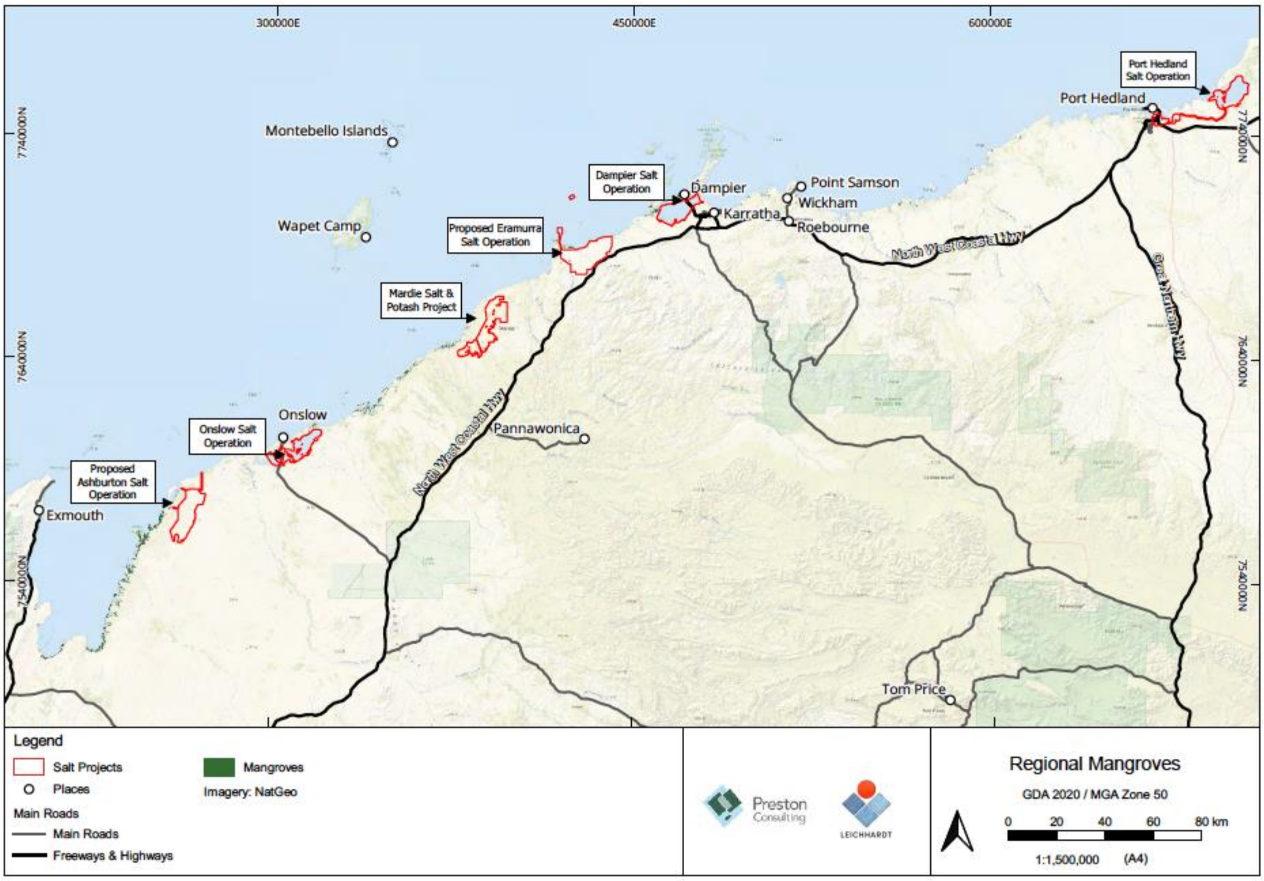

Figure 2–4: Figure 2 4 Extent of mangroves along the West Pilbara Coast in relation to salt projects (Preston Consulting, 2023a).

The region contains an estimated 41,574 ha of algal mats, with up to ~1,930 ha combined estimated disturbance by ESSP (1,033 ha), Mardie (880 ha) and Ashburton (16.7 ha) solar salt projects (Figure 2–5). Overall, cumulative (historical and future proposed) impacts are estimated to account for 5 – 10 % of the total regional extent, depending on the scale of historical losses (Preston Consulting, 2023a). Little is known about the ecological role of tidal samphire mudflats and blue-green algal mats, making it challenging to predict potential impacts to the marine environment and fisheries species. To address these knowledge gaps, the Western Australian Marine Science Institution (WAMSI) is currently coordinating a $2.5M research initiative to map the original and current extent of samphire and algal mat communities along the west Pilbara Coast, identify and quantify the potential effects of sea level rise on mangroves, samphire and algal mat communities, and identify the ecological roles, values and functions of algal mat in this region. This program has been developed as part of the (Optimised) Mardie Project Marine and Intertidal Research Offsets, and program results are expected in 2026 (WAMSI and BCI Minerals Ltd, 2024).

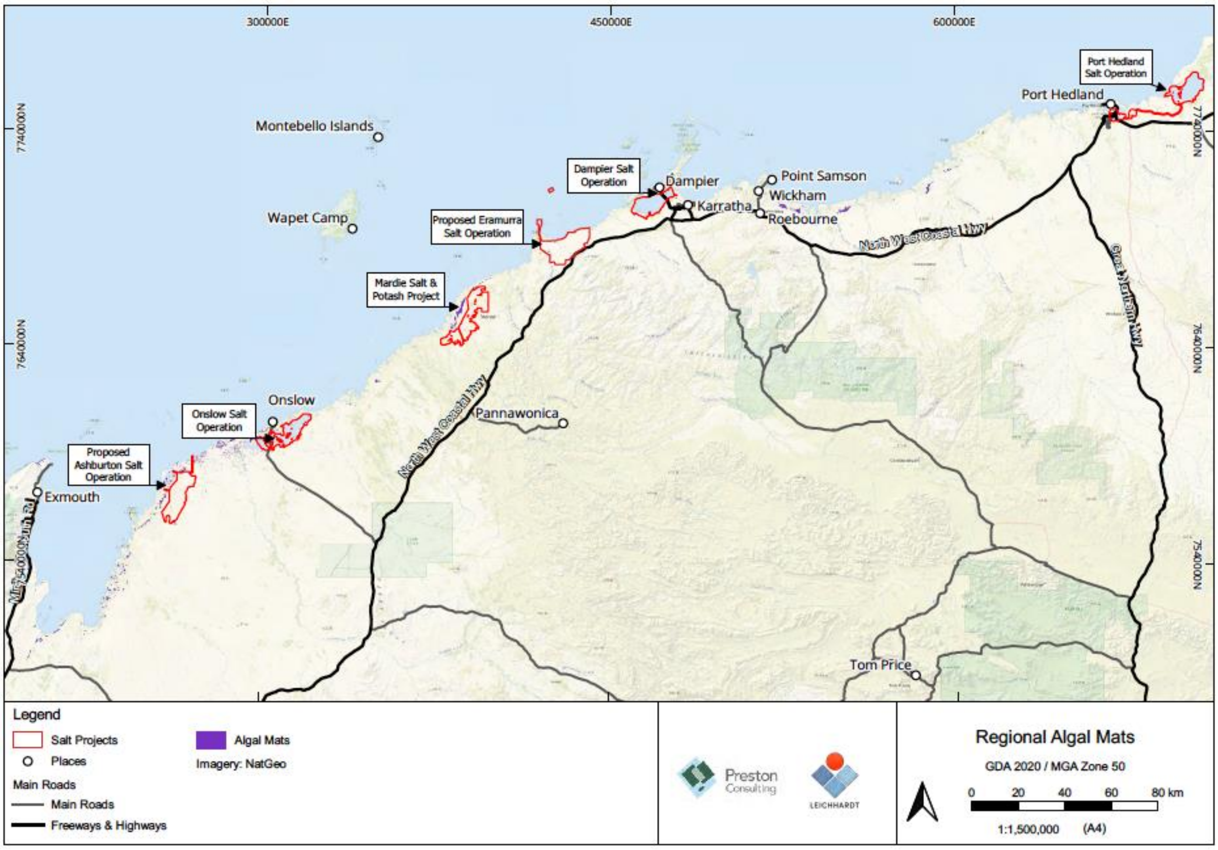

Figure 2–5: Extent of algal mats along the West Pilbara Coast in relation to salt projects (Leichhardt, 2024).

2.4.2 Operations: seawater intake

Seawater intakes are used to feed the solar salt production and desalination processes. Seawater intakes are also used to pre-dilute bitterns prior to discharge. Based on available information, proposed salt projects will intake a combined total of 590 GL of seawater per year (160 GL at ESSP, 250 GL at Ashburton, and 180 GL at Mardie). There is an additional 22 GL of seawater intake at the proposed Dampier Seawater Desalination Plant and 1.62 GL at the Onslow Seawater Desalination Plant.

Proposed projects have a maximum intake flow rate of 0.15 m per second, which has been shown to protect 96 % of fish species. Intakes are likely to result in localised reductions in marine fauna (through entrapment and entrainment (Preston Consulting, 2023a).

2.4.3 Operations: bitterns/brine discharge

The ESSP will discharge up to 5.4 GL of bitterns per year (360 ppt salinity). Other solar salt projects and desalination plants in the West Pilbara Coast region, including those already operating and relevant future projects, also discharge bitterns/brine into the marine environment. Nearly all the salt taken into desalination is returned to the ocean via the discharge. Solar salt operations rely on water evaporation to concentrate seawater and assist in extracting salt precipitate, prior to discharging a concentrated bittern stream. Salt operations generally discharge a low volume of high salts concentration bitterns.

Different salt operations apply various degrees of salt concentration and extraction prior to discharge—traditional salt operations extract 55 – 70% of the original salt (including 70 – 90 % of the sodium chloride). Operations that also produce potash (e.g. Mardie) will extract nearly 80 % of the original salt (targeting 100 % recovery of the sodium chloride and potassium) (Preston Consulting, 2023a).

Based on this information, these projects have the following approved/estimated discharge rates:

- Onslow salt (existing): 6 GL per year
- Sino Iron Project Desalination Plant and Bulk Loading Facility (existing): 64 GL per year
- Dampier Salt (existing): 3.86 GL per year[3]
- Dampier Seawater Desalination Plant (future): 13 GL per year
- Mardie Project (future): 5.5 GL per year
- Cape Preston East (future): 3 GL per year
- Ashburton Salt Project (future): 10 GL per year
- Perdaman Urea (future): 20 GL per year
- Onslow Seawater Desalination Plant (future): 0.9 GL per year

This equates to a total of approx. 126.26 GL of bitterns/brine discharged each year.

Leichhardt has explored potential cumulative impacts of combined levels of bitterns/brine discharge in the West Pilbara Coast region (Preston Consulting, 2023a). Coastal waters in this region exhibit a typical salinity of approximately 36 ppt, equivalent to 35 g of salt per litre, with sodium chloride constituting 73% of the salt content. This baseline salinity is primarily regulated by natural processes, including evaporation and mixing with offshore waters.

Leichhardt estimated the salt loads of each identified project and evaluated first-order impacts from discharging the streams into an equivalent volume of seawater, plus additional salts (based on the excess salinity above seawater of each stream). Note, this approach only considers total salts and does not account for changes in ionic composition, such as those arising from the removal of original salt content during solar salt production. Based on these assessments, Leichhardt estimates a combined ‘excess salt’ discharge of ~ 17 Mt per year from the projects (i.e. ESSP, Ashburton Salt, Onslow Salt, Mardie Salt/SoP, Sino Iron Desalination, Dampier Salt, Dampier Desalination, and the Burrup Hub, including Burrup Peninsula Desalination, Yara Pilbara Fertiliser, Yuri Renewable Hydrogen, and Perdaman’s Urea Plant). The increased salinity is equivalent to the removal of 490 GL of freshwater from this same area each year. This amount is substantially less than changes due to natural evaporation each year. Net evaporation rates, after accounting for rainfall and reduced evaporation over wet surfaces, are approx. 1.8 m per year offshore, resulting in an annual water loss of approximately 29,000 GL across the region (Preston Consulting, 2023a).

Each brine/bittern discharge has a localised impact area near its release point, where salinity levels may temporarily increase. However, these effects are limited by the wide distribution of discharge points along the coast, which prevents significant overlap in impact zones, and natural mixing processes (wind, tides and currents) that mix nearshore and offshore waters.

2.5 Fisheries values

Relevant fisheries values for the impact assessment were identified based on their potential vulnerability to the ESSP project and their significance in the region, with species and/or fishing sectors

[3] Estimated from publicly available information, which indicates 4.2 Mt per year of salt production, with conservative assumptions for weather variability and non-recycled losses (Preston Consulting, 2023a).

likely to be directly or indirectly impacted by ESSP activities prioritised. This includes species and fisheries that are:

- Found or operating within or near the ESSP area and may be affected by ESSP activities, or ESSP activities in combination with other relevant future projects (cumulative impacts).
- Socially, economically, or culturally important, including indicator species used by DPIRD to monitor fisheries resources; recreationally or culturally important species; or important use/access areas.
- At risk of serious or irreversible harm, e.g., because they are particularly sensitive to habitat loss, water quality, or other potential impacts from the project.
- To facilitate the assessment process, target species have been grouped into ecological suites, based on the general habitat and depth where they are commonly found and/or harvested. These suites are used by DPIRD to assess and manage fisheries resources (Newman et al. 2023b; Figure 2–6).

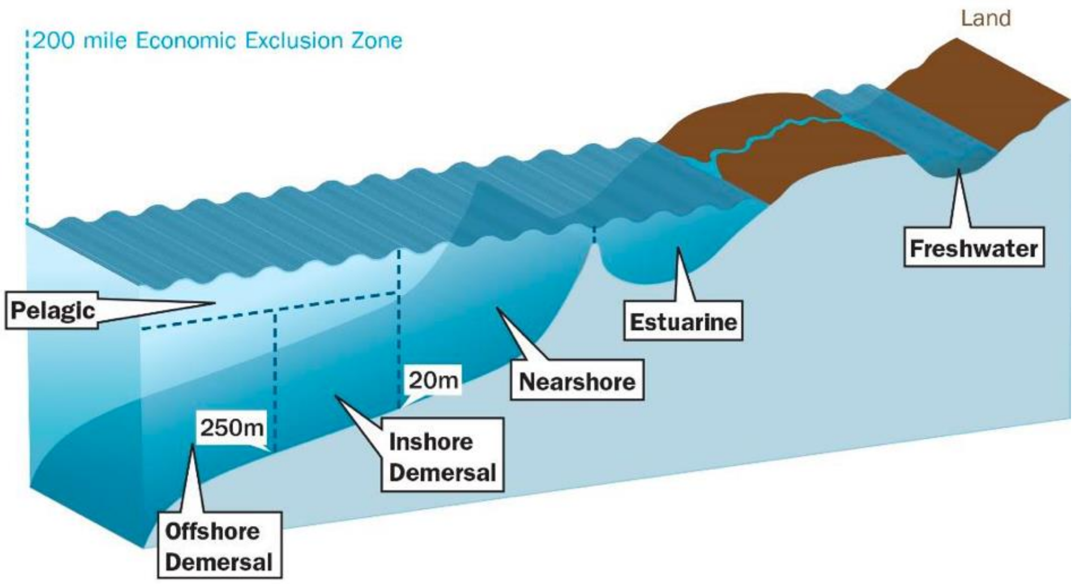

Figure 2–6: Ecological suites used to group fisheries species for the risk assessment, based on the resource management approach used by WA DPIRD (Newman et al. 2023b).

Fisheries resources in the ESSP area are harvested by commercial, recreational and Indigenous (customary) sectors. These fisheries are managed by DPIRD in consultation with the WA Fishing Industry Council (WAFIC), Recfishwest, and other stakeholders. Multiple commonwealth-managed fisheries also operate in offshore waters adjacent to the ESSP area; however, these fisheries are unlikely to be impacted by project activities (O2 Marine, 2023a). A summary of relevant fisheries resources, associated fishing sectors, and key species for the ESSP assessment is provided in Table 2-6.

- Information on the baseline conditions of fisheries values has been obtained from published reports, including field studies, modelling and analyses undertaken to inform the ESSP's environmental impact assessment (e.g. O2 Marine 2023b), the most recent fisheries status and assessment reports (e.g., Newman et al. 2023b).

Table 2-6: Fisheries resources within the ESSP vicinity, associated fisheries, key species/groups (e.g. target or indicator species), and current condition, based on their most recent stock assessment.

**Denotes indicator species used by DPIRD to represent a suite of similar species. N/A indicates no assessment information available.*

Resource	Associated fisheries/sectors	Key species / groups	2024 Condition
Terrestrial (land-based)			
Hermit crab	Commercial fishing: • Hermit Crab Fishery	Australian land hermit crab, *Coenobita variabilis*	Adequate – Catch has been within target range since 2010 (Newman et al. 2023a)
Estuarine/Nearshore (0 – 20 m depth)			
North Coast crab	Commercial fishing: • Pilbara Developing Crab Fishery Recreational fishing	Blue swimmer crab, *Portunus armatus*	Adequate – Catch rates above threshold level (Johnston et al. 2023a)
Sea cucumber	Commercial fishing: • Sea Cucumber Fishery	Redfish, *Actinopyga echinites*	Adequate (Kimberley) – Biomass above target level (Hart et al. 2023b) Adequate (Pilbara) – Biomass above target level (Hart et al. 2023b)
		Sandfish, *Holothuria scabra*	Adequate (Kimberley) – Biomass above target level (Hart et al. 2023b) Inadequate (Pilbara) – Biomass below limit level (Hart et al. 2023b)
Pearl oyster	Commercial fishing: • Pearl Oyster Managed Fishery Customary fishing	Silver-lipped pearl oyster, *Pinctada maxima*	Adequate (Hart et al. 2023a)
Marine aquarium species	Commercial fishing: • Marine Aquarium Fish Managed Fishery	Fish (teleosts and elasmobranchs; 250 taxa) Syngnathids Invertebrates (100 taxa) Hard coral, Order Scleractinia Anemones, Order Actinaria Zoanthids, Order Zoantharia	Adequate – Small numbers of individual species taken annually (Newman et al. 2023a)

Resource	Associated fisheries/sectors	Key species / groups	2024 Condition
		Corallimorpharians, Order Corallimorpharia Living rock and sand Sponges Algae/seagrasses	
Statewide specimen shell	Commercial fishing: • Specimen Shell Fishery Customary fishing	200 species (e.g., cowries, cones, murexes, volutes)	Adequate – Catch rate within target range (Bruce et al. 2023)
Inshore demersal (20 – 250 m depth)			
North Coast prawn	Commercial fishing: • Onslow Prawn Managed Fishery • Nickol Bay Prawn Managed Fishery	*Brown tiger prawns, *Penaeus esculentus* *Banana prawns, *Penaeus merguiensis* *Western king prawns, *Penaeus latisulcatus*	Adequate – Very low catch and effort (Wilkin et al. 2023) Adequate – Catch within target range (Wilkin et al. 2023) Adequate – Very low catch and effort (Wilkin et al. 2023)
North Coast demersal scalefish	Commercial fishing: • Pilbara Fish Trawl (Interim) Managed Fishery • Pilbara Trap Managed Fishery • Pilbara Line Fishery • Northern Demersal Scalefish Fishery Recreational fishing Customary fishing	*Bluespotted emperor, *Lethrinus punctulatus* *Red emperor, *Lutjanus sebae* *Rankin cod, *Epinephelus multinotatus* Goldband snapper, *Pristipomoides multidens* 50+ other demersal scalefish species	Sustainable – Relative spawning biomass below target but about threshold levels (Wakefield et al. 2024) Depleted – Relative spawning biomass just above limit level and predicted to fall below limit (Wakefield et al. 2024) Adequate – biomass around target (Wakefield et al. 2023) Depleting – Spawning biomass below threshold but above limit levels (Wakeford et al. 2024) Status represented by above indicator species
Pelagic			
Statewide large pelagic scalefish	Commercial fishing: • Mackerel Managed Fishery	Narrow-barred Spanish mackerel, *Scomberomorus commerson*	Adequate – Catches below tolerance range and below average nominal catch rates (Lewis and Rynvis, 2023)

Resource	Associated fisheries/sectors	Key species / groups	2024 Condition
	Recreational fishing	Grey mackerel, *Scomberomorus semifasciatus*	Adequate (Lewis and Rynvis, 2023)

2.5.1 Commercial fisheries

Commercial fisheries operating the ESSP vicinity

Multiple state-based commercial fisheries operate in the ESSP area targeting blue swimmer crabs, prawns, holothurians (sea cucumbers), pearl oysters, demersal and pelagic finfish and range of aquarium species, including giant clams, angelfish, seahorses, sponges and hard and soft corals.

Commercial fisheries operating in the ESSP vicinity and potentially affected by project activities include the Hermit Crab Fishery (HCF), the Marine Aquarium Fish Managed Fishery (MAFMF), the Specimen Shell Managed Fishery (SSMF), the Sea Cucumber Managed Fishery (SCMF), the Pilbara Demersal scalefish fisheries (PDSF), the Onslow Prawn Managed Fishery (OPMF) and the Mackerel Managed Fishery (MMF).

The Hermit Crab Fishery (HCF) targets the Australian land hermit crab (*Coenobita variabilis*) for domestic and international markets. The fishery operates year-round, with operators permitted to fish north of Exmouth Gulf. Operators use four-wheel drive vehicles to access remote beaches where they collect crabs. Catches have been stable over the last 13 years, within the historical range of 50,000 – 106,000. Two (of 5) licences were active in 2022 (Newman et al. 2023a).

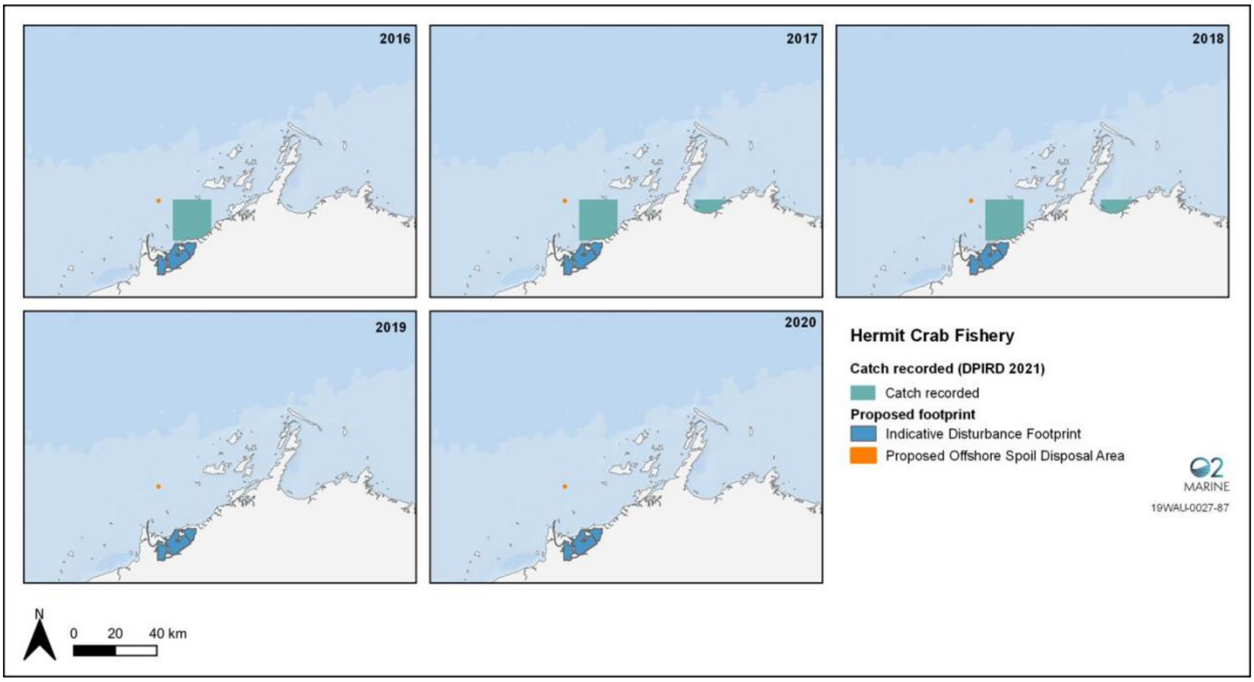

Figure 2–7: Hermit Crab Managed Fishery catch locations in the ESSP vicinity, 2016 – 2020 (O2 Marine, 2023b).

The Marine Aquarium Fish Managed Fishery (MAFMF) operates across WA waters, primarily south of Broome. The fishery includes over 1,500 marine aquarium species including hard and soft coral, living rock and sand, sponges, algae, seagrass, small aquarium fish, syngnathids, and other invertebrates (e.g., giant clam). Total catch in the MAFMF in 2022 was 98,694 fishes and invertebrates, 17.83 t of coral, live rock and living sand, and 39 L of marine plants and live feed. Fishers usually operates from small vessels, working in small teams to collect specimens on SCUBA or surface-supplied air (hookah). All specimens are collected for the live market, with catches limited by the fishers' ability to safely handle and transport catches without compromising their quality. Eleven (out of 12) licences were active in 2022. The MAFMF is estimated to be valued at $1 – 5M (Newman et al. 2023a).

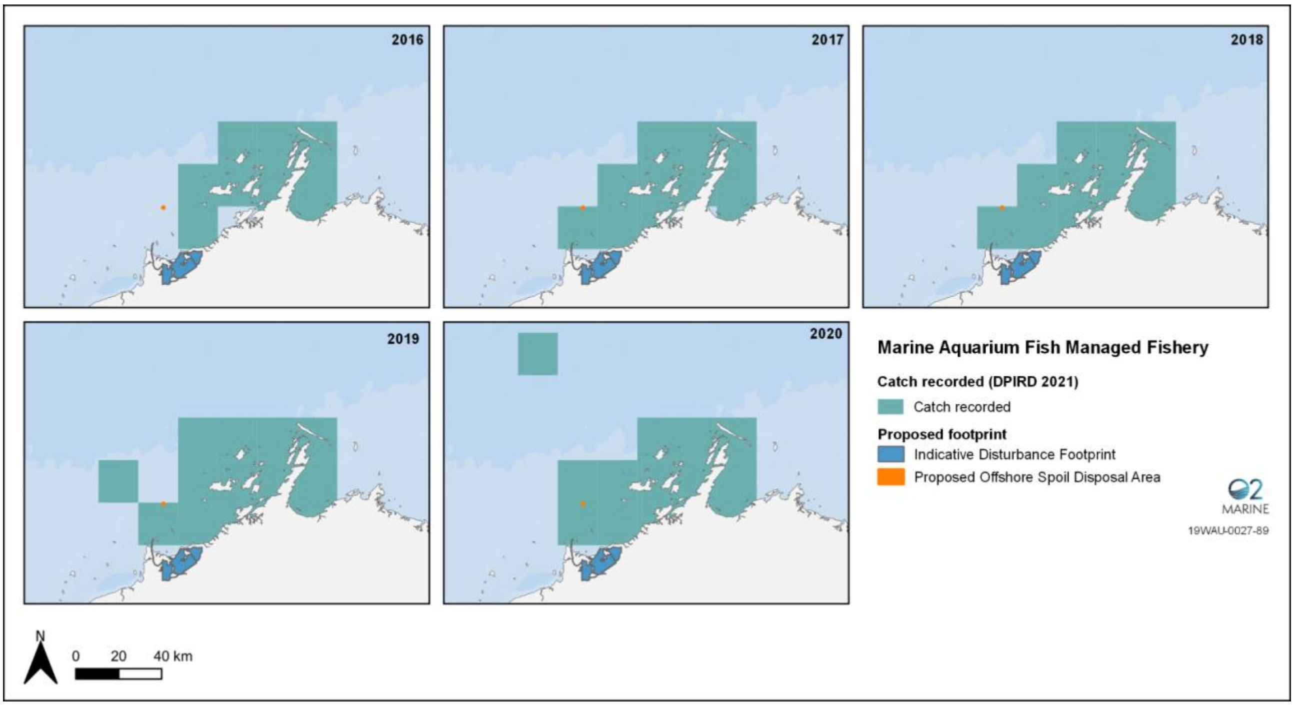

Figure 2–8: Marine Aquarium Fish Managed Fishery catch location (by grid block) in the ESSP vicinity, 2016 – 2020 (O2 Marine, 2023b).

The Specimen Shell Managed Fishery (SSMF) collects individual shells for display, collection, cataloguing, classification and sale. Around 200 shells are collected each year. The shells are collected by hand by small groups of divers operating from small boats in shallow coastal waters, by wading along coastal beaches, or with the use of remotely operated underwater vehicles. The fishery extends along the entire WA coast, with effort concentrated near population centres including Broome and Exmouth. There are 30 licences in the fishery—16 licences were active in 2022, with 5,074 shells collected comprising over 200 species. Popular species include cowries, cones, murexes and volutes (Bruce et al. 2023).

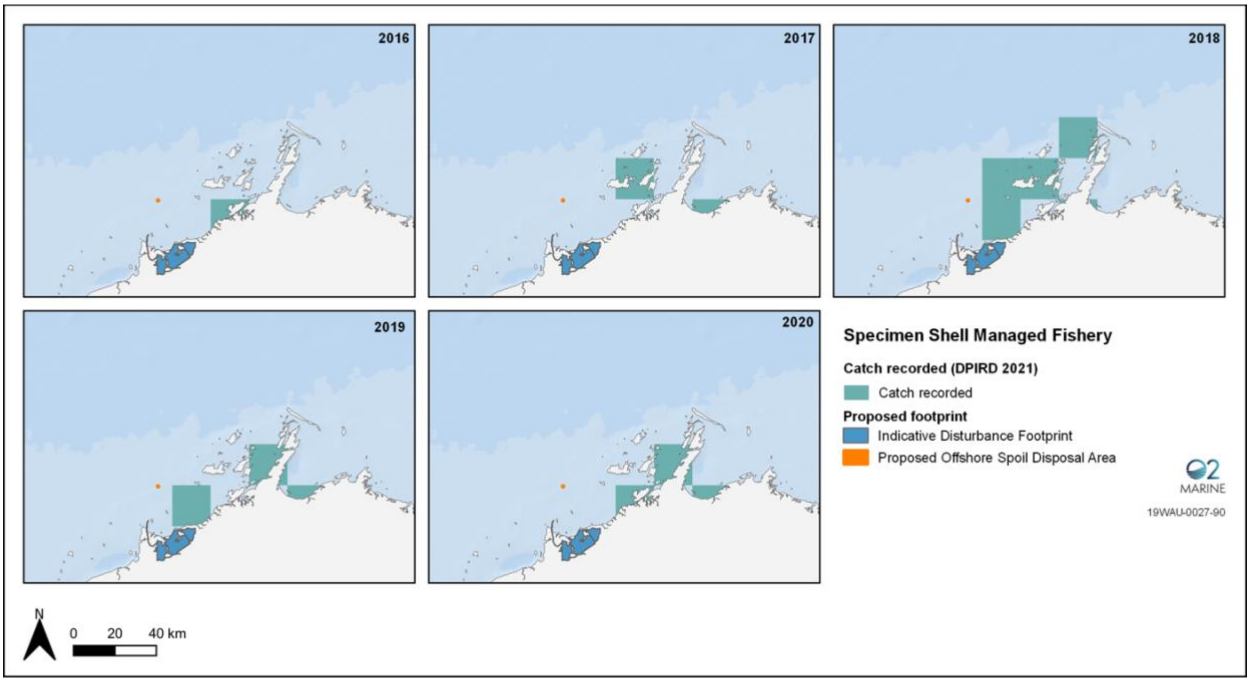

Figure 2–9: Specimen Shell Fishery catch location (by grid block) in the ESSP vicinity, 2016 – 2020 (O2 Marine, 2023b).

The Sea Cucumber Managed Fishery (SCMF) targets sandfish (*Holothuria scabra*) and redfish (*Actinopyga echinites*) in the Kimberley and Pilbara regions. Sea cucumbers are collected by hand while driving on hookah, SCUBA, or free diving from small dories. Within the Pilbara, redfish are mainly taken within and around the Dampier Archipelago and Barrow Island. There has been some exploratory fishing around Regard Island (within the ESSP vicinity). The Pilbara sandfish fishery has been closed since 2022, due to localised depletion. Between one and three vessels operate in the fishery each year. In 2023, total fishing effort in the Pilbara region was 312 crew days, with a total harvest of 105.6 t redfish (Smith et al*.* 2024a).

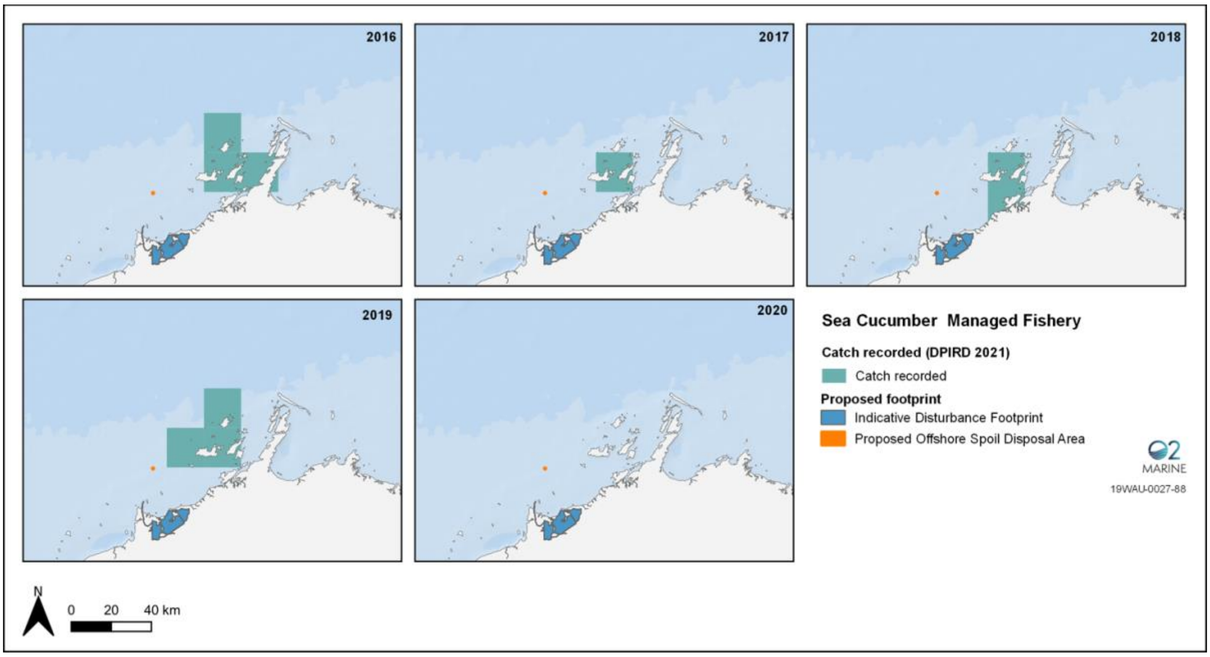

Figure 2–10: Sea Cucumber Managed Fishery catch locations in the vicinity of the ESSP, 2016 – 2020 (O2 Marine, 2023).

The Pilbara Demersal Scalefish Fishery (PDSF), which comprises three mixed-species fisheries: the Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF), Pilbara Trap Managed Fishery (PTMF), and Pilbara Line Fishery (PLF; Figure 2–11). These fisheries harvest over 50 different demersal fish species, including snappers, emperors and cods/groupers in 20 – 250 m depths. Together, these fisheries landed 2,485 t in 2022. Approximately 70 % of the total demersal finfish catch comes from the trawl fishery, 23 % from the trap fishery, and 4 % from the line fishery; however, catch composition varies between sectors. The trawl catch is dominated by bluespotted emperor and threadfin bream, while trap and line caches are dominated by red emperor and goldband snapper.

The PDSF is managed using limited entry, effort (time) allocations, gear limits and spatial zoning (Wakefield et al. 2024). For example, inshore waters around the ESSP are closed to the trap and trawl fisheries to protect important nursery grounds for target species (Newman et al*.* 2003). The PDSF consists of approx. 43 fishers operating 13 vessels and has an estimated economic annual value of $10 – 20 M (Wakefield et al. 2023).

Three species, bluespotted emperor (*L punctulatus*), red emperor (*Lutjanus sebae*) and Rankin cod (*Epinephelus rankini,* are used as indicator species to assess the state of the North Coast demersal resource. Although not an indicator species, goldband snapper were also assessed in 2023 given their high abundance within the catch (Wakefield et al. 2024).

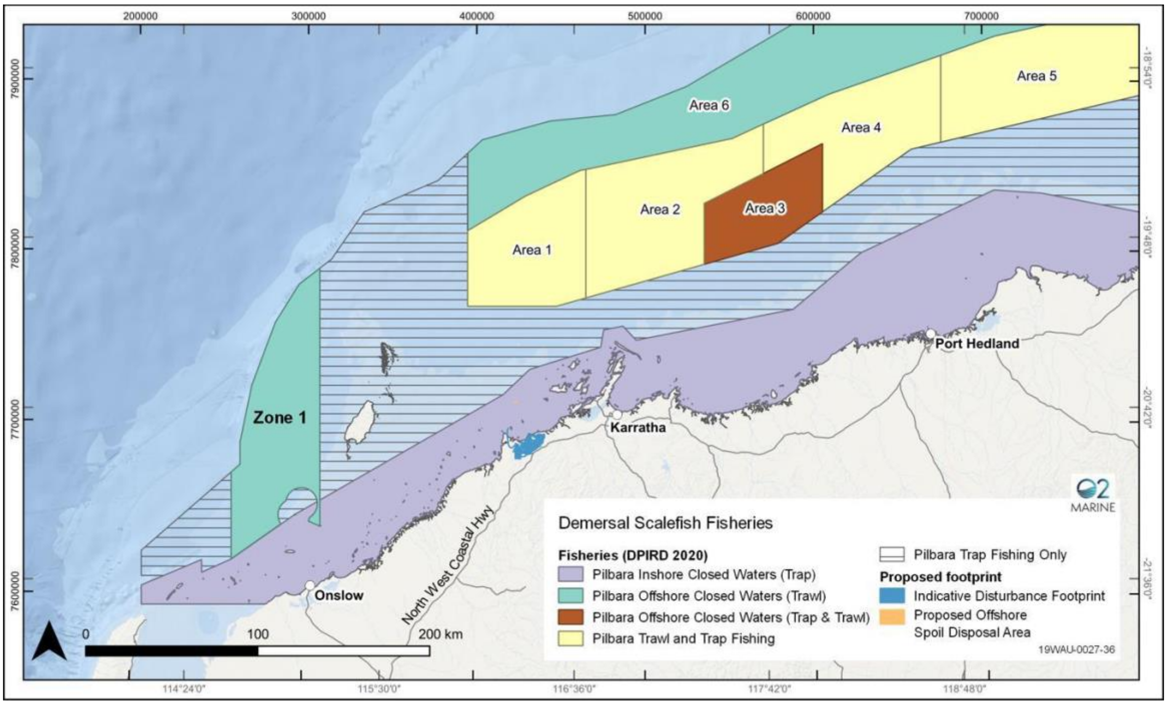

Figure 2–11: Boundaries and zoning of the Pilbara Demersal scalefish fisheries, alongside ESSP area (Preston Consulting, 2023b).

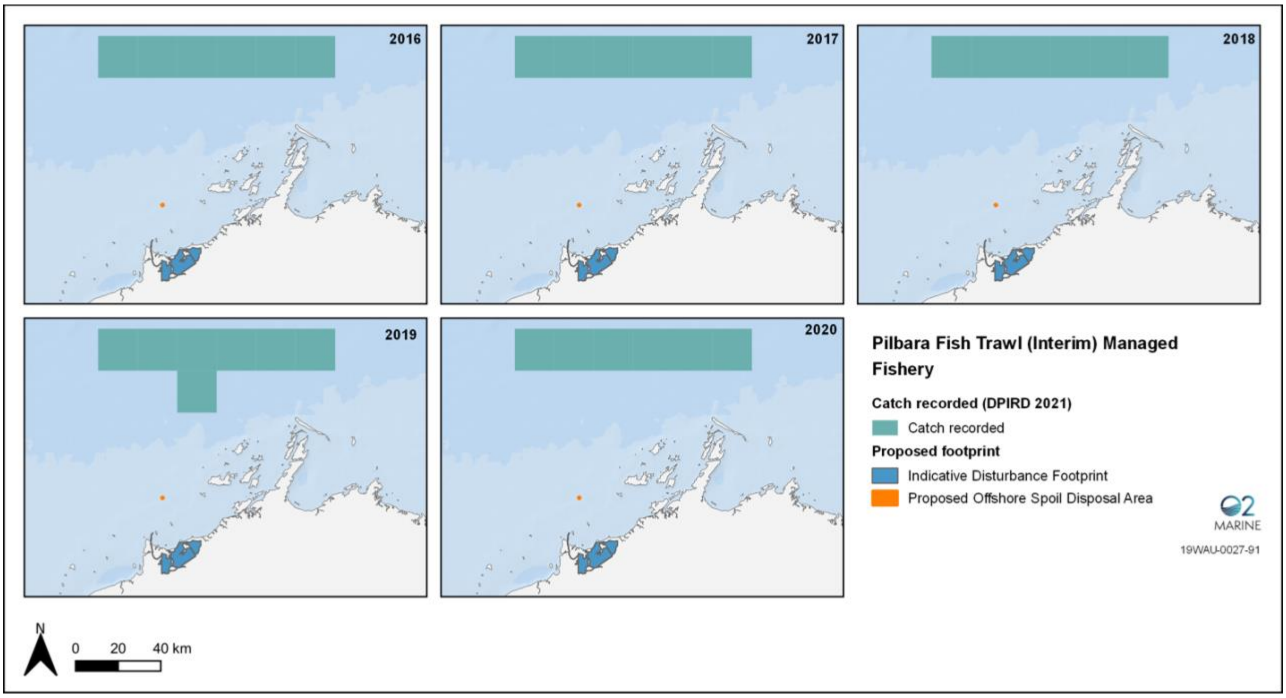

Figure 2–12: Catch locations (by grid block) for the Pilbara Fish Trawl (Interim) Managed Fishery, 2016 – 2020 (O2 Marine, 2023b)

The Onslow Prawn Managed Fishery (OPMF) targets western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*P. esculentus*) and banana prawns (*P. merguiensis)* in the Onslow area (Figure 2–13).

The OPMF uses low opening, otter prawn trawl system. Trawl shots are usually 60 – 180 minutes duration; they rarely operate in in a straight line, with turns common – resulting in a variable overall area fished and trawl footprint (Kangas et al*.* 2007).

Very low effort has been expended in the OPMF since 2012, due to the construction of a gas facility and the associated wharf, dredging, and exclusion zones that disrupted fishing activities during the most productive part of the season (Butler et al*.* 2023a). Only one boat operated in the OPMF in 2022, with other operators fishing elsewhere. Less than 60 t have been caught annually over the last few years, mainly due to the low effort (Kangas et al. 2023; Wilkin et al. 2023). Spatial information regarding fishing catch and effort is not publicly available due to confidentiality requirements; however, most fishing occurs away from the ESSP area, with the nearest fishing patch located near Onslow (Fishwell Consulting, 2023).

Management is based on input controls, including limited entry, gear controls (maximum headrope length), seasonal and spatial openings and closures (i.e. size management fish grounds), which allow access to target species at appropriate times. The opening and closing dates for these areas vary each year depending on the lunar phase and results of pre-season surveys to determine size and abundance (WA, Department of Fisheries, 2009). There is also a permanent trawl closure at Dampier (Wilkin et al. 2023).

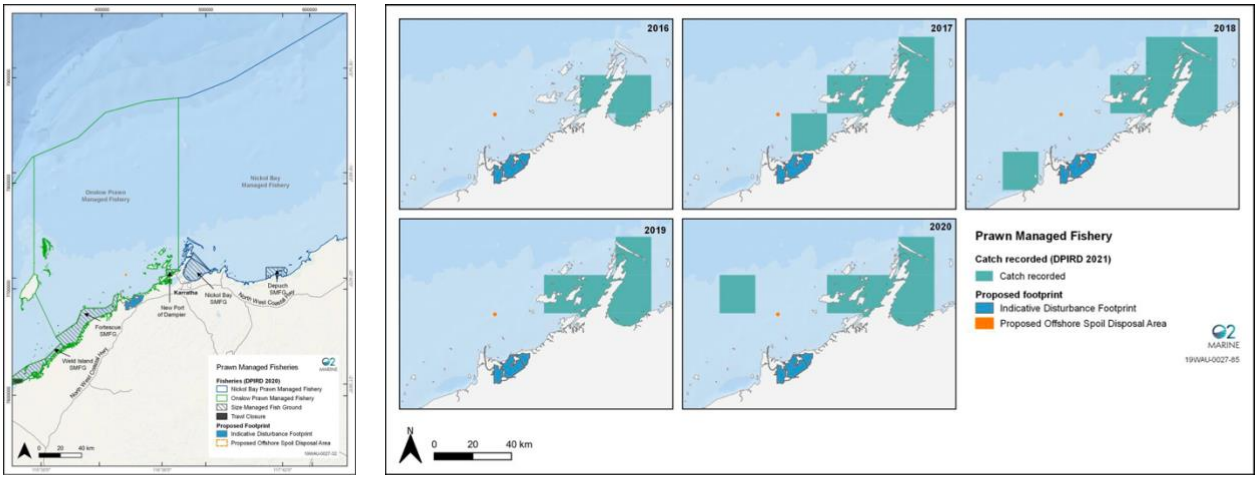

Figure 2–13: Boundaries and spatial management areas of the Onslow and Nickol Bay Prawn Managed Fisheries, alongside ESSP area (left panel) and Location of prawn catches in the ESSP vicinity, 2016 – 202 (right panel) (Preston Consulting, 2023b; O2 Marine, 2023).

The Mackerel Managed Fishery (MMF) operates across the Kimberley, Pilbara and Gascoyne regions, primarily targeting narrow-barred Spanish mackerel (*Scomberomorus commerson*) and grey mackerel (*S. semifasciatus*). Fishers use near-surface trolling and handlines to target mackerel around reefs, shoals and headlands. Trolling is the primary method, but baits and lures are also drifting or cast from anchored or drifting boats. Vessels operating in the Pilbara generally troll 6 or 7 lines and have 1 to 2 crew. There were 189 days fished in Pilbara region (by seven vessels) in 2022, with a total catch of 56.2 t. Thirteen boats operated in the MMF (all regions) in the 2022 season (mainly May – November), with approximately 30 – 40 people directly employed in the fishery (Lewis and Rynvis, 2023).

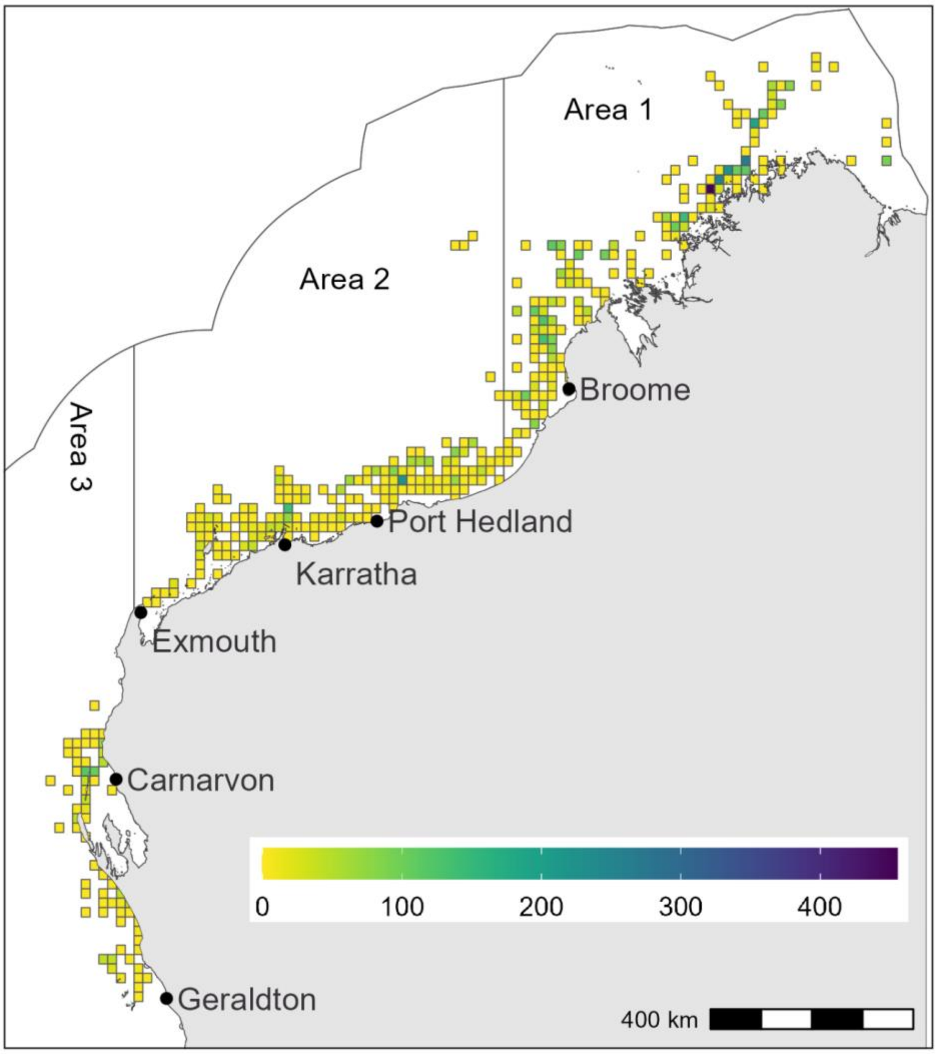

Figure 2–14: Spatial distribution of fishing effort in the Mackerel Managed Fishery from 2018 – 2022 (by 10 x 10 nm grid block) (Smith et al. 2024).

Other commercial fisheries in the region

Other commercial fisheries allowed to operate in the area, but that have not recently recorded catches in the ESSP vicinity, include the Pearl Oyster Managed Fishery (POMF), the Pilbara Crab Managed Fishery (PCMF), and the Sea Cucumber Managed Fishery (SCMF).

The Pearl Oyster Managed Fishery (POMF), which is only remaining significant wild-harvest pearl oyster fishery in the world. The POMF is a quota-based dive fishery, with divers collecting silver-lipped pearl oyster (*Pinctada maxima*) within shallow waters along the Pilbara and Kimberley coasts. The ESSP sits withing Zone 1 of the fishery. There are five wildstock licences with permanent quota units within Zone 1; however, the area has not been fished since 2008 (within a small fishing patch off Onslow; DPIRD, 2024).

Wild harvest of pearl oysters is one component of the pearling industry's activities, along with the seeding and grow-out of pearl oysters to produce pearls. Seeded oysters are returned to the ocean in panels at a holding site or pearl lease, before being transported to surface lines at a pearl farm for cultivation. Pearl leases are located between the NT border and Exmouth Gulf, including within the Montebello Islands, Dampier Peninsula, and Onslow region. In 2022, the total catch increased to

756,531 shells, up from 590,064 oysters in 2021. This increase is attributed to an increased total allowable catch (TAC) and a notable abundance of oysters at historical levels. The number of operational vessels rose from four to six, although four primary vessels still harvested 95 % of the quota. (Smith et al*.* 2023).

The Pilbara Crab Managed Fishery (PCMF) targets blue swimmer crabs (*Portunus armatus*) using hourglass traps in the inshore waters around Nickol Bay. In 2022, 11.2 t of blue swimmer crabs were harvested in the PCMF. The fishery is managed using minimum size limits, protection of breeding females, effort controls and spatial closures, including around the Burrup Peninsula and Dampier Archipelago. Crabs are sold through local and interstate markets, with an estimated gross value of product (GVP) of ~ $190,000 (combined with the Kimberley mud crab fishery; Johnston et al*.* 2023).

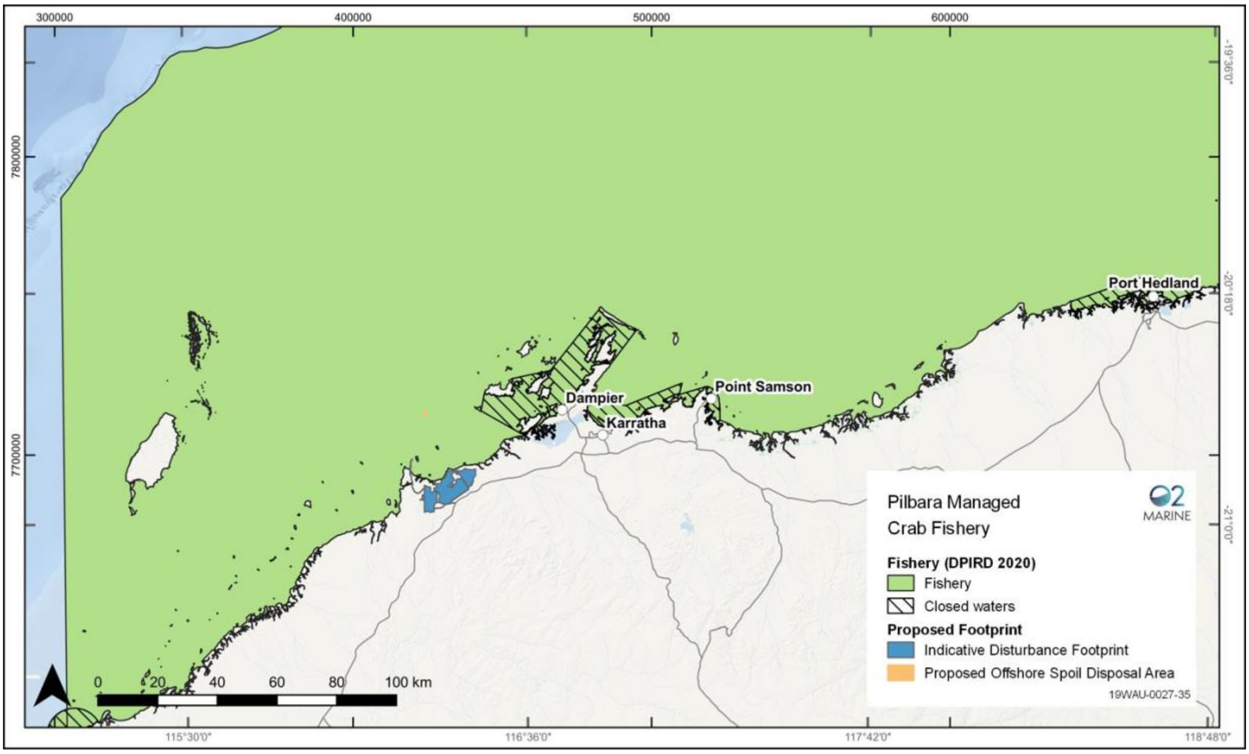

Figure 2–15: Pilbara Crab Managed Fishery boundaries and the ESSP area (O2 Marine, 2023b).

The **Nickol Bay Prawn Managed Fishery (NBPMF)** operates between 116° 45' E and 120° E longitude targeting banana prawns (*P. merguiensis*). Western king prawns, brown tiger prawns and endeavour prawns are also caught in lower amounts. In 2022, trawling primarily occurred in the western half of Nickol Bay and around Breaker Inlet, approx. 80 km north-east of Port Hedland. Catches have been highly variable over time, often driven by fluctuating prawn biomass levels due to environmental conditions, such as cyclones and rainfall events. For example, a positive relationship has been observed between summer rainfall and banana prawn landings, particularly in the NBPMF. Fifty-one tonnes of prawns were landed in the NBPMF in 2022, primarily banana prawns (42 t). During this time, there were three boats operating in the fishery, which fished a total of 62 days, down from the previous year's 175 days effort and 124 t catch (Wilkin et al*.* 2023).

2.5.2 Charter and recreational fisheries

Recreational fishing is a popular activity in the Pilbara—87 % of the approx. 6,600 resident recreational fishing from boat licence (RFBL) holders reported fishing at least once in 2020/21, with most licence holders fishing more than 15 days of the year (Ryan et al. 2022).

Recreational fishing is mainly conducted using line methods from private boats and charter vessels, with effort concentrated around key population centres. Commonly caught finfish species include grass emperor, striped snapper, coral trout, spangled emperor, red emperor, and Chinaman rockcod, while blue swimmer crab, squid and mud crabs are the most-commonly-caught invertebrates (Ryan et al*.* 2022).

The Pilbara region has an active charter (fishing tour) industry, offering fishing expeditions to target specific species (e.g., barramundi) and to offshore islands and reefs, such as Montebello Island and Rowley Shoals (Ryan et al*.* 2022). Charter operators in the Pilbara region catch a range of finfish species, including barramundi, king threadfin, Spanish mackerel and grey mackerel (Newman et al. 2023b). For example, in 2022, the estimated annual value of the Spanish mackerel catch for recreational fishers was between $2.5 million and $3 million (Smith et al. 2024b).

2.5.3 Indigenous and customary fishing

The ESSP is located within the Yaburara and Mardudhunera people's Land and Sea Country. The Yaburara and Mardudhunera peoples have a profound connection to the area and have harvested land and sea resources in this region for millennia. Under Native Title, the Traditional Owners maintain the right to hunt, fish, gather and use traditional resources; take and use water, engage in cultural activities and protect places of cultural or spiritual importance. The preservation and recognition of these fishing rights are integral to sustaining their connection to land and sea, as well as supporting the wellbeing of their communities.

Customary fishers along the Pilbara harvest range of nearshore and inshore finfish and invertebrates (YMAC, 2010); however, quantitative data on customary catches and important species is not available.

2.5.4 Key fisheries resources – Terrestrial environment

Crustaceans – Australian land hermit crabs (*Coenobita variabilis*)

The Australian land hermit crab is a terrestrial species in coastal areas throughout tropical Australia, from northern WA to Queensland. Within WA, they are caught commercially in the HCF, which operates north of (and including) Exmouth Gulf. There are no documented recreational or customary fisheries in WA (Newman et al. 2023a).

Hermit crabs (Family: Coenobitidae) are relatives of true crabs that use empty gastropod shells for protection. They are typically found in intertidal and supratidal zones, up to 100 m inland, preferring areas near mangroves but also inhabiting sandy and rocky shorelines. Nocturnal by nature, they seek shelter from the heat during the day under rocks, logs, and mangrove roots (van Dam et al. 2018). As omnivorous scavengers, they consume terrestrial debris and play a key role in nutrient cycling and seed dispersal (Hsu et al*.* 2019). The reproductive season runs from November to March, during which females return to the sea to release their eggs, which hatch into planktonic larvae that spend approximately six days in the water before migrating back to shore. Once on land, the larvae burrow into the sand to complete metamorphosis into juvenile crabs (Harvey et al. 1992; Newman et al. 2023a).

Crustaceans are essential in coastal ecosystems, playing an important role in the structure of food webs and energy flow. The effects of ecological disturbances on crustaceans have been widely studied, with salinity fluctuations and pollutants known to disrupt physiological processes, impairing their behaviour and overall ecosystem functioning (Ragagnin et al*.* 2018). Human activities in coastal regions, such as development that increases sedimentation, nutrient loading, and pollution, may negatively affect both larval and adult hermit crabs, reducing larval survival rates and compromising adult fitness (Fishwell Consulting, 2021; O2 Marine, 2023a). As hermit crabs grow, they require progressively larger shells, making the availability of suitable shells critical for their development and population health. This dependence on shells shapes their behaviour and links them closely to the health and dynamics of their coastal habitats (Hsu et al. 2019).

Within WA, this species is considered a single stock for management purposes. Harvest levels within the HCF are relatively low, particularly considering the broad distribution of this species across WA. A Productivity Susceptibility Analysis (PSA) was performed for the hermit crab, resulting in a PSA score of 2.18. This score indicates a low risk, reflecting the species' biological characteristics, such as rapid growth, early maturity, and long lifespan. These findings suggest that the current biomass of the Australian land hermit crab in the HCF is unlikely to be overexploited. Additionally, the current fishing mortality rate is stated not to pose a significant threat to recruitment or the sustainability of the population. Therefore, the HCF breeding stocks of the Australian land hermit crab are deemed sustainable-adequate (Newman et al. 2023a).

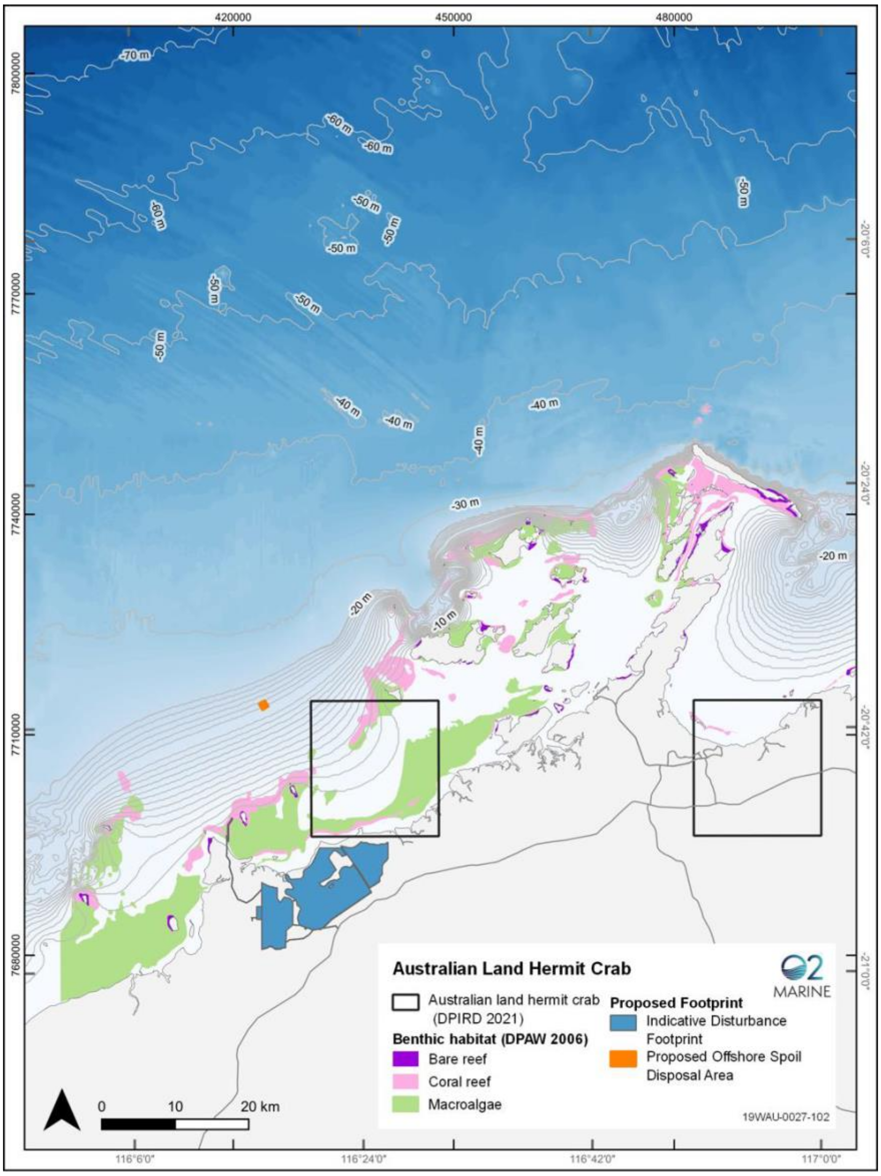

Figure 2–16: Australian land hermit crab presence (by grid block) within the ESSP vicinity (based on 2016 – 2020 catch data) (O2 Marine, 2023b).

2.5.5 Key fisheries resources – Estuarine/Nearshore environment (0 – 20 m depth)

Crustaceans – Blue swimmer crabs (Portunus armatus)

Blue swimmer crab (Family: Portunidae) is a key marine species in the Indo-West Pacific. Blue swimmer crabs populations along the Pilbara coast, including areas like Exmouth Gulf, Onslow, Nickol Bay and Port Hedland are thought to be genetically similar, likely due to mixing facilitated by coastal currents. However, stocks in the Exmouth Gulf are considered distinct from those further south, including Shark Bay, suggesting limited gene flow between these regions (Johnston et al*.* 2020).

Blue swimmer crabs are used as an indicator species for the North Coast Crab Resource and are commercially targeted by the PCMF. Blue swimmer crabs are also caught as byproduct by three prawn trawl fisheries: the Exmouth Gulf Prawn Managed Fishery (EGPMF), OPMF and NBPMF. Blue swimmer crabs are also a valuable recreational species. In the 2020/21 season, the total recreational catch for blue swimmer crabs in the North Coast Bioregion was estimated between 0.1 and 1.0 t, representing approximately 2 % of the statewide catch (Johnston et al*.* 2023a).

While blue swimmer crabs have been extensively studied in Shark Bay (400 km south), populations along the Pilbara coast and Exmouth Gulf are less researched. Given the similarities in habitat and environmental conditions, the biology and ecology of blue swimmer crabs are suggested to be likely comparable between regions (Johnston et al. 2020).

Blue swimmer crab is most abundant in shallow nearshore and estuarine habitats (≤ 20 meters deep), particularly in sandy, muddy, algal, and seagrass areas. Being primarily carnivorous and opportunistic feeders, they consume a variety of benthic organisms, such as bivalve molluscs, other crustaceans, polychaetes, and brittle stars. Their diet shifts based on size and shell condition, occasionally feeding on marine plants such as seagrass (Johnston et al. 2011; Johnston et al*.* 2020).

Reproduction in blue swimmer crabs can occur year-round, but peak spawning in the Pilbara region occurs from July – September. Mating generally occurs in warmer months, with females often migrating offshore to spawn, although some remain near estuary mouths. This movement to oceanic waters supports larval survival, as estuarine conditions likely lack sufficient oxygen and food for young crabs. Females reach sexual maturity around 10 – 12 months or 110 mm carapace width (CW), while males mature slightly earlier, at 105 mm CW. Both sexes reach the commercial size of 135 mm CW at approximately 15 months. The size at which blue swimmer crabs reach maturity tends to be inversely related to water temperature and, therefore, varies considerably between southern and northern populations in WA.

Juvenile crabs (under 100 mm in CW) rely on dense seagrass beds, where habitat structure plays a crucial role in their growth and survival. They gradually move to deeper waters as they mature during autumn and winter, where adult crabs thrive in similar benthic environments.

The blue swimmer crab’s high reproductive capacity and short life cycle reduce its inherent vulnerability to fishing; however, environmental conditions significantly influence recruitment, leading to variable catch rates. Temperature plays a critical role, with catch rates rising to an optimal range and decreasing beyond. Other influential factors include wind, tide height, and depth, while high lunar illumination and freshwater flow negatively impact catchability (Johnston et al. 2020; Johnston et al. 2021).

The PCMF's primary performance measure is the annual standardised commercial catch rate of blue swimmer crabs. This strategy applies specifically to the Nickol Bay area, where most fishing has historically occurred. The reference period spans 2005 to 2015, when the developing fishery formally commenced, following an earlier an exploratory fishing period (2001 – 2004). The annual catch tolerance for Pilbara blue swimmer crabs is 20 – 73 t, based on historical data and estimates of maximum sustainable yield (MSY) for this reference period. In 2022, the PCMF catch was 11.2 t (~ 2 % of the state catch) with a catch rate of 0.84 kg per trap lift. Based on these values, the stock is considered sustainable and adequate, with an acceptable level of risk under current management arrangements (Johnston et al. 2023a; Johnston et al. 2023b).

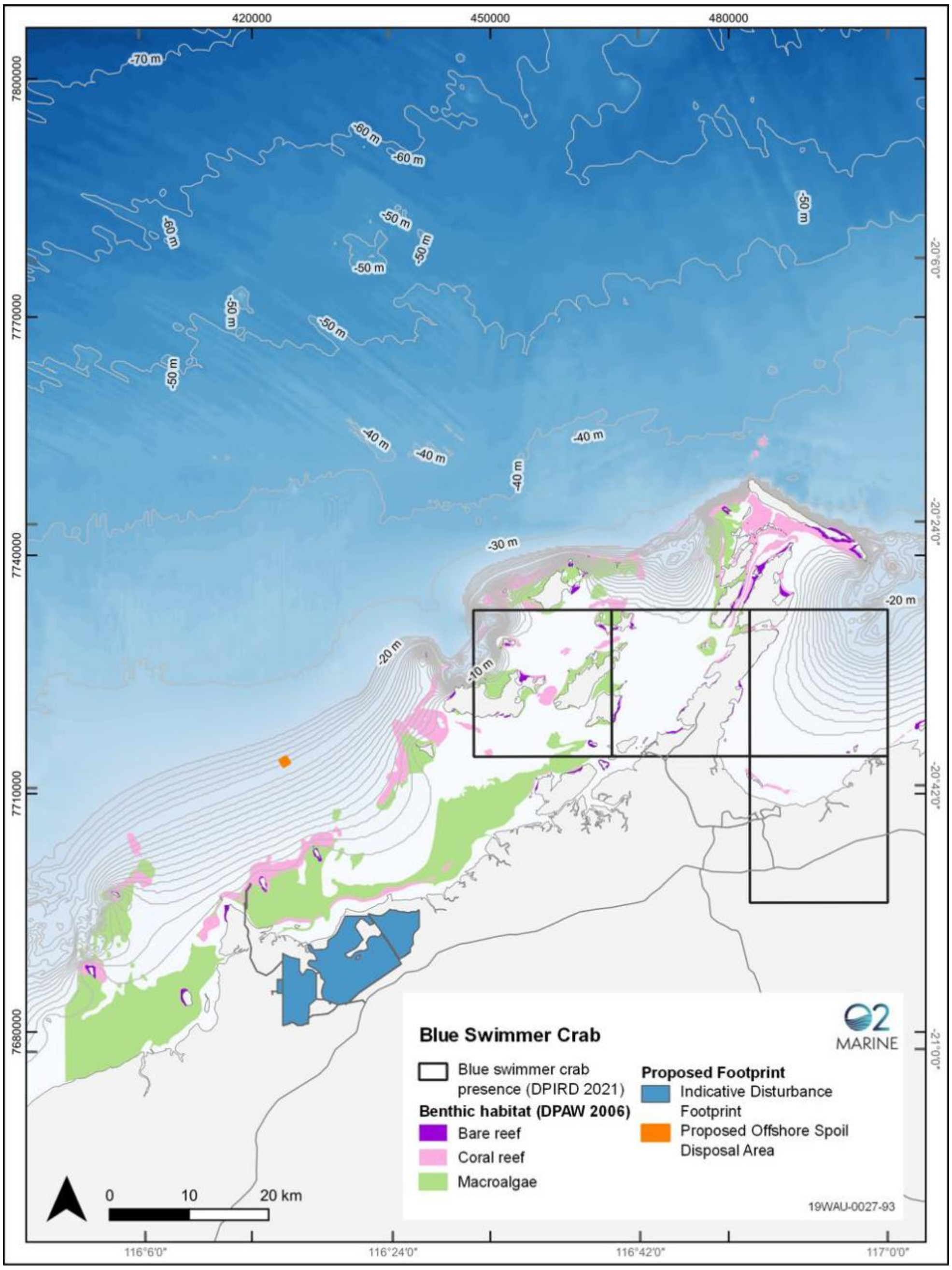

Figure 2–17: Blue swimmer crab presence (by grid block) within the ESSP vicinity (based on 2016 – 2020 catch data) (O2 Marine, 2023b).

Sea cucumber – Redfish (Actinopyga echinites) and sandfish (Holothuria scabra)

Sea cucumbers (Family: Holothuroidea) are soft-bodied, tubular benthic animals with generally low mobility. They are found extensively across the Indo-Pacific region and inhabit calm environments in tropical WA, such as fringing reefs or within protected bays. (Hart et al. 2018). Sea cucumbers are targeted by commercial, customary, and to a small extent, recreational fishers. There is also a high level of illegal take by foreign fishing vessels, particularly in the Kimberley region.

Sea cucumber catches are dominated by redfish (*A. echinites*) and sandfish (*H. scabra*), which are taken for human consumption within the SCMF. Approximately 14 other species are also taken in small quantities for consumption or aquarium displays (as part of the commercial MAFMF) (Smith et al. 2024).

In WA, sandfish mature at approximately two years of age and 150 mm length. Spawning can occur year-round, with up to 17 million eggs produced per female. Spawning is triggered by temperature, salinity, and lunar phase, with aggregations occurring in deeper waters, where gametes are fertilised externally and dispersed by ocean currents. After several weeks, pelagic larvae settle in sheltered, shallow-water areas with suitable substrates, predominantly seagrasses. Laboratory experiments have shown poor survival rates in the absence of appropriate substrates. Juveniles remain in seagrass habitats for 4 – 5 weeks until they reach 90 – 100 mm in length and then transition to sandy or muddy flats in deeper water (Smith et al. 2024).

Redfish mature at two years and 120 mm long, with up to 25 million eggs produced per female. Like sandfish, spawning aggregations occur in deeper waters, and pelagic larvae settle after approximately two weeks into sheltered, shallow-water areas. However, redfish juveniles prefer limestone and dead coralline substrates, while adults occupy macroalgae-dominated habitats (Smith et al. 2024).

Due to their chemical defences, adult sea cucumbers have relatively few natural predators; however, during larval and early juvenile stages, they are predated by small invertebrates and fish. Sea cucumbers play a critical ecological role in food webs. As deposit feeders and detritivores, they oxygenate sedimentary deposits through disturbance and convert organic detritus into animal tissue and nitrogenous waste. This process supports nutrient recycling, benefiting algae and seagrasses while enhancing coral reef productivity. Excessive removal or loss of sea cucumbers could disrupt these essential ecosystem functions (Smith et al. 2024).

Redfish and sandfish populations in the Pilbara are considered as a separate stock to the Kimberley region for management purposes (Hart et al. 2023b). Redfish have moderate international commercial value and were globally classified as “Vulnerable” by the IUCN in 2010. The most recent assessment of the Pilbara stock indicated that the biomass was above target level and therefore classified as ‘adequate’ (Hart et al. 2023b).

Alternatively, sandfish is classified as a ‘first grade’ product on international markets for human consumption and was classified by the IUCN as “Endangered” in 2010. Within the Pilbara, population modelling indicated that from 2017 to 2022, biomass declined to 25 % of its unfished biomass, falling below the established limit reference point and suggesting recruitment impairment. Catch rates also significantly decreased between 2015 and 2019. A fishery-independent survey supported these findings, reporting an 80 % reduction in biomass from 2017 to 2020. Collectively, this evidence highlighted critical stock depletion in 2022. In line with the harvest control rules, the sandfish fishery has been legislatively closed for three years, with the closure effective until 31 July 2026. The stock is considered inadequate and unsustainable (Hart et al. 2023b).

Pearl oyster – Silver-lipped pearl oyster (Pinctada maxima)

Silver-lipped pearl oyster (*P. maxima*) is a filter-feeding bivalve mollusc found in the Indo-Pacific region. In Australia, it is found from north of Exmouth to Queensland, primarily along the Pilbara and Kimberley coasts. Recent genetic studies have shown differentiation among populations in WA, the Northern Territory, and Indonesia. Within WA, only minor genetic differences have been found between populations in Exmouth Gulf and the northern Kimberley region, and it is considered a single stock for management purposes (DPIRD, 2022a).

The silver-lipped pearl oyster inhabits shallow subtidal zones with strong tidal currents from five to 50 m depths. It is a broadcast spawner, with a life cycle featuring a planktonic egg and larval stage, lasting between 28 to 35 days. This species exhibits protandrous hermaphroditism, maturing first as males at around three to four years old (approximately 110 to 120 mm in shell length) before transitioning to females (190 mm shell length). Spawning occurs annually from September to May, with peak activity between October and December and a secondary, more minor spawning event in February and March. Females can produce between 20 and 50 million eggs, with juvenile recruitment influenced mainly by environmental factors, such as sea surface temperatures, rainfall, and wind. Natural mortality rates are relatively low, ranging from 0.1 to 0.18 per year, translating to an annual mortality of 10 % to 16.5 %.

Silver-lipped pearl oysters are used as wild stock to produce cultured pearls within the POMF. Based on current information and analyses, there is a low risk to pearl oysters in Zone 1 of the POMF (where the ESSP is located). This reflects the minimal amount of fishing mortality in this area. Therefore, the stock is considered to be adequate (Hart et al*.* 2023a).

Under the Pearling Act 1990, recreational fishing for silver-lipped pearl oysters is prohibited. The shell holds cultural significance for local Aboriginal communities, which have harvested it for approximately 20,000 years. However, the exact quantity of the customary catch remains undocumented, as no formal records are maintained by DPIRD (O2 Marine, 2023c; DPIRD, 2022a).

Aquarium species

Aquarium species – marine aquarium finfishes, Syngnathids, hard coral, soft coral, living rock and sand, sponges, algae/seagrasses, other invertebrates

Over 1,500 aquarium species are harvested commercially in the MAFMF, including finfish, syngnathids, hard and soft corals, tridacnid clams, crabs, sponges, and live rock and sand. There are specific performance measures, including catch limits for Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) listed species, as part of its wildlife trade conditions (see DPIRD, 2018).

Over 250 taxa of tropical finfish are harvested, including blennies (Family: Blenniidae), angelfish (Families: Chaetodontidae and Pomacanthidae), gobies (Family: Gobiidae), wrasse (Family: Labridae), chromis, damselfish, and anemonefish (Family: Pomacentridae), and butterflyfish (Family: Chaetodontidae).

The MAFMF is also permitted to take certain species of seahorses, sea dragons, and pipefish (Family: Syngnathidae). These species primarily inhabit nearshore and inner shelf environments, favouring shallow coastal waters among seagrasses, mangroves, coral reefs, macroalgae-dominated reefs, and sandy or rubble substrates. Their populations are particularly vulnerable due to several biological characteristics, i.e. low population densities, prolonged parental care, small brood sizes, and strict monogamous relationships, all limiting reproductive rates. A catch limit of 2,000 individuals applies to all Syngnathiformes, although only 127 were harvested in 2022. The catch and export of leafy sea dragons (*Phycodurus eques*) is prohibited (Newman et al*.* 2023a).

Hard corals harvested included whisker coral (*Duncanopsammia axifuga*), anchor/hammer coral (*Euphyllia ancora*), open brain coral (*Trachyphyllia geoffroyi*), torch coral (*E.glabrescens*), elegance coral (*Catalaphyllia jardinei*), giant star coral (*Moseleya latistellata*) and grape/bubble coral (*Plerogyra sinuosa*). Most hard coral species occur in turbid off-reef environments. Biological and ecological factors, such as age or size at maturity, are highly variable among species and are affected by environmental conditions. Sexual reproduction generally occurs via broadcast spawning. In WA, this is typically over several nights between March and April (DPIRD, 2018).

A total catch limit of 15,000 kg applies for hard and soft coral (combined), excluding Corallimorpharia and Zoantharia species. In 2022, 8,140 kg of hard coral and 432 kg of soft coral were harvested, along with 2,364 kg of Corallimorpharia and Zoantharia species (Newman et al. 2023a).

Two species of giant clams (Family: Tridacnidae) are targeted by the MAMF based on size and colour: the small giant clam (*Tridacna maxima)* and the fluted giant clam (*T. squamosa*). Giant clams are hermaphroditic batch spawners, typically spawning from October to February. A catch limit of 2,400 Tridacnid clams applies for all species, and in 2022, 1,870 individuals were harvested (Newman et al. 2023a).

Species within the MAFMF are all considered to comprise a single stock for management. Given the diverse range of species captured by the MAFMF, traditional stock assessments are not performed. Instead, the status of target species is evaluated through annual commercial catch data. In 2022, the total annual catch was 98,994 fish and invertebrates, 17.83 t of coral, live rock, and living sand, and 39 L of marine plants and live feed. Based on the very low catch levels per species, the breeding stocks of aquarium species are classified as sustainable and adequate (Newman et al. 2023a).

There are no documented recreational or customary fisheries for these species (Newman et al. 2023a).

Specimen shells species

On average, about 200 species of specimen shells are collected each year within the commercial SSMF, mostly in low numbers per individual species. There is some focus on popular mollusc species, including cowries (Family Cypraeidae), cones (Family Conidae), murexes (Family Muricidae) and volutes (Family Volutidae).

Molluscs are the most diverse marine phyla and play vital roles in aquatic ecosystems, functioning as predators and prey for many species. The characteristic mollusc shell, primarily composed of calcium carbonate ($CaCO_3$), is shaped by a combination of environmental and biological factors and mainly serves to protect the soft tissues within.

As natural ecosystem engineers, they add complexity to benthic environments, contributing to habitat structure and supporting processes at the population, community, and ecosystem levels (Gutiérrez et al. 2003; Chavan and Chondekar, 2023). Furthermore, their reliance on calcium carbonate for shell formation renders molluscs sensitive to changes in ocean chemistry, with potential repercussions for both mollusc populations and the ecosystems they support. Consequently, molluscs and their shells are increasingly utilised as bioindicators of environmental contamination and ocean acidification (Fortunato et al. 2015).

Based on the national specimen shell industry, six species of cowrie (*Austrocypraea reevei, Zoila friendii vercoi, Z. marginata albanyensis, Z. marginata consueta, Z. rosselli and Z. venusta*) and two volutes (*Amoria damonii damaonii f. keatsiana* and *A. damonii damonii reevei*) in WA were identified as potentially vulnerable to overharvesting (based on their biology, accessibility and rarity; Ponder and Grayson, 1998). Shell sighting is used to monitor these eight species, with approx. 50 % of the sighted shells of these species remaining unharvested in 2022. In 2022, the catch rate was approx. 13 shells per day. Based on these values, the breeding stocks of landed species are considered to be sustainable-adequate (Bruce et al. 2023).

2.5.6 Key fisheries resources – Inshore demersal environment (20 – 250 m depth)

North coast prawns – brown tiger prawns (P. esculentus) and banana prawns (P. esculentus)

Multiple species of prawns are caught in the Pilbara region, primarily brown tiger prawns (*P. esculentus*; indicator and primary target species for the OPMF) and banana prawns (*P. merguiensis*; indicator species and target species for the NBPMF). Western king prawns (*P. latisulcatus*) and endeavour prawns (*Metapenaeus* spp.) are also caught in very low amounts in the OPMF and NBPMF. Prawns are also targeted by fisheries in the adjacent Kimberley and Gascoyne regions (Butler et al. 2023).

Prawns eat plant material, decaying organic matter, micro-organisms, small shellfish and worms (Wassenberg and Hill, 1987). Squid, cuttlefish and demersal (bottom-dwelling) fish prey on juvenile and adult prawns (Dall et al. 1990). They are particularly vulnerable during the larval period, when predators are responsible for high death rates. The growth, survival and abundance of various life stages of penaeid prawns are sensitive to extreme temperatures and shift in temperature regimes (Hobday et al. 2008). Brown tiger prawns are considered to be at high risk to the effects of climate change, while western king prawns are at moderate-high risk (Caputi et al. 2015).

Brown tiger prawns are endemic to tropical and subtropical Australian waters, ranging from central New South Wales to Shark Bay (WA). Genetic evidence suggests distinct stocks on the east and west coasts of Australia (Ward et al. 2006); however, the biological stock structure across northern Australia remains uncertain. It is therefore treated as a single stock along the WA North Coast for management and assessment purposes (Butler et al. 2023).

Brown tiger prawns live for 1 – 2 years (55 mm carapace length (CL)) and reach sexual maturity at around six months. Spawning typically occurs between August and October. Post-larval brown tiger prawns are usually found in shallow (< 2 m depth) seagrass and algae beds, often near mangroves. They have a strong association with structured habitats (e.g. Loneragan et al. 2013), and settlement in unsuitable habitats can lead to high mortality. In Exmouth Gulf (WA), the loss of seagrass and macroalgae cover to <2 % following a major cyclone in 1999 led to a significant decline in brown tiger prawn landings, from approximately 400 t to less than 100 t (Loneragan et al. 2004; Loneragan et al. 2013). As juveniles grow, they move into deeper waters. Adult brown tiger prawns are generally found down to approx. 60 m depth (Grey et al. 1983). They tend to be found in mostly high mud content sediments and are mostly commonly captured in mud or sandy mud areas at 10 – 20 m depth. Brown tiger prawns tend to be active day and night (Caputi et al. 2015).

Historical commercial catch levels across all north coast prawn fisheries (OPMF, NBPMF, Broome Prawn Managed Fishery and Kimberley Prawn Managed Fishery) have been used to calculate target catch ranges for assessment purposes. In 2022, these fisheries had a combined landing of 16.6 t of brown tiger prawns. This is likely to due to reduced effort in these fisheries. Based on this information, the brown tiger prawn stock is considered sustainable-adequate (Wilkin et al. 2023).

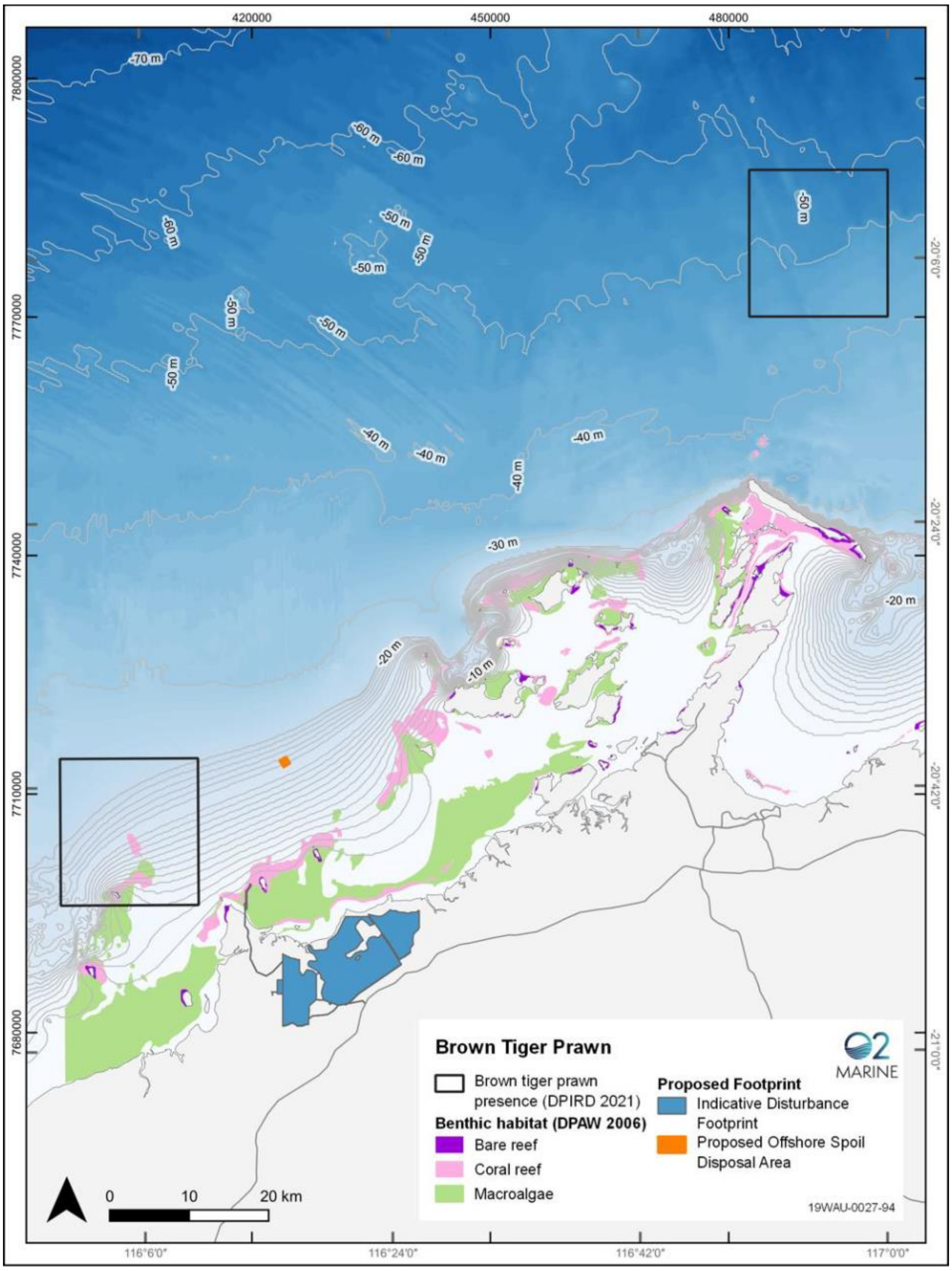

Figure 2–18: Brown tiger prawn presence (by grid block) within the ESSP vicinity (based on 2016 – 2020 catch data) (O2 Marine, 2023b).

Banana prawns are found across northern Australia, from WA to Queensland. Banana prawns have a short lifespan of 1 – 2 years and reach maturity at approximately six months of age (Butler et al. 2023b). They inhabit muddy and sandy bottoms in coastal waters and estuaries. Mangroves habitat provides the primary nurseries of juveniles, with offshore catches correlated with the abundance of estuarine and coastal mangroves (Sheaves et al. 2012). They are typically found at depths of 16 – 25 m but can occur as deep as 45 m. Redleg banana prawns are found in deeper waters, ranging from 35–90 meters. Banana prawns exhibit schooling behaviour, forming dense aggregations near the surface. Catch rates are believed to be positively associated with high riverine discharge by enhancing juvenile emigration from estuaries to offshore habitats, where survival and growth improves (Turschwell et al. 2022).

Within WA, banana prawn stocks are assessed at a management unit level (i.e. for the OPMF and NBPFM). Historical commercial catch levels in the OPMF and NBPMF have been used to calculate target catch ranges for stock assessment. The target catch range for the NBPMF is 40 – 220 t and 2 – 90 t for the OPMF (Turschwell et al. 2022; DPIRD 2022b). Wet season rainfall (December – March) is also used to estimate the predicted commercial catch for Nickol Bay. For the 2022 season, the catch projection was 20 – 40 t. The actual catch was 42 t, which is above the projected catch range but within the target catch range. Based on the annual catch and effort trends, catch rates, and the results of a preliminary state space biomass biodynamics model (DPIRD, 2022b), the banana prawn stock in Nickol Bay is considered to be sustainable – adequate (Wilkin et al. 2023).

The western king prawn management unit comprises the four separate north coast prawn fisheries (Onslow, Nickol Bay, Broome and Kimberley), but it is reported as one unit due to the very low catches. Western king prawn forms a very minor part of total prawn landings in these fisheries, and in some years, no king prawns are landed in any of these fisheries. In 2022, the total commercial catch was less than one tonne. Based on the low catch and effort, the stock is considered to be sustainable-adequate (Wilkin et al. 2023). Western king prawns are found across Australia's temperate, subtropical, and tropical waters. While no studies have been conducted on their biological stock structure in WA, treated as a single stock along the WA North Coast for management and assessment purposes (Heldt et al. 2023).

Western king prawns thrive in high-salinity environments within marine embayments. Western king prawns mature at 6 – 9 months of age and can live for up to four years. Spawning occurs from August to May, with juveniles in shallow areas between September and April peaking in January. Post-larval and juvenile stages occur in shallow tidal flats with sand or mud substrates, often near mangroves and seagrass beds (Kangas and Jackson, 1998). After three to six months in these nursery areas, juveniles migrate offshore to trawl fishing grounds, in bare sand or silt substrates. This species is generally found down to 80 m depths. Western king prawns are sensitive to light, burying themselves during the day and actively feeding at night (Caputi et al. 2015).

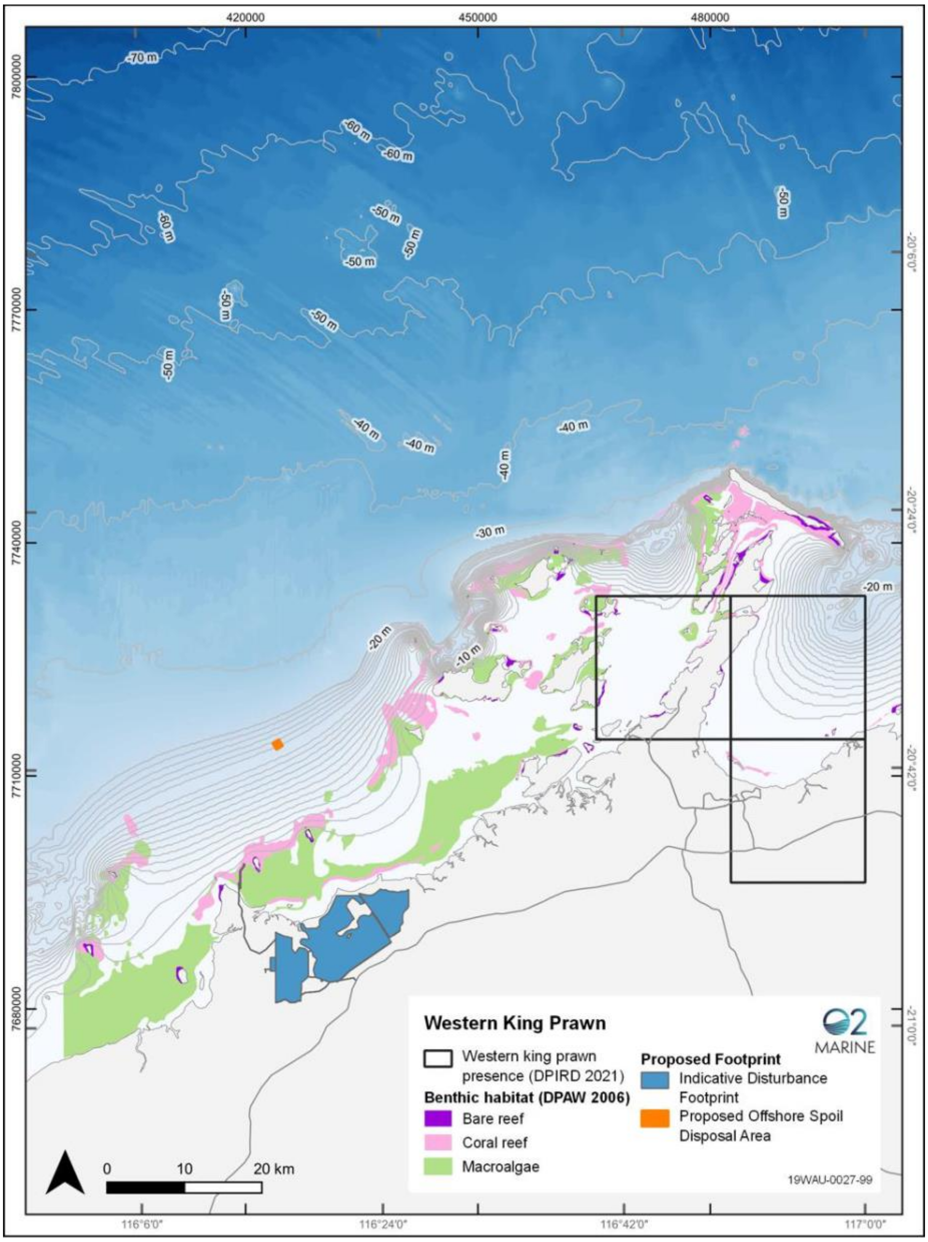

Figure 2–19: Western king prawn presence (by grid block) within the ESSP vicinity (based on 2016 – 2020 catch data). (O2 Marine, 2023b).

Endeavour prawns, including blue and red endeavour prawns, are found across the northern part of Australia. Endeavour prawns have a lifespan of 1 – 2 years and mature around six months, with spawning occurring from August to October. Their stock structure is poorly understood, and in WA, they are assessed at a management unit level. Blue endeavour prawns (*Metapenaeus endeavouri*) are landed in low numbers in the north coast prawn fisheries, including the Onslow, Nickol Bay, Broome and Kimberley prawn managed fisheries. In the past decade (2012 – 2021), combined blue endeavour prawn landings across these fisheries have been between ranged from two to 15 t. The total combined catch for all the fisheries in 2022 was 4 t. The low catch levels, and maintenance of these catches over time, suggests that the biomass of this stock is unlikely to be depleted. Therefore, the stock is classified as sustainable-adequate (Wilkin et al. 2023).

North coast demersal scalefish

North coast demersal scalefish – red emperor (*Lutjanus sebae*), bluespotted emperor (*Lethrinus punctulatus*), Rankin cod (*Epinephelus multinotatus*), goldband snapper (*Pristipomoides multidens*)

Demersal finfish species are of significant social and economic importance, providing a major source of protein and commerce worldwide. Over fifty demersal scalefish species are caught by commercial, charter and recreational fisheries in the Pilbara region, including emperors (Family Lethrinidae), tropical snappers (Family Lutjanidae), and cods (Family Epinephelidae).

The Pilbara region supports the highest annual catches of demersal scalefish in WA, with 2,571 t harvested in 2022. Species caught in substantial amounts include goldband snapper (*Pristipomoides multidens*), red emperor (*Lutjanus sebae*), bluespotted emperor (*Lethrinus punctulatus*), saddletail snapper (*Lutjanus malabaricus*), Rankin cod (*Epinephelus rankini*), crimson snapper (*Lutjanus erythropterus*), rosy threadfin bream (*Nemipterus furcosus*), and brownstripe snapper (*Lutjanus vitta*). Most of the catch is harvested by the commercial sector, with ~3 % of catches caught by charter and recreational fishers (Wakefield et al. 2024).

Red emperor, bluespotted emperor and Rankin cod are used as indicator species to represent the status of the Pilbara demersal scalefish resource. Although not a formal indicator species, goldband snapper was also assessed in 2023, given its relatively high abundance in annual catches, particularly in deeper (~ 100 m depth) waters within the western Pilbara region (Wakefield et al. 2024).

Red emperor is a relatively slow-growing and moderately long-lived (~ 40 years) species. Within Australian waters, they are found from Cape Naturaliste in southwest WA, across the northern part of Australia, to the southeast coast to Sydney. Genetic analysis indicates the eastern and western populations form a single biological stock (van Herwerden et al. 2009); however, juveniles and adults undertake limited movements throughout their range (Stephenson et al. 2001), making them vulnerable to localised depletion. Furthermore, stable isotope analysis from individuals at Shark Bay, Pilbara, and Broome differed significantly, inferring separate stocks along the northwestern Australian coastline (Stephenson et al. 2001). Accordingly, populations are managed separately within the Pilbara, Kimberley and Gascoyne (Shark Bay) regions.

Red emperors opportunistically broadcast spawn throughout the year, with peaks in October and March. Juvenile red emperors (< 20 cm long) are common in nearshore turbid waters, occurring in coastal or offshore reefs and mangrove areas (Williams and Russ 1992, Allen 1985). Individuals move to deeper waters as they grow, with adults found in sandy and rubble areas near coral and rocky reefs across the mid-shelf in depths of 50 – 180 m. Within the Pilbara region, they are found in the highest abundance in 30 – 60 m depths off the coast between the Burrup Peninsula and Port Hedland (i.e. PDSF Areas 2 and 3; Wakefield et al. 2024).

In WA, red emperors mature at around 4 – 6 years of age, with a maximum lifespan of 40 – 45 years (860 mm total length). Their diet predominantly consists of bottom-dwelling fish, crustaceans and cephalopods.

Red emperor is primarily harvested in the commercial trap and trawl fisheries (53 % and 39 % of catches, respectively), while charter and recreational fishing accounted for approx. 7.5 % of catches. In 2022, 157 t were caught commercially in the Pilbara region. The latest (2023) assessment of red emperor in the Pilbara region classified the stock as depleted, with a severe risk of the population becoming overfished in the next five years. The integrated assessment model results indicate that overfishing is likely occurring. If future catches remain at current levels, the stock is projected to fall below the limit reference level (i.e., 20 % of unfished spawning biomass) by 2027 (Wakefield et al. 2024).

Bluespotted emperor is endemic to northwestern Australia and is found from Geraldton (WA) northward to Darwin (in the Northern Territory (NT)), occurring in the greatest abundance in the western Pilbara region. While there is some gene flow between WA and Northern Territory populations, there is limited adult movement (Moran et al. 1993), and populations are treated as separate stocks for management purposes.

Bluespotted emperor is a relatively short-lived (16 years), fast-growing species that matures in its second year of life. Bluespotted emperor broadcast spawn from June to April. Juveniles occur almost exclusively in shallow (< 10 m depth**)** inshore macroalgae habitats (i.e. *Sargassum* complex). The greatest abundance of this habitat type is in the western Pilbara, particularly around the Dampier Archipelago and Cape Preston area. There are predominantly two cohorts per year recruiting from these nursery habitats along the Dampier Archipelago. These recruitment cohorts coincide with the biannual peaks in the spawning period. Individuals move across the shelf as they grow, and adults are found in coral reefs, seagrass beds and sand and rubble areas to 150 m depths. There are substantially higher abundances of adults in areas adjacent to large areas of macroalgae habitat, e.g. off the Dampier Archipelago, with adult abundance decreasing as depth increases (Wakefield et al. 2024).

In 2022, 285 t of bluespotted emperor were commercially caught in the Pilbara region. Bluespotted emperor is predominantly caught in the commercial trawl and trap fisheries (69 % and 31 %, respectively, based on 2022 catches). The most recent (2023) assessment indicated that the stock is sustainable, with the relative spawning biomass midway between the target and threshold levels (based on the level 5 assessment model). Although the component of the stock vulnerable to overfishing is heavily exploited, this species is relatively resilient to fishing pressure due to its early maturity and limited growth in the following years (Wakefield et al. 2024).

Rankin cod are widely distributed throughout the Indian Ocean. Within Australia, they are found from the Houtman Abrolhos Islands in WA, north to Darwin in the NT. There is no evidence of discrete breeding populations in WA, indicating a single biological stock (Johnson et al. 1993; Stephenson et al. 2001). Although adults do not mix extensively across regions, they all contribute to the total adult spawning biomass and larval dispersal. The limited mixing of adults among locations, however, results in the potential for localised depletion. Accordingly, stocks are assessed at a management unit level (i.e. Pilbara and Northwestern Australia; Wakefield et al. 2023).

Rankin cod inhabit clear to turbid waters on drop off and deep rocky reefs. Juveniles are found in inshore reefs, while adults are found in deeper offshore sandy areas and rocky reefs.

Rankin cod are protogynous hermaphrodites, changing sex from female to male during their life cycle. In WA, females mature at around two years old, and the life span is at least 22 years (Bray et al. 2023). Rankin cod spawn for 8 – 10 months of the year, predominantly between June and December.

In 2022, 136 t of rankin cod was caught by the PDSF. In 2015, an integrated age structure model was used to assess Rankin cod in the Pilbara. Based on the model estimates, relative spawning biomass have fluctuated above the target reference level since 1990. Based on this information, the stock is classified as sustainable – adequate (Wakefield et al. 2023).

Goldband snapper is widely distributed throughout the tropical Indo-Pacific. In WA, goldband snapper are found from Cape Pasley, west and northwards towards the NT. Separate biological stocks exist between Kimberley, Pilbara, and Gascoyne, and Northern Australia. Stock status is reported at the level of these individual stocks.

It is a long-lived species (approximately 30 years) that reaches maturity relatively late at age four. It grows rapidly until age nine and reaches a maximum length of approximately 80 cm at 18 years of age (Gastauer et al. 2017; Wakefield et al. 2024). Goldband snapper inhabits hard bottom areas of vertical relief with a depth range of 60 to 200 m, with a markedly higher relative abundance at depths of 90 to 120 m. Adults do not typically move along the coastline (Newman et al. 2000; Wakefield et al*.* 2024).

In 2022, 177 t of goldband snapper were commercially caught in the Pilbara region, predominantly by the commercial line fishery (60 %), then the trap fishery (27.5 %), as well as 12 % by charter and 0.5 % by recreational fishing (Wakefield et al. 2024).

The most recent stock assessment indicates the goldband snapper stock is heavily exploited, with relative female biomass between the threshold and limit reference levels. A high-risk level for stock depletion is considered likely, and the stock is classified as depleted (Wakefield et al. 2024).

2.5.7 Key fisheries resources – Pelagic environment

Large pelagic scalefish – Spanish mackerel (*Scomberomorus commerson*) and grey mackerel (*S. semifasciatus*)

The statewide large pelagic finfish resource is distributed across Western Australia. It encompasses a variety of tropical and temperate species and is accessed by the commercial, recreational and charter fishing sectors (Lewis and Rynvis, 2023). The MMF is responsible for approximately 56 % of the total landings of the resource. It predominantly catches Spanish and grey mackerel in the North Coast Bioregion, where they also serve as key indicator species. The MMF is the only commercial fishery permitted to land mackerels in WA waters and is separated into three population areas: Kimberley, Pilbara and Gascoyne/West Coast (Smith et al. 2024).

Spanish mackerel

Spanish mackerel is widely distributed throughout the Indo-Pacific region, and in WA, it is typically found from Geographe Bay, Busselton, to the NT border. Three distinct Australian stocks exist: the Northern/Western Australian, the Torres Strait, and the East Coast Australian. While there are likely to be several smaller subpopulations due to limited connectivity and adults displaying restricted movements (less than 1000 km), Spanish mackerel is managed as a single management unit within WA.

Spanish mackerel are characterised by their rapid growth, moderate lifespan (approximately 26 years), high reproductive capacity, and young age at maturity (approximately two years old). These life-history traits suggest a high production potential; however, in WA, the productivity of this species is comparatively low. This is primarily due to low primary and secondary production levels in the Kimberley and Pilbara regions, where nutrient-poor currents limit overall biological output in shelf waters. Consequently, the low productivity of Spanish mackerel in WA leads to diminished sustainable catch levels, restricting the potential for large-scale fishery development.

Juvenile Spanish mackerel primarily inhabit shallow inshore waters, often near mangroves and reef structures, whereas adults inhabit coastal waters at depths ranging from 15 to 200 m, frequently around reef systems and islands. Spanish mackerel form schools from an early juvenile stage, a behaviour that persists into adulthood. Their carnivorous diet includes fish, squid, prawns, and mantis shrimp (Newman et al*.* 2012; Smith et al*.* 2024). They typically form seasonal aggregations in shallow coastal areas for foraging and gonadal development before spawning. In the Pilbara region, spawning occurs from October to January (Mackie et al*.* 2003). The fishing season in WA runs from May to October, and little is known regarding the location of most of the population outside the primary fishing season (Smith et al*.* 2024).

The landed catch has been relatively stable, and the age-based mortality estimates are similar to the previous estimates in 2002. The 2022 catch was below the target commercial catch range for Spanish mackerel in the MMF of 246 – 430 t. In 2022, 13.5 t of Spanish mackerel were landed by charter boat operators across WA. This is similar to catch ranges prior to 2020, ranging from 14 – 20 t with a further 34 – 61 % released/discarded. In 2022, 81 % the statewide charter catch was taken in the north coast (Pilbara and Kimberley), with 32 % released (Lewis and Rynvis, 2023). Spanish mackerel are the third most recreationally retained finfish species by weight, primarily caught in WA's North Coast and Gascoyne regions (Ryan et al. 2022).

The most recent weight-of-evidence stock assessment for the entire WA Spanish mackerel stock, plus assessments for each of the three management areas, was undertaken in 2023. The evidence used in the evaluation included a level 3 age-based analysis of fishing mortality and biomass estimates along with trends in catch, effort, catch rates, and a vulnerability assessment. The results indicated a moderate stock depletion, mainly due environmental conditions and the level of targeting in commercial and recreational sectors. Based on this information, the stock is classified as sustainable – adequate (Lewis and Rynvis, 2023; Smith et al. 2024).

However, assessments differed between management areas, with the Pilbara being classified as **high-risk**. The age structure and mortality estimates have shifted significantly since the 2002 assessment, with current samples revealing a depleted age structure and elevated fishing mortality rates that exceed the established reference limits. The biomass estimate is below the critical threshold, while the spawning potential has reached that threshold. Despite these concerning indicators, catch levels have remained low but stable since the last assessment. Additionally, standardised catch rates suggest that abundance in the Pilbara is greater than other management regions (Smith et al. 2024).

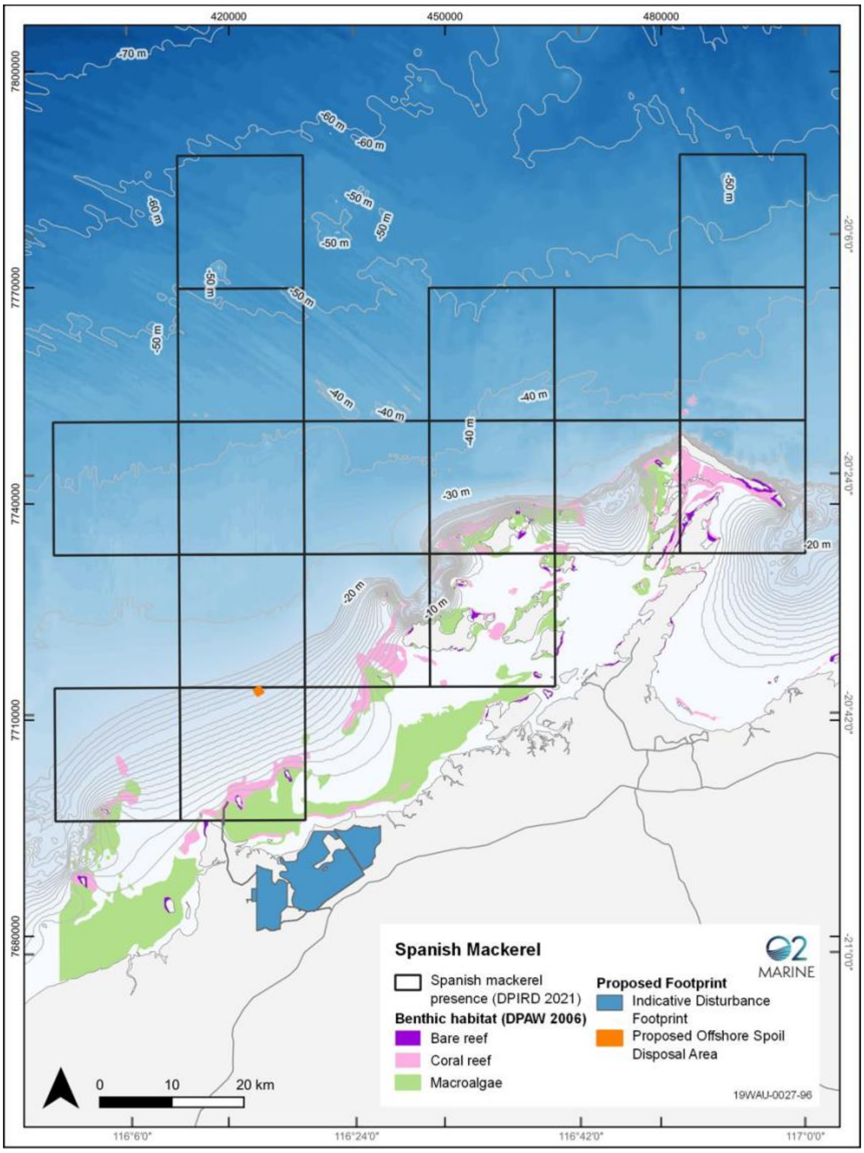

Figure 2–20: Spanish mackerel presence (by grid block) within the ESSP vicinity (based on 2016 – 2020 catch data). (O2 Marine, 2023b).

Grey mackerel

Grey mackerel is endemic to the Australian waters of Perth, northern New South Wales, and southern Papua New Guinea (Allen and Swainston 1998). Five grey mackerel stocks are known across northern Australia, with a single genetic stock in WA due to high spatial separation from the other populations (Broderick et al*.* 2011).

Juveniles and larvae are often located in coastal bays and estuaries with freshwater sources, whereas adults typically inhabit turbid tropical and subtropical waters at depths of 3 – 30 m, favouring areas near rocky headlands, reefs, and sandy or muddy substrates where baitfish are abundant (Smith et al. 2024)

Grey mackerel grow rapidly, reaching maturity at around two years and approximately 70 cm in length. Individuals can reach up to 1.2 meters and live up to 14 years. As batch spawners, they can produce around 250,000 eggs during an extended spawning season, which runs from December to January. Larvae and juveniles are found in coastal bays and the inner margins of the lagoon, often in estuarine environments that are influenced by freshwater run-off and low salinity surface waters. The species forms large schools from June to September and form spawning aggregations at known locations (Smith et al. 2024).

Grey mackerel catches in the MMF since 2000 have been relatively low, ranging from 3.5 to 24 t, well below the total annual commercial catch (60 t for each of the three management areas).

Recreational fishing occurs year-round, with peak catches typically in autumn and spring. The recreational catch of grey mackerel is very low, with an estimated 2 t retained by boat-based fishers in 2020/21 (Ryan et al. 2022). The charter boat fishery annual catch has been 1 t or less since 2003. All recreational catches occur in the north coast and Gascoyne coasts, with fish mainly harvested by line fishing. Approximately half the recreational catch is released. As with Spanish mackerel, post-release mortality is considered to be high.

The latest stock assessment (2022) based on catch data and a productivity-susceptibility analysis estimated the grey mackerel population was at 74% of its unfished level. The stock is classified as sustainable-adequate (Lewis and Rynvis, 2023).

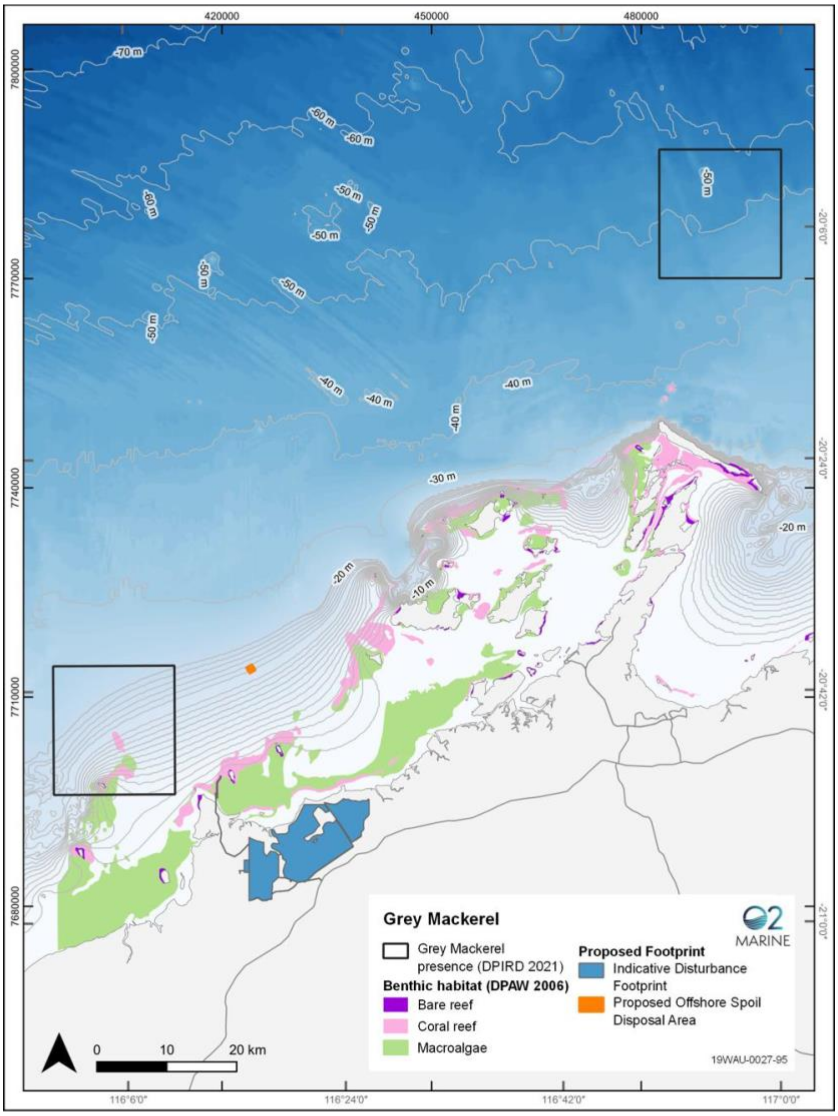

Figure 2–21: Grey mackerel presence (by grid block) within the ESSP vicinity (based on 2016 – 2020 catch data). (O2 Marine, 2023b).

2.6 Issue identification and impact pathways

We conducted a comprehensive issue identification and impact pathway analysis for ESSP activities during **(1) project construction and development** and **(2) operational phases**. The analysis focuses on two primary metrics:

- changes in fish species abundance, distribution or populations dynamics, as a key indicator for biodiversity values.
- impacts on social, cultural and economic values, as a key indicator for social surrounds.

In this context, an *issue* refers to the combination of an *activity* (e.g. bitterns discharge) and a *fisheries value* (e.g. a resource, species, or fishing sector) that may potentially be impacted by this activity. *Impacts* refers to noticeable effects an activity could have on a value, e.g. change in behaviour or physical injury.

Risk is then assessed as the likelihood and consequence of these potential impacts occurring. By identifying and analysing each *issue*, we can evaluate the *risks* associated with project activities and determine how likely and severe specific impacts might be on relevant fisheries values.

Identified potential impacts were categorised as 'direct' or 'indirect', based on their immediacy, location and impact pathway:

- **Direct impacts** involve activities resulting in immediate disturbances to individual organisms, including injury, mortality or behavioural responses, which can influence a species' abundance, distribution, and population dynamics. These impacts occur at or very near the activity source and are often visible and measurable within a short time frame (immediately or less than a few months).

  For example, habitat loss during pond construction can directly reduce or fragment critical nursery habitats, leading to mortality or displacement of juvenile fish that rely on these areas. These individual-level impacts can scale up to population-level consequences by reducing recruitment rates, limiting available resources, or changing population structure.

- **Indirect impacts** include secondary or cascading effects arising from an activity (or combination of activities), which alter essential ecological processes or services that support fish and invertebrate populations. These impacts often manifest over time and occur through complex ecological or social pathways, making them more challenging to measure.

  For example, increased turbidity from regular dredging can reduce light penetration to benthic habitats like seagrass and corals, gradually degrading these habitats. Over time, this degradation may affect species that rely on these habitats for protection, foraging or spawning. This can ultimately lead to decreased juvenile growth, shifts in species distributions or reduced reproductive success.

This assessment focuses on issues within the ESSP's immediate geographical area of influence. Identified issues are provided in Table 2-8, Table 2-9, Table 2-10, and Table 2-11 below. Each identified 'issue' was assessed for key target species/group of species (Table 2-7). Species were grouped where they displayed similar life history characteristics, habitat associations, or represented a range of species within a broader resource, e.g. the Pilbara Demersal Scalefish resource. This grouping allowed for a streamlined assessment while still accounting for variability across species.

Each identified 'issue' was assessed for each key target species or fishing sector/fishery. Where grouped, we considered those species with the worst likely outcomes (i.e.. those with high habitat dependency or depleted population status) to ensure the cumulative impacts were assessed conservatively. This approach acknowledges that species within the same group are likely to experience similar levels of impact while focusing on those most at risk.

Table 2-7: Fisheries species/species grouped assessed for each scoring issue. Species are grouped by ecological suite.

Ecological suite	Species/Group of species assessed
Terrestrial	Australian land hermit crab
Nearshore/Estuarine	Blue swimmer crab
	Silver lipped pearl oyster
	Sea cucumbers: sandfish
	Sea cucumber: redfish
	Aquarium: finfish
	Aquarium: syngnathids
	Aquarium: hard and soft corals
	Aquarium: giant clams
	Specimen shell species
Inshore demersal	North Coast demersal scalefish
	Brown tiger prawns and banana prawns
	Western king prawns
Pelagic species	Spanish mackerel
	Grey mackerel
Fishing sector	**Fishery**
Commercial fishing	Hermit Crab Fishery
	Pilbara Developing Crab Fishery
	Sea Cucumber Fishery
	Pearl Oyster Managed Fishery
	Marine Aquarium Fish Managed Fishery
	Specimen Shell Fishery
	Onslow Prawn Managed Fishery
	Pilbara Fish Trawl (Interim) Managed Fishery
	Pilbara Trap Managed Fishery
	Pilbara Line Fishery
	Mackerel Managed Fishery
Recreational fishing	Marine invertebrates
	Marine finfish
Customary fishing	Marine invertebrates
	Marine finfish

Note, the introduction of marine invasive or pest species has not been included at a project level, as shipping activities are considered separately under the Cape Preston East Port development proposal.

Table 2-8: Assessment Issues: Potential impacts on fisheries values (marine fauna and BCH) from ESSP construction and development activities (4 years).

Activity	Potential impact	Impact pathway description
Pond and infrastructure development, including pond/ crystalliser construction, processing plant, water supply, administration, and associated works (e.g. roads). **and** **Marine development** including installation of bitterns pipeline and outfall diffuser, channel dredging, and dredge spoil disposal.	(Direct) Physical injury, physiological stress, displacement, or mortality of fisheries species	Construction and development activities will directly impact fisheries species inhabiting habitats within the project footprint, resulting in potential physical injury, physiological stress, displacement, or mortality. These effects are acute and occur immediately within the construction area, primarily from habitat removal, dredging, and other construction-related disturbances. Immediate physical injury or mortality is expected to affect low mobility and habitat-dependent species, especially those within the dredging or construction zones. Critical Habitats: • Pond Development Area: Includes mangroves, mudflats, and bare sediments, which are essential for fish and invertebrates during vulnerable life stages, such as breeding, foraging, and nurseries. • Marine Development Area: Contains subtidal habitats, such as seagrasses, macroalgae, and coral reefs, which provide shelter, spawning, and feeding grounds for many species. Direct disturbance will result in irreversible loss of 24.6 ha of vegetated subtidal BCH including high cover filter feeders (3.1 ha), low-moderate cover coral reef (17.9 ha), and macroalgae (3.6 ha), including 1.1 ha of seagrass/macroalgae. An additional 125.3 ha of bare substrate (e.g. coarse sand) will also be directly impacted (O2 Marine, 2023b). Dredging activities result in the direct removal or destruction of benthic habitats within the dredge and disposal area and habitat loss through smothering (sedimentation of the dredge plume) or light attenuation (suspended sediments/turbidity). Modelling indicates no irreversible loss of seagrass or macroalgae from dredge plumes. Worst-case scenario (winter conditions) estimated loss of 81 ha corals, with no significant impact to seagrasses and macroalgae (O2 Marine, 2023b). Construction and dredging operations also generate significant underwater noise and vibrations, causing acute physiological stress to species sensitive to sound. Prolonged exposure can interfere with communication, predator avoidance, and navigation, potentially leading to reduced reproductive success or displacement.
	(Indirect) Long-term habitat loss or fragmentation	Development and construction activities will modify or remove existing habitats, resulting in a loss of overall habitat area (extent) or habitat fragmentation, reducing the overall availability and connectivity of critical ecosystems required by fisheries species for essential life stages, including spawning, feeding, and shelter.

Activity	Potential impact	Impact pathway description
		Key habitat loss: • Terrestrial and intertidal habitats: Irreversible loss of 1,267 ha, including mangroves, samphire shrublands, mudflats, algal mats, beaches, and rock platforms. • Subtidal habitats: Irreversible loss of 24.6 ha of vegetated benthic communities, including coral reefs (17.9 ha), macroalgae (3.6 ha), and seagrass/macroalgae (1.1 ha). An additional 125.3 ha of bare substrate will be directly impacted (O2 Marine, 2023b). Some of these habitats, including mangroves, seagrass/macroalgae, and coral reefs, provide critical services for fisheries species and their removal can lead to an immediate loss of individuals (and associated population decline) that use these areas for spawning, feeding, or shelter. The ecological roles of other habitats, such a algal mats, is less understood and is currently being explored (WAMSI and BCI Minerals, 2024). Species with strong habitat dependence (e.g. sea cucumbers, syngnathids, certain scalefish species, and prawns) would be especially vulnerable to these impacts. Additionally, altered habitat structure and function may disrupt ecosystem structure and function by changing nutrient cycling, sediment dynamics, or predator-prey relationships, leading to cascading ecological effects. Over time, these shifts may contribute to broader declines in biodiversity, resilience, and ecosystem productivity.
	(Indirect) Altered hydrodynamics	The construction of ponds and related infrastructure will alter natural hydrodynamic processes, including surface runoff patterns or tidal flows, that sustain critical intertidal and coastal habitats. Construction may divert natural runoff into adjacent intertidal flats or bypass key habitat areas, altering salinity, sediment composition, and nutrient inputs, while pond walls and drainage systems can impede or modify tidal flows, leading to reduced flushing, altered sediment deposition, and restricted water movement to critical habitats, such as mangroves and algal mats. Altered sediment transport and reduced mixing can lead to sediment build-up or erosion, affecting coral reefs, seagrass beds, and other benthic habitats. The loss of regular tidal inundation can degrade or shift the composition of habitats (e.g. mangroves, mudflats, and algal mats), reducing their capacity to support fisheries species.

Activity	Potential impact	Impact pathway description
		Altered salinity and temperature regimes can create conditions unfavourable for sensitive species, potentially leading to shifts in species composition and trophic interactions, and potentially reduce ecosystem productivity and resilience.
All construction and development activities combined	(Indirect) Combined ecological effects of multiple activities	The cumulative impacts of construction and development activities—including habitat loss, altered hydrodynamics, sedimentation, and changes to water quality—can lead to interconnected and long-term consequences for coastal and marine ecosystems. These combined effects exacerbate individual impacts, undermining ecosystem health and the resilience of fisheries species. Key combined stressors: • Habitat Loss and Fragmentation: Direct destruction of critical intertidal and subtidal habitats (e.g. mangroves, seagrasses, coral reefs) is compounded by fragmentation, limiting species' ability to move between critical areas and reducing overall habitat functionality. • Altered Hydrodynamics: Changes to natural tidal flows and surface water runoff disrupt sediment transport, nutrient cycling, and flushing processes, further degrading habitat quality and availability. • Sedimentation and Turbidity: Construction activities increase suspended sediments and smother benthic habitats, reducing light penetration and primary productivity. This indirectly affects species reliant on these ecosystems for food or shelter. • Water Quality Changes: Runoff, nutrient inputs, and pollutants from construction activities alter salinity and nutrient levels, potentially causing localised eutrophication and further stressing habitats and species.

Table 2-9: Assessment Issues: Potential impacts on fisheries values (marine fauna and BCH) from ESSP operational activities (60 years).

Activity	Potential impact	Impact pathway description
Seawater intake	(Direct) Larvae and juvenile entrainment and entrapment	The seawater intake system, drawing approximately 160 GL annually from nearshore waters around McKay Creek, has the potential to cause direct physical impacts on fisheries species, particularly during their early life stages. Fish and invertebrate larvae can also become concentrated in nearshore waters, around the intake area, from local hydrodynamic processes (e.g. flood tides). Many fisheries species also have early life history states that depend on nearshore habitats like seagrass, mangroves and macroalgae, and are commonly found in these areas. The small size and proximity of larvae and juvenile individuals makes them vulnerable to being drawn into the seawater intake system. Small fish and invertebrate larvae can be trapped against intake screens due to suction forces (known as entrapment). The ESSP will have an intake flow rate of 0.15 m/s, which is recognised to minimise impacts to 96 % of fish and invertebrate species (USEPA, 2014). Larvae and juveniles small enough to pass through intake screens may be drawn into the system along with seawater, entering the concentrator pond system (known as entrainment). Larvae and juveniles may also be directly drawn into intake pipes along with seawater, entering the concentrator pond system (known as entrainment). Studies elsewhere in WA have shown that species like prawns, mud crabs, blue swimmer crabs and finfish are susceptible to these impacts (Molony and Parry, 2002).
	(Indirect) Altered environmental flows, including sediment transport and nutrient distribution	The extraction of large volumes of seawater (160 GL per year) from McKay Creek and the surrounding nearshore environment has the potential to alter natural hydrodynamic processes, impacting the transport and distribution of nutrients, sediments, and organic matter. These disruptions could indirectly affect the structure and function of ecosystems that support fisheries species. Seawater intake may reduce nutrient availability in nearshore waters by altering water circulation patterns and the supply of organic matter to benthic habitats. Reduced nutrient transport could also diminish primary productivity (e.g. seagrass and algae growth), indirectly affecting species dependent on these habitats for food and shelter.

Activity	Potential impact	Impact pathway description
		Hydrodynamic changes might modify sediment deposition and erosion patterns, potentially increasing sedimentation in some areas and causing substrate instability in others. These changes could degrade critical habitats, such as seagrass beds, mangroves, and algal mats, leading to habitat loss or reduced habitat quality for fisheries species. Such disruptions may affect fish recruitment, growth, and survival, particularly for species reliant on the productivity and stability of nearshore habitats.
Salt concentration process	(Direct) Physical injury, physiological stress, displacement, or mortality of fisheries species from pond wall failure	Seawater is stored and moved through concentration ponds, progressively increasing the salt concentration, and into crystallisers to form precipitate (salt crystals). If the pond walls fail, a large volume of concentrated seawater will be released into nearby waters. Marine species within the failure area may be directly harmed through toxic effects of hypersalinity. The pond walls have been designed in accordance with international standards, with details of the wall design provided in CMW Geosciences (2022). The CMW Geosciences geotechnical review found that the pond wall design includes a significant safety factor, which sufficiently mitigates the risk of pond wall failure.
	(Indirect) Altered groundwater salinity from pond seepage	Seawater is stored and moved through concentration ponds, progressively increasing the salt concentration, and into crystallisers to form precipitate (salt crystals). Seepage from salt ponds can increase groundwater salinity in surrounding areas, potentially altering the balance of freshwater and saltwater in coastal and nearshore ecosystems. These changes can affect the health and composition of benthic habitats, such as mangroves and algal mats, which provide critical habitats for fisheries species. Over time, these habitat changes may indirectly impact fisheries species reliant on these ecosystems for shelter, foraging or breeding, leading to shifts in species abundance, distribution, or population dynamics.
Bitterns discharge	(Direct) Physical injury, physiological	The salt production process will produce a high-salinity bittern (360 ppt salinity) that will discharge up to 5.4 GL of bitterns each year into the marine environment.

Activity	Potential impact	Impact pathway description
	stress, displacement, or mortality of fisheries species	Bitterns contain a high concentration of salts, such as magnesium chloride, calcium chloride, potassium chloride and other minerals, which may have toxic effects on fisheries species. Fish and invertebrates in the discharge area experience physiological stress or mortality due to the increased salinity and chemical exposure. Impacts are likely greater for sensitive life stages (e.g. larvae or juveniles) or species that cannot move away from the affected area.
	(Indirect) Long-term habitat loss around the discharge area	The salt production process will produce a high-salinity bittern (360 ppt salinity) that will discharge up to 5.4 GL of bitterns each year into the marine environment. Hydrodynamic modelling indicates an irreversible loss of coral reef (1.4 ha), macroalgae (2.5 ha), and seagrass/macroalgae (1.1 ha) in the bitterns discharge area (LEPA zone). These areas can provide critical habitat for fisheries species and their loss can lead to an immediate decline in populations that use these areas. Ongoing bitterns discharge can lead to long-term habitat degradation and loss, reducing their suitability and availability for fisheries species that rely on these habitats. Over time, habitats can become fragmented, diminishing connectivity between critical areas and impeding the movement of species essential for completing life stages. Habitat changes can also disrupt key ecosystem processes, such as nutrient cycling, water quality, and trophic dynamics, leading to shifts in species distributions, predator-prey relationships, and community composition. Ultimately, such changes can decrease biodiversity, reduce ecosystem resilience, and lower productivity in the affected areas.
	(Indirect) Eutrophication	The operational activities of the project, particularly the discharge of high-salinity bitterns into the marine environment, present a potential risk of eutrophication due to nutrient inputs. While the bitterns primarily contain high concentrations of salts, they may also include organic matter or trace nutrients that could contribute to nutrient enrichment in receiving waters. Over time, the accumulation of these nutrients could lead to elevated primary productivity, algal blooms, and oxygen depletion in affected areas.

Activity	Potential impact	Impact pathway description
		Nutrient loading from the project, combined with natural or anthropogenic sources (e.g. riverine inputs, upwelling events, agricultural runoff, or other developments), may exacerbate eutrophication risks. These combined impacts can disrupt ecosystem processes and dynamics, with cascading effects on fisheries species. The spatial extent of eutrophication impacts is expected to be localized near the LEPA and MEPA discharge zones but could expand into adjacent habitats under certain conditions, such as weak tidal flushing or prolonged periods of discharge. Sensitive nearshore and benthic habitats, such as mangroves, seagrasses, and coral reefs, and the fisheries species they support are particularly vulnerable to these changes.
All operational activities combined	(Indirect) Combined ecological effects of multiple activities	The combined effects of operational activities, including chronic stress from seawater intake, bitterns discharge, pond wall failure, and altered groundwater salinity, have the potential to create cumulative and interconnected impacts on surrounding coastal and marine ecosystems. These activities may interact synergistically, amplifying the severity and persistence of ecological changes. Key combined stressors: • Seawater intake can disrupt nutrient flows and sediment transport, reducing productivity and connectivity between habitats critical for fisheries species. • Bitterns discharge contributes to long-term habitat degradation, reducing the availability and quality of essential habitats for spawning, foraging, and shelter. • Changes in groundwater salinity from pond seepage may disrupt the balance of freshwater and saline systems, potentially degrading intertidal habitats such as mangroves and algal mats. Combined, these changes can shift community structures, disrupt predator-prey relationships, and lead to cascading effects through the ecosystem. The cumulative nature of stressors, particularly for species whose populations are already depleted or under significant pressure (e.g. sandfish, red emperor, goldband snapper), may impair recruitment, growth, and survival, reducing recovery potential for these populations.

Table 2-10: Assessment Issues: Potential impacts on fisheries values (social surrounds) from ESSP construction and development and operational activities.

Activity	Potential impact	Impact pathway description
All construction and development activities combined	(Direct) Loss of access / displacement	Fishers may lose access to or be displaced from fishing areas due to construction and development activities. This can result in immediate loss of access to key fishing grounds, reducing the ability of fishers to maintain catch rates. Fishers may be forced to travel farther or to less productive areas, leading to a decrease in overall fishing success and efficiency. These changes may be temporary or permanent (i.e. certain areas are permanently restricted or reduced).
	(Indirect) Reduced catches due to long-term ecological changes	Impacts from construction and development, including habitat loss and changes in water quality, can lead to long-term changes in ecosystem structure and function. Over time, these changes may impact the availability of fisheries species by reducing local abundance, distribution shifts, or sustained population declines, contributing to reduced catch rates and catches.
	(Indirect) Economic impacts	The combined effects of habitat loss, fisher displacement and reduced availability of fisheries species can lead to negative economic outcomes for fishers including decreased revenue due to lower catches (commercial only), increased operational costs to access alternative fishing grounds, or reduced food security for local communities.
	(Indirect) Social and cultural impacts	Fisher displacement and disruption can lead to a breakdown of community bonds and loss of cultural heritage associated with fishing. These impacts may also lead to social conflicts over access and resource allocation.
All operational activities combined	(Direct/Indirect) Loss of access/ displacement	During the operational phase, continued infrastructure presence and activities like bitterns discharge and seawater extraction can restrict fishers' access to fishing grounds. These activities may directly limit or block assess (e.g. due to infrastructure or access restrictions) or indirectly affect fishers through changes in ecological conditions (e.g. habitat degradation, species shifts), requiring fishers to travel elsewhere.

Activity	Potential impact	Impact pathway description
	(Indirect) Reduced catches due to long-term ecological changes	Ongoing impacts from operational activities, including habitat degradation, sedimentation and altered water quality, can lead to long-term changes in ecosystem structure and function. Over time, these changes may impact the availability of fisheries species by reducing local abundance, distribution shifts, or sustained population declines, contributing to reduced catch rates and catches.
	(Indirect) Economic impacts	During the operational phase, continued ecological impacts (e.g. from habitat degradation or altered water quality) will continue to affect fish availability. As a result, fishers across all sectors may experience ongoing economic challenges due to reduced catches and increased operational costs. These changes may also impact food security for the local community, leading to a greater reliance on alternative food sources.
	(Indirect) Social and cultural impacts	As operational activities continue to affect fishing access and availability, fishing communities may experience sustained social and cultural challenges – weakening communities ties and the loss of cultural heritage and practices associated fishing. These may lead to increased competition and conflict over access to fishing grounds and resource allocation.

Table 2-11: Assessment Issues: Potential cumulative impacts on fisheries values (marine fauna, BCH and social surrounds) from ESSP and other relevant future projects.

Activity	Potential impact	Impact pathway description
Cumulative site construction and development (excluding dredging)	(Indirect) Cumulative impacts from habitat loss	The cumulative development of ESSP and other future projects along the West Pilbara Coast will result in the permanent loss of critical habitats, such as mangroves, coral reefs, seagrass beds, algal mats, and intertidal flats. These habitats are essential for supporting the breeding, nursery, and feeding stages of various fish and invertebrate species. These losses can reduce recruitment due to the loss of nursery areas, shift species' distributions, and diminish ecosystem functionality including altering predator-prey dynamics, nutrient cycling and productivity.
Cumulative dredging and dredge spoil disposal (construction and operations)	(Indirect) Cumulative impacts from dredging and dredge spoil removal	Dredging and spoil disposal during construction and operations result in the direct removal of benthic habitats within the dredge and disposal area. Increased sedimentation and turbidity can cause physical injury, physiological stress, or displacement of fish within the immediate dredge area. Noise and vibrations from dredge operations can also harm marine species, particularly those reliant on sound for navigation, communication, or predator avoidance. Ongoing dredging during operations may create prolonged sediment (re)suspension, leading to reduced light availability and habitat degradation. Over time, these impacts can decrease fish abundance and recruitment, disrupt trophic interactions, and shift species distributions as populations migrate towards more suitable conditions.
Cumulative seawater intake	(Direct) Entrapment/ entrainment from cumulative seawater intake	Cumulative seawater intake from multiple salt production and desalination projects along the West Pilbara Coast, including the ESSP and future projects, will withdraw a combined total of approximately 590 GL/year. Seawater intake systems can directly entrap and entrain small fish and invertebrates, particularly early life stages (larvae and juveniles) that may be unable to avoid the intake screens or flow rates. Despite the low intake velocity (0.15 m/s) adopted across most projects, which protects approximately 96% of mobile species, the cumulative scale and duration of intake (over 60+ years) could lead to: • Localised depletion of larvae and juveniles in nearshore habitats where hydrodynamic processes concentrate early life stages. • Lowered recruitment success for species that depend on affected areas for spawning or as nursery grounds.

Activity	Potential impact	Impact pathway description
		• Population-level impacts for species with depleted or regionally limited stocks, such as sandfish and red emperor.
	(Indirect) Altered environmental flows from cumulative seawater intake	The cumulative seawater intake of approximately 590 GL/year from multiple projects along the West Pilbara Coast, including solar salt and desalination plants, can disrupt natural hydrodynamic processes, particularly in nearshore areas. This large-scale water extraction may alter sediment transport and deposition, leading to changes in substrate composition and structure; reduce the transport of organic matter and nutrients critical for maintaining productivity in benthic habitats like mangroves, seagrass beds, and coral reefs; cause localised reductions in water flow that affect tidal flushing, sediment flushing, and nutrient cycling, potentially altering water quality; or indirectly reduce the availability and suitability of critical habitats for fisheries species, especially those dependent on nursery, feeding, and spawning grounds in nearshore areas.
Pond storage (operations)	(Indirect) Cumulative seepage impacts from salt ponds	Seepage from salt ponds introduces highly saline water into adjacent groundwater systems, gradually increasing salinity in nearby coastal and nearshore environments. Over time, elevated groundwater salinity can: • Alter the balance between freshwater and saltwater, impacting coastal vegetation and benthic habitats (e.g., mangroves, algal mats, and tidal flats). • Reduce the suitability of these habitats for fisheries species dependent on stable salinity conditions for foraging, breeding, and shelter. • Lead to long-term habitat degradation and loss, contributing to cumulative ecological stress, particularly in areas already affected by other industrial activities along the West Pilbara Coast.
Cumulative bitterns disposal (operations)	(Direct) Physical injury, physiological stress, displacement, or mortality of fisheries species	Bitterns discharge introduces highly concentrated salts and minerals into the marine environment, creating localized zones of hypersalinity and altered water chemistry. Fisheries species within or near these zones are exposed to acute physiological stress or mortality due to osmotic shock or toxicity. The combined bitterns and brine discharge from the projects along the West Pilbara Coast is estimated at approximately 128 GL per year, including contributions from the ESSP (5.4 GL/year), Ashburton Salt Project (10 GL/year), Mardie Project (5.5 GL/year), Dampier Seawater Desalination Plant (12 GL/year), and other existing and proposed projects (e.g. Perdaman Urea Plant: 20 GL/year).

Activity	Potential impact	Impact pathway description
		These effects are most severe within the low ecological protection area (LEPA) near discharge points but are expected to diminish with distance due to dilution and mixing processes. Over 60+ years of cumulative bitterns disposal (estimated 128 GL/year across all projects), these impacts may intensify due to chronic exposure.
	(Indirect) Long-term habitat loss or degradation from bitterns disposal	The combined bitterns and brine discharge from the projects along the West Pilbara Coast is estimated at approximately 128 GL per year. Over the course of the projects' lifetimes, these inputs can result in sustained salinity increases, leading to the loss of essential BCH including coral reefs, macroalgae and seagrasses. Habitat degradation beyond these zones occurs gradually, affecting ecosystem functionality, species recruitment, and trophic relationships. Over time, habitat fragmentation diminishes biodiversity and ecosystem resilience, particularly for species reliant on stable nearshore environments. Cumulative discharge volumes, when combined with natural evaporation-driven salinity dynamics in the West Pilbara Coast, may exacerbate localized habitat changes, particularly in shallow, low-flush areas.
	(Indirect) Eutrophication	Bitterns contain high concentrations of salts (e.g. magnesium chloride, calcium chloride, potassium chloride). While not direct nutrients like nitrogen or phosphorus, their discharge can alter salinity and ionic composition, which can stress ecosystems and indirectly exacerbate eutrophication risks. Cumulative bitterns/brine discharge from ESSP and other future projects (estimated at 128 GL per year) has the potential to exacerbate eutrophication in the West Pilbara Coast. The ionic imbalance and salinity changes caused by cumulative discharges can trigger cascading effects on coastal ecosystems including: • increased salinity and altered water chemistry, which can create conditions favourable for salt-tolerant algae, particularly in areas with poor flushing. • oxygen depletion due to the decomposition of algae and organic matter can cause hypoxia or anoxia, which degrades habitat quality and reduces fish recruitment and survival. • sensitive benthic habitats like seagrass, macroalgae, and coral reefs can be displaced or degraded, indirectly contributing to shifts in food web dynamics and trophic relationships.

Activity	Potential impact	Impact pathway description
		While each individual project's nutrient input may be minor, cumulative contributions across multiple projects, particularly when concentrated near sensitive habitats, can increase eutrophication.
Combined cumulative ecological effects (all activities)	(Indirect) Combined ecological effects from cumulative activities	The combined cumulative effects of construction and operational activities from multiple projects along the West Pilbara Coast—including habitat loss, hydrodynamic changes, altered sediment and nutrient flows, seawater intake, and bitterns/brine discharge—have the potential to significantly disrupt nearshore and coastal ecosystems. This includes through: • fragmentation and loss of critical habitats that support fisheries productivity. • altered hydrodynamics and sediment transport, disrupting habitat connectivity and ecosystem processes. • changes in species composition and distributions as species shift toward more favourable conditions. • diminished biodiversity and ecosystem resilience, due to compounded habitat degradation and disruption of ecosystem processes.
Combined cumulative social effects (all activities)	(Indirect) Reduced catches due to long-term ecological changes	The combined effects of ESSP and other future projects may lead to long-term changes in fish populations, including reduced abundance, altered species distributions, or disruptions in breeding and feeding patterns. These changes can reduce the availability of fish in key fishing areas, ultimately leading to lower catch rates for commercial, recreational, and customary fishers. Over time, these ecological changes may impact the sustainability of these fisheries.
	(Indirect) Economic impacts	Long-term ecological changes, such as reduced fish availability and shifts in distribution, can have significant economic implications for fishers in the region. For commercial fishers and charter fishing companies, decreased catch rates may result in reduced profits and increased operational costs. Recreational and customary fishers may face increased travel costs, as they may need to fish in other areas or take longer trips to maintain catches.

Activity	Potential impact	Impact pathway description
	(Indirect) Social and cultural impacts	Fisher displacement and disruption can lead to a breakdown of community bonds and loss of cultural heritage associated with fishing. These impacts may also lead to social conflicts over access and resource allocation.

2.7 Assessment Method

2.7.1 Risk-based approach

The assessment is designed to evaluate the risk that the EPA's environmental objectives for marine fauna, BCH and social surrounds will not be met. This will be done using a structured approach to evaluate the likelihood and potential consequence of ESSP activities, utilising publicly available data and expert knowledge and insight.

It is important to note that *a higher risk score does not mean that a specific outcome will occur*, but rather that *there is a higher level of uncertainty or possible impact*. In such cases, additional research or data collection may be needed to improve confidence in the likely outcome and/or additional mitigation measures may be needed to effectively manage the risk to an acceptable level.

2.7.2 Risk analysis and scoring

The risk analysis process uses a consequence-likelihood matrix to quantify risk for each identified issue. This involves evaluating the severity or magnitude of impact on a particular value (consequence) and the likelihood of these impacts occurring from a given activity (likelihood).

Likelihood levels are defined in Table 2-12, and consequence levels are defined in

Table 2-13 (*Marine fauna*) and

Table 2-14 (*Social surrounds*).

To determine the risk level, the likelihood that each defined level of consequence will occur for a given issue is evaluated. The risk score (Table 2-15) is then calculated by multiplying the assigned likelihood and consequence levels, with the final risk score representing the highest (likelihood x consequence) result. Issues where there is no likelihood of occurring (L = 0) or a negligible consequence (C = 0) are scored as 'No risk'.

The amount of information available for other relevant future projects is highly variable, resulting in a high level of uncertainty in predicting cumulative impacts. Accordingly, the assessment will use a combination of quantitative (where sufficient data exist) and qualitative (where there is limited data) approaches to assess impacts. The assessment will take a *conservative approach*, assuming 'worst case' scenario based on the information available. When assessing cumulative impacts, we will also that identified impacts from other relevant future projects will materialise in the environment (i.e., that each project will be approved and operate as described).

The accuracy and credibility of the risk scores will be improved by incorporating a broad range of expertise and knowledge sources including quantitative studies and input from fishers, fisheries scientists, ecologists, Traditional Owners, and government officials.

Table 2-12: Likelihood levels used to assess risk to fisheries values.

Likelihood level	Score	Description
Remote	*1*	*Very unlikely to occur, except in exceptional circumstances (< 5% chance of occurring).*
Unlikely	*2*	*Possible but unlikely to occur; may occur under specific conditions (5 – 25 % chance of occurring).*

Possible	*3*	*Clear evidence to suggest this is possible in this situation (25 – 50 % chance of occurring).*
Likely	*4*	*Likely to occur under most conditions (> 50 % chance of occurring).*

Table 2-13: Consequence levels used to assess risk to natural fisheries values (i.e. marina fauna, BCH). Note, Consequence level is 0 where there is no measurable impact (i.e. a negligible risk).

Consequence level	*Score*	*Description*
Minor	*1*	*Localised or temporary changes in species abundance, distribution, or population dynamics. Impacts are restricted to a small area and short duration, with recovery expected within 1-2 years. No measurable long-term effects on species populations or recruitment. Ecosystem structure and function remains largely intact.*
Moderate	*2*	*Regionally or temporally significant changes in species abundance, distribution, or population dynamics. These changes may affect species recruitment or population structure but are expected to recover within five years. Ecosystem impacts, if present, are minor and localised.*
Major	*3*	*Significant, sustained changes in species abundance, distribution, or population dynamics. Substantial reductions in recruitment or changes in population structure that may affect species across region. Ecosystem disruptions may exacerbate population impacts. Recovery is slow (5 – 15 years).*
Severe	*4*	*Widespread, irreversible declines in species abundance, distribution shifts, or altered population dynamics. Reduced abundance and low recruitment lead to long-term impacts on key species. Ecosystem function and structure are disrupted, with recovery unlikely or extremely slow (15+ years).*

Table 2-14: Consequence levels used to assess risk to economic, social and cultural fisheries values (i.e. social surrounds). Note, Consequence level is 0 where there is no measurable impact (i.e. a negligible risk).

Consequence level	*Score*	*Description*
Minor	*1*	*Temporary or localised inconvenience to recreational, customary, or commercial fishing activities, with no measurable effects on livelihoods, cultural practices, or social outcomes. Recovery is rapid (< 1 year).*
Moderate	*2*	*Noticeable, lingering impacts on social, cultural, or economic values. Reduced access or participation in fishing activities for some groups, causing moderate disruptions to social outcomes, cultural practices, or commercial viability. Recoverable within five years.*
Major	*3*	*Substantial and prolonged impacts on social, cultural, or economic values. Broad restrictions on access or participation in fisheries-related activities. Significant effects on livelihoods, commercial fishing operations, cultural practices, or community well-being. Recovery is slow (5 – 15 years) and may require mitigation or intervention.*
Severe	*4*	*Widespread and irreversible impacts on social, cultural, or economic values. Permanent loss of access to fishing areas or key species, loss of culturally significant practices, or long-term economic impacts for*

Consequence level	Score	Description
		commercial fisheries. Profound, long-lasting effects on fishing sectors. Recovery unlikely, extremely slow (15+ years), or requiring significant intervention.

Table 2-15. Consequence and Likelihood matrix used to determine final risk score

Consequence/Likelihood	1 – Remote	2 – Unlikely	3 – Possible	4 – Likely
1 – Minor	Low (1)	Low (2)	Low (3)	Low (4)
2 – Moderate	Low (2)	Low (4)	Medium (6)	High (8)
3 – Major	Low (3)	Medium (6)	High (9)	V High (12)
4 – Severe	Medium (4)	High (8)	V High (12)	V High (16)

The risks scores can be interpreted as follows and used to inform additional mitigation activities:

- Low risk: minimal impact and low likelihood of objectives not being met; generally acceptable without additional management measures.
- Medium risk: moderate impact and likelihood of objectives not being met; monitoring and potential additional mitigation should be considered.
- High risk: significant impact and high likelihood of objectives not being met; additional mitigation measures needed to reduce risk.
- Very high risk: severe impact or very high likelihood of objectives not being met; strong mitigation measures or redesign needed to reduce risk.

3 Conclusion

This review identifies several potential direct and indirect impact to fisheries values at a local and regional scale. Leichhardt has made substantial efforts to mitigate these impacts through avoidance, minimisation, and management and monitoring programs; however, some issues remain unresolved due to uncertainty around combined and cumulative effects across the region, where multiple developments may interact over time to influence fisheries productivity, access, or ecosystem health.

The next step is to assess the impacts in greater detail and develop mitigation strategies, where needed. Given the level of uncertainty, this process will be improved by incorporating insight from fish biologists, ecologists, fisheries managers, fishers, and Traditional Owners to develop a comprehensive understanding of potential impacts and help inform the development of mitigation measures to effectively limit fisheries impacts.

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Appendix A - Cumulative impacts on BCH from relevant future projects

Table 4-1: Total BCH Cumulative Loss Assessment for Eramurra Solar Salt Project (ESSP) across all LAU's (1-13). Area expressed hectares & % of current or pre-European (Adapted from O2 Marine, 2023b, Table 8.).

Within the ESSP study area (local assessment units)	Extent	Intertidal BCH									Subtidal BCH							Bare substrate
		Beach	Mangroves		Mudflat	Samphire Shrublands	Tidal Creek	Rock Platform	Mudflat / Algal mat	Samphire shrublands (inc. Algal Mat)	Coral Reef		Filter Feeders		Macroalgae		Seagrass / Macroalgae	
			SC	CC							HC	L-M C	HC	L-M C	HC	L-M C	L-M C	
Estimated pre-European extent	ha	80.7	625.2	686.0	2574.5	379.8	586.3	788.0	3295.0	711.7	10.0	1780.5	44.0	768.4	898.0	4171.3	1372.0	68061.3
Current extent	ha	78.5	625.0	685.4	2573.9	372.8	586.3	771.0	3294.7	710.9	10.0	1773.7	44.0	768.4	898.0	4159.1	1371.6	68052.0
	%	97.3%	100.0%	99.9%	100.0%	98.2%	100.0%	97.8%	100.0%	99.9%	100.0%	99.6%	100.0%	100.0%	100.0%	99.7%	100.0%	100.0%
Irreversible loss due to ESSP	ha	0.1	6.10	1.8	35.8	190.9	0.0	0.0	771.1	261.1	0.0	17.9	3.1	0.0	0.0	2.5	1.1	125.3
	%	0.1%	1.0%	0.3%	1.4%	50.3%	0.0%	0.0%	23.4%	36.7%	0.0%	1.0%	7.0%	0.0%	0.0%	0.1%	0.1%	0.2%
Recoverable impact due to ESSP	ha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	76.0	0.0	0.0	0.0	2.5	0.0	20.4
	%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	50.0%	4.3%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Total Loss (Historical Loss + ESSP impacts)	**ha**	**2.3**	**6.3**	**2.4**	**36.4**	**197.9**	**0.0**	**17.0**	**771.4**	**261.9**	**0.0**	**24.7**	**3.1**	**0.0**	**0.0**	**14.7**	**1.5**	**134.6**
	%	**2.9%**	**1.0%**	**0.3%**	**1.4%**	**52.1%**	**0.0%**	**2.2%**	**23.4%**	**36.8%**	**0.0%**	**1.4%**	**7.0%**	**0.0%**	**0.0%**	**0.4%**	**0.1%**	**0.2%**
Note, recoverable impacts are not included in the total loss.																		

Table 4-2: Total BCH Cumulative Loss Assessment for Ashburton Salt Project. Area expressed hectares & % of current or pre-European (K+S, 2023).

Ashburton Salt	Extent	Intertidal BCH									Subtidal BCH						Bare Substrate
		Beach	Mangroves	Mudflat	Samphire*	Tidal Creek	Rock Platform	Algal mat	Samphire shrublands (inc. Algal Mat)	Bare Salt Flat*	Sparse Coral & Macroalgae	Filter Feeders HC	Filter Feeders L-M C	Macroalgae	Seagrass / Macroalgae L-M C	Soft Sediment	
Estimated pre-European extent	ha	298.0	3724.0	7987.0	1717.0	899.0		6199.0		26665.0	325.0			147.0		8966.0	*see 'Bare salt flat' and 'Soft sediment'*
Current extent	ha	298.0	3724.0	7987.0	1717.0	899.0		6199.0		26665.0	325.0			147.0		8966.0	
	%																
Irreversible loss due to Ashburton*	ha	1.0	4.6	17.8	158.2	0.6		16.7		10634.0	0.1			4.6		4.0	
	%	0.3%	0.1%	0.2%	9.2%	0.1%		0.3%		39.9%	0.0%			3.1%		0.0%	
Recoverable impact due to Ashburton	ha																
	%																
Total Loss	**ha**	**1.0**	**4.6**	**17.8**	**158.2**	**0.6**		**16.7**		**10634.0**	**0.1**			**4.6**		**4.0**	
	%	**0.3%**	**0.1%**	**0.2%**	**9.2%**	**0.1%**		**0.3%**		**39.9%**	**0.0%**			**3.1%**		**0.0%**	

Given there is no existing development on the Eastern Exmouth Gulf (including within the LAUs) the BCH mapping represents the pre-European extents (that is 100% of the pre-European extent is assumed to be remaining).

* Reports the sum of direct and indirect impacts as a combined impact loss (ha). Indirect losses are not described as recoverable, so we have assumed that all effects combined are irreversible for this assessment.
*Ashburton reports categories 'Samphire' and 'Bare Salt Flat' as supratidal, but for the purpose of this assessment they are categorised as intertidal.

Table 4-3: Total BCH Cumulative Loss Assessment for Mardie and Optimised Mardie Projects. Area expressed hectares & % of current or pre-European (O2 Marine, 2020; EPA, 2023).

Mardie & Optimised Mardie Project	Extent	Intertidal BCH										Subtidal BCH			Bare Substrate
		Beach	Mangroves SC	Mangroves CC	Samphire Mudflat	Samphire shrublands	Foreshore Mudflat / Tidal creek	Rock Shores	Algal mat	Samphire shrublands (inc. Algal Mat)	Mudflat or Saltflat	Coral / Macroalgae*	Filter feeders / Seagrass / Macroalgae (5-10% cover)	Bare Bioturbated Sand	
Estimated pre-European extent	ha	32.0	2327.0	1282.0	6032.0		5014.0	59.0	3523.0		10602.0	189.0	445.0	6827.0	*see 'Bare Bioturbated Sand'*
Current extent	ha	32.00	2326.00	1282.00	5993.00		5014.00	59.00	3459.00		10509.00	189.0	445.0	6827.00	
	%	100.0%	100.0%	100.0%	99.4%		100.0%	100.0%	98.2%		99.1%	100.0%	100.0%	100.0%	
Irreversible loss due to Mardie	ha											44.0	35.0	104.0	
	%													1.5%	
Recoverable impact due to Mardie	ha											69.0	133.0	595.0	
	%													8.7%	
Total Loss*	**ha**	**0.0**	**<1**	**17.0**	**1193.0**		**5.0**	**0.0**	**880.0**		**6505.0**	**44.0**	**35.0**	**104.0**	
	%	**0.0%**	**<1%**	**1.3%**	**19.8%**		**0.1%**	**0.0%**	**25.4%**		**61.9%**	**23.3%**	**7.9%**	**1.5%**	

Due to the remote nature and historical land uses, the Mardie Project area is considered representative of the pre-European extent except for a gas pipeline, for which historical loss percentages are so small they display as 100 % when rounded to the nearest whole figure.

*Total loss is reported in EPA (2023) as cumulative loss (total historical losses, plus the total direct and indirect loss of the combined Mardie and Optimised Mardie Project).
*Coral / Macroalgae subtidal BCH represents low (5-10 %), moderate (10-25 %), dense (> 25 %) – macroalgae dominated, and dense (> 25 %) – coral dominated cover. Exact figures can be referenced in O2 Marine (2020).
*Total loss of 1193 ha of Samphire Mudflat represents coastal and landward samphire (EPA, 2023).

Table 4-4: Total BCH Cumulative Loss Assessment for Cape Preston East Port (CPE). Area expressed hectares & % of current or pre-European (Preston Consulting, 2013; Leichhardt, 2021; EPA, 2020).

Cape Preston East (CPE)	Extent	Intertidal BCH									Subtidal BCH						Bare substrate
		Beach	Mangroves		Mudflat	Samphire Shrublands	Tidal Creek	Rock Platform	Algae dominated limestone pavement	Samphire Shrublands (inc. Algal Mat)	Coral / Macroalgae	Filter Feeders		Macroalgae		Seagrass / Macroalgae	
			SC	CC								HC	L-M C	HC	L-M C	L-M C	
Estimated pre-European extent	ha																
Current extent	ha																
	%																
Irreversible loss due to CPE	ha																
	%																
Recoverable impact due to CPE	ha								5.0		0.7						
	%																
Total Loss	**ha**								**5.0**		**0.7**						
	%																

Table 4-5: Total BCH Cumulative Loss Assessment for <u>Dampier Seawater Desalination Plant</u> (DSDP). Area ex-pressed hectares & % of current or pre-European (Rio Tinto, 2022).

Dampier Seawater Desalination Plant (DSDP)	Extent	Intertidal BCH									Subtidal BCH						Bare substrate
		Beach	Mangroves		Mudflat	Samphire Shrublands	Tidal Creek	Rock Platform	Mudflat / Algal mat	Samphire Shrublands (inc. Algal Mat)	Sparse Mixed Assemblage*	Filter feeders		Macroalgae		Seagrass / Macroalgae	
			SC	CC								HC	L-M C	HC	L-M C	L-M C	
Estimated pre-European extent	ha																
Current extent	ha																
	%																
Irreversible loss due to DSDP	ha										1.0						
	%																
Recoverable impact due to DSDP	ha																
	%																
Total Loss	**ha**										**1.0**						
	%																

*Sparse mixed assemblage community (< 5 % cover): Consists of turf algae, occasional small (< 30 cm) corals, sparse sponges, and zoanthids on highly disturbed substrate. The percentage of live coral cover on 1 ha patch is 3-5 %. Located 120 m south of the outfall and is of low ecological value.

Table 4-6: Total BCH Cumulative Loss Assessment for Dampier Cargo Wharf Extension (DCWE) for all LAU's (1-15). Area expressed hectares & % of current or pre-European (O2 Marine, 2022; O2 Marine, 2023g).

Dampier Cargo Wharf Extension (DCWE)	**Extent**	**Intertidal BCH**									**Subtidal BCH**						**Bare Substrate**
		Beach	Mangroves		Mudflat	Samphire Shrublands	Tidal Creek	Rock Platform	Mudflat / Algal mat	Samphire shrublands (inc. Algal Mat)	Coral	Filter feeders / Seagrass / Macroalgae		Macroalgae		Seagrass / Macroalgae	
			SC	CC								HC	L-M C	HC	L-M C	L-M C	
Estimated pre-European extent	ha										294.5						
Current extent	ha										264.4						
	%										89.8%						
Irreversible loss due to DCWE	ha										0.8						
	%										0.3%						
Recoverable impact due to DCWE	ha										0.2						
	%										0.1%						
Total Loss	**ha**										**30.9**						
	%										**10.5%**						

While 5 key types of BCH were categorised and found within the Port (coral, seagrass, macroalgae, mangroves (and saltmarsh), and mixed community), only losses of coral habitat were reported. LAU1 contains all the predicted irreversible impacts to BCH from the project and was the focus of the BCH cumulative assessment by O2 Marine (2022), but here data is present for all LAU's.

Table 4-7: Total BCH Cumulative Loss Assessment for Perdaman Lateral Project (PLP). Area expressed hectares & % of current or pre-European (AGIG, 2024).

Perdaman Lateral Project (PLP)	Extent	Intertidal BCH									Subtidal BCH							Bare Substrate
		Beach	Mangroves		Mudflat (no vegetation)	Samphire Shrublands	Tidal Creek	Rock Platform	Mudflat / Algal mat	Samphire shrublands (inc. Algal Mat)	Coral Reef		Filter feeders		Macroalgae		Seagrass / Macroalgae	
			SC	CC							HC	L-M C	HC	L-M C	HC	L-M C	L-M C	
Estimated pre-European extent	ha																	
Current extent	ha																	
	%																	
Irreversible loss due to PLP	ha				1.2													
	%																	
Recoverable impact due to PLP	ha																	
	%																	
Total Loss	**ha**				**1.2**													
	%																	

Table 4-8 Total BCH Cumulative Loss Assessment for Onslow Seawater Desalination Plant (OSDP). Area expressed hectares & % of current or pre-European (O2 Marine, 2021).

Onslow Seawater Desalination Plant (OSDP)	**Extent**	**Intertidal BCH**									**Subtidal BCH**							**Bare Substrate**	**Unknown Habitat**
		Beach	Mangroves		Mudflat (no vegetation)	Samphire Shrublands	Tidal Creek	Rock Platform	Mudflat / Algal mat	Samphire shrublands (inc. Algal Mat)	Coral Reef		Filter feeders		Macroalgae		Seagrass / Macroalgae		
			SC	CC							HC	L-M C	HC	L-M C	HC	L-M C	L-M C		
Estimated pre-European extent	ha																		
Current extent	ha																		
	%																		
Irreversible loss due to PLP	ha																		0.02
	%																		
Recoverable impact due to PLP	ha																		
	%																		
Total Loss	**ha**																		**0.02**
	%																		
Loss of 0.02 ha of intertidal and subtidal BCH.																			

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