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Potential impacts on commercial fishing and aquaculture operations resulting from the Mardie Project development

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fishwell CONSULTING

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NOTE: This is a preliminary report - Fishwell has yet to conduct Phase 2 of the project, which will reveal more information on potential impacts. We have developed a questionnaire for aquaculture and commercial fishing operators regarding the potential impact of the Mardie Project on their businesses. This survey will be conducted by WAFIC on behalf of BCI and Fishwell and the results reported back. Also, we have accessed catch and effort logbook data which will provide more detailed information on the potential impacts on fishing operations.

1. Contents

2. Executive Summary

In relation to the BCI Minerals Mardie Project in the Pilbara region of Western Australia, Fishwell Consulting was contracted to quantify the potential impact of the Project nearby on aquaculture ventures and fishing grounds, catches and economic return. Specifically, the objectives of the project were to:

a) Identify the aquaculture activities and commercial fishing sectors that operate in the area;
b) Supply background information on these sectors;
c) Provide the scale of the fishing effort present (catches, species, extrapolate value); and,
d) Identify the best contact points for affected sectors.

This project was staged into two phases, with Phase 1 delivering objectives a) and b) in a relatively short time period, and later delivering aims c) and d) in Phase 2 allowing for the data request to be fulfilled, and consultation with industry.

There are four commercial fisheries that reported effort in the Mardie Project area between 2010–2011 and 2018–2019. These are:

- Onslow Prawn Managed Fishery;
- The Mackerel Managed Fishery;
- The Marine Aquarium Fish Managed Fishery; and,
- The Specimen Shell Managed Fishery.

Of these, the Onslow Prawn Managed Fishery may be directly impacted by the Mardie Project due to disturbance to the Fortescue Size Managed Fishery Ground (SMFG).

In addition, there are five other commercial fisheries that have the potential to operate within the Mardie Project area, but which did not report effort in the Mardie Project area between 2010–2011 and 2018–2019. These are:

- Pilbara Demersal Scalefish Fisheries;
- The Western Australia Pearl Oyster Managed Fishery;
- The Western Australian Sea Cucumber Fishery;
- The Pilbara Crab Managed Fishery; and,
- The Hermit Crab Managed Fishery.

There are no aquaculture operations currently operating in the Mardie Project area. However, the Pilbara Rock Oyster Research & Development Project is currently underway near Karratha, and several pearl oyster leases exist in the broader area.

The key fisheries concern regarding the Mardie Project is the effects of disturbance caused by shipping and dredging on the benthos, project infrastructure, clearing of coastal vegetation, and loss of primary productivity, and the impact of these activities on the Fortescue SPMFG.

3. Introduction

3.1. Ecology of the Western Pilbara Coast & North Coast Bioregion

The marine waters of Western Australian are separated into several recognised Bioregions for management based on their environmental characteristics. The Mardie Project Area is located within the North Coast Bioregion (NCB), which extends all the way from Ashburton River south of Onslow to the Northern Territory border encompassing both the Pilbara and Kimberly. The coastal waters of the NCB have a variety of distinguishing characteristics, including a wide continental shelf, extreme tidal regimes, strong currents, frequent cyclones, warm low nutrient waters, and unique geomorphology (Brewer *et al.* 2007). The western Pilbara is characterised by a variety of low-relief islands, such as the Dampier Archipelago, Barrow Island and the Montebello Islands. Ecosystems in these coastal and intertidal areas include rocky and coral reefs, soft sediments, salt-marshes and mangrove communities.

3.2. Commercial fishing in the Western Pilbara

The coastal ecosystems of the Western Pilbara provide habitat for a wide range of commercially valuable tropical fishes and invertebrates, including species with wide Indo-Pacific distributions and others that are restricted to Western Australia. In total, 9 State-managed fisheries can legally operate within the Western Pilbara and the Mardie Project area.

3.3. Aquaculture activities in the Western Pilbara

Within the Western Pilbara there are extensive areas of land and coastal waters highly suitable for aquaculture development; however, to date the region remains under developed. The feasibility of aquaculture operations are currently under assessment and opportunities for investment in Pilbara aquaculture are actively promoted.

3.4. This report

The following report reviews publicly available information to summarise each of the fisheries that are legally able to operate within the Mardie Project area. For each fishery, a range of key information is provided including an overview, the spatial extent of the fishery, fishing methods used, fishing effort and management controls. The ecology of key species in each fishery are then discussed including stock structure and life history, associated habitats, diet, trophic level and ecosystem role, and current risks and vulnerabilities. Current and planned aquaculture activities in the Mardie Project area are also summarised with…

4. Methods

4.1. Qualitative review of fisheries in Mardie Project Area

For each fishery identified as overlapping with the Mardie Project, publicly available material was used to gather information on the main target species of each fishery, methods used, the level of effort, number of operators, management arrangements and gross value of production. These data were mostly fishery-wide, not localised to the Mardie Project area. Publicly available GIS layers will be used to identify which fishery/aquaculture operations are permitted to fish in the area of the Dredged Material Placement Area (DPMA) and the dredge channel. For each of the main target species, information was gathered on the biology, lifecycle, population dynamics and distribution to assess the likelihood of impact from the Mardie Project.

5. Fishery Operations in Mardie Project Area

In total, 8 State-managed fisheries can legally operate within the area of interest. While the spatial boundaries of 8 fisheries overlap with the Area of Interest, the vast majority do not fish in the area. A list of the fisheries that can legally operate in the area of interest, and an indication of whether or not they do so, is provided in Table 1 below.

Table 1: Fisheries that can legally operate in the Project Area. Fisheries that have reported recent effort in the Project Area are classed as active, while those that have not reported effort in this area are classed as inactive.

Active	Marine Aquarium Managed Fishery
	Mackerel Managed Fishery
	Onslow Prawn Managed Fishery
Inactive	Pearl Oyster Managed Fishery
	WA Sea Cucumber fishery
	Pilbara Crab Managed Fishery
	Hermit Crab Managed Fishery
	Pilbara Line Fishery
	Specimen Shell Managed Fishery*

Note that the with boundary of the Abalone Fishery extends the length of the WA coastline, but the distribution of the target species do not extend into the area of interest.

*The was a small number of records of effort in the Specimen Shell Managed Fishery, but they recorded no catch.

6. Status of Fishery Operations

A total of 8 fisheries were identified as capable of legally operating within the Mardie Project Area (Table 1); however, of these, four did not report effort in this area between 2010–11 to 2018–19. In the following sections (6.1 – 6.9), the status of each fishery is outlined, including a general overview and information on its spatial boundaries, commercial methods used, current effort with reference to the area of interest, management controls, ecology of target species, and the vulnerability of these species to environmental impacts.

6.1. Onslow Prawn Managed Fishery (OPMF)

6.1.1. Fishery overview

Prawns are crustaceans which are found throughout the coastal waters of Western Australia. A variety of prawns are harvested in the North Coast Bioregion, with the industry targeting larger, more valuable species. Prawns are often highly migratory over their lifecycle, developing in shallow nursery grounds for a period of months before moving into deeper waters as adults. Here, they are available to the fishery and are caught by trawling.

As a whole, the North Coast Prawn fishery operates as four separate fisheries, Kimberley, Broome, Nickol Bay and Onslow. Of these, the Mardie Project Area falls within the Onslow Prawn Managed Fishery (OPMF). The OPMF is further split into three management areas and nursery areas, with the Mardie Project Area falling within Area 3 and the Fortescue Nursery Area (Fig 1). The OPMF targets three species of prawn. Management is based on a number of input controls including limited entry, seasonal and area closures, and gear controls, while Vessel Monitoring System (VMS) is used to monitor all vessel activity. As a whole, prawning is Western Australia's third most valuable commercial fishing industry, worth $25–35 million per year. The fisheries have Commonwealth export approval until 2025.

The Mardie Project Area can be fished by licence holders and there is a very small amount of effort reported from within the vicinity of the Mardie Project Area; however, most fishing effort in the Pilbara occurs away from this area, with the closest fishing patch located off Onslow (Gaughan & Santoro 2020). Thus, any impact of the Mardie Project on the current OPMF is likely to be minimal. The **Annual Economic Value** of the OPMF is considered **Negligible** (Gaughan & Santoro 2020). The **Stock Status** of prawns in the OPMF is considered **Sustainable-Adequate** (Gaughan & Santoro 2020).

6.1.2. Extent of the fishery

The OPMF extends from Dampier (116° 45.00' E) to just west of Onslow (114° 38.82' E) (Fig 1). The OPMF is divided into three Fishing Areas with associated Size Management Fish Grounds (SMFG). The Mardie Project Area falls within Area 3 and overlaps with the associated Fortescue SMFG (Fig 2). Each Area and SMFG has its own opening and closing dates which protects smaller prawns and allows access to the various target species at appropriate times.

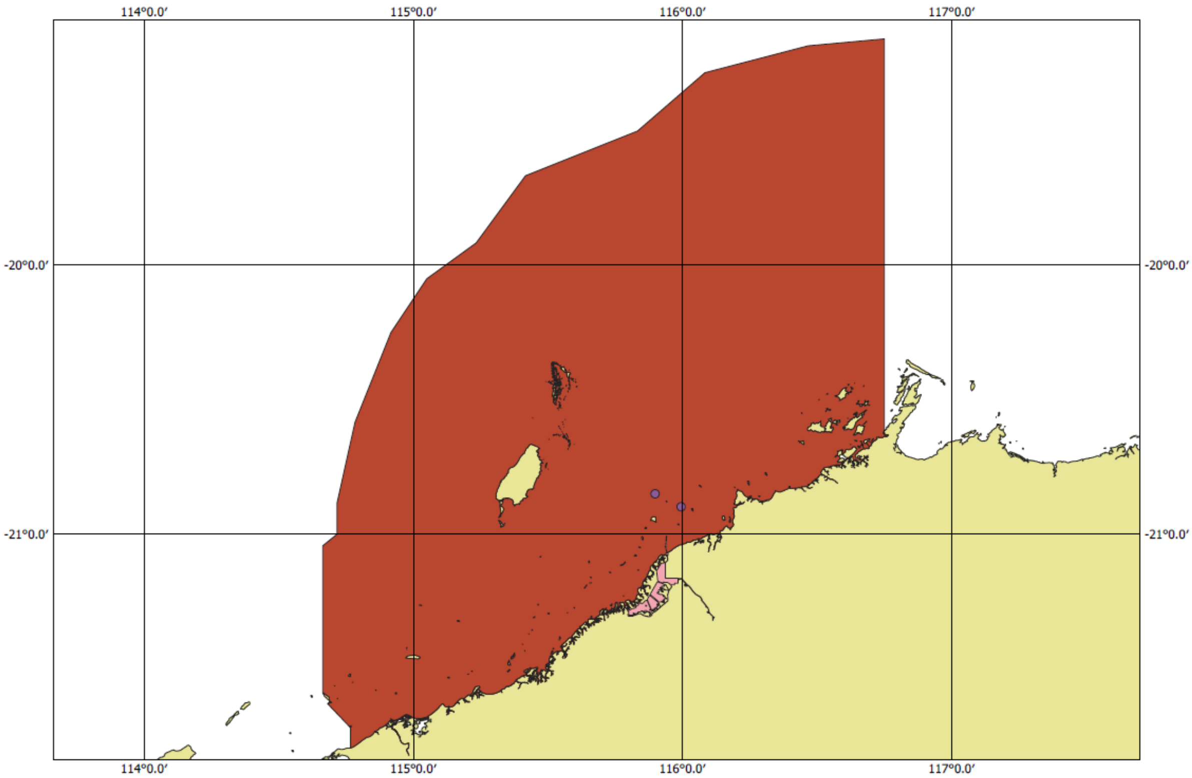

Fig 1. Spatial boundaries of the Onslow Prawn Managed Fishery.

6.1.3. Fishing methods

Vessels in the fishery all use low opening, otter prawn trawl systems (Gaughan & Santoro 2020). Trawl shots generally take between 90-180 minutes depending on the species targeted, and when targeting Banana Prawn aggregations, trawl shots may be as short as 30 minutes. Trawling depth also depends on the target species, but is generally between 8–15 metres. Trawl speed is generally between 3–4 knots (Dept. of Fisheries 2003).

6.1.4. Fishing effort

Despite there being 30 Onslow Prawn Managed Fishery licences, fishing effort in the OPMF is low. In 2018, the total landings were less than 60 t across the OFMF, below the target catch range of 60–180 t. Forty-nine days of fishing effort (509 hours) was undertaken by one boat in 2018, the highest amount of effort since 2011 (Gaughan & Santoro 2020).

From 2010–2011 to 2018–2019, OPMF effort in the vicinity of the Mardie Project was only reported from August 2010 and July and August 2011. In reporting block 205155, Moreton Bay Bug (*Thenus* spp.), Blue Endeavour Prawn, Velvet Prawn (*Metapenaeopsis* spp.) and Western King Prawn were caught, however this catch was taken by less than three vessels and so catch weights and values were not provided. There is little to no OPMF effort in the vicinity of the Mardie Project

6.1.5. Management controls

Management of this fisheries is based on input controls, including limited entry, gear controls (i.e. maximum headrope length, mandatory fish escape devices on all trawl nets), seasonal and area closures (i.e. in each Area and SMFG). In Area 3, a maximum headrope length of 29.27 metres (16 fathoms) is permitted in either twin or quad gear configuration. The fishery is exempt from the 375-boat unit rule which puts a ceiling on the size and engine power of any replacement vessels. The Department of Fisheries Vessel Monitoring System (VMS) monitors the activities of all boats in the fishery.

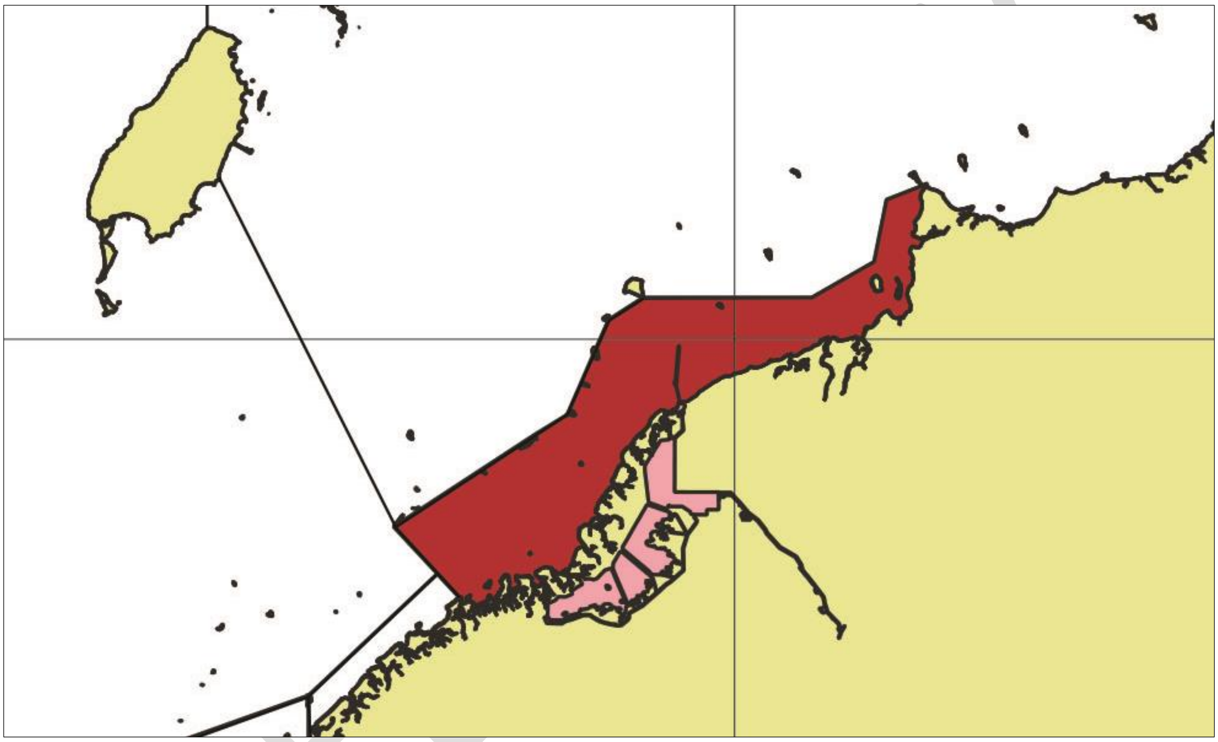

Fig 2. Detail of the Onslow Prawn Managed Fishery showing the location of the Fortescue Size Managed Fishing Ground (SMFG) in brown.

6.1.6. Ecology of t*arget species*

Three species of prawn are targeted by the OPMF (Fig 3); Western King Prawns (*Penaeus latisulcatus*), Brown Tiger Prawns (*P. esculentus*) and Endeavour Prawns (*Metapenaeus spp*.).

Fig 3: The Onslow Prawn Managed fishery targets three species of prawn, including Endeavour Prawns (L) and Brown Tiger Prawns (R) (Wikimedia Commons: CC BY-SA 3.0/ BY 3.0).

6.1.7. Stock structure & life history

Western King Prawns are found throughout the Indo–West Pacific and occur around much of Australia (Grey *et al.* 1983). No research has examined the stock structure of Western King Prawn in Western Australia and so stock status is reported at the management unit level (Noell *et al.* 2018). Brown Tiger Prawns are endemic to Australian tropical and subtropical waters. There is some evidence of genetic separation of Brown Tiger Prawn stocks from the east and west coasts of Australia (Ward *et al.* 2006); however, status of Western Australian stock is reported at the management unit level (Larcombe *et al.* 2018).

Endeavour Prawns as a category consist of two species, the Blue Endeavour Prawn (*M. endeavouri)*, and Red Endeavour Prawn (*M. ensis)*, which both occur around much of Northern Australia. They are generally not distinguished in fisheries, although they are caught in differing proportions in different regions. Little is known about the biological stock structure of Blue and Red Endeavour Prawn populations, and so stock status is reported at the management unit level. However, Blue Endeavour Prawns appear more common in the North Coast Bioregion, making up 60–80% of the catch (Roelofs *et al.* 2018).

The generalised life cycle of all three species consists of multiple life history stages. Fertilised eggs hatch and then go through several stages of larval development over several weeks before settling to the sea floor in nursery areas, such as shallow sand flats or seagrass. Juveniles subsequently grow and migrate into deeper waters where they are available to the fishery. All three species reach maturity in about 6 months. Western King Prawns have a life span of 2–3 years while Brown Tiger and Endeavour Prawns live for between 1–2 years. The main spawning time for Brown Tiger Prawns is between August and October, and recruitment usually occurs during summer and autumn if each year (Department of Fisheries, 2003).

In Queensland, peak spawning of Blue Endeavour Prawn occurs during March and September, while recruitment in the Torres Strait is mainly in the summer months (Department of Fisheries, 2003). Western King Prawns spawn numerous times throughout the year, and recruit during summer and autumn (Department of Fisheries, 2003).

6.1.8. Habitat

Stocks of adult prawns are harvested in deeper water offshore from nursery areas, generally over soft sandy mud habitats. Nursery areas are shallow coastal or estuarine environments such as seagrass and mangroves.

6.1.9. Diet, trophic level and ecosystem role

Prawns are opportunistic generalist feeders, eating a range of molluscs, bryozoans, small crustaceans, plant material and detritus. In turn, they provide an important food source for larger fishes and invertebrates. Thus, prawns play an important link in the coastal food chain.

6.1.10. Current risks and vulnerabilities

Low effort within the OPMF relative to the extent of the fishery means that breeding stocks are not considered to be at risk of overexploitation at present (Gaughan & Santoro 2020).

As with other coastal marine species, prawns are vulnerable to a range of ecological disturbance risks. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Bashevkin *et al.* 2020). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Przeslawski et al 2008).

The availability of shallow coastal nursery grounds, such as seagrass beds, is an important factor for maintaining the prawn stocks in the OPMF, and the loss of these habitats can lead to dramatic declines in catch rates (Loneragan *et al.* 2013). Coastal nursery habitats can be affected by direct disturbance, such as trawling or dredging, and current management options include the closure of areas to trawling for this reason (Kenyon *et al.* 2015). In addition to direct physical disturbance, the health and resilience of these critical nursery habitats can also be affected by various factors that reduce water quality such as chemical pollution, eutrophication, and increased sedimentation (Ralph *et al.* 2006; Saunders *et al.* 2017).

6.1.11. Statement of p*otential risk to the OPMF*

The PDSF does not overlap with the Fortescue Size Managed Fishing Ground, however the area of the dredging operation does. Brown Tiger Prawns and Blue Endeavour Prawns prefer structured habitat such as seagrass and mangroves for settlement and as juveniles, while Western King Prawns prefer shallow and/mud flats (Department of Fisheries, 2003). These prawns spawn at multiple time of the year and it would be difficult to time dredging operations to avoid spawning periods, but avoiding summer and autumn would be the best option to negate impacts on spawning and recruitment for all three species.

Prawns have a boom and bust life cycle meaning that any potential impacts would likely be short term, and not be realised by the fishery until they recruit into deeper water. The OPMF is a relatively small fishery with few active operators and little to no effort in the vicinity of the Mardie Project. It is unlikely that the Mardie Project have any effect on the OPMF, however there is considerable latent effort in the fishery which could become active, and the target catch is under caught, so there is potential for an increase in effort, increasing the potential impact to the fishery.

6.2. Pilbara Demersal Scalefish Fisheries (PDSF)

6.2.1. Fishery overview

The Pilbara Demersal Scalefish Fisheries (PDSF) represents a combination of three mixed-species fisheries that operate in the Pilbara region; the Pilbara Fish Trawl (Interim) Managed Fishery (PFTIMF), the Pilbara Trap Managed Fishery (PTMF), and the Pilbara Line Fishery (PLF). As a whole, the PDSF employs around 43 fishers operating from 13 vessels. It is an important supplier of fish to Perth, with catches from the Pilbara supporting the local fish-processing industry and retail markets. The fishery harvests a wide range of species (45-50), primarily snappers, emperors, and cod.

The Mardie Project Area overlaps with the PLF, with the coastal waters it encompasses currently closed to both trap and trawl methods (harvest strategy). The PLF currently consists of 9 licenses, with these allowed to commercially fish for a nominated five-month block period each year. Total catch by line has remained relatively consistent over the past decade, averaging at 106 t per year (Gaughan & Santoro 2020). The **Annual Economic Value** of the PDSF is estimated at **$10-20 million**, (Gaughan & Santoro 2020). The **Stock Status** of fishes in the PDSF is considered **Sustainable-Adequate** (Gaughan & Santoro 2020).

6.2.2. Extent of the fishery

As a whole the PDSF extends from Cape Range east to the south end of Eighty Mile Beach. Gear restrictions exist within much of the fishery (Fig 4). The Mardie Project area is closed to both trawl and trap fishing but is open to the line fishery, with licensees permitted to operate anywhere within Pilbara waters which extend from the coastline out the edge of the Exclusive Economic Zone.

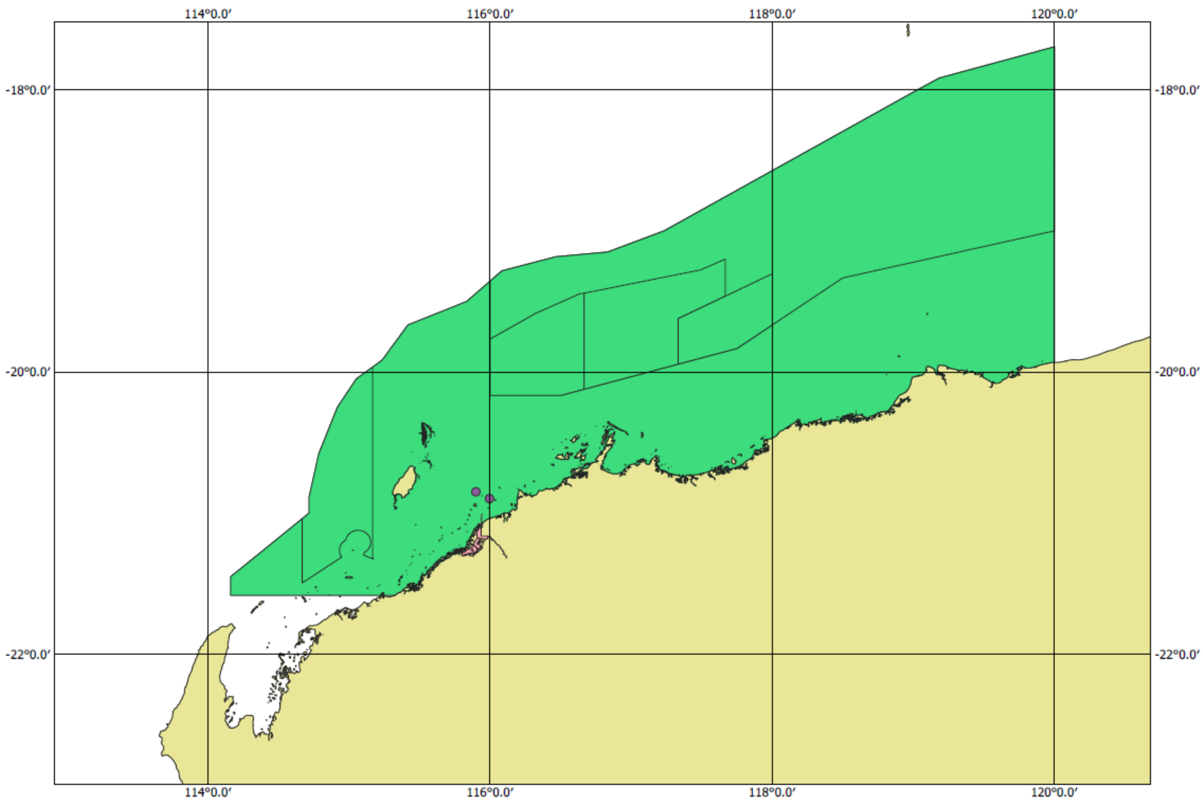

Fig 4. Spatial boundaries of the Pilbara Demersal Scalefish Fishery

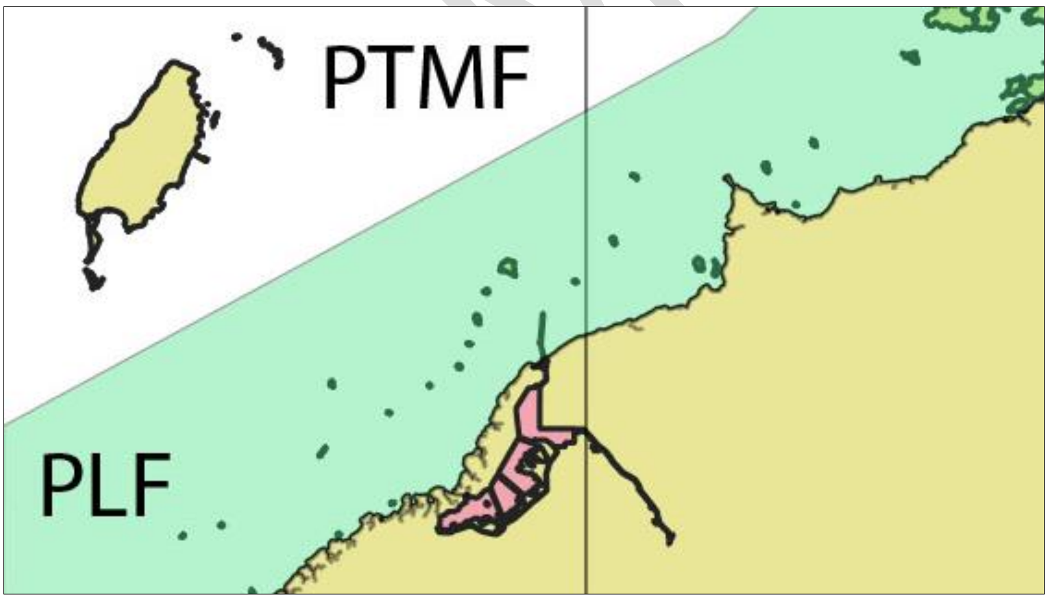

Fig 5. Details of the Pilbara Demersal Scalefish Fishery in the Mardie Project Area, showing area open to line fishing only (PLF) and both line and trap fishing (PTMF).

6.2.3. Fishing methods

Fishing in the PLF is restricted to hook and line. Fishers are not permitted to use metal wire or chains within one metre of any hook.

6.2.4. Fishing effort

There are 9 licensees within the PLF operating from 7 vessels and employing about 21 people. Licensees within the PLF are exempt from a line fishing prohibition order for a specified five-month block period within a year, typically during the winter months (May to September). Effort in the line fishery has declined since a peak in 1990 (Fig 6), and there has also been increased effort on fishing grounds that are greater than 100 metres depth and farther from port (Looby 1997).

From 2010–2011 to 2018–2019, there was no PLF effort reported in the vicinity of the Mardie Project.

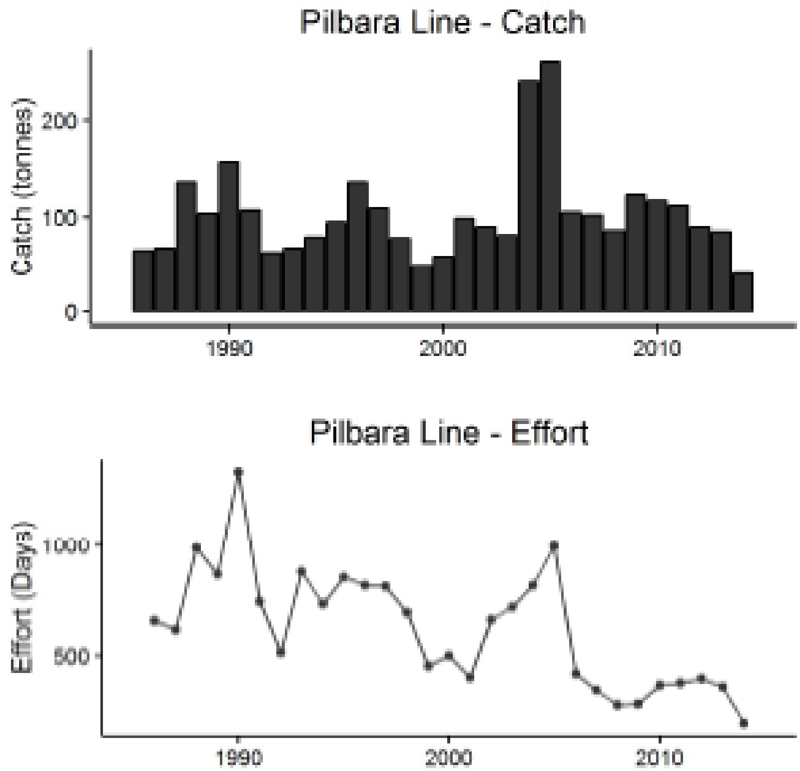

Fig 6. Annual total retained catches (tonnes) and fishing effort (days fished) in the commercial PLF between 1986-2014 (from Dept. Primary Industries and Regional Development 2020).

6.2.5. Management controls

As a whole, the PDSF uses a combination of vessels, effort allocations (time), gear limits, plus spatial zones (including extensive areas closed to trap and/or trawl fishing) as management measures. Minimum legal lengths (MLLs) are also in place for some fish species.

6.2.6. Ecology of *Target species*

The PLF harvests a wide range of species (45-50), similar to the other fisheries in the PDSF. However, PLF catches can include some species, such as flame snapper and eight bar grouper, which only occupy deeper habitats. The PDSF as a whole uses three indicator species for assessment of the fishery: the Red Emperor (*Lutjanus sebae*), Bluespotted Emperor (*Lethrinus punctulatus*) and Rankin Cod (*Epinephelus multinotatus*). These species will be discussed below.

Fig 5. The Pilbara Demersal Scalefish Fishery targets a range of fishes, two of the primary species being Red Emperor (L) and Rankin Cod (R) (Wikimedia Commons: CC BY 2.0/ BY-SA 4.0).

6.2.7. Stock structure & life history

Red Emperor are found throughout the Indo-Pacific. In Australia, they occur in northern Australia from Cape Naturaliste in Western Australia to Sydney. There is little genetic differentiation between Australian populations (van Herwerden *et al.* 2009); however there appears to be limited mixing of fishes between Shark Bay, Pilbara and Kimberly (Stephenson *et al.* 2001). Bluespot Emperor have a far more restricted distribution, only occurring from Exmouth to Darwin. Rankin Cod occur across the Indian Ocean and occur along the West Coast of Western Australia to Darwin. For all three species the regional stocks are considered separate for management.

Red and Bluespot Emperor are both gonochoristic while Rankin Cod are protogynous hermaphrodites. All three are broadcast spawners and have pelagic larvae. Red Emperor opportunistically spawn throughout the year, while Bluespot Emperor spawning from June to April and Rankin Cod from June to December.

6.2.8. Habitat

Adult Red Emperor are found across the mid-shelf and are associated with coral reef lagoons, reefs, epibenthic communities, limestone sand flats and gravel patches (Kailola *et al.* 1993). Adult Bluespot Emperor occur in high abundance in shelf waters near large inshore macroalgae beds, especially in the western Pilbara. Rankin Cod have patchy distributions across the shelf. Juvenile Red Emperor are common in turbid coastal waters as well as inshore and offshore coral reefs, while Bluespot Emperor are generally found in coastal algae beds. Juvenile Rankin Cod are found across the shelf in similar habitats to adults.

6.2.9. Diet, trophic level and ecosystem role

All three species are carnivorous, feeding on smaller fishes and invertebrates. In turn juveniles and adults are prey for larger fishes and sharks. As such, they form an important component of the coastal food chain.

6.2.10. Current risks and vulnerabilities

All three species have limited movement and so are at risk of localised depletion due to overfishing.

Demersal tropical fishes are, in general, vulnerable to a range of ecological disturbance risks associated with human activities. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Munday *et al.* 2008). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Wenger *et al.* 2011; Besson *et al.* 2020).

The Pilbara stocks of Red Emperor (Newman *et al*. 2018a), Bluespotted Emperor (Newman *et al*. 2018b) and Rankin Cod (Newman *et al*. 2018c) are all considered sustainable, with the biomass of the stock unlikely to be depleted, recruitment unlikely to be impaired and that the current level of fishing mortality is unlikely to cause the stock to become recruitment impaired.

6.2.11. Statement of potential risk to the PLF

Red Emperor are a widely distributed species inhabiting waters across northern Australia. The whole of the PDSF overlaps with only 6% of the Australian distribution of this species, however there is evidence of limited mixing between Shark Bay, Pilbara and Kimberly (Stephenson *et al*. 2001), meaning that localised impacts could affect stocks at the management unit level (Pilbara). Bluespotted Emperor have a much more limited distribution, and while we did not have the data to calculate the overlap of the fishery with their distribution, it is very likely that it is much higher than as for Red Emperor. In Australian waters, Rankin Cod are restricted to west of Darwin (NT) and north of Geraldton (WA). The

PDSF overlaps with about 14% of their Australian distribution, but as for Red Emperor and Bluespotted Emperor, there is considered to be little mixing of adults among locations, so there is the potential for localised depletion of the management unit level.

Given the lack of fishing effort in the vicinity of the Mardie Project, it is very unlikely that it will have any effect on the PLF.

6.3. The Western Australia Pearl Oyster Managed Fishery (WAPOF)

6.3.1. Fishery overview

The Silverlip Pearl Oyster, *Pinctada maxima*, is a filter-feeding bivalve mollusc found throughout the North Coast Bioregion and as far south as Shark Bay. It is found on a variety of substrates, including mud, sand, gravel, seagrass and deep reefs, and is most abundant in areas of high water flow, nutrient inputs and productivity (Yukihira *et al.* 1999). Their namesake pearl is formed when the oyster coats small particles or grit with a form of calcium carbonate termed nacre, or mother of pearl.

The Western Australia Pearl Oyster Managed Fishery (WAPOF) is the world's only remaining significant wild-stock pearl oyster fishery, managed as three separate management zones. The area of interest is within Zone 1 (Fig 7); however, however the vast majority of fishing effort takes place within Zone 2. In addition to the collection of wild oysters, the Western Australia Pearling Industry's other primary activities involve the production of hatchery-reared pearl oysters and the seeding of pearls for grow out on pearl farm leases. Overall, the pearl oyster fishery is the second most valuable fishery in Western Australia, contributing about $60 million to the State's economy per year (Hart *et al.* 2014).

The area of interest can be fished by licence holders; however, the minimal collections in the Pilbara occur away from this area, with the closest fishing patch located near Onslow (Hart *et al.* 2016). Thus, impact of the Mardie Project on the current WAPOF is likely minimal. The **Annual Economic Value** of the WAPOF component of the fishery is difficult to quantify. However, the value of the Western Australian Pearl Oyster Industry as a whole was estimated a **$63.5 million** for 2018 (Gaughan & Santoro 2020). The **Stock Status** of Pearl Oysters in the POMF (Zone 1) is considered **Sustainable-Adequate** (Gaughan & Santoro 2020).

6.3.2. Extent of the fishery

The WAPOF stretches from Exmouth east to Kununarra and out to 200 nm. The fishery is split into 4 zones, Zones 1-3 and the Kimberly Development Zone (Fig 7). The Mardie Project Area is located within Zone 1.

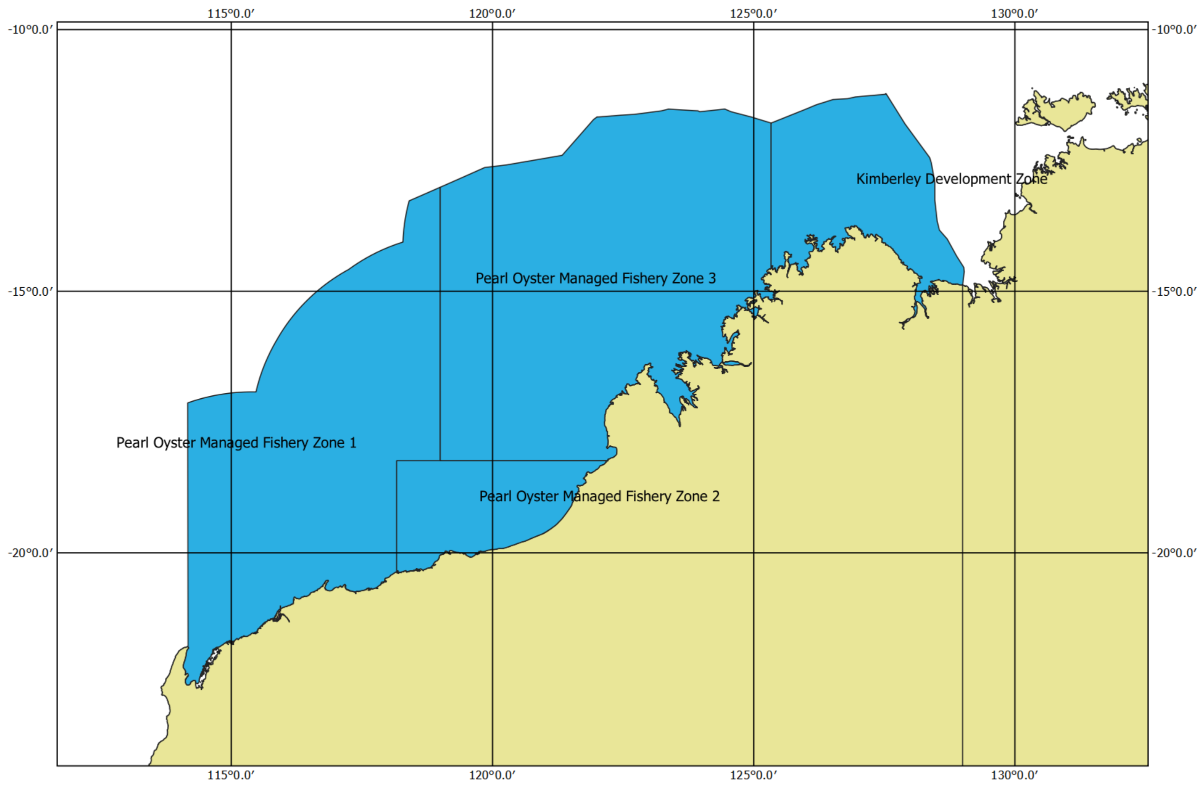

Fig 7: Spatial boundaries of the Western Australia Pearl Oyster Managed Fishery

6.3.3. Fishing methods

The WAPOF operates for several months per year, generally between March and July, with exact start and end dates variable depending on current quota and environmental conditions (e.g. cyclone activity). Oysters are collected by divers, who are towed behind large (approximately 35 m), often purpose-built vessels, with each pearling vessel having a total crew of between 10 – 12 people (Fletcher *et al.* 2006). As diving is frequently hazardous in fishing patches due to the strong currents in these areas, fishing is often further restricted to neap periods when currents are minimal (Fletcher *et al.* 2006).

Once fishing can commence, booms are extended outwards from each side of the vessel. Each boom supports a number of weighted lines that hang into the water to a depth of 1–2 m above the seabed. Generally, each boom supports 3 lines, allowing 6 divers on hookah to fish simultaneously. During fishing, the vessel drifts while in gear from one end of the fishing patch at a rate of about 1 knot while divers place all culture shell-quality oysters encountered into holding bags. Substantial effort is made to prevent excessive contact between fishing gear and the substrate as catch rates rely on good visibility. Divers generally make 8–10 dives per day, aiming to collect around 250 oysters in total (Fletcher *et al.* 2006).

Back on board, oysters are graded and cleaned, with those outside of the required size range returned to the water. Oysters are then placed into transport panels and taken to a nearby holding site where they remain attached to lines for 2–3 months prior to further transport to a farm lease. This long holding period allows oysters to recover from the stress of collection, which reduces losses due to factors such as bacterial infection.

6.3.4. Fishing effort

Fishing effort in Zone 1 is historically low (Fig 8), with no fishing at all between 2008 and 2014. This trend has continued recently with no catch recorded in either 2017 and 2018 and only 4,594 culture shells taken in 2016. In contrast, over 600,000 oysters were collected in Zones 2 and 3 in just 2018. The limited effort in Zone 1 is primarily due to economic reasons, with industry either deciding to use hatchery bred pearl oysters or obtain oysters from the Zone 2 fishery. The fishery is currently accredited to export under the EPBC Act for a ten year period, to be re-assessed in 2025, and was certified under the MSC certification process in 2017.

There has been no POMF effort recorded from the vicinity of the Mardie Project from 2010–2011 to 2018–2019.

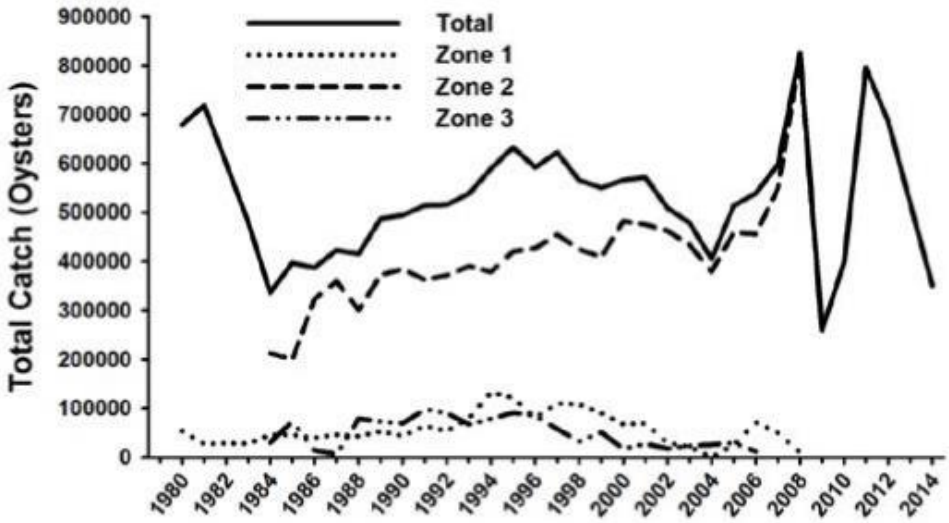

Fig 8. Total Pearl Oyster catch per management zone (1–3) between 1980-2014 showing the historically low catch rate in Zone 1 which overlaps with the Mardie Project (From Hart et al. 2016).

6.3.5. Management controls

The fishery is now managed under the Aquatic Resources Management Act 2016 (ARMA), which replaced the Pearling Act 1990 in 2019. Management is primarily through output controls, in the form a total allowable catch (TAC) divided into 572 individually transferable quota (ITQ) units allocated across Zones 1-3.

6.3.6. Ecology of *Target species*

The WAPOF targets the Silverlip Pearl Oyster, one of four species of *Pinctada* oysters found in Western Australian waters and the largest species pearl oyster in the world.

Fig 9. The Pearl Oyster, Pinctada maxima, are the target species of the Pearl Oyster Managed Fishery. Oyster in its natural soft-sediment habitat (L), and the interior mantle showing developing pearls (DOF 2016, Wikimedia Commons: CC BY 2.5)

6.3.7. Stock *structure & life history*

The Silverlip Pearl Oyster (Fig 9) is found through much of the central Indo-Pacific. In general, the Western Australian population is highly connected with some evidence for differentiation between Exmouth and northern populations (Benzie & Smith-Keune 2006). However, it is considered a single stock for management (Hart *et al.* 2016). The spawning season extends from spring to autumn, with the primary spawning period generally occurring between October-December. These oysters are hermaphroditic broadcast spawners producing up to 30 million eggs that are fertilized in the water column. Resulting larvae then spend up to 3 weeks in the plankton before settling to the substrate and metamorphosing into spat. Spat require a hard substrate to anchor on to, with those settling on to unsuitable habitat dying (Department of Fisheries, 2016). Oysters mature at around 3–4 years of age, first as males, at around 110 mm.

'Because they are broadcast spawners with a 3 week pelagic larval stage and high fecundity, Silverlip Pearl Oyster recruitment is unpredictable — good recruitment can appear in an area where there was previously poor recruitment and visa versa.

6.3.8. Habitat

Silverlip Pearl Oyster are found from subtidal depths down to depths in excess of 50 m and inhabit a variety of benthic habitats such as mud, sand, and gravel beds. Strong tidal currents are a common factor of important habitats.

6.3.9. Diet, trophic level and *ecosystem role*

Pearl oysters are suspension feeders, trapping suspended particulate organic matter. A range of predators feed on both juvenile and adult wild oysters, including benthic fishes, rays, octopus, and sea stars. As such, Pearl oysters play an important role in the marine food chain linking organic detritus to higher trophic levels.

6.3.10. Current risks and vulnerabilities

Silverlip Pearl Oysters in Western Australia have proven vulnerable to diseases and parasites. Infections caused by the *Haplosporidium* sp. Parasite have occurred on three occasions and while the extent of infections to date has been minimal, this parasite is considered a serious threat to the WA pearling industry (Bearham *et al.* 2008). Both bioeroding sponges and diseases such as oyster oedema disease (OED) have also caused considerable concern and lost revenue, however, these primary affect oysters once transferred to farm leases rather than wild stock (Hart *et al.* 2016).

Pearl oysters are vulnerable to changes in environmental conditions. No negative effects of climate change on Silverlip Pearl Oysters have been recorded; however, a recent risk assessment judged this species to be at medium-high risk (Caputi *et al.* 2015). The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Przeslawski *et al.* 2008; Bashevkin *et al.* 2020). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Przeslawski *et al.* 2008).

Weather events within the boundaries of the fishery, such as seasonal cyclone activity, can also negatively impact wild oyster beds.

The Western Australian stock of Silverlip Pearl Oyster is classified as sustainable with a biomass that is unlikely to be recruitment overfished (Hart *et al.* 2018).

6.3.11. Statement of potential risk to the WAPOF

Being sessile, Silverlip Pearl Oysters is the areas being dredged and within the zone of impact of the dredge spoils are likely to be significantly affected. Those directly in the path of the dredge would not likely survive the dredging process. Animals within the Dredge Material Placement Area (DMPA) could be smothered by the predicted change in seabed heights, with an increase in height of mostly more than 0.5 m (Baird, 2020). High sediment loads such as those caused by cyclonic condition are known to choke the filter mechanisms of Silverlip Pearl Oysters, leading to mortality during early juvenile stages (Hart *et al.* 2011). Its uncertain how sediment loads in the zones of impact reported by (Baird, 2020), but it is likely that there will be some mortality of juvenile Silverlip Pearl Oysters in the zones. In addition, within the DMPA, and likely to some extent in the zones of impact, hard habitat suitable to settlement will be covered with sediment.

However, the predicted size of the greatest zone of impact (the zone of medium impact or ZoMI) reported by (Baird, 2020) is only 36.7 km^2, the DMPA is 1 km^2 and the area to be dredged is about 0.65 km^2. These areas represent a very small fraction of the Silverlip Pearl Oysters distribution, and the Mardie Project is very unlikely to affect the stock as a whole.

Given the current lack of catch and effort in Zone 1 and the small overlap of ZoMI, DMPA and area to be dredged, the impact of the Mardie Project on the WAPOF is likely minimal. However, if the area that is currently fished suffers poor recruitment, and good recruitment is observed around the Mardie Project, the WAPOF could be affected.

6.4. The Western Australian Sea Cucumber Fishery (WASCF)

6.4.1. Fishery overview

Sea cucumbers, otherwise known as 'trepang' and 'bech-de-mer' are soft-bodied echinoderms closely related to sea stars and sea urchins. They are bottom-dwelling animals, found on or buried in soft substrates where they feed on detritus. In the North Coast Bioregion the main commercially harvested species, Sandfish *Holothuria scabra*) and Redfish (*Actinopyga echinites*), primarily occur in shallow low energy environments sheltered by fringing reefs or within bays.

In WA, commercial fishing for sea cucumbers goes back as far as the mid-1800s; however, the modern fishery has existed since 1995. Today, it is a small low-value fishery, with six licence holders allowed to operate under a Ministerial exemption allowing the collection of sea cucumber. The fishery is managed at the state level, following the WASCF harvest strategy, and is also subject to a variety of input controls.

The Mardie Project can be fished by licence holders; however, at present collections in the Pilbara occur away from this area, around the Montebello Islands, Barrow Island, and the Dampier Archipelago. Thus, any impact of the Mardie Project on the current WASCF is likely to be minimal. The **Annual Economic Value** of the WASCF was estimated at **$263,500** for 2018, prior to processing (Gaughan & Santoro 2020). The **Stock Status** of both Pilbara Sandfish and Redfish are considered **Sustainable-Adequate** (Gaughan & Santoro 2020)**.**

6.4.2. Extent of the fishery

The WASCF is permitted to operate throughout Western Australian waters to a distance of 3 nm (Fig 10); however, to date fishing has only occurred in the northern half of the state and for tropical species (Hart *et al.* 2018). Fishing is prohibited in marine parks, reserves, sanctuaries and some other specific areas. The closest closed areas to the Mardie Project are the Barrow Island Marine Park and Nickol Bay.

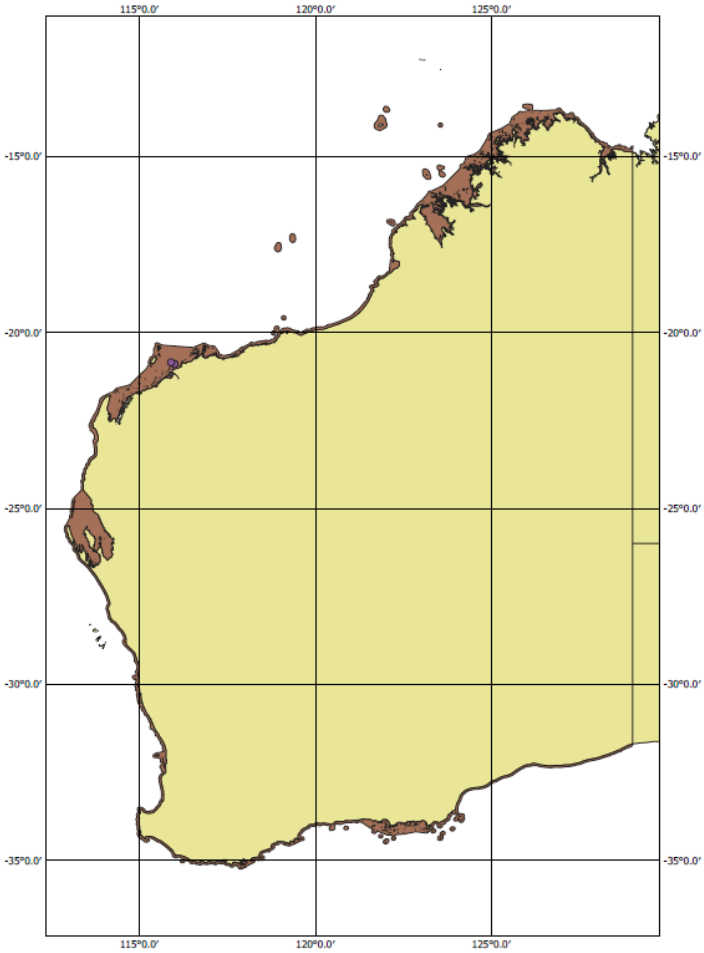

Fig 10. Spatial boundaries of the Western Australian Sea Cucumber Fishery

6.4.3. Fishing methods

Collection is by hand, with 95% of catch collected by diving and 5% by wading. Main vessels used are between 10–12 m (Hart *et al.* 2018). Diving-based collections are conducted on hookah while drifting at depths of less than 5m. Fishers generally work in teams of two, with one diving and one tending. Initial processing of the catch occurs on the main vessel, and involves gutting, boiling, drying before the catch is frozen in blocks. Secondary processing occurs in Melbourne followed by export to the Asian market (Hart *et al.* 2018).

6.4.4. Fishing effort

The WASCF as a whole currently operates a maximum of 6 vessels across both the Kimberly and Pilbara regions, with a total of 6 permits issued. However, only 1–2 vessels tend to operate in any given year. The fishery employed less than 10 people in total as of 2018 (Hart *et al.* 2018).

The Pilbara Sandfish and Redfish fisheries primarily target dense but localised populations found in the Montebello Islands, Barrow Island, and the Dampier Archipelago (Fig. 4). Thus, while the area of interest is within the managed area and may be subject to future effort, collections have not occurred in the immediate vicinity from 2010–2011 to 2018–2019.

6.4.5. Management controls

The WASCF is managed at the state level. Fishers in the WASCF operate under an exemption to Fisheries Notice No. 366 under Section 7.3.c. of the *Fish Resources Management Act* (FRMA).

The WASCF harvest strategy uses a *constant exploration approach*, where the catch varies in proportion to variation in stock abundance (Dept. of Primary Industries and Regional Development 2018a). Key considerations informing the WASCF harvest strategy are the geographical isolation of the fishery, the spatially discrete nature of stocks, and the vulnerability of discrete stocks to overexploitation. For the fishery as a whole, the principal performance indicators are spawning biomass indices. For both Pilbara Sandfish and Redfish, this is an estimate of annual biomass derived from a biomass dynamics model.

The WASCF is also subject to input controls including limits on entry, limits on the maximum number of divers, spatial closures, species restrictions and minimum legal sizes, and gear restrictions (Hart *et al.* 2018.).

6.4.6. Ecology of Target species

Fishers operating in the Pilbara region primarily target two species, Sandfish (*Holothuria scabra*) and Redfish (*Actinopyga echinites*), with these species accounting for 99% of catch across the entire fishery (Fig 11). There are six other species that can legally be retained by commercial fishers, Black Teatfish (*H. whitmaei*), White Teatfish (*H. fuscogilva*), Lollyfish (*H. atra*), Prickly Redfish (*Thelenota ananas*), Curryfish vastus (*Stichopus vastus*) and Curryfish hermanni (*S. hermanni*). For the purposes of this assessment only Sandfish and Redfish will be discussed.

Fig 11. Target species of the Western Australia Sea Cucumber Fishery; the Sandfish (L) and Redfish (R) (Wikimedia commons: CC BY-SA 2.0/3.0).

6.4.7. Stock structure & life history

Both Sandfish and Redfish have similar distributions, found throughout the tropical Indo-Pacific extending to East Africa and into the Central Pacific (Bell *et al.* 2008). The Pilbara and Kimberly stocks of Sandfish are considered separate for management, while Redfish are only harvested in the Pilbara and so are considered a single stock. Both species are gonochoric broadcast spawners. Sandfish spawn year-round but appear to have a main spawning period between September and November, with spawning triggered by fluctuations in environmental conditions.

While the spawning frequency of Pilbara Redfish is poorly known, populations at similar latitudes primarily spawn between December-January and again in May (Kohler *et al.* 2009). Larvae spend a period of time in the plankton (about 2 weeks for Redfish) before settling to shallow benthic habitats at about 1 mm in length. Sandfish settle to seagrass and mangroves while Redfish settle to limestone and coralline material, where they remain until they reach 10 mm in length. Sexual maturity for both species takes around two years, by which time they have reached 120–150 mm in length.

6.4.8. Habitat

Both species are found on soft sediment, sand and rubble habitats in low energy environments such as behind fringing reefs or within protected bays. Both species are common in shallow areas but can occur down to around 40 m depth.

6.4.9. Diet, trophic level and e*cosystem role*

Both species are deposit and detritus feeders, ingesting sediment and extracting organic material from it. Relatively few predators consume adult sea cucumbers due to the toxins they contain; however, the larvae and juveniles form a prey item for other planktonic organisms as well as demersal fishes. Sea cucumbers play an important ecosystem role by oxygenating sediments and converting detritus to nitrogenous waste that can be taken up by sea grass and algae.

6.4.10. Current risks *and vulnerabilities*

Sea cucumber populations are inherently vulnerable to overexploitation given their ease of capture, inability to avoid fished areas, and because their reproductive success is density dependent. Where local populations have been overexploited elsewhere due to a lack of management, they have proven slow to recover (Skewes *et al.* 2000). However, the comprehensive management controls in place in the WASCF and limited fishing effort means the level of risk is minimal for Pilbara stocks.

Sea cucumbers are vulnerable to changes in environmental conditions. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Przeslawski *et al.* 2008; Bashevkin *et al.* 2020). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Przeslawski *et al.* 2008). Habitat loss, in particular declines in available settlement habitat (e.g. mangroves and seagrass) could pose a risk to sea cucumber populations.

6.4.11. Statement of potential risk to the WASCF

Sea cucumbers are slow moving animals, without the ability to move out of the way of dredging operations or deposited dredge spoils. It is likely that any sea cucumbers in the direct path of the dredge, or within the DMPA would not survive. There is some chance that increase suspended sediment caused by the dredging operations may have some negative affect on nearby habitats such as seagrass, which could decrease the amount of suitable habitat for settlement.

As for Silverlip Pearl Oysters, the predicted size of the ZoMI, the DMPA and the area to be dredged represent a very small fraction of the Sandfish and Redfish distribution, and the Mardie Project is very unlikely to affect the stocks as a whole. Further, most of the effort in this fishery in the Pilbara is around the offshore Montebello Islands, Barrow Island, and the Dampier Archipelago. No fishing effort was reported in the vicinity of the Mardie Project from 2010–2011 to 2018–2019, and so there is unlikely to be any impact of the Mardie Project on the WAPOF.

6.5. The Pilbara Crab Managed Fishery (PCMF)

6.5.1. Fishery overview

Blue Swimmer Crabs (*Portunus armatus*) are found in estuarine and coastal water less than 50 m depth along the entire Western Australian coastline. It is the primary target species of the Pilbara Crab Managed Fishery, which extends from 120° E to 23° 34’ S, but currently operates in offshore waters from Onslow to Port Hedland (Fig 12). In addition to Blue Swimmer Crabs, Coral Crab (*Charybdis ferriata*), Ridged Swimming Crab (*C. natator*), and Three Spot Sand Crab (*P. sanguinolentus*) can also be retained as by-product. The fishery was first established in 2001 as the Pilbara Developing Crab Fishery (PDCF) and transitioned to the managed fishery in 2018. There is a single licence holder operating two vessels and employing 4 people.

The Mardie Project is within the open fishery, although effort in this area appears to be minimal. The **Annual Economic Value** of the PCMF was estimated at ~**$200,000** for 2018 (Gaughan & Santoro 2020). The **Stock Status** of both Blue Swimmer Crabs within the PCMF are considered **Sustainable-Adequate** (Gaughan & Santoro 2020)**.**

6.5.2. Extent of the fishery

The total area of the PCMF extends from 120° E to 23° 34’ S; however, large areas of the potential fishery are closed and the broad area open to fishing extends from 120° E to 115° 6.5’ E (effectively Onslow to Point Headland). However, additional closed areas exist in inshore waters adjacent to Onslow, Karratha, the Dampier Archipelago, and Port Headland. The waters of the Exmouth Gulf also comprise the separate Exmouth Gulf Developing Crab Fishery (EGDCF).

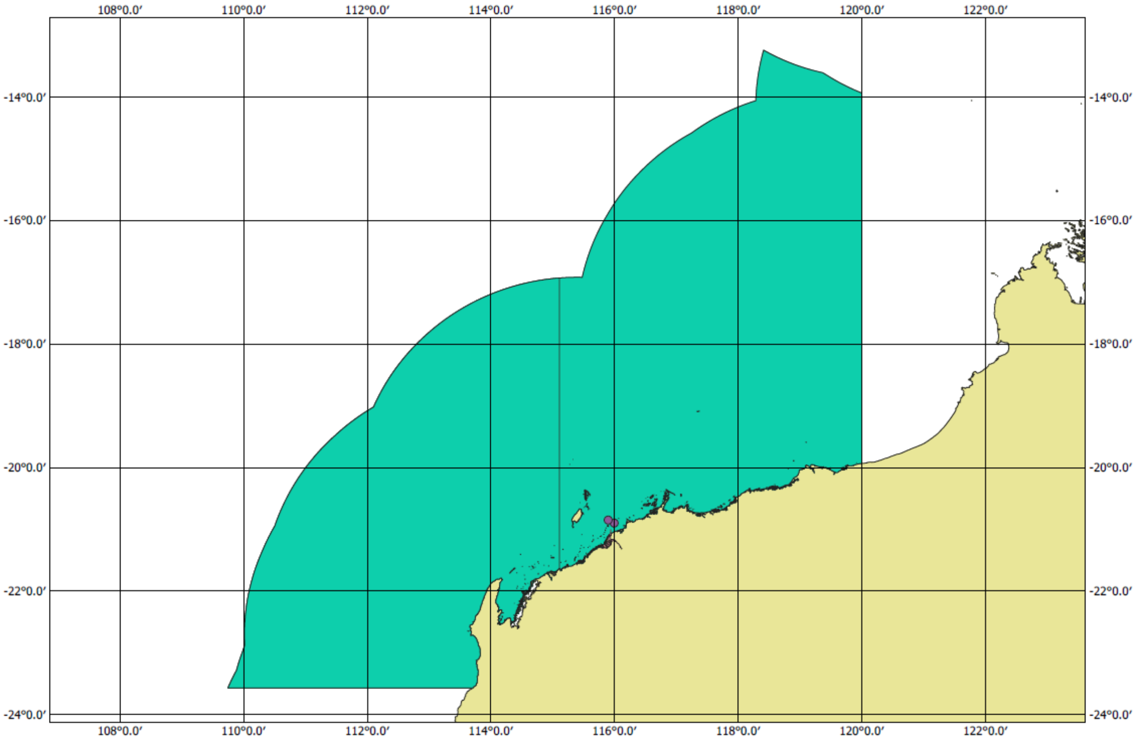

Fig 12. Spatial boundaries of the Pilbara Crab Managed Fishery

6.5.3. Fishing methods

Fishing in the PCMF is done using purpose-build hourglass traps, with a total of 600 traps allowed in the fishery as a whole. Traps are set on lines, with a maximum of 20 traps per line.

6.5.4. Fishing effort

There is a single licence holder in the PCMF, operating one 10 m vessel and one 17 m vessel. This licence holder has the capacity to deploy 600 traps across the two vessels. There is an annual season closure between 15 August and 15 November (inclusive) which protects berried and mated pre-spawning female crabs. Annual total catches have been variable (Fig 13) with catches of 30.2 t and 19.3 t from 30,220 and 19,327 trap lifts were reported for 2018 and 2019, respectively. No PCMF fishing effort was recorded from within the vicinity of the Mardie Project from 2010–2011 to 2018–2019.

6.5.5. Management controls

While a large area is open to fishing, the majority of effort if focussed on open waters within Nickol Bay. Historical fishing data suggests commercially viable stocks of Blue Swimmer Crabs exist along much of the coastline within the fishery; however, because many of these areas are located a substantial distance from port and the fact that crabs must reach market 1–2 days following being caught, harvesting in these areas is not economically viable.

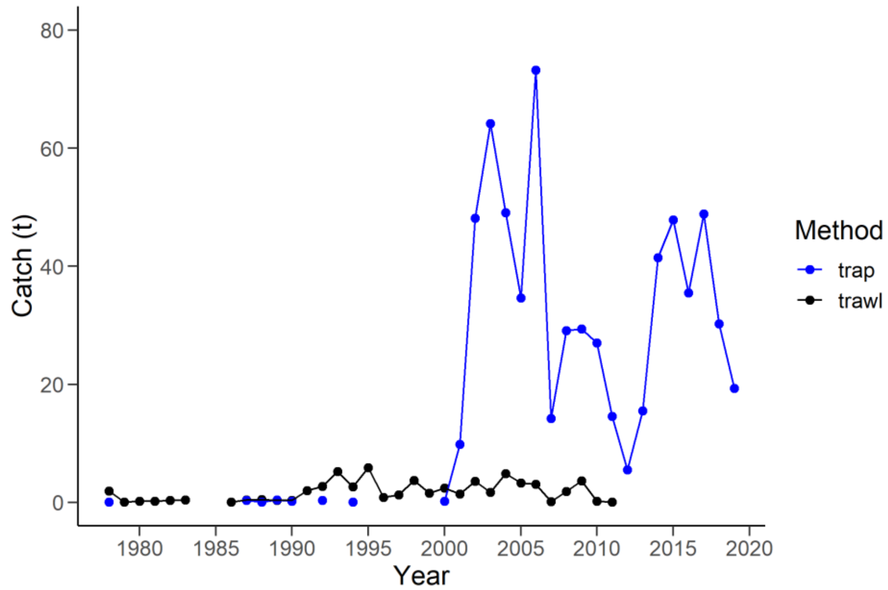

Fig 13. Annual commercial blue swimmer crab catch (tonnes) in the Pilbara region of Western Australia by trap and trawl fishing from 1978 to 2019 (from Johnston et al. ***2020).***

6.5.6. Ecology of t*arget species*

Fishers operating in the Pilbara region primarily target Blue Swimmer Crabs (*Portunus armatus)* and this species accounts for almost the entire catch. Several other species are occasionally caught and can be retained as byproduct, including Coral Crab (*Charybdis ferriata*), Ridged Swimming Crab (*C. natator*), and Three Spot Sand Crab (*P. sanguinolentus*) (Fig 14). For the purposes of this assessment only Blue Swimmer Crabs will be discussed.

Fig 14. Blue Swimmer Crabs (L) are the target species of the Pilbara Crab Managed Fishery with some additional species, such as Coral CrI(R) are also retained (Wikimedia commons: CC BY-SA 3.0).

6.5.7. Stock structure & life history

Blue Swimmer Crabs are widely distributed throughout the Indo-Pacific from east Africa to French Polynesia, and occur along the entire Western Australian coastline. In Western Australia, stocks of Blue Swimmer Crab become more genetically distinct with increasing spatial distance. Thus, Blue Swimmer Crab comprise multiple management units, which correspond to the management areas of the commercial fisheries. It is likely that crabs from fished areas within the Pilbara are highly connected and genetically similar to due to the dispersal ability of eggs and larvae and relatively small distances between areas (Johnston *et al.* 2020).

The reproductive cycle of Western Australian Blue Swimmer Crabs is highly influenced by water temperature (de Lestang *et al.* 2010). Peak spawning occurs in the winter months, with crabs often moving into deeper waters to do so. After spawning, eggs remain in the plankton for around 2 weeks before hatching. The resulting larval phase consists of 5 distinct stages that lasts between 3–6 weeks depending on temperature. At this time, larvae move inshore and settle into shallow nursery habitats. Juvenile crabs reach maturity at around 100 mm, and reach legal size in around 10–14 months. Thus, they have a chance to spawn before being available to the fishery.

6.5.8. Habitat

Blue Swimmer Crabs inhabit a wide range of inshore and continental shelf ecosystems, from the intertidal zone to at least 50 m in depth (Kangas 2000). However, they are most abundant in shallow inshore sandy, muddy or seagrass habitats and estuaries. Crabs will migrate between areas and depths in response to changes in temperature and salinity.

6.5.9. Diet, trophic level and ecosystem role

Blue Swimmer Crabs are opportunistic predators, feeding on a range of sessile invertebrates, bivalve molluscs, crustaceans, polychaete worms and brittle stars. They are subject to predation throughout their lifespan; eggs and larvae provide food for larval fishes in the plankton, juveniles provide food for smaller benthic fishes and invertebrates, while adults are preyed on by larger rays and sharks (Johnston *et al.* 2020). Thus, Blue Swimmer Crabs play an important link in the coastal food chain.

6.5.10. Current risks and vulnerabilities

Blue Swimmer Crabs are vulnerable to the parasitic barnacle, *Sacculina granifera*, with this parasite regularly found in catches within the PCMF (Bellchambers *et al.* 2005). The parasite occupies the space normally occupied by developing eggs in females and causes degeneration of the sex organs in both males and females. However, some infected females are still able to produce egg clutches. Infestation rates in the PCMF are about 3%, and so this parasite is not considered to pose a major threat to the stock. It does not affect the marketability of infected crabs once physically removed (Johnston *et al.* 2020).

Blue Swimmer Crabs are highly fecund and have short life spans and thus vulnerability to fishing pressure is considered low (Gaughan & Santoro 2020).

As with other coastal marine species, Blue Swimmer Crabs are vulnerable to a range of ecological disturbance risks. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Bashevkin *et al.* 2020). Recruitment is significantly influenced by variations in environmental conditions (de Lestang *et al.*, 2010), catches can fluctuate between years based on these factors (Johnston *et al.* 2020). Human development in coastal areas may also have an effect on both larval and juvenile/adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Przeslawski *et al.* 2008).

The stock of Blue Swimmer Crabs fished by the PCMF is considered sustainable, with the biomass unlikely to be depleted and with current levels of fishing mortality that are unlikely to cause them to become recruitment impaired.

6.5.11. Statement of potential risk to the PCMF

Blue Swimmer Crabs are motile with some ability to avoid threats potentially including the ability to move out of the way of dredging operations or deposited dredge spoils. They are a widely distributed species, and given the predicted size of the ZoMI, the DMPA and the area to be dredged represent a very small fraction of their distribution, and the Mardie Project is very unlikely to affect the stock as a whole.

Given nearly all fishing effort occurs in Nickol Bay, the lack of fishing effort reported from the area and that there are limitations in where the fishery can operate due to a lack of infrastructure, the Mardie Project is very unlikely to affect the PCMF.

6.6. The Mackerel Managed Fishery (MMF)

6.6.1. Fishery overview

The Western Australia large pelagic finfish resource includes a number of tropical and temperate species distributed across Western Australia. In the Northeast Bioregion, commercial access to this resource is primarily via the Mackerel Managed Fishery (MMF), with this fishery also extending into the Gascoyne Bioregion as far south as Augusta. The primary target species for the MMF is Spanish Mackerel (*Scomberomorus commerson*), with this and the Grey Mackerel (*S. semifasciatus*) making up almost the entire catch and acting as the indicator species for the fishery. Established in 2006, the MMF accounts for around 80% of the large pelagic finfish harvest in WA, and has an annual value of $3-5 million (Lewis 2020).

The **Annual Economic Value** of the state-wide Spanish Mackerel catch was estimated at **$2 million** for 2018, while for Grey Mackerel and other species this is estimated at **$500,000** for 2018 (Gaughan & Santoro 2020). The **Stock Status** of both Spanish and Grey Mackerel in the MMF are considered **Sustainable-Adequate** (Gaughan & Santoro 2020)**.**

6.6.2. Extent of the fishery

The MMF extends from the WA/NT border to Augusta and is managed as three separate areas (Fig 15); Area 1 covers from the NT border to the southern end of Eighty-Mile Beach (121° E), Area 2 from this point to Cape Range (114° E), and Area 3 south to Augusta (about 34° S). Thus, the area of interest is within Area 2. Catches are reported separately for each area.

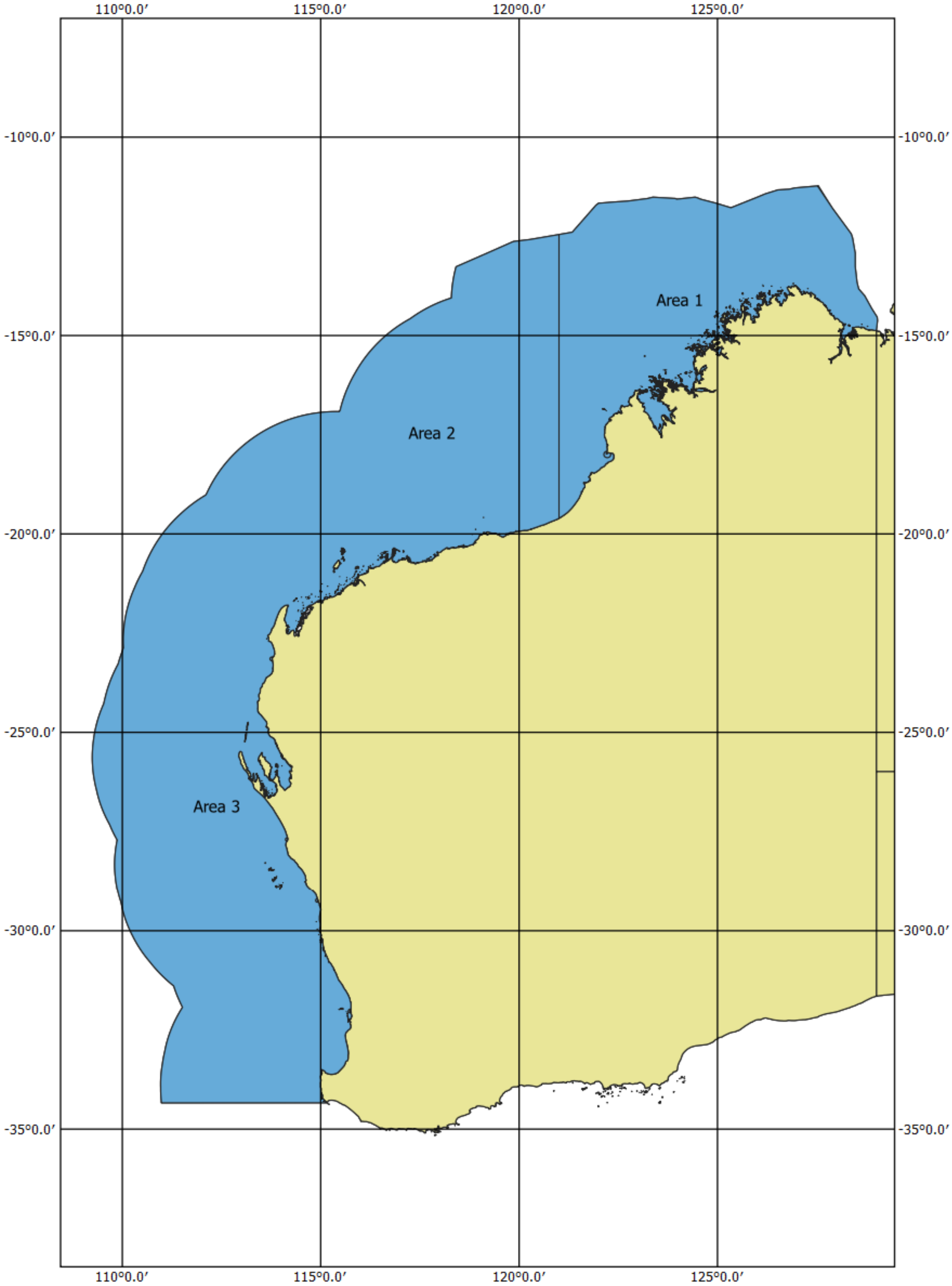

Fig 15. Spatial boundaries of the Mackerel Managed Fishery, indicating the three managed areas.

6.6.3. Fishing methods

The primary fishing method in the MMF is surface and midwater trolling. Jigging is also used to catch Grey Mackerel, but this is mainly in the Gascoyne and West Coast sectors. A range of baits, lures, and jigs will be trolled. However, bait (garfish and mullet) are generally the most efficient and so are used on about 70% of lines. Line lengths are usually between 5–30 m, with a 3–7 knot trolling speed depending on conditions (Lewis 2020).

Fishing methods do differ slightly between the three areas. In the Pilbara (Area 2), the vessels used are between 9–15 m in length with 1–2 crew. 6–7 lines are trolled, consisting of 180 kg mono line and wire trace. The use of dories (smaller vessels) is only allowed by licence holders that also fish in Area 1 and who have permission to do so there.

6.6.4. Fishing effort

There are currently 65 permits in the MMF overall with 21 licences in Area 2 (Pilbara), and 23 and 21 licences in Areas 1 and 3 respectively. Quota allocations are consolidated onto 16 boats operating across the fishery, with 3 operating in Area 2 (Pilbara), and 4 and 9 in Areas 1 and 3 respectively (Lewis 2020). Spanish Mackerel accounts for about 95% of the catch. The total commercial catch of Spanish Mackerel by the MMF has ranged between 270–330 t between 2006–2018, with the 2018 catch the lowest on record at 213 t. Grey Mackerel is the second most important species in the fishery, accounting for less than 5% of the catch. The commercial catch of Grey Mackerel has consistently been below 20 t since 2006, with a total catch of 14 t in 2018 (Lewis 2020).

Fishing effort has only been recorded from the area of interest during one month from 2010–2011 to 2018–2019. During November 2018, less than three vessels caught Spanish Mackerel, however the catch weight and value were not provided to maintain confidentiality.

6.6.5. Management controls

The MMF is managed at the state level. It operates under an Individual Transferrable Quota system which includes setting Total Allowable Commercial Catches for each of the three Areas, the allocation of quota in the form of units, and establishing minimum quota holding requirements.

Management is also based on a number of input controls including limits on the number of licences in the fishery and the types of gear allowed. Vessels in the MMF are not permitted to fish within closed waters. This includes port areas, Commonwealth marine reserves, marine protected areas and other marine parks closed to commercial fishing. The Department of Fisheries Vessel Monitoring System (VMS) monitors all vessel activity.

6.6.6. Ecology of Target species

The primary target of the MMF is Spanish Mackerel (*Scomberomorus commerson*), the largest, and most abundant of the *Scomberomorus* species found in Western Australia. This and the Grey Mackerel (*S. semifasciatus*) comprise the majority of the catch. Both are members of the family Scombridae (mackerels, tunas and bonitos).

Fig 16. Spanish Mackerel are the target species of the Mackerel Managed Fishery in the Pibara (Wikimedia commons: public domain).

6.6.7. Stock structure & life history

Both Spanish and Grey Mackerel are pelagic species. Spanish Mackerel are found throughout the Indo-West Pacific and occur across northern Australia. Grey Mackerel occur north of Perth to New Guinea and Indonesia. Three genetic stocks of Spanish Mackerel have been identified in Australia; an east coast stock, a Torres Strait stock, and a Northern Australia stock which covers the Gulf of Carpentaria to Western Australia. Thus, the Western Australian population is considered one stock for management. While at least 5 biological stocks of Grey Mackerel exist in Australia it is managed as a single stock in Western Australia (Roelofs *et al.* 2014).

Both Spanish and Grey Mackerel are gonochoristic broadcast spawners. For Spanish Mackerel, 50% of females and 95% of males attain maturity by 900 mm total length, which is the minimum legal size (Mackie *et al.* 2003, 2005). Fish aged 2–4-year-old form the basis for the fishery, accounting for 70% of the catch; however, Western Australian fish can reach 22 years and a maximum size of 180 cm for males and 140 cm for females (Lewis 2020). Life history characteristics of Western Australian Grey Mackerel are less known, although fish reach spawning size in 2–3 years. They can reach a maximum age of 14 years and maximum size of 120 cm (Lewis 2020).

6.6.8. Habitat

Spanish Mackerel are found in offshore surface waters, with evidence suggesting those in northern waters move over an area of around 100 km. Critical habitat includes oceanic features such as offshore and inshore reefs and islands which attract prey. Grey mackerel are generally found in turbid water between 3–30 m depth, often near rocky reefs and sandy mud habitats where they form large schools during the fishing season. Grey mackerel larvae and juveniles are found in coastal bays and estuarine environments (Lewis 2020).

6.6.9. Diet, trophic level and ecosystem role

Spanish Mackerel feed on a range of small prey species such as fish, cephalopods and other invertebrates that aggregate in the waters around offshore reefs and islands. Grey Mackerel on the other hand feed exclusively on the small bait fishes, such as anchovies, sardines, and herrings that are found in the turbid habitats they occupy (Cameron & Begg 2002). In turn, both Spanish and Grey Mackerel provide prey for larger species such as marlin, sharks and dolphins. As such, these mackerels play an important role as mesopredators within coastal habitats.

6.6.10. Current risks and vulnerabilities

Mackerel are vulnerable to parasites, with adults carrying hundreds of parasitic organisms such as copepods. However, these are harmless to humans. Both Spanish and Grey Mackerel are considered low to moderately vulnerable to fishing. Both are fast growing, rapidly reach spawning size, occur over large areas and have prolonged spawning seasons. This, along with the limited fishing effort in the MMF suggest they are at low risk of overexploitation.

Fishes at tropical latitudes are, in general, vulnerable to a range of ecological disturbance risks associated with human activities. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Munday *et al.* 2008). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Wenger *et al.* 2011; Besson *et al.* 2020).

The Western Australian stocks of both Spanish and Grey Mackerel are considered sustainable with a biomass that is unlikely to be depleted, recruitment that is unlikely to be impaired and a current level of fishing mortality that is unlikely to cause the stock to become recruitment impaired (Langstreth 2018, Helmke2018).

6.6.11. Statement of potential risk to the *MMF*

Spanish and Grey Mackerel are highly motile and would likely avoid dredging operations or deposited dredge spoils. They are both widely distributed species, and the Mardie Project is very unlikely to affect either stock as a whole. They are both widely distributed species, and the Mardie Project is very unlikely to affect either stock as a whole. Given the lack of fishing effort reported in the vicinity of the Mardie Project, it is unlikely that it will impact the MMF.

6.7. The Marine Aquarium Fish Managed Fishery (MAFMF)

6.7.1. Fishery overview

The State-managed Marine Aquarium Fish Managed Fishery (MAFMF) operates in all Western Australian waters, but is most active south of Broome. It is a species rich fishery, which potentially includes over 950 species of fishes collected for the aquarium trade. In addition to fishes, operators in the MAFMF are also permitted to collect numerous other organisms for this trade including corals, live rock, algae, seagrass, and various invertebrates.

The area of interest is within the MAFMF with collections made in this area. The **Annual Economic Value** of the MAFMF (when combined with the HCF) was estimated at **$1–5 million** for 2018 (Gaughan & Santoro 2020). The **Stock Status** of landed species within the MAFMF are considered **Sustainable-Adequate** (Gaughan & Santoro 2020)**.**

6.7.2. Extent of the fishery

The MAFMF extends across the entire Western Australian coastline; however, it is most active from Broome southwards with most effort around the Capes region, Perth, Geraldton, Exmouth, Dampier and Broome (Fig 17).

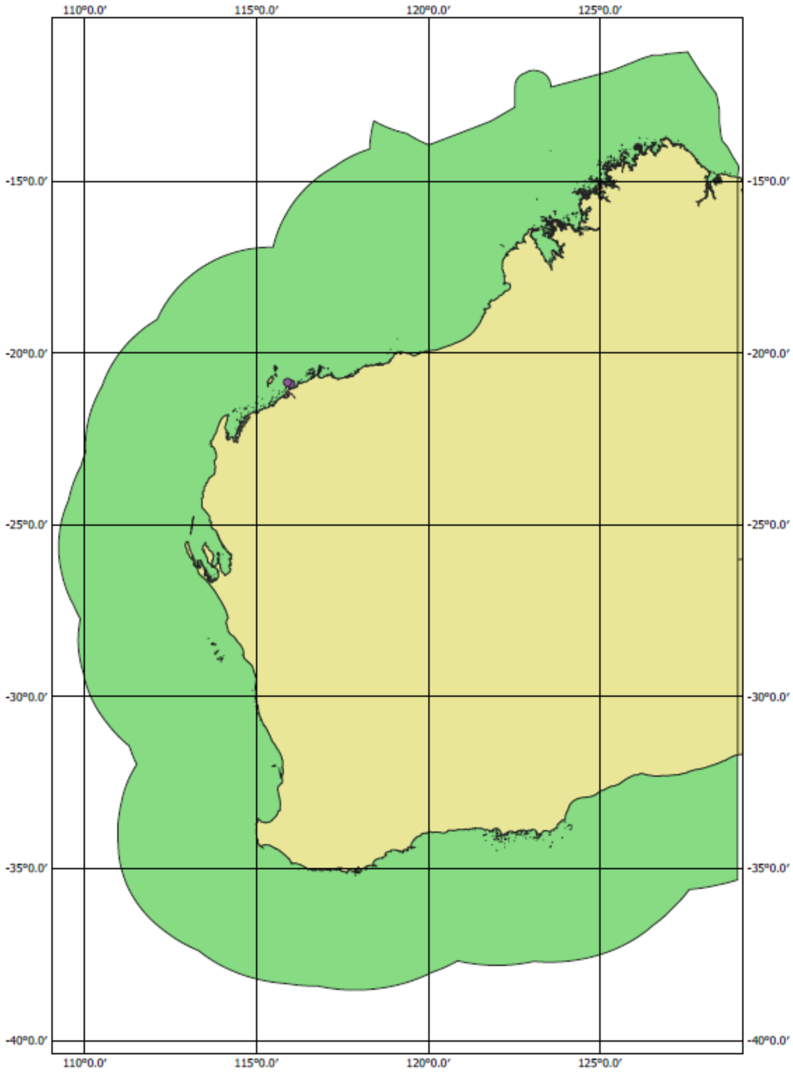

Fig 17. Spatial boundaries of the Marine Aquarium Managed Fishery.

6.7.3. Fishing methods

The fishery is primarily dive based, with collections allowed using hand lines, hand held nets, and hand operated tools only. Thus, commercial divers work on either SCUBA or hookah during collections, placing fishes in buckets that are then slowly brought to the surface to allow gradual decompression. Each licence allows for one primary vessel and up to two tenders, and one nominated operator and three collectors at any time. As the value of the catch is dependent on the health and survival of the collected species, all animals are handled with utmost care during collection and transport.

6.7.4. Fishing effort

The MAFMF is a low-effort, high value fishery which operates year round to supply the domestic and international aquarium industry (Dept. of Primary Industries and Regional Development 2018b). There are currently 12 licences in the fishery, all of which were active in 2018. Total catch in 2018 was 156,188 fishes, 32 t of coral, live rock, and living sand, and 176 l of marine plants. Fish catches consisted of over 280 species, while over 100 invertebrate taxa were collected (e.g. gastropods, crabs, anemones and corallimorphs) (Gaughan & Santoro 2020).

From 2010–2011 to 2018–2019, effort in the vicinity of the Mardie Project was only recorded during August 2010 while diving. A total of 23 different species were recorded including hard and soft corals, anemonefish, crabs, carpetsharks, gobies, algae, echinoderms, scorpianfish, coralfish, catfish, bannerfish and anglefish. Catch weight/number and value were not provided to maintain confidentiality.

6.7.5. Management controls

Management of the MAFMF is somewhat complicated by the vast number of species and taxa it encompasses, and the recognised conservation importance of various species involved. Under the Marine Aquarium Fish Managed Fishery Management Plan 2018, species with a high conservation value such as CITES listed species and 'live rock' are managed using output controls in the form of individual transferrable quota.

Remaining species are instead managed using input controls such as limits on entry, gear restrictions, and restrictions on the number of vessels and collectors allowed. In addition, the current harvest strategy for the Marine Aquarium Fish Resource of Western Australia (2018 – 2022) defines threshold Levels for a range of species including for sensitive taxa (Dept. of Primary Industries and Regional Development 2018b). In 2018, no threshold levels were exceeded.

6.7.6. Ecology of Target species

The MAFMF targets a wide range of fishes, hard and soft corals, crustaceans, molluscs, echinoderms, other invertebrates, plants and natural materials which supply the domestic and international aquarium live-stock trade. For this section these will be referred to in the following taxonomic groups; fishes, crustaceans (crabs, shrimps etc.), anthozoans (hard and soft corals, anemones etc.), echinoderms (sea stars, urchins etc.), molluscs (sea snails, clams, nudibranchs etc.), plants (sea weeds and sea grass), other invertebrates (sea squirts, worms etc.), and live aqua-scaping materials (live rock and live sand).

Fig 18. The Marine Aquarium Fish Managed Fishery targets a wide range of fish and invertebrates. Two of the most frequently collected species include the Scribbled Angelfish (L) and Hammer Coral (R) (Wikimedia Commons: CC BY 3.0).

6.7.7. Stock structure & life history

The targets of the MAFMF are taxonomically and ecologically diverse, ranging from fishes to live sand (sand containing the natural microbial community). Thus, the species within the fishery encapsulate a wide range of reproductive strategies and life cycles. **However, species within the MAFMF are all considered to comprise a single stock for management**.

In the tropics, most marine fishes, as well as many cnidarians, crustaceans, echinoderms, molluscs, and other invertebrates have a bipartite lifecycle consisting of an adult reproductive stage and a pelagic larval stage that facilitates dispersal (D'Aloia *et al.* 2015). Most of the fishes targeted are either gonochoristic (both sexes) or sequential hermaphrodites. Fertilisation is generally external, with males and females either releasing their gametes into the water column at the same time (broadcast spawning) which allows eggs to be fertilised, or females laying eggs onto the substrate which are then fertilised by the male (Johannes 1978). Once the free-floating or benthic eggs hatch, the resulting larvae spend a period of time in the plankton. The length of this larval stage differs between species and can vary from hours to months (Green 2014). At the end of this planktonic stage, larvae undergo metamorphosis and settle to the substrate as juveniles.

Most crustaceans, echinoderms, anthozoans, and molluscs are also gonochoristic, and some, such as corals, can also reproduce asexually via fragmentation. Similarly, most are broadcast spawners; however, some female crustaceans and echinoderms will carry eggs (i.e. berried lobsters and crabs). As in fish, these groups generally have a larval stage that facilitates dispersal; however, for many invertebrates such as crustaceans and echinoderms, the planktonic period consists of several stages of metamorphosis prior to settlement as juveniles (McEdward 1995). Please see section 5.8.6. for details of mollusc life history.

6.7.8. Habitat

While a wide range of species are collected, all with unique habitat requirements, the majority of tropical fishes and invertebrates are collected from shallow coral reefs and nearby areas that can be easily accessed by divers. Within these environments a wide range of habitats are occupied by species within the fishery. The small fishes that are commonly targeted include species which school above the reef, such as damselfish, small blennies and gobies which live in close association with the substrate, and more mobile, roaming species such as wrasses and angelfish (Gaughan & Santoro 2020). Some have highly specialised habitats, such as the clownfish that associated with sea anemones. The echinoderms and crustaceans, as well as many of the molluscs and other invertebrates targeted by the fishery are benthic-associated mobile species and occur on both soft substrates and on the reef itself.

The anthozoans targeted by the fishery (i.e. hard and soft corals, anemones, corallimorphs, and sea pens), as well as molluscs such as clams, and other invertebrates such as sea squirts are all sessile species, that is they remain in one place following larval settlement. For this reason, the range of environmental conditions these species can tolerate are often quite narrow and survival is dependent on these conditions being stable throughout the animal's life. For instance, hard corals and clams have a symbiotic relationship with photosynthetic algae in their cells (zooxanthellae) which provide food via photosynthesis (Rowan & Powers 1991). For these animals, the level of ambient light is important which restricts the depth range in which these species can live (Roth 2014).

6.7.9. Diet, trophic level and ecosystem role

The majority of fishes collected are relatively small, colourful species such as blennies, gobies and glassfish which feed on small benthic invertebrates living on the substrate, or damselfish which feed on plankton up in the water column. Benthic-dwelling mobile crustaceans, echinoderms and molluscs feed on a similarly wide range of items, as well as organic detritus. These animals in turn provide food for a range of larger predators and so represent an important component of the marine food web (Glynn 2004). In addition, some popular aquarium species, such as cleaner wrasse and sea urchins, play important functional roles which can help increase biodiversity and the resilience of these ecosystems (Grutter *et al.* 2003; Young & Bellwood 2014).

Sessile animals either feed on captured detritus and organic material, or rely on nutrients produced by their zooxanthellae (hard corals and giant clams). These sessile species provide food for various fishes and other predators, but more importantly the act as 'ecosystem engineers', creating habitat for other animals and increasing the biodiversity of the overall ecosystem (Wild 2011). Marine plants, such as algae and seagrass provides food for herbivorous fishes, as well as larger organisms such as turtles and dugong. They also create important habitats in of themselves, with seaweed- and seagrass-beds critical for juvenile prawns and fishes (Jackson *et al.* 2001).

6.7.10. Current risks and vul*nerabilities*

Effort within the fishery is relatively constant year to year and very low relative to the widespread distribution of the numerous species targeted. No other fisheries collect these species and so there is limited potential for any impact on breeding stocks. Restrictions on where fishes and corals can be collected further limits any impact.

Mobile fishes, crustaceans, echinoderms and other species are vulnerable to a range of ecological disturbance risks. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Munday *et al.* 2008; Bashevkin *et al.* 2020). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Wenger *et al.* 2011; Besson *et al.* 2020).

As they have a limited capacity to move and rely on environmental stability for survival, sessile animals in the fishery are at particular risk from impacts that change local environmental conditions. A key risk is the effects of climate change such as increased temperature which can cause corals, giant clams and other zooxanthellae-baring animals to bleach and die (Hughes *et al.* 2018), and more frequent and severe weather events which can change damage the underlying habitat and reduce structural complexity (Graham 2014). These sessile animals are also at risk from the effects of human development in coastal environments, such as dredging which can reduce light levels below what is required for photosynthesis or even smother the animal directly, or cause changes to salinity or nutrient levels that push these parameters beyond those required by these species (Jones *et al.* 2019).

6.7.11. Statement of potential risk to the MA*FMF*

Species caught by the MAFMF and the life histories of those species are very diverse, and are there for at different levels of risk from the Mardie Project. Sessile species are much more at risk to the dredging operation and through being smothered by dredge spoils. Zoxanthellae-baring animals and marine plants are susceptible to shading effects of increased suspended solids, reducing productivity, fitness and potentially survival, while filter-feeders could suffer choking if their filter mechanisms leading to mortality during early juvenile stages.

Because the MAFMF extends around the entire coast of Western Australia, it overlaps with relatively large proportions of some of the main target species from the Pilbara, despite those species being distributed across northern Australia. For example, the fishery overlaps with 33% and 34% of the Australian distributions of Hammer Hard Coral (*Euphyllia ancora*) and Whisker Hard Coral (*Duncanopsammia axifuga*), and 19%, 46% and 37% of the Australian distributions of Trochus (*Trochidae, Margaritidae, Solariellidae, Tegulida*), Margined Coaralfish (*Chelmon marginalis*) and Scribbled Angelfish (*Chaetodontoplus duboulayi*) respectively.

Given the lack of fishing effort reported in the vicinity of the Mardie Project, it is unlikely that it will impact the *MAFMF*.

6.8. The Specimen Shell Managed Fishery (SSMF)

6.8.1. Fishery overview

The shells of many of Western Australia's endemic marine molluscs are highly attractive leading to consumer demand for these shells as curios and specimens. Subsequently, the Specimen Shell Managed Fishery (SSMF) is based on the collection of individual shells for the purposes of display, collection, cataloguing, classification and sale. Around 200 species are collected each year. The fishery is managed through a variety of input controls including limited entry, gear restrictions and permanent closed areas.

The area of interest is within the SSMF with collections made in this area. The **Annual Economic Value** of the SSMF is currently **Not Assessed** (Gaughan & Santoro 2020)**.** The **stock status** of landed species within the SSMF are considered **Sustainable-Adequate** (Gaughan & Santoro 2020)**.**

6.8.2. Extent of fishery

The SSMF extends across the entire Western Australian coastline; however, effort is primarily near population centres (Fig 19).

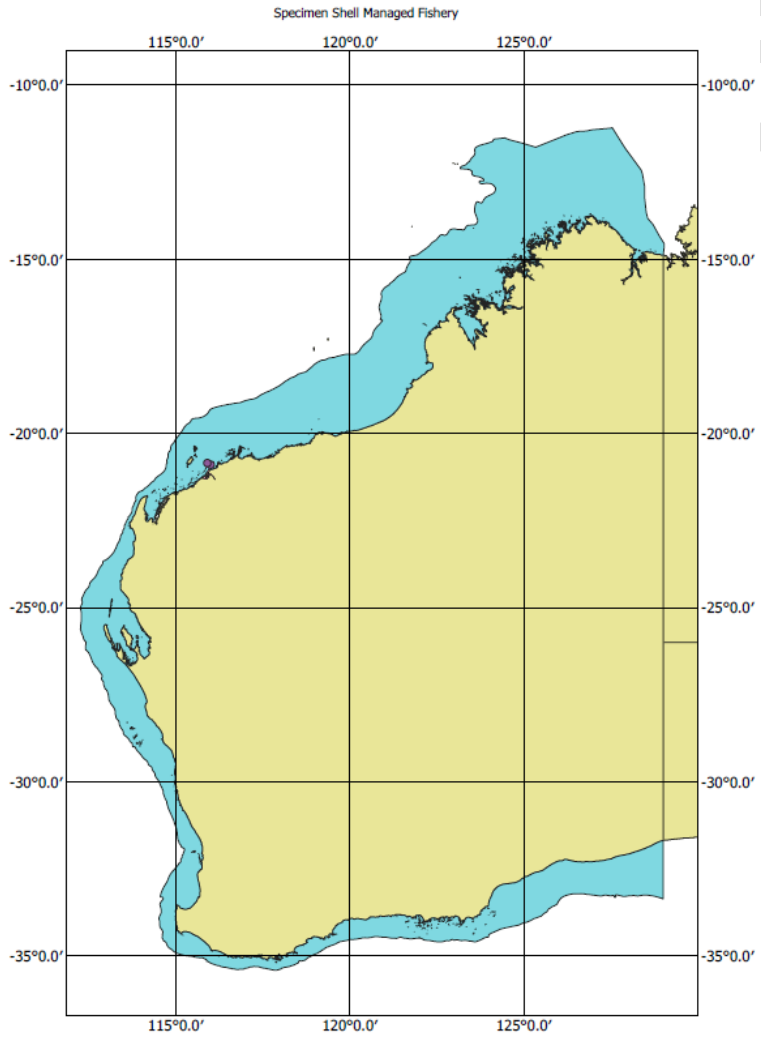

Fig 19. Spatial boundaries of the Specimen Shell Managed Fishery.

6.8.3. Fishing methods

A number of methods used in this fishery, with the primary ones being hand collection by divers operating from small boats and hand collection by fishers wading along coastal beaches. Remote operated vehicles are also allowed (1 per licence), as part of an ongoing trial.

6.8.4. Fishing effort

There are currently 31 licences in the fishery, of which 20 fished in 2018. Total effort in the fishery for 2018 was 636 days, which matches the past-5 year average of 630 days per year. The total number of shells collected in 2018 was 7,628 from 197 species. Species collected per year averages at about 200, with specimens from over 450 species collected at some point over the past five years (2018/2019 summary). Effort is focused on those species and families which are most popular with collectors, including cowries, cone snails, and volutes.

From 2010–2011 to 2018–2019, there was only one record of effort in the vicinity of the Mardie Project, which recorded no catch. This effort took place during August 2010 in reporting block 205155 while diving.

6.8.5. Management controls

The fishery currently operates under an informal harvest strategy based on a *constant exploitation approach*. The 2018 total catch of 7,628 shells was less than the set range (i.e. 10,000 – 25,000 shells) as was the daily catch rate of 12 shells/day (i.e. 10–40 shells). In addition, the fishery is managed through a number of input controls such as limited entry and gear restrictions. Each of the 31 licences allows a maximum of 4 divers in the water at any one time.

While the fishery is state wide there are a number of areas that are permanently closed to the SSMF, including marine parks, aquatic reserves, Reef Observation Areas, and Fish Habitat Protection Areas. Finally, the SSF is not permitted to take species for which separate management arrangements exist such as pearl oysters.

6.8.6. Ecology of Target species

The SSF targets a wide range of benthic-dwelling molluscs, with over 197 species collected in 2018 (Gaughan & Santoro 2020). The majority of collected shells are from the Families Cypraeidae (cowries), Muricidae (murex shells and their relatives), Conidae (cone shells) and Volutidae (volutes) (Dept. of the Environment and Heritage 2005). Collected shells fall into two broad taxonomic groups; Gastropods (i.e. sea snails, including the families outlined above), and Bivalves (molluscs with two shells such as scallops and clams).

Fig 20. The Specimen Shell Fishery targets a wide range of species, including tropical species such as the Tiger Cowrie (L) and Textile Cone (R) (Wikimedia Commons: CC BY 2.0/ BY-SA 3.0).

6.8.7. Stock structure & life history

In addition to taxonomy, specimen shells taken in the SSMF can also be divided into three groups of species based on their distribution; tropical northern species which occur throughout the Indo-West Pacific; temperate species; and species that are endemic to WA (about 10%). Most endemic species are restricted to the West Coast Bioregion, although some also occur in the North Coast Bioregion. All collected species are considered as a single stock for management.

Life cycles vary between species. However, there are some broad differences between bivalves and gastropods, which may reflect their relative ability to move around as adults. In bivalves, which are often sessile, the sexes are generally different. Reproduction is external, with males and females releasing eggs and sperm which are then fertilised in the water column and disperse. Most marine gastropods also have separate sexes, although some species are hermaphroditic. However, reproduction in gastropods is generally internal with individuals searching out mates. For most species the female will then lay a clutch of fertilised eggs on the substrate that subsequently hatches into free-living larvae that disperse in the water column.

For both bivalves and gastropods, the larvae then live in the plankton for a period of time before undergoing metamorphosis and settling to the substrate as juveniles. This planktonic stage allows the larvae to disperse over a larger area, carried by water currents and other hydrodynamic events. However, some target species (*Zoila* cowries and volutes) lack a planktonic phase with the young directly emerging from eggs as crawling juveniles. The lack of planktonic larvae may explain the reduced distributions of some of these species (and subspecies), and thus their vulnerability to overexploitation. Maturity is reached at different rates, with some species of sea shell living for decades (Dept. of Fisheries 2005).

6.8.8. Habitat

Given the wide range of species in the fishery, habitat requirements vary with both bivalves and gastropods occurring in a range of benthic environments such as soft sand, mud, and coral reefs. While gastropods are generally mobile, able to crawl over the substrate to look for food and mates, some bivalves are comparatively sessile, burying into the sediment or attaching themselves to hard structure using byssal threads. Some species collected have very specialised habitats, such as the frequently collected *Zoila spp.* cowries only found living on sponges (Dept. of the Environment and Heritage 2005). The depth ranges for shells targeted for collection is equally variable, with shells found from 1 m to more than 200 m depth, which can reflect the availability of different habitats.

6.8.9. Diet, trophic level and ecosystem role

Gastropods, such as the cowries, murex, cone shells and volutes targeted, have a range of diets and actively look for food. Some feed on algae and detritus while others, such as cone snails, are active predators that use highly toxic venoms to capture prey. In contrast, most bivalves are suspension feeders which remain in place on the substrate and use their gills to capture small plankton and particles of detritus from the water column. In turn, both gastropods and bivalve molluscs provide a source of food for a range of demersal scalefishes, rays and sharks, and larger invertebrates such as lobsters and crabs. Thus, they play an important link in the coastal food chain.

6.8.10. Current risks and vulnerabilities

Risk of overexploitation due to fishing is considered minimal due to the highly target nature of the collection methods, limited effort and inherent restrictions on collecting, and wide geographic distributions of all species (including prized subspecies). In addition, only high-quality shells are collected (i.e. specimens with small imperfections are left in place) reducing the impact on individual species (Dept. of Fisheries 2005, Enzer 2002).

Both gastropods and bivalves are vulnerable to changes in environmental conditions. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Przeslawski *et al.* 2008; Bashevkin *et al.* 2020). Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Przeslawski *et al.* 2008).

6.8.11. Statement of potential risk to the SSF

While most bivalves are sessile and so cannot avoid the dredging operation or dredge spoil deposition, motile bivalves and gastropods generally move slowly, and so are also unlikely to be able to avoid the dredging operation or dredge spoil deposition. Animals within the Dredge Material Placement Area (DMPA) could be smothered and those that get caught in the dredge would be unlikely to survive. Further, high sediment loads are likely to choke the filter mechanisms of bivalves, leading to some mortality.

Given the current lack of catch and effort by the SSF in the vicinity of the Mardie Project, the impact of the Mardie Project on the fishery is very likely to be minimal.

6.9. The Hermit Crab Managed Fishery (HCF)

6.9.1. Fishery overview

Hermit Crabs are crustaceans closely related to true crabs which carry an empty gastropod shell for protection. This fascinating behaviour, and their ease of care in captivity, has made them increasingly popular in the pet and aquarium trade. The Australian Land Hermit Crab (*Coenobita variabilis*) is a terrestrial species found in coastal areas throughout tropical Australia. In Western Australia, the State-managed Hermit Crab Fishery (HCF) is one of only two land-based commercial fisheries and operates year-round. The HFC targets Australian Land Hermit Crab for both the domestic and international live pet trade and operates under Ministerial Exemptions north of Exmouth Gulf.

The area of Mardie Project is within the HCF. The **Annual Economic Value** of the HCF (when combined with the MAFMF) was estimated at **$1–5 million** for 2018 (Gaughan & Santoro 2020)**.** The **Stock Status** of hermit crabs within the HCF are considered **Sustainable-Adequate** (Gaughan & Santoro 2020)**.**

6.9.2. Extent of the fishery

The HCF is currently permitted to fish Western Australian waters north of Exmouth Gulf (22°30'S) (Fig 21).

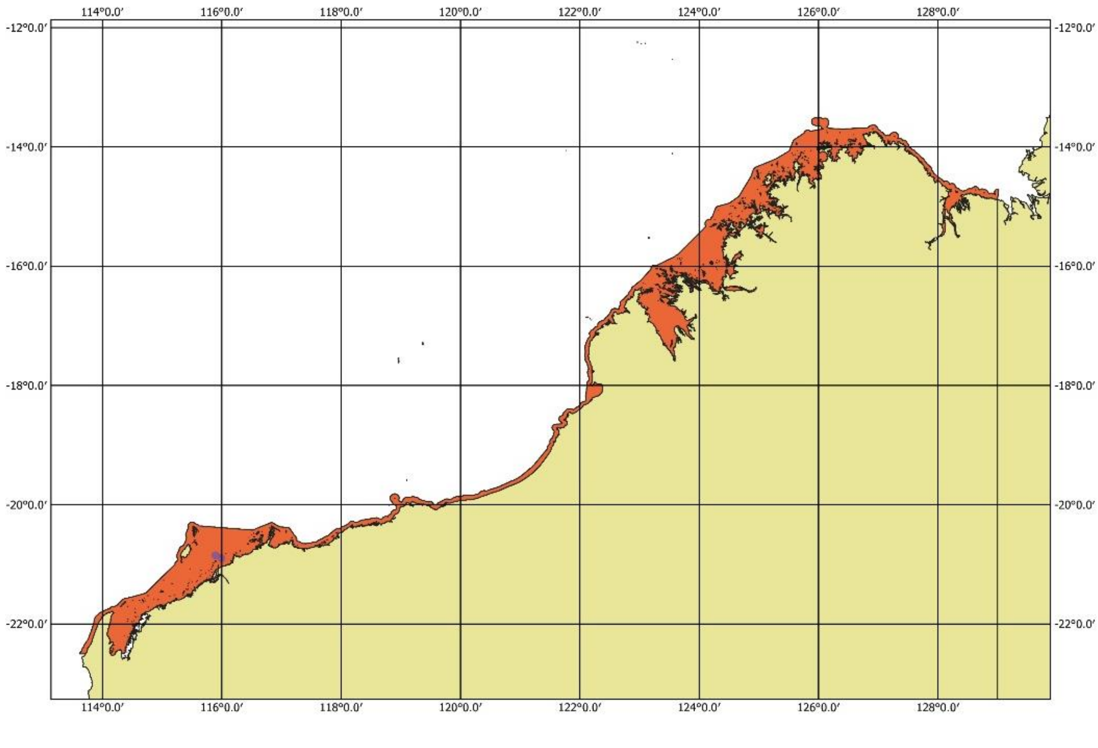

Fig 21. Spatial boundaries of the Hermit Crab Managed Fishery.

6.9.3. Fishing methods

Collections are made by hand only, usually at night when the nocturnal crabs are most active. As a land-based fishery, collectors use four-wheel drive vehicles to access remote beaches where collections take place.

6.9.4. Fishing effort

The level of harvest in the HCF is considered low and stocks are considered sustainable-adequate (Gaughan & Santoro 2020). A total of 5 Ministerial Exemptions allowing the collection of hermit crabs are currently granted in the HCF, with 3 active during 2018. Total catch in 2018 was 62,300 crabs, with the annual catch between 2008–2018 ranging from 58,643–118,203 crabs.

There was no HCF effort reported from within the vicinity of the Mardie Project from 2010–2011 to 2018–2019.

6.9.5. Management controls

This fishery is primarily managed through input controls in the form of limited entry via Ministerial Exemption, nominated operators, species restrictions, gear restrictions and permanent closed areas.

6.9.6. 5.9.6. Ecology of Target species

The target species of the HCF is the Australian Land Hermit Crab (*Coenobita variabilis*). This species is unique in that it is the only true terrestrial hermit crab found in Australia (Fig 22).

Fig 22. The Australian Land Hermit Crab (L) is the target species of the Hermit Crab Managed Fishery, which occurs in coastal habitats across tropical Western Australia (R) (Wikimedia commons: CC BY 2.0/ public domain).

6.9.7. Stock structure & life history

This species is distributed across tropical Australia from Western Australia to Queensland, with hermit crabs within the HCF considered as a single stock for management. While adults remain on land females must release their eggs in the ocean which then develop into planktonic larvae. This planktonic stage facilitates their dispersal, which helps to explain their wide distribution across Northern Australia, from Western Australia to Queensland. Following the completion of the larval stage, juvenile crabs find a small gastropod shell and move on land. Crabs exchange each shell for a larger one as they grow and so the distribution and abundance of crabs is dependent on the availability of gastropod shells.

6.9.8. Habitat

Land Hermit Crabs occur in a range of coastal habitats including sandy beaches, mangroves, and rocky areas. While they live on land, terrestrial hermit crabs such as the Australian Land Hermit Crab still breathe via large gill chambers which must be kept moist. Thus, crabs require moist, humid environments to survive which can mediate their distribution.

6.9.9. Diet, trophic level and ecosystem role

Australian Land Hermit Crabs are omnivorous scavengers. Adults carry a shell throughout their lifespan which provides protection from predators such as birds and reptiles, and environmental extremes. Hermit crabs play an important role in the coastal food chain linking organic detritus to higher predators.

6.9.10. Current risks and vulnerabilities

Relatively little is known about Australian Land Hermit Crabs in Australia; however, risk to populations is considered minimal given their high abundance over a broad geographic area and minimal fishing pressure. As with other coastal wildlife and species with an oceanic larval stage, changes to environmental conditions such a water temperature will likely have an effect on some ecological parameters (e.g. larval duration).

Coastal species with a planktonic larval stage, hermit crabs are vulnerable to a range of ecological disturbance risks. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Bashevkin *et al.* 2020. Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and dispersal of larvae, and fitness of adults (Przeslawski *et al.* 2008).

6.9.11. Statement of potential risk to the HCF

Australian Land Hermit Crab are widely distributed across northern Australia. The large amount of suitable habitat available, wide distribution, lack of effort I the area and suggests the impact of the Mardie Project on the Australian Land Hermit Crab stock and the HCF can be considered minimal.

7. Aquaculture operation in Mardie Project Area

With regards to aquaculture, the Pilbara region remains undeveloped. However, there are extensive areas of land and coastal waters suitable for aquaculture development with the feasibility of these operations under assessment. Current production and value is negligible, although opportunities for investment in Pilbara aquaculture are actively promoted.

Currently, this includes the assessment of rock oyster aquaculture in the area. Past projects have included small scale algal culture near Karratha. Several oyster farm holdings are in the general area (Table 2).

Table 2: Aquaculture industries identified as potentially operating within the Mardie Project Area, and whether they are currently active or inactive.

	Active projects	Inactive projects
Aquaculture operations	Pilbara Rock Oyster Research & Development Project	
	Algal Aquaculture	
		Peal Oyster Farming

8. Status of Aquaculture operations

A total of 3 aquaculture industries were identified as potentially operating within the Mardie Project Area (Table 2); however, these are either currently not active or in the initial assessment stages and thus, current production and value is negligible. In the following sections, the status of each aquaculture operation is outlined, along with the ecology of target species and the vulnerability of these species to environmental impacts.

8.1. Pilbara Rock Oyster Research & Development Project

8.1.1. Operation overview

This project, established in 2017, is examining the feasibility of developing a commercial rock oyster industry in the Pilbara region. It is a partnership between the Pilbara Development Commission, Fisheries Research Development Corporation on behalf of the Australian Government, City of Karratha, Murujuga Aboriginal Corporation and Maxima Pearling Company.

The initial project has established a trial farm at Flying Foam Passage on the Birrup Peninsula (Fig 23). In early 2020, additional leases were established in Withnell Bay on the Burrup Peninsula and offshore from Cossack, to the east of Karattha. The project aims to assess the potential of growing locally-sourced rock oysters using modern aquaculture methods for the domestic and international markets.

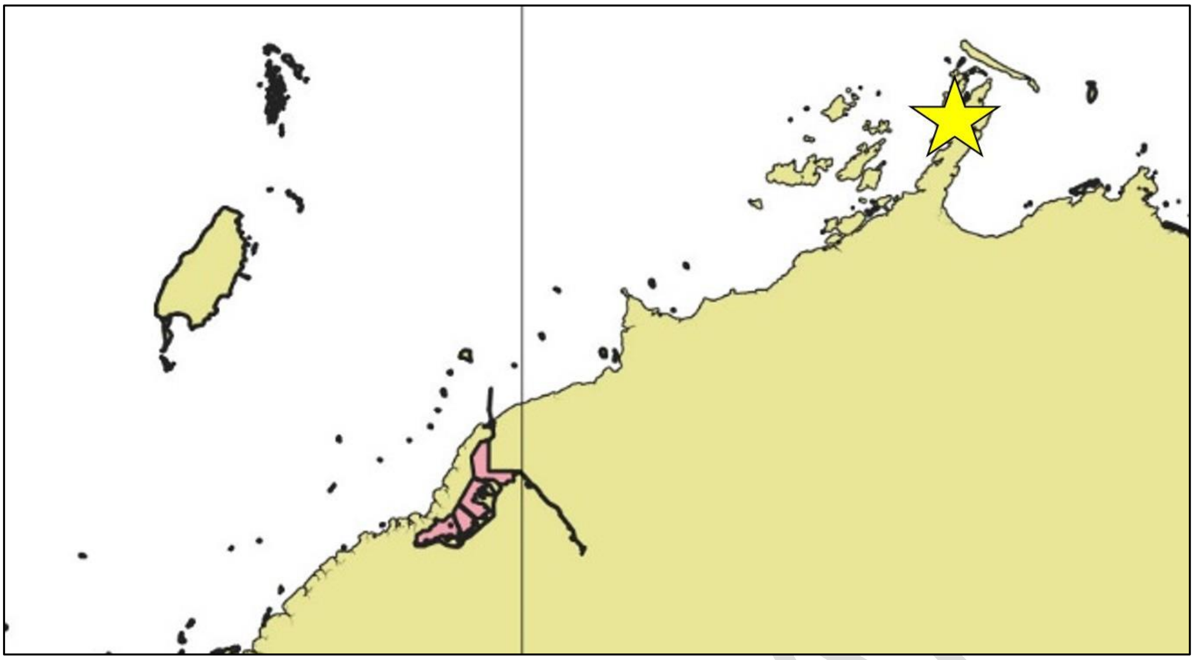

Fig 23. Location of the currently operation trial oyster farm at Flying Foam Passage.

8.1.2. Ecology of Target species

Several species of tropical rock oysters grow naturally along the Pilbara coast. As of 2020, the Blacklip Oysters (*Saccostrea echinata*) will be the focus of trials going forward (Fig 24). This oyster is a common intertidal and subtidal species found throughout northern Australia and the Pacific (Nowland *et al*. 2018). As with other oyster species they are broadcast spawners and have a pelagic larval stage that facilitates dispersal (Nowland *et al*. 2018).

Rock oysters are suspension feeders, trapping suspended particulate organic matter. A range of marine and terrestrial predators feed on both juvenile and adult wild oysters, including benthic fishes, rays, octopus, sea stars and birds. As such, wild oysters play an important role in the marine food chain linking organic detritus to higher trophic levels.

Fig 24. Tropical rock oysters grow naturally along the Pilbara coastline and are the focus of the Pilbara Rock Oyster Research & Development Project (Wikimedia commons: CC BY-SA 3.0).

8.1.3. Current risks and vulnerabilities

Tropical rock oysters under aquaculture conditions can be vulnerable to diseases and parasites (Nowland *et al.* 2020), and so measure to combat these issues must be taken by farmers. Rock oysters are also vulnerable to changes in environmental conditions. The effects of climate change may have a particular impact on the larval stages, affecting growth, survival and dispersal potential (Przeslawski *et al.* 2008; Bashevkin *et al.* 2020).

Human development in coastal areas may also have an effect on both larval and juvenile/ adult stages, with increased sedimentation, nutrient enrichment and other pollution impacting the survival and growth of farmed stock (Przeslawski *et al.* 2008).

Statement of potential risk to the Pilbara Rock Oyster Research & Development Project

Currently all operations in this research are based in Karratha and the Dampier Archipeligo. However, there is significant interest in this research, with a number of companies considering culturing this species once husbandry and grow-out methods have been refined. Locations of future culture sites are unknown, but likely to be between Exmouth and Broome. Give the lack of infrastructure (e.g. boat ramps, ports) in the area of the Mardie Project, it is unlikely that they would be sited there.

8.2. Algal Aquaculture

8.2.1. Operation overview

Algae have previously been farmed in the Pilbara region in small pilot projects. Products that can be produced from these algae can include biofuel, health and pharmaceutical products and protein for use in feedstock. Algae are generally produced in land-based ponds filled with sea water. Production also requires the addition of freshwater to raceways to offset evaporation.

The cost of supplying this freshwater has proven prohibitive in the past, preventing large scale projects. At least one algae aquaculture project is currently operating at Karratha.

8.3. Pearl oyster farming

8.3.1. Operation overview

In addition to the collection of wild oysters outlined in Section 5.3, the Western Australia Pearling Industry's other primary activities involve the production of hatchery-reared pearl oysters and the seeding of pearls for grow out on pearl farm leases. Overall, the pearl oyster fishery is the second most valuable fishery in Western Australia, contributing ~$60 million to the State's economy per year (Hart *et al.* 2014).

There are a number of Pearl oyster holding facility leases in the Pilbara area — near Onslow, on the Birrup Peninsula, and off the north coast of Barrow Island (Gaughan & Santoro 2020).

These appear inactive (PDC), however, these pearl leases and licenses still remain 'live' and could be activated should economic conditions change for the local pearl industry.

9. Contacts

To be completed.

10. References

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