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Ecosystem-Based Fisheries Management (EBFM) Risk Assessment of the Western Australian Silver-Lipped Pearl Oyster (Pinctada maxima) Industry

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Western Australian Marine Stewardship Council Report Series
No. 6, 2016

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Fish for the future

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Terms, Acronyms & Abbreviations

AMM	Annual Management Meeting
Broodstock	Any pearl oyster (*Pinctada maxima*) over 120 mm SL which is (intended to be) used for breeding
C	Consequence level
CALM Act	*Conservation and Land Management Act 1984*
Department	Department of Fisheries, Western Australia
Dump site	Area near fishing grounds where pearl oysters are temporarily held or placed prior to transport to a holding site and/or farm lease.
EBFM	Ecosystem-based Fisheries Management
ENSO	El Niño / Southern Oscillation
ERA	Ecological Risk Assessment
ESD	Ecologically-Sustainable Development
ETP	Endangered, threatened or protected
Farm lease	Pearl oyster farm lease issued under section 23(1) of the *Pearling Act 1990*
FRDC	Fisheries Research and Development Corporation
FRMR	*Fish Resource Management Regulations 1995*
Hatchery activities	As per the *Pearling Act* 1990, hatchery activities includes the (attempted) collection of pearl oyster spat; the (attempted) collection of pearl oysters for breeding stock; the (attempted) production of pearl oysters by acclimatisation's, propagation, hatching, breeding, rearing or raising; or moving, dumping, holding, storing or transporting pearl oysters for the above purposes.
Holding site	Area used to temporarily hold seeded pearl oyster prior to transport to farm leases (issued under section 19 of the *Pearling Act 1990*)
L	Likelihood level
OHS	Occupational Health and Safety
MOP	Mother-of-Pearl
MoU	Memorandum of Understanding
MPG	Ministerial Policy Guideline
MSC	Marine Stewardship Council
NATA	National Association of Testing Authorities, Australia
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority

NCB	North Coast Bioregion
NT	Northern Territory
Nursery site	All or part of a farm lease which is used for the growing out of spat
OCS	Offshore Constitutional Settlement
OOD	Oyster oedema disease
PA	*Pearling Act 1990*
Pearl culture	Any technique or practice used to produce or encourage the production of pearls from pearl oysters
Pearl oyster	*Pinctada maxima*, including the shell of the pearl oyster and any pearl contained in that shell
Pearling activities	As per the *Pearling Act* 1990, pearling activities include taking or attempting to take pearl oysters; removing, or attempting to remove, pearls from pearl oysters; moving, dumping, holding, storing or transporting pearl oysters; or practising or attempting to practice pearl culture techniques.
Pearling industry	Industry that targets *Pinctada maxima* for wild collection and hatchery activities.
POF	Western Australian Pearl Oyster Fishery (wild collection of *Pinctada maxima* only)
PPA	Pearl Producers Association
PR	*Pearling (General) Regulations 1991*
SAWG	Stock Assessment Working Group
Seeding	Specific pearl culture technique of inserting a nucleus into a pearl oyster
SL	Dorso-ventral shell length, excluding the fingers
SLA	Service Level Agreement
SOI	Southern Oscillation Index
Spat	Pearl oysters at any stage prior to settlement or which, having settled, are less than the minimum length
SST	Sea surface temperature
TAC	Total allowable catch
VMS	Vessel Monitoring System
WA	Western Australia
WAFIC	Western Australian Fishing Industry Council

Executive Summary

The Department of Fisheries utilises an ecosystem-based fisheries management (EBFM) approach which considers all relevant ecological, social, economic and governance issues to deliver community outcomes. In order to assess the level of fisheries' impacts and prioritise management activities across these four areas, periodic ecological risk assessments are undertaken for fisheries resources in Western Australia.

This report provides a comprehensive overview of the Western Australian silver-lipped pearling (*Pinctada maxima*) industry and the outcomes from the 2015 ecological risk assessment of this industry. The *P. maxima* pearling industry has been operating in Western Australia since the 1880s, initially harvesting pearl oysters for mother-of-pearl production. The industry is currently comprised of three components: the collection of pearl oysters from the wild, the production of hatchery-reared pearl oysters and the seeding of pearls within pearl oysters for grow-out on pearl farms throughout northern Western Australian waters and the Northern Territory. Additional information has been provided on the NT pearling industry within the justification of particular risks. This is especially relevant in the ecological sustainability components of this report.

The risk analysis methodology utilised for the 2015 risk assessment is based on the global standard for risk assessment and risk management (AS/NZS ISO 31000). This methodology utilises a consequence-likelihood analysis, which involves the examination of the magnitude of potential consequences from fishing activities and the likelihood that those consequences will occur given current management controls. Initial scoping work to identify components and sub-components within each of the four EBFM areas was undertaken by Departmental research and management staff and the pearling industry prior to a formal stakeholder workshop held in Broome, Western Australia, in August 2015 in which these issues were scored.

Seventy-seven issues were identified and scored. The majority of issues identified for the pearling industry were considered to be a low or negligible risk, and no issues related to ecological sustainability were considered to be medium or high risk. Thirteen issues were scored as a medium risk, and 10 issues were scored as a high risk. Appropriate management actions for medium and high risk issues will be developed through a consultative process between the Department, the pearling industry and other agencies, as required.

1. Introduction

Ecologically sustainable development (ESD) is the concept that seeks to integrate short- and long-term ecological, social and economic effects in all decision-making. The Western Australian (WA) Government is committed to the concepts of ESD, and these principles are implicitly contained in the objectives of fisheries legislation. In 2002, the then Minister for Fisheries released a *Policy for the Implementation of Ecologically Sustainable Development for Fisheries and Aquaculture within Western Australia* (Fletcher 2002) to articulate how the Department of Fisheries (the Department) can demonstrate to both the government and the broader community that these requirements are being achieved.

A major element of this policy was reporting on the progress of each commercial fishery against the major ESD objectives, and this document reports on the progress of the WA *Pinctada maxima* pearling industry (WA pearling industry) against these objectives. The reporting framework operates by identifying the relevant issues for a fishery (or in this case, industry) within three main categories of (1) ecological sustainability, (2) community well-being and (3) ability to achieve; completing a risk assessment on each of the identified issues and then providing detailed reports on their status (Fletcher et al. 2002).

This report provides a comprehensive overview of the information pertaining to the WA pearling industry. Where appropriate, information has been provided on the NT pearling industry. Several key documents were consulted for preparing the following background information on the industry, particularly the *MSC Report for the Western Australian Pearling Industry* (Hart et al. in prep) and relevant legislation (see Section 2.1.5). These documents should be referred to for additional information.

This report should also be read in conjunction with the *Western Australian Silver-lipped Pearl Oyster (Pinctada maxima) Resource Harvest Strategy* (Department of Fisheries, in prep.), which outlines the operational objectives, performance indicators and reference levels used to assess the performance of the wild-collection Pearl Oyster Fishery (POF). The performance of the POF against these objectives is reported in the annual *Status Reports of the Fisheries and Aquatic Resources of Western Australia: the State of the Fisheries*.

The scope of this report includes the next five years of industry operations (through August 2020). It is envisioned that ecological risk assessments (ERAs) will be undertaken periodically (approximately every five [5] years) to reassess any current or new issues that may arise in the industry; however, a risk assessment can also be triggered if there are significant changes identified in industry operations, management activities or controls that may change current risk levels. This cycle coincides with the review of the harvest strategy.

2. Overview

The WA pearling industry is managed under the *Pearling Act 1990*, which regulates the collection of the silver-lipped pearl oyster (*P. maxima*) for pearl culture, MOP and pearl oyster meat and pearl oyster hatchery activities. The industry has operated under a detailed and sophisticated management regime since the early 1980s, when quotas were first introduced. Currently, the industry is managed using a quota system, including quotas for wild pearl oysters and seeding of wild and hatchery-reared pearl oysters, size limits and spatial restrictions (zoning). Each of these measures has been refined through time and is subject to regular reviews to achieve the overall aim of successful management.

The *Pearling Act 1990* provides the legislative framework to implement the management arrangements for the WA pearling industry, while the *Pearling (General) Regulations 1991* support this Act by providing the framework for management of administrative and technical matters. The pearling industry also operates in the Northern Territory jurisdiction and is managed under NT legislation

The combination of having a large amount of relevant and accurate information on the biology of *P. maxima*, extensive knowledge about the history of the WA pearling industry, combined with the extensive catch and effort data and the sophisticated suite of management arrangements in place, have resulted in the maintenance of *P. maxima* stocks at sustainable levels, as well as the successful development and continuation of the industry.

The WA pearling industry has minimal impacts on the wider ecosystem, primarily due to the selective method of fishing used and the highly-productive nature of the North West Shelf marine environment. The pearling industry has also taken additional steps to minimise its impacts, including the development of an Environmental Code of Conduct (PPA 2002).

3. WA Pearling Industry Background

3.1 Description

The WA pearling industry is the world's top producer of the highly-prized, silver-white Australian South Sea Pearls, which come from the silver-lipped pearl oyster, *Pinctada maxima*. The pearls produced in WA are well regarded in the industry worldwide, with the value of cultured pearls and other related products considered to be approximately AUD 61 million in 2013 (Hart et al. 2014).

The pearling industry is comprised of three vertically-integrated components: the collection of pearl oysters from the wild (as part of the POF); the production of hatchery-reared pearl oysters; and the seeding of pearls within pearl oysters for grow-out on farm leases (Figure 1). Additionally, pearl oysters collected from the wild, as well as grow-out pearl oysters, can be utilised for MOP and pearl oyster meat.

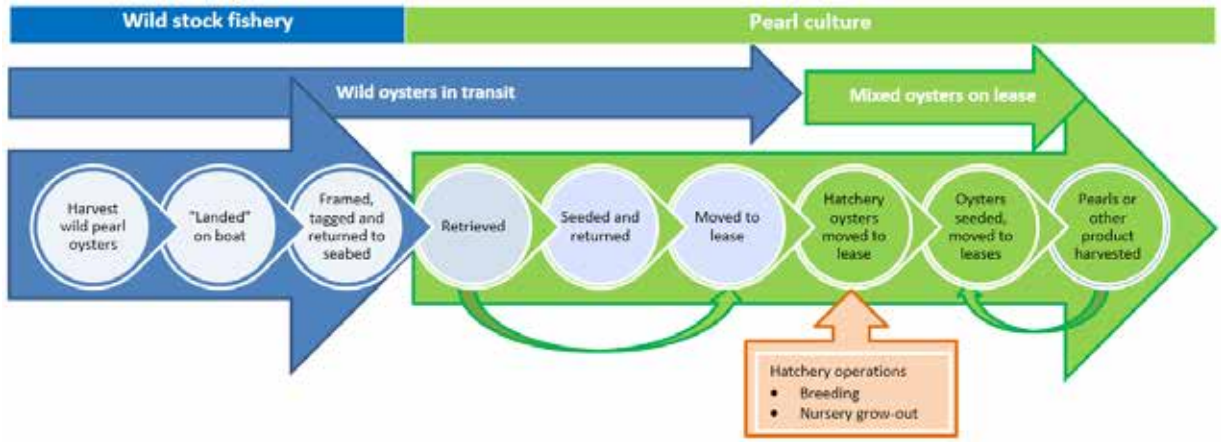

Figure 1. Overview of the pearling industry, which integrates the capture of wild oysters with hatchery-produced stock for pearls, mother-of-pearl and oyster meat production

As part of the pearl production process, pearl oysters are caught in the wild, seeded with a nucleus at sea on board specially-built vessels and are grown out in controlled pearl oyster farm leases for two years to produce cultured pearls. Prior to the development of hatchery technology in the 1990s, the WA pearling industry relied on the capture of live pearl oysters from the wild, which were seeded to stimulate pearl formation, then moved to farm leases for the grow-out of pearls. In recent decades, the production of pearl oyster spat from hatcheries has become an increasingly important component of the supply of pearl oysters for seeding. The end product for industry from either process is primarily high-quality pearls, with a small amount of pearl oyster meat and mother-of-pearl (MOP) shell products.

3.2 Industry Operations

3.2.1 Wild Collection

The WA pearling industry currently comprises 15 wildstock licences that can collectively take *P. maxima* from Exmouth Gulf to the NT border (see Figure 2), although harvesting is focused between Exmouth Gulf and Cape Leveque, with most individuals collected off

Eighty Mile Beach (Figure 3). Highly-trained divers collect *P. maxima* while being towed behind large (~ 35 m long) boats (Figure 4). Many of these boats have been custom designed for the pearling industry and have a total crew of 10 – 12 people (Fletcher et al. 2006).

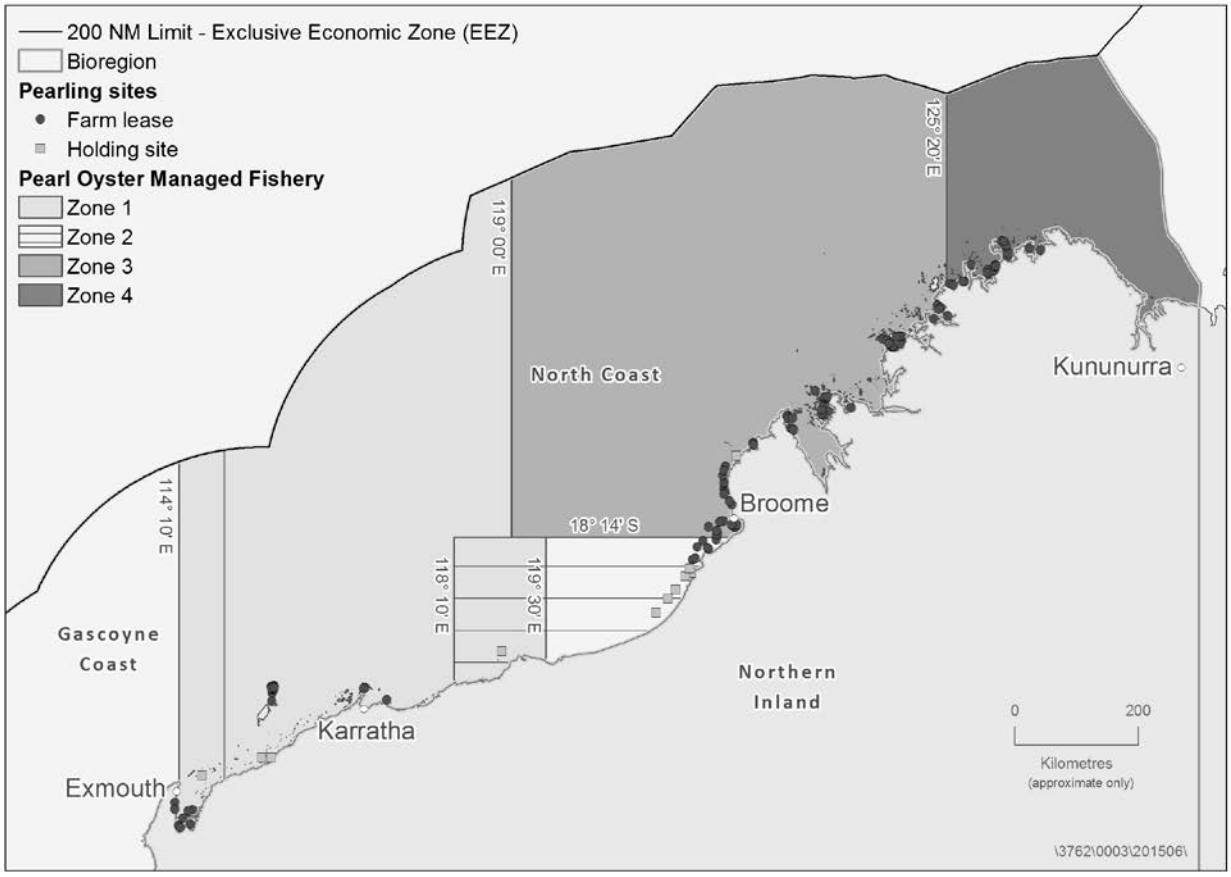

Figure 2. Fishing boundaries and zones of the Western Australian Pearl Oyster Fishery including holding sites and farm lease areas

Collection activities generally occur for 3 – 4 months per year, usually over the winter season. Fishing for pearl oysters generally involves the extension of booms outwards from each side of the vessel (Figure 4), with a number of weighted ropes hung vertically from each boom to a height of approximately one to two metres above the seabed. Most boats use three lines per boom, which allows six divers to work simultaneously. Divers operate on hookah with air supplied from a surface compressor. Coded signals are used by the head diver to communicate with the crew on the boat in order to control factors like the speed and direction of the boat and height of the weights etc. Since water clarity is paramount to divers being able to identify the appropriate sized pearl oysters, significant effort is put in place to ensure the weight does not strike the sea floor. Therefore, the diver will signal to the vessel to raise the weight according to the sea floor height — thus preventing the weight from striking the bottom (Fletcher et al. 2006).

During fishing activities, the vessel begins "drifting" (towing) at one end of a pearl oyster patch and moves slowly across the patch at a rate of about one knot. The engine remains in gear to maintain steerage of the vessel, but even at minimum speed, the boat moves too fast for the divers, and so a stern drogue is deployed to act as a sea anchor and slow the boat.

Ropes attached to the drogue can be manipulated to open the drogue fully and slow the boat or partially close it to increase speed. Each diver wears a neck bag during the dive (Figure 4), and as pearl oysters are collected, they are kept in the neck bag until it is full. Only pearl oysters that are deemed the appropriate size and health, are collected. The collected pearl oysters are transferred to the holding bag at the end of each weighted rope. The divers swim about 1.5 metres off the seabed to obtain the maximum field of view (Figure 4). Even in murky water when the divers swim closer to the bottom, they are still above the bottom substrate. Each diver makes an average of eight to 10 dives per day, and a good diver aims to collect an average of 250 pearl oysters per day (Fletcher et al. 2006).

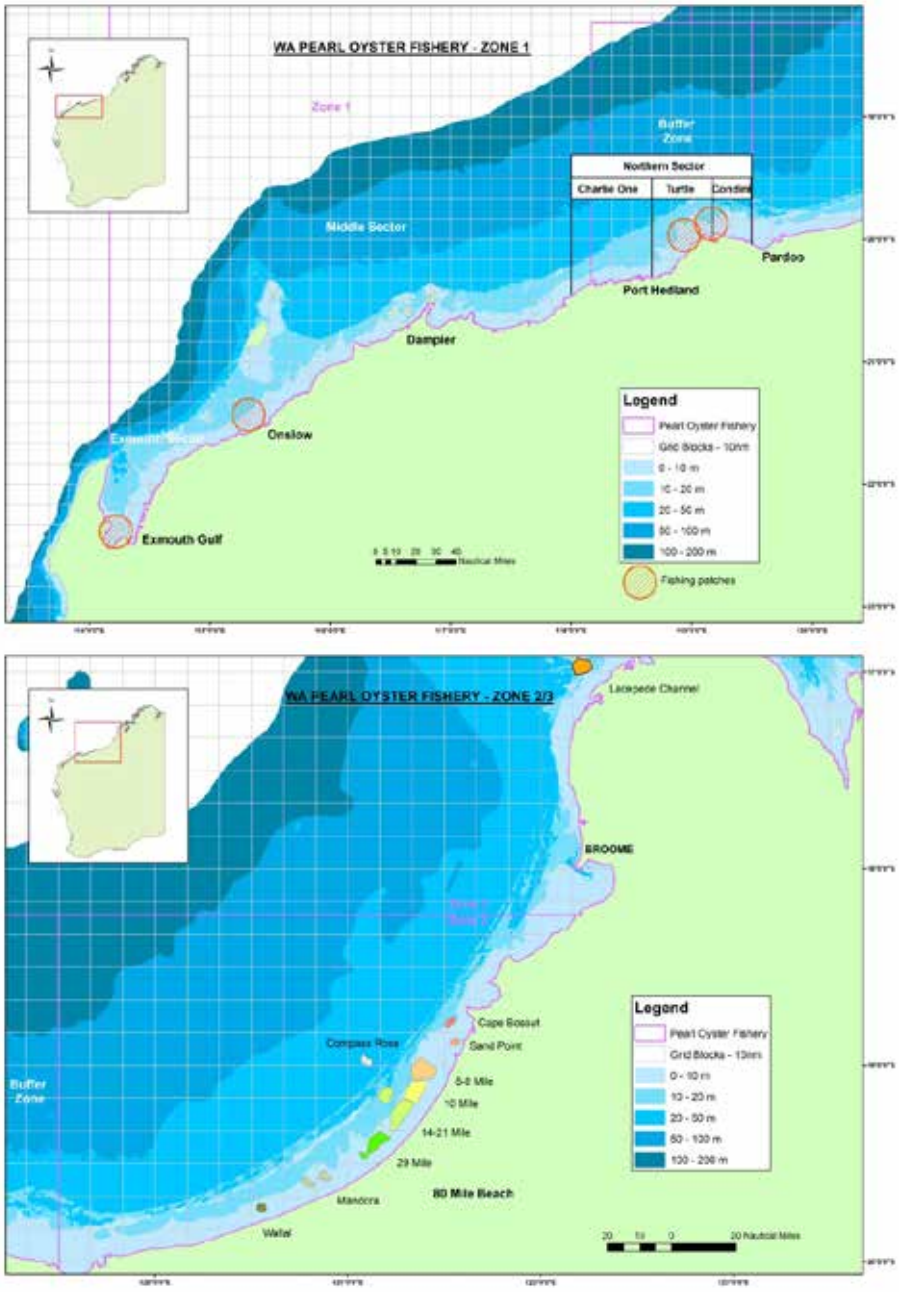

Figure 3. Location of main 'fishing patches' in Zone 1 (top) and Zones 2/3 (bottom) of the Western Australian Pearl Oyster Fishery

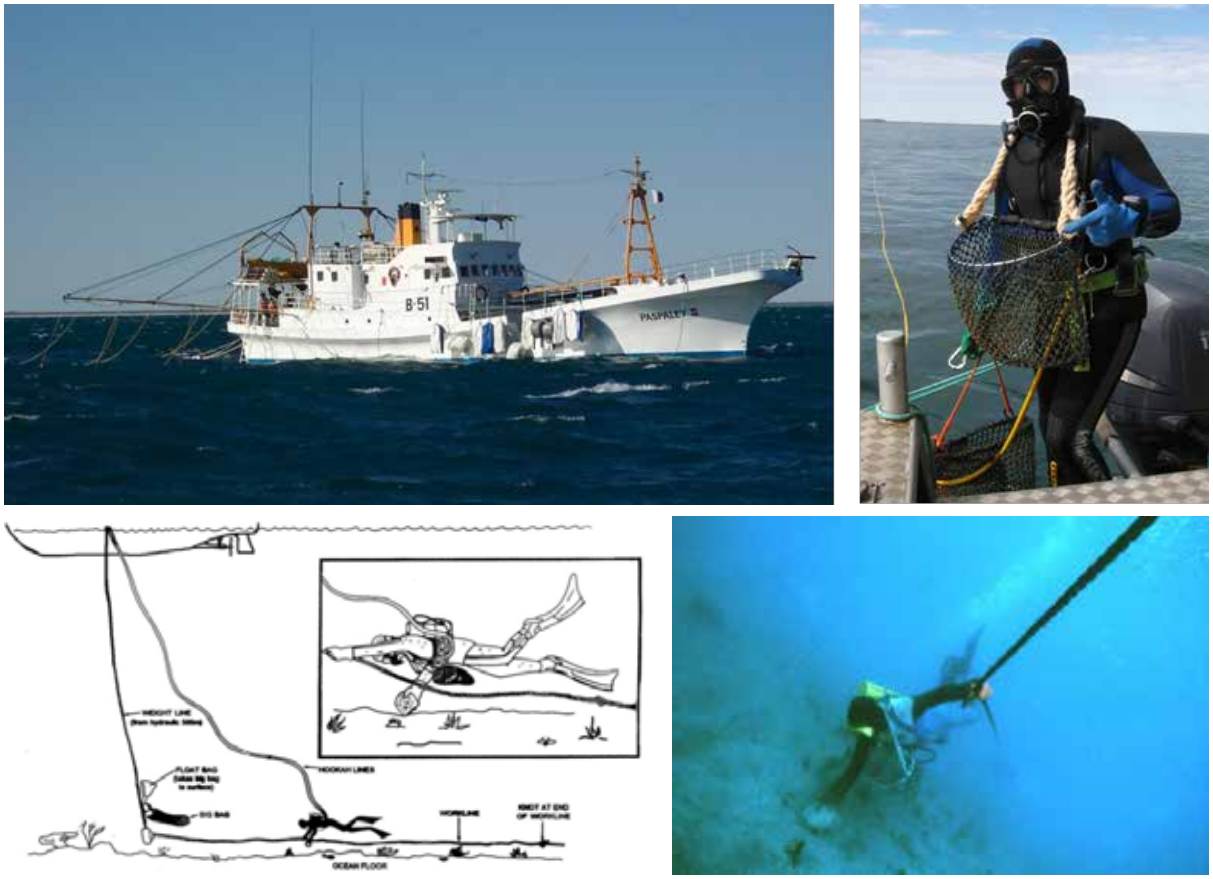

Figure 4. Pearl oyster fishing vessel and diver (top); schematic of pearl oyster diving operations (bottom left) and photo of diver collecting a pearl oyster (bottom right). Source: Department of Fisheries (n.d); PPA (2008a)

A Code of Practice for diving in the pearling industry has been developed, and in addition to operating their own hyperbaric chamber, the pearling industry has appointed both a health and safety officer and a doctor specialising in hyperbaric and diving medicine. In furtherance of the PPA Code of Practice, divers adhere to strict diving profiles that greatly reduce the risk of decompression sickness.

At the end of the dives, the pearl oysters that have been collected are recovered and graded. Pearl oysters that are too big or too small are returned immediately within the vicinity where they were taken. Pearl oysters of the target size are cleaned with a cleaver by scraping off encrusting organisms on the shell. A high-pressure hose is then used to wash the pearl oyster; no chemicals are used in the process. If the pearl oysters are to be used for culturing purposes, they are placed in transport panels on the boat that hold six to eight animals each, and every panel is individually tagged to indicate which company has collected the pearl oysters. The tags are numbered, and each company is only issued sufficient tags by the Department to match its quota (Fletcher et al. 2006). If the pearl oysters are to be used for MOP purposes they will be placed in an approved container (as approved by pearling inspectors).

Once all the pearl oysters have been placed in the frames, they are taken to a dump site (and subsequently moved to a holding site) or are moved directly to a holding site (generally located near the fishing grounds), where they are placed on the seabed in a marked area by divers for later usage. The sea floor at the dump and holding sites is deliberately selected to be very similar to that found on the fishing grounds. Thus, they are mostly sand bottom with occasional sponges, soft corals, sea fans, and other fauna present, including some *Turbinaria* corals (Fletcher et al. 2006). At the holding site, the panels are attached at 900 mm intervals to lines, which may be several hundred metres long.

Applications for holding sites are considered under *Ministerial Policy Guidelines* (MPGs) *Nos. 8* and *17*, with a holding site gazetted for a three year term (under section 19 of the WA *Pearling Act 1990*). The total area of pearl farm holding sites in 2014 and 2015 was 105 km^2 and 95 km^2 (~ 30 nm^2), respectively. All holding sites occur in waters of less than 30 m depth (Dept. of Fisheries, unpublished). Pearl oysters are moved from fishery areas to the dump and/or holding sites in accordance with Regulation 42 of the WA *Pearling (General) Regulations 1991* and Part 13A of the WA *Fish Resource Management Regulations 1995* (FRMR).

3.2.2 Hatchery Operations

Hatchery techniques for *P. maxima* are a relatively recent development and were pioneered by Rose & Baker (1994).

After carefully selected broodstock complete spawning, the fertilised eggs are stocked into tanks of filtered seawater. After approximately 24 hours, metamorphosis from egg to free-swimming larvae is complete, and cultured microalgae are added to the rearing tanks. Gentle aeration is supplied to mix the suspension within the tank, and algal concentrations are increased during the culture period. Water changes are conducted every two to four days, at which time culling and size grading of the larvae also take place (PPA 2008).

Larvae begin to metamorphose into spat (juvenile pearl oysters) on day 24. Settlement occurs either on the tank walls and bottom or on collectors hung inside the tanks. In the hatchery, newly settled spat are treated in a similar manner to larvae. As they become larger, the feeding rates and water circulation are increased to ensure that attached spat have sufficient access to food and oxygen. Spat are commonly held in the hatchery until they are large enough to be placed into mesh cages or other structures. Once spat attain about 20 to 50 mm in shell height, they are generally transferred to small mesh panels on surface longlines in the ocean. As the spat size increases, they are transferred to panels with progressively larger mesh size (PPA 2008).

The spat is cleaned at approximately four week intervals. Given that the nursery period before the spat grow out to a seedable size (i.e. can be utilised for pearl production) is two to three years, the efficiency and effectiveness of the farm cleaning program is optimised in order to reduce the considerable costs and infrastructure involved. Most farms now have personnel specialising in the maintenance of the spat to seeding size (PPA 2008).

The *Pearl Oyster Translocation Protocol* reflects the translocation and hatchery requirements under the WA *Pearling Act 1990*, the WA *Pearling (General) Regulations 1991* and FRMR (Part 13A), as well as additional protocols for commercial pearl oyster hatcheries in WA. This includes annual inspections to authorise minimum standards for filtration of incoming seawater, cleaning and disinfecting procedures, health testing, sterilisation of effluent seawater and record keeping. Similar legislation and protocols for the translocation and health testing of pearl oysters are also in place in the NT.

3.2.3 Pearl Culture

Cultured pearls are produced by placing an inert foreign object (referred to as a 'nucleus') into a pearl oyster. The pearl oyster secretes shell material that seals the nucleus completely from the remainder of the body, and over time, the animal continues to add layers over the pearl, enlarging it. The most common type of pearl nucleus is made of shells from freshwater bivalves (Bivalvia: Unionidae) from the USA, although other materials may also be used.

Seeding is generally undertaken on a purpose-built vessel or shore-based facility by a skilled seeding technician. Pearl oysters from the POF are seeded at either the holding sites or at the farm leases (depending on company preference), while those from hatchery-produced stocks are seeded on nearby farm leases and may then be moved, depending on the preferred location for pearl production. The surgical instruments used are sterilised before use according to a protocol developed by the PPA. This practice is intended to minimise the risk of spreading disease between individual pearl oysters as they are seeded.

When they are to be seeded, the pearl oysters are recovered from the holding site or pearl oyster farm lease, and a piece of mantle tissues from another animal is inserted into the host oyster gonad, along with the nucleus of the pearl. The inserted mantle tissue becomes part of the host oyster's tissues, creating a sac around the nucleus. If the pearl oyster is subsequently used to produce a second pearl, the same sac is used (Joll 1996). After the nucleus is inserted, the animals are returned to the ocean in panels at the holding site or farm lease. After an initial recovery period of 7 – 8 days, the pearl oyster panels are turned by divers every 2 – 5 days. This helps develop the sac around the nucleus and prevents the nucleus from breaking out of the tissue. Pearl oysters are x-rayed after 4 – 6 months to determine if the nucleus has been retained and the pearl has started to grow (Wells & Jernakoff 2006).

3.2.4 Pearl Oyster Grow-Out

If seeded on a holding site, after two to three months of resting the pearl oysters are transported by boat to a farm lease[1]. All transport approvals and health certificates required for movement are outlined in Regulation 42 of the *Pearling (General) Regulations 1991* and Part 13A of the FRMR. Additionally, the *Pearl Oyster Translocation Protocol* reflects this legislation and provides further guidance for translocation procedures, health sampling procedures and any health certification approval required prior to the movement of any pearl

[1] All pearl oysters must be cleared from the holding sites by 31 December each year.

oysters between farm leases, as well as the movement of hatchery-produced pearl oysters and the movement of pearl oysters into WA.

Farm leases are located between Arnhem Land in the NT and Exmouth Gulf in WA, although the majority of grow-out activities occur in the remote Kimberley region of northern WA (see Figure 2). The Kimberley region is a very high-energy environment, with tidal amplitudes up to 10 m and strong tidal currents. These currents constantly renew the available phytoplankton, which nourish the pearl oysters and reduces the potential for localised impacts from pearl farms (Wood & Mills 2008; Eliot 2010; Jelbart et al. 2011).

The total area of pearl oyster farm leases in WA in 2014 and 2015 was 645 km^2 (188 nm^2) and 640 km^2 (186 nm^2), respectively. The majority of farm leases occur in waters of less than 30 m depth, and no pearl oyster farm leases are located in waters deeper than 40 m depth (Dept. of Fisheries, unpublished). The process of obtaining marine leases for pearling activities is outlined in MPG Nos. 8 and 17. Farm leases are separated from each other, usually by 5 nm, to counter disease transfer; however, if the holder of an existing farm lease agrees, a new farm lease can be established within 5 nm of an existing farm lease and if the farm lease is owned by the same legal entity a new pearl oyster farm lease maybe established within 2 nm. The site of a farm lease is chosen based on protection from cyclones and the sediment characteristics. Mud-bottom areas are preferred, as mud provides the best holding ground for the longline anchor system used in pearl culture activities. Estuarine areas and submerged reefs are avoided as they act as reservoirs for problematic fouling organisms, such as barnacles and other oysters (from estuarine areas) and pathogens, e.g. *Cliona* (from reef areas) (PPA 2008).

On delivery to a pearl oyster farm lease, the panel of seeded pearl oysters are placed onto surface longlines consisting of a rope backbone with attached surface floats anchored at each end in the thick mud bottom by specially-designed anchors (up to 2 m deep). Panels are attached to longlines by short lengths of rope ('droppers') at regular intervals. Vertical lines with panels containing pearl oysters are hung from the buoys and are maintained well off the bottom to avoid fouling. The lines are at least 100 m offshore and are 20 – 30 m apart to avoid entanglement if one line breaks. An average line is 100 m long, with panels every metre for a total of ~ 600 pearl oysters per line (PPA 2008).

The pearl oysters are cleaned regularly (every 4 – 5 weeks) to remove biofouling organisms, which would compete with the pearl oyster for available food. The pearl oysters are cleaned at the surface by spraying them with high-pressure seawater. Hard fouling species, such as barnacles or other oysters, are removed by cleaning personnel with stainless steel chisels. No chemicals are used in the cleaning process (PPA 2008).

Pearls are generally harvested during winter (July – August; Scoones 1991). When harvested, the panels of seeded pearl oysters are delivered to the harvest vessel or land site where the pearl oysters are opened and given to technicians, who surgically remove the pearl from the sac (PPA 2008). If the quality of the pearl is judged to be appropriate and the pearl oyster is

in good condition, a new nucleus is then inserted into the pearl sac. Following this reseeding, the pearl oyster is placed back into the panel and returned to the farm lease, where over the next two years, the pearl production process is repeated. As many pearl oysters as possible are reseeded; approximately 40 – 50 % of the pearl oysters can be used a second time, and 40 – 50 % of these can be reused a third time (Wells & Jernakoff 2006). Pearl oysters that have not produced a pearl of sufficient quality are not reseeded and are processed to produce saleable end products, such as pearl oyster meat and MOP.

3.3 Management System

3.3.1 Legislation and Arrangements

The WA *Pearling Act 1990* and the *Pearling (General) Regulations 1991*, together with subsidiary instruments including regulatory notices, MPGs, leases, licences and licence conditions, provide power for the management of all aspects of the WA pearling industry. This includes the wild collection, hatchery and translocation of pearl oysters to farm leases.

It is important to note that the WA pearling legislation and management arrangements are currently being transitioned to the *Aquatic Resource Management Act* (currently before Parliament as the *Aquatic Resource Management Bill 2015*); however, no significant changes to the management system will occur as part of this process.

There is a Memorandum of Understanding (MoU) in place between the WA Minister for Fisheries and NT Minister for Primary Industry and Fisheries regarding the management of the *P. maxima* pearling industry between WA and the NT. This MoU has been developed (1) to ensure that consistent standards of management and compliance exist within the WA and NT pearling industries; and (2) to ensure that efficiencies and synergies in pearling management and compliance are achieved through cooperative arrangements.

The WA pearling industry is managed using the following controls:

Wild Collection:

- **Species restrictions**: *P. maxima* is the only pearl oyster species managed under the *Pearling Act 1990* and is the only species collected in the POF or used for pearl cultivation by the WA pearling industry (as considered here);
- **Size Limits:** The minimum size limit for the collection of *P. maxima* from the wild is 120 mm[2] shell length (i.e. 3 – 4 year old animals). There is also a legal maximum size limit of 160 mm shell length in place for *P. maxima* in Exmouth Gulf.
- **Zone restrictions:** The WA pearling industry is separated into four zones (see Figure 2) in order to manage wild stocks and translocation:

[2] Note the harvest of pearl oysters between 100 and 119 mm shell length was approved in 2011 for an initial three years, and was extended for another three years in 2013. This approval was subject to the harvest level of pearl oysters of this size being less than 15 % of the TAC.

- **Zone 1** extends from the Northwest Cape (including Exmouth Gulf) to 119° 30' E longitude and includes 115 wildstock quota units. There are currently five wildstock licences that have permanent quota units in Zone 1;
- **Zone 2** extends east of Cape Thouin (118° 10' E) and south of 18° 14' S and includes 425 wildstock quota units. There are currently eight wildstock licences that have permanent quota units in Zones 2/3 (note these licensees also have full access to Zone 3).
- **Zone 3** extends west of 125° 20' E and north of 18° 14' S and includes 32 wildstock quota units. There are currently three wildstock licences that have permanent quota units in Zone 3; these licence holders also have access to Zone 2.
- **Zone 4** extends east of 125° 20' E to WA/NT border. All licensees have access to this Zone, although no TAC is set or fishing occurs in Zone 4. Note pearl farming occurs in Zone 4.

- **Quota system:** The (wild collection) POF is managed through output controls in the form of a total allowable catch (TAC), which is divided into individually-transferable quotas. There are 572 total quota units, allocated between 15 wildstock licences[3] across management Zones 1 – 3. The value of these quota units varies depending on the status of pearl oyster stocks and the annual TAC (as set by the CEO of the Department, based on advice from the Pearling Stock Assessment Working Group [SAWG], the PPA and the Department).

  Each operator has an annual quota of pearl oysters, which is given effect as a licence condition that establishes a number of quota units (on each licence). The 2015 TAC and associated quota unit values were as follows:

  - **Zone 1:** TAC of 54 970 pearl oysters, which equated to 478 pearl oysters per unit;
  - **Zones 2/3:** TAC of 612 380 pearl oysters, which equated to 1340 pearl oysters per unit (within the TAC there was an agreement that 502 700 pearl oysters between 100 – 175 mm SL could be taken, equating to 1100 pearl oysters per unit; and 109 680 pearl oysters greater than 175 mm SL could be taken, equating to 240 pearl oysters per unit);
  - **Total 2015 TAC:** 667 350 pearl oysters.

Hatchery Activities:

Companies producing hatchery-reared pearl oysters must hold the appropriate hatchery licences and relevant seeding quota to seed the pearl oysters. The impacts from hatchery activities are managed primarily through the spatial separation of most of the farm leases

[3] Note that some licences have quota in more than one Zone of the POF.

from the main wild stock fishing areas — hatchery activities primarily occur in Zone 4 and the NT, while fishing activities are focused on Zones 2/3. Other important management controls include:

- A limit on the number of hatchery-produced pearl oysters that can be seeded each year (enforced by quota licence conditions and compliance monitoring);
- The use of WA-origin, wildstock pearl oysters for all hatchery broodstock (i.e. broodstock must be taken from Zone 1, 2 or 3 of the POF or have originated from WA stock) ; and
- Legislation that controls the movement of pearl oysters into WA.

Translocation:

The movement of pearl oysters is regulated by Regulation 42 of the *Pearling (General) Regulations 1991* and Part 13A of the FRMR. Detailed guidelines on the translocation of pearl oysters are outlined in the *Pearl Oyster Translocation Protocol*. The protocol reflects the legislation and provides guidance on:

- The movement of hatchery-produced pearl oysters;
- The movement of all pearl oysters between farm lease areas[4];
- The reporting of hatchery-settled pearl oyster spat (via a *Pearl Oyster Settlement Form P9*);
- The requirements for spat leaving a hatchery and the testing of hatchery spat by a fish pathologist;
- The requirements for pearl oyster spat transported from a hatchery to a farm lease site (including submission of required log sheets);
- The translocation and handling procedures when unusually high mortality levels indicate there may be a disease risk;
- The requirements and procedures for health testing and the destruction of pearl oyster spat that has failed health testing; and
- The minimum standards required for hatchery accreditation, including the cleaning/disinfecting schedule and the disinfection of hatcheries when a batch fails health certification.

3.3.2 Compliance System

The long-term sustainability of wild *P. maxima* stocks is primarily managed through the setting of an annual TAC that is divided into individually-transferable quotas and allocated to licensees based on permanent quota units held.

[4] Note the *Pearl Oyster Translocation Protocol* does not apply to the initial movement of wildstock pearl oysters sourced from the fishing beds within WA to a dump site/holding site within WA. However pearling activity and transport approvals under the PA are still required.

Quotas are monitored through a combination of quota tags and a paper audit trail using logbooks, forms and transport approvals. Serially-coded lockable tags are issued to licensees by the Department on an annual basis based on quota allocations. Three forms/log sheets are also used in the tracking and enforcement of quota:

1. A *Notice of Pearling or Hatchery Activity* (Form P2), which must be completed prior to any pearling activity associated with collecting, transporting or operating on pearl oysters;
2. A *Pearl Oyster Fishing Daily Logsheet*, which captures daily records of pearl oysters collected by each diver and vessel and the tags used; and
3. A *Transport Logsheet* (Form P6), which is required for the transport of wild stock pearl oysters from dump sites to holding sites and from holding sites to farm lease areas.

Compliance strategies and activities include pre-season briefings of pearling company staff and pearling vessel crews; in-port inspections of pearling vessels and at-sea inspections of pearl oysters to ensure they are appropriately tagged by fishers, as well as inspections of pearling leases and pearling equipment.

Some vessels operating within the POF have been fitted with Automatic Location Communicators on a voluntary basis. This is used to track the location of the vessel by transmitting information as geographical position, course and speed of the vessel to Vessel Monitoring System (VMS) compliance officers at the Department. The use of VMS in the POF allows to the Department to carry out real-time monitoring of the pearling fleet movement, provides intelligence for inspections and investigations and provides information and analysis to research and management branches on vessel activities and patterns.

3.3.3 Industry Initiatives

Both the NT and WA pearling industries have adopted a *Pearling Environmental Code of Conduct* (PPA 2007), which outlines the environmental responsibilities of license holders. The Code stipulates that the pearling industry will work in conjunction with government and other stakeholders to ensure it is managed sustainably (ecologically and economically) and that social, economic and environmental benefits are maintained. The pearling industry has also implemented a *Whale Management Policy and Protocol* (PPA 2008b), which includes an overview of industry instructions for preventing whale entanglements and interactions at the farm leases, an overview of local whale species and identification guides and a response protocol should an interaction or entanglement occur.

3.4 *Pinctada maxima* Biology

The silver-lipped pearl oyster, *P. maxima*, is widespread throughout the Indo-West Pacific (Figure 5). In WA, this species has been recorded as far south as Shark Bay, but it is not commercially collected south of the North West Cape. Individual pearl oysters can be found from shallow subtidal areas to depths in excess of 50 m (Talavera 1930).

The genetic connectivity of *P. maxima* populations across WA, the NT and Indonesia was investigated using microsatellite markers by Benzie & Smith-Keune (2006). Results indicated high levels of gene flow and connectivity among populations at the Lacepedes, Eighty Mile Beach (both shallow and deep water areas), Port Hedland and Exmouth Gulf. There was some evidence of genetic differentiation, however, between Exmouth Gulf and the more northern WA populations, as well as between WA populations and Darwin (NT) populations. The Indonesian populations were significantly different from all Australian populations, suggesting little or no direct recruitment to WA or the NT from Indonesian sources (Benzie & Smith-Keune 2006).

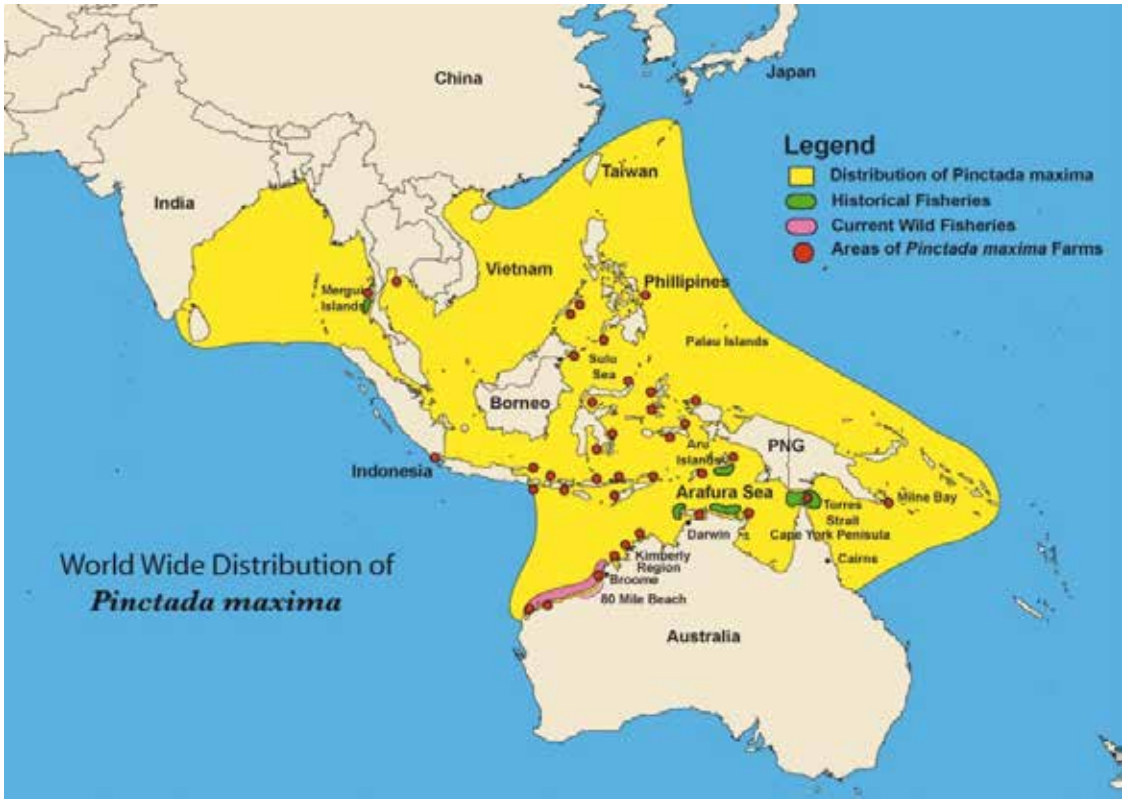

Figure 5. Distribution of silver-lipped pearl oysters (*Pinctada maxima*) and areas of historical and current wild capture fisheries and pearl farms

The life cycle of *P. maxima* is typical of many marine bivalves — they are a broadcast spawner, with each individual capable of producing millions of viable eggs (Rose & Baker 1994). *P. maxima* are a protandrous hermaphrodite, i.e. the animals maturing first as males at approximately 3 – 4 years of age and at a size of 110 to 120 mm SL, then undergoing a sex change and becoming female, with majority female by 190 mm SL. *P. maxima* are also rhythmic hermaphrodites and can have more than one sex reversal during their lifetime (Saucedo & Southgate 2008).

The breeding season of *P. maxima* is very long, occurring from spring (September / October) to autumn (April / May). Although there is variability from month to month, the primary spawning occurs from the middle of October through December. A smaller secondary spawning event occurs in February and March (Rose et al. 1990; Rose & Baker 1994).

During the spawning season, gametes (both sperm and eggs) are released into the water column, where fertilisation occurs.

After fertilisation, the animals develop into a tiny veliger stage. This planktonic veliger stage is a distributional phase that allows the young pearl oysters to colonise new areas, if suitable substrates can be found. The movements of larvae prior to settlement on the benthos are dictated to by physical oceanographic processes, such as wave action, prevailing winds and currents. During this period, *P. maxima* larvae on WA's north-west shelf are predominantly transported < 30 km; however, some can be transported as far as 60 km (Condie et al. 2006).

Like most bivalves, *P. maxima* are filter feeders, i.e. they use their gills to filter small food particles out of the surrounding water column. Growth rates are initially fast; field measurements at Eighty Mile Beach have shown that *P. maxima* reach 120 mm SL in their third year of life. They can be fished for three to four years before growing to a size where they are no longer suitable for round pearl culture (i.e. > 175 mm SL). *P. maxima* can reach 270 mm SL (Rose & Baker 1994) and live for 15 – 20 years (Joll 1996).

3.5 Research and Monitoring Activities

3.5.1 Statutory Reporting

There is a statutory obligation for fishers in the POF to provide a daily catch and effort logbooks (recorded in 10 x 10 nm statistical reporting blocks), which includes information on daily catch by numbers of the two size classes (i.e. 100 – 175 mm SL and > 175 mm SL), effort in dive hours, depth fished, statistical reporting block, visibility, quota record and tag numbers for the panels where oysters are stored. This information has been collected since the 1980s, although catch information is also available dating back to the 1890s.

3.5.2 Additional Monitoring

Monitoring of wild *P. maxima* stocks is undertaken by the Department in order to better estimate stock abundance and fishing impacts. Regular monitoring activities include:

- Annual length-frequency monitoring: Research observers take measurements of pearl oysters during approximately three of the 5 – 10 discrete fishing trips that occur each year, with 4000 – 13 000 pearl oysters measured from 100 – 200 sites per year. Data collected include length frequency information, spatial location and incidence of bio-eroding sponge infestation, which is a general measure of the health of the pearl oyster.
- Population surveys: Population surveys have been undertaken annually since 2007 and provide an independent time series of stock abundance to compare against fishery catch rates. Population length-frequency data are collected by spatial location (GPS) and depth, with 3000 – 5000 pearl oysters measured from 30 – 150 sites per year. These surveys provide both an index of pre-recruitment abundance, which can be compared with earlier predictions from the recruitment spat surveys, and an index of breeding stock abundance (pearl oysters > 175 mm SL), which can be compared over time.

- Recruitment monitoring: Recruitment monitoring is used to measure the abundance of each year class using a 'piggyback' spat recruitment index (Hart and Joll 2006). The index involves counting juvenile pearl oysters (spat) that have recently settled on adult pearl oysters ('piggybacked'). The annual change in recruitment strength measured by this index is one of the primary tools used to forecast future stock abundance and consequently, the annual TAC. Spat samples are obtained during 200 – 800 drift dives per fishing year, and are counted, measured, and separated into two age classes (age 0+ or age 1+) based on their size frequency. Between 30 000 and 155 000 adult pearl oysters are inspected each year.

  Environmental monitoring: The environmental monitoring program consists of two components: (a) on-board vessel monitoring for three key environmental factors, depth, water visibility, and habitat type and (b) long-term monitoring of broad environmental factors such as sea surface temperature (SST), rainfall, frequency of cyclones, wind components and the Southern Oscillation Index (SOI), which are obtained from independent environmental monitoring programs implemented by various Government agencies and other organisations.

  Environmental factors have been found to have a relatively large influence on both pearl oyster abundance and fishing efficiency. Significant negative relationships have been found between pearl oyster abundance and rainfall, with positive relationships between abundance and temperature for both spat settlement and fishery catch rates at appropriate lags (Hart et al. 2010).

3.5.3 Other Research

In addition to the research conducted as part of the above monitoring programs, the Department's Fish Health Unit also provide a comprehensive disease-testing program to the WA pearling industry.

There are several other research projects being conducted by the WA pearling industry focusing on environmental management, improved health and safety for pearl divers and pearl oyster health, including investigating aspects of oyster oedema disease (OOD) in *P. maxima* in order to assist in mitigating the impacts and understanding pathways to diseases and disease response.

3.6 Catch and Effort in the POF

The ongoing recording of catch and effort provides a long time series of information the catch of *P. maxima* and fishing effort in the POF.

Since 1979, total annual catches of *P. maxima* have fluctuated between 330 000 and 830 000 pearl oysters (with an average of 530 000 pearl oysters ± 120 000 SD; Figure 6). The POF is primarily based in Zone 2, which has supplied 70 % of the total harvest of *P. maxima* in the past 30 years. In more recent years, Zone 2 has supplied all of the *P. maxima* catch due to the cessation of fishing in the Zones 1 and 3 for economic reasons (Figure 6). In 2014, the WA pearling industry recommenced fishing in the buffer zone (area between Zone 1 and 2). Since

1979, total effort in Zones 2/3 has fluctuated between 3000 and 23 000 dive hours, with an overall average of 14 400 dive hours ± 4000 SD (Figure 7).

A high proportion of the TAC has been caught every year since the TAC was introduced in the early 1980s, except for the last few years of operation (Figure 8). The TAC was not caught during this time for two reasons: (1) the reduced market demand for pearls due to the global financial crisis, which began in 2008, and (2) the very high abundance of *P. maxima* in 2009 – 2012 due to an exceptional year of settlement in 2005, which resulted in a stock abundance well in excess of the capacity of the fishing fleet and market demand.

Catch rate indices for 100 – 175 mm SL *P. maxima* are derived from the daily catch and effort reported by fishers in their logbooks. The data collected are of the finest possible resolution, i.e. full details are recorded for every single dive. These indices are standardised to account for variables that influence catching efficiency and *P. maxima* abundance. Catch rates in recent years have been exceptionally high due to good recruitment, and although catch rates are now returning to normal levels, they are still within the target range (Figure 9).

Between 1987 and 2009, very little fishing occurred on the breeding stock (i.e. *P. maxima* greater than 175 mm SL), providing a very high level of protection to the overall stock. Since that time, very limited and tightly controlled fishing for these larger pearl oysters has taken place.

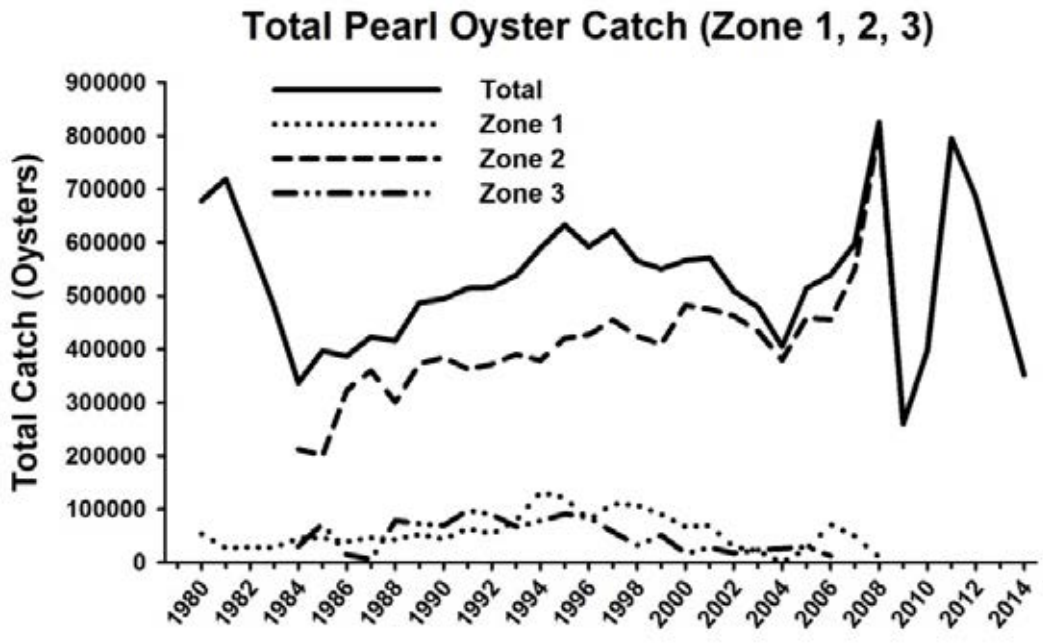

Figure 6. Catch (in numbers) of *Pinctada maxima* in the Western Australian Pearl Oyster Fishery by fishing zone and the combined total catch; Note 2014 data incomplete at time of publication.

Figure 7. Total nominal effort (dive hours) in Zones 2/3; Note 2014 data incomplete at time of publication.

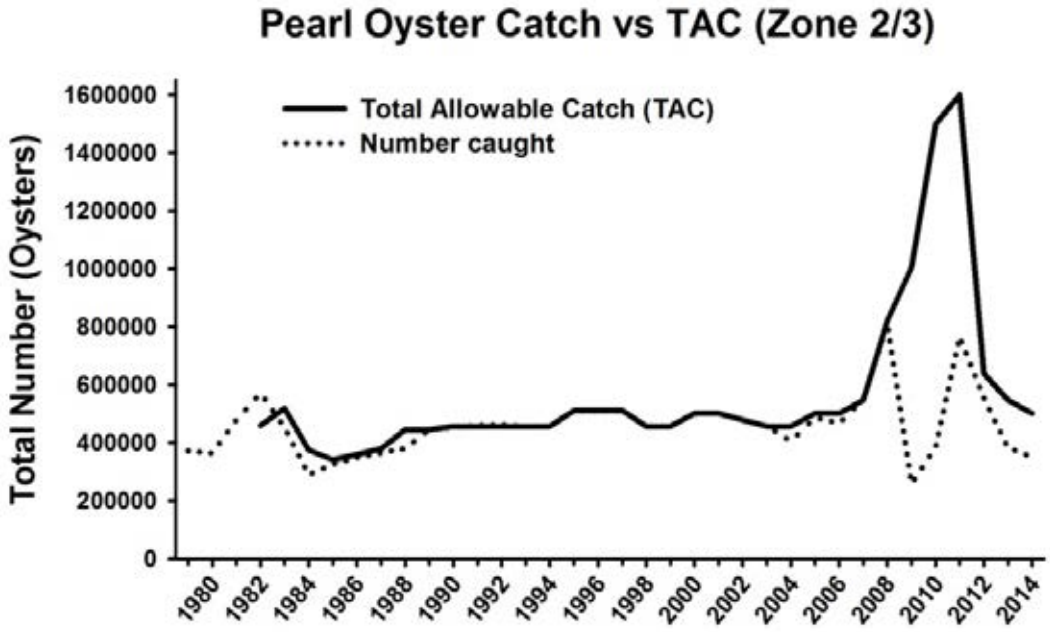

Figure 8. Total catch of culture shell (in numbers) of *Pinctada maxima* compared with the annual total allowable catch (Total Allowable Catch) for Zones 2/3; Note 2014 data incomplete at time of publication.

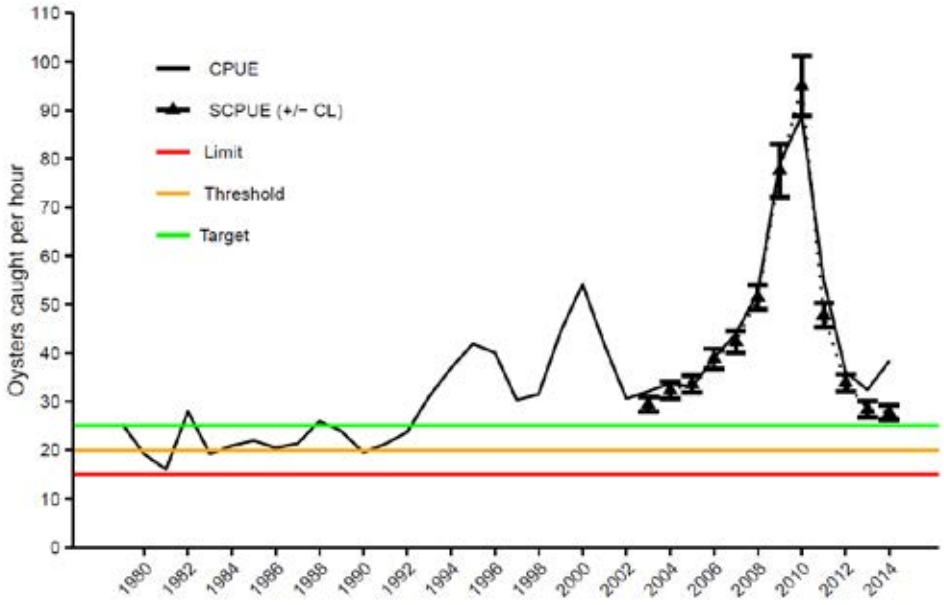

Figure 9. Raw CPUE and standardised CPUE of pearl oysters (120 – 175 mm shell length) in Zone 2 of the Pearl Oyster Fishery. Harvest reference levels are also shown.

3.7 Major Environments

3.7.1 Physical Environment

WA pearling industry operations extend across two Bioregions, from Exmouth Gulf in the Gascoyne Coast Bioregion northwards across the North Coast Bioregion to the NT border, although the majority of activities occur in the North Coast Bioregion along the Pilbara and Kimberley coasts. Wild pearl oysters are mainly collected off Eighty Mile Beach and in a channel between the mainland and the Lacepede Islands at approximately 10 – 20 m depths.

The Gascoyne Coast Bioregion represents a transition zone from the warm, tropical waters of the north and the cooler, more temperate waters in the southwest. Average temperatures range from 17º C to 27º C, with the coolest temperatures during July. Rainfall averages ~ 300 mm annually, with rainfall in both winter and summer because of the influence of tropical cyclones, the incursion of warm, moist air from the Kimberley region and mid-latitude depressions. Tropical cyclones in the north around Exmouth Gulf (Zone 1 of the POF) with wind speeds in excess of 40 – 50 knots occur every three to five years, with less intensive systems occurring annually from January to March (Fletcher et al. 2006).

The North Coast Bioregion is known for its unique combination of features that distinguish it from other marine bioregions around Australia, including a wide continental shelf, very high tidal regimes, high cyclone frequency, unique current systems and warm oligotrophic surface waters (Brewer et al. 2007). The North Coast Bioregion exhibits monsoonal climatic patterns, with a pronounced cyclone season between December and March each year. During this time, the northern Kimberley region experiences a wet season with large influxes of run-off, and the Pilbara coast is subject to sporadic and intense storms (DEWHA 2008). The Bioregion is subject to very high evaporation rates (3 metres per year), although the Pilbara coastline is more arid than the Kimberley due to its lower annual rainfall. Ocean temperatures range

between 22° C and 33° C, with localised higher temperatures in coastal waters, particularly along the Pilbara coast (Fletcher & Santoro 2014).

Most of the marine habitats of the Pilbara coast are considered to be in relatively pristine condition. Coastal and shallow water habitats along the Pilbara coast include mangrove forests, macroalgae and seagrass beds and fringing coral reefs around some of the nearshore islands (CALM 2005; NWSJEMS 2007). Algae and coral are dominant on shallow sandbars, platforms, reefs and ridges in the southern section of the region, although patchy seagrasses can also be found on the limestone flats. Several types of coral reefs characterise the coral communities of the Pilbara coast, which comprise both turbidity-adapted communities in inshore environments and offshore, clear-water coral communities. Scleractinian corals can be found in the turbid nearshore waters, although most coral reefs are developed around the more distant islands, notably those in the Dampier Archipelago (IMCRA 1998).

The Kimberley coast is one of the most remote and inaccessible stretches of the Australian coast, extending for a distance of over 1000 km, much of which is uninhabited. Due to this lack of development and isolation, the Kimberley marine environment is recognised as among the world's most pristine and ecologically diverse (Masini et al. 2009). The large tidal amplitudes and the extensive and complex coastline combine to produce ecologically-diverse and highly-productive intertidal areas ranging from cliffed coasts to wide expanses of mud flats, sand banks, coral and algal reef flats, mangrove forests and beaches (Masini et al. 2009).

Subtidal habitats include macroalgal reefs, corals, seagrasses and filter-feeding communities. Mangrove communities are well developed along the Kimberley coast and are considered to be relatively pristine (Wilson 1994). Extensive and diverse intertidal seagrass meadows occur around islands in the western Kimberley. Filter-feeder communities (e.g. sponge beds) are patchily distributed and vary in spatial extent, diversity and cover, but generally appear to be associated with stable, hard substrates overlain by sand veneers in areas of gently shelving bathymetry. Coral communities are not well developed in the western Kimberley. North and east of Cape Leveque, however, coral communities become well developed in nearshore environments (with the exception of within King Sound due to high water turbidity).

3.7.1.1 Habitats Encountered by Industry

The seabed in pearl oyster fishing grounds is typically a flat basement rock with very little relief. Fine sediment accumulates on this rock to a depth of a few millimetres, obscuring the underlying rock surface. A variety of organisms attach to the rock surface and provide a vertical relief of up to one metre off the bottom (Fletcher et al. 2006; Daume et al. 2009). The pearling industry has recognised a variety of bottom types within the pearl oyster fishing grounds and has developed names for them over the years, such as 'stone', 'potato' and 'garden' bottoms. All habitats share a common feature of being located over rock substrate and comprise a wide variety of invertebrates.

A 'stone' bottom is comprised of stone and coral rubble of various sizes covered by coralline red algae and rounded by the rolling effect from tides and currents. A mixture of whips corals, sea fans, sponges and coloured corals can be attached (Daume et al. 2009). 'Potato'

bottom areas are dominated by low, round, densely-spaced ascidian species, which live attached to the bottom. The seafloor has a flat plate of underlying rock, overlain with a few millimetres of sand. In areas of heavy 'potato' bottom, the ascidians are almost completely dominant. Sponges are the next main group, with a large variety of vase-shaped, basket and massive sponges up to 0.5 metres high interspersed with smaller sponges only a few centimetres high. Total diversity is low, with very few corals present. Bare sand patches can be interspersed between areas of 'potato' bottom, and faunal density rapidly decreases in areas where sediment is 2 – 3 cm deep (Fletcher et al. 2006; Figure 10a). The 'garden' bottom is a very diverse assemblage dominated by hydroids. The hydroids grow rapidly up to one metre in height and quickly become encrusted with a variety of organisms, some of which are very colourful. Distance between hydroids is variable, but on average, they grow about one metre apart. Other than hydroids, a variety of sponges are present on the bottom. Ascidians are also present but are a larger species than that found on 'potato' bottom. Other fauna present include soft corals, sea pens and crinoids. No hard corals are generally found (Fletcher et al. 2006; Figure 10b).

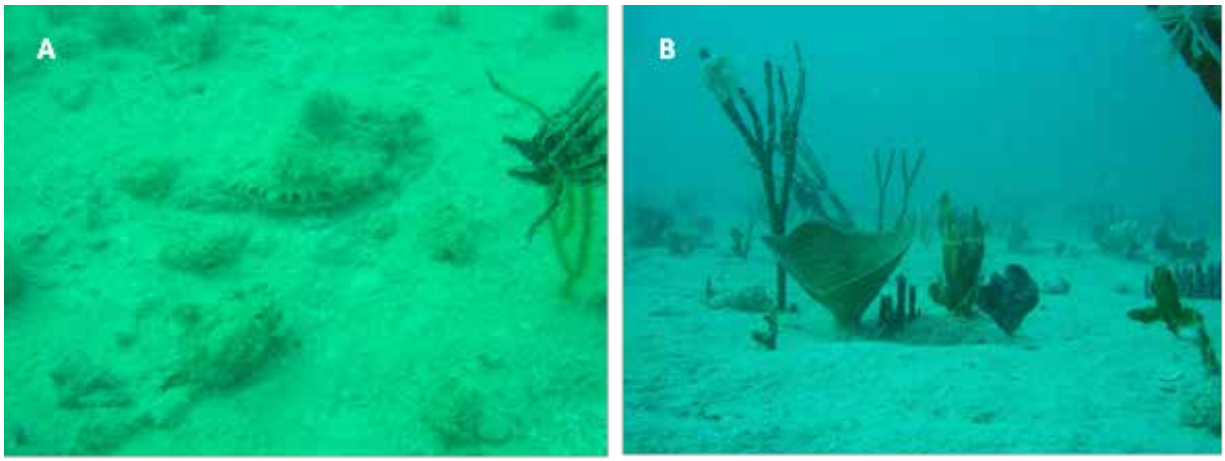

Figure 10. Example of the two main habitat types encountered in the Pearl Oyster Fishery: (a) 'potato' bottom (with pearl oyster) and (b) 'garden' bottom

3.7.2 Social Environment

Pearl oyster fishing vessels operate from the Lacepedes north of Broome south to Exmouth Gulf. There are currently 6 – 10 fishing vessels, each with 10 – 14 crew members, operating between January and August each year. These vessels also support a number of other pearl farm functions throughout the year, and fleet managers are employed by pearling companies to coordinate and support vessel operations.

The WA pearling industry employs approximately 1500 people from regional centres, primarily Broome (Fletcher et al. 2006).

3.7.3 Economic Environment

The pearls produced in WA are well regarded in the industry worldwide, with the value of cultured pearls and other related products considered to be approximately AUD 61 million in 2013 (Hart et al. 2014). In addition to pearls, which are supplied to a global market, pearl meat and MOP for buttons and inlay work are sold nationally and internationally.

4. Risk Assessment Methodology

4.1 Framework

Implementing ESD in fisheries means that fisheries managers not only need to consider the effects of the fishing industry on the target species, but also what effects there may be on the rest of the ecosystem. Fisheries managers also need to recognise the economic and social sustainability of an industry, such as profits or fisher satisfaction, relies on maintaining essential ecological processes. Additionally, the ongoing utilisation of industry resources requires the broader community to be satisfied with the management of the industry and be convinced that the industry provides sufficient social and/or economic benefits to justify any negative impacts it may have. Finally, the processes and procedures involved in managing a fishing industry, i.e. its governance, have to be appropriate to meet the ESD challenge (Fletcher et al. 2002).

The Department has implemented an ecosystem-based fisheries management (EBFM) approach as the primary strategy to achieve the goal of ESD for fisheries in WA. EBFM deals with the aggregate management of all fisheries-related activities within an ecosystem or bioregion and takes into account the impacts of fishing on retained species, discarded (bycatch) species, protected species, habitats and the broader ecosystem — regarded as 'ecological assets / components' — as well as associated social, economic, and governance outcomes. In utilising a broad EBFM approach, fisheries managers are required to consider a wide and diverse set of issues.

Risk assessments offer a means to filter and prioritise the various identified issues for management and have been used in fisheries management in Australia for over a decade (Fletcher et al. 2002). The risk analysis methodology utilised for the WA pearling industry risk assessment is based on the global standard for risk assessment and risk management (AS/NZS ISO 31000), which has been adopted for use in a fisheries context (see Fletcher et al. 2002; Fletcher 2005; Fletcher 2015). In line with Fletcher et al. (2002), the risk analysis process undertaken for the WA pearling industry involved: (1) the identification of fishery components and sub-component, i.e. building component trees; (2) an examination of the sources of risk associated with each component, i.e. issue identification; and (3) the scoring of the potential consequences (impacts) associated with each issue and the likelihood (probability) of a particular level of consequence actually occurring.

4.2 Scope

This risk assessment covers the wild capture, hatchery and cultivation activities that occur as part of the WA pearling industry.

For the purpose of this assessment, risk was defined as *the uncertainty associated with achieving a specific fishery management objective or outcome* (adapted from Fletcher 2015). Thus, the risk scores reflect the uncertainty in meeting the management objective for each component of the WA pearling industry over the next five years.

4.3 Building Component Trees and Identifying Issues

In line with the principles of ESD, four aspects were considered in the risk assessment:

- Ecological sustainability — the impact of the pearling industry on ecological resources/assets;
- Community wellbeing — the contribution of the WA pearling industry to local, regional and global social and economic wellbeing;
- External factors — external environmental, social and economic drivers that impact the WA pearling industry's performance; and
- Governance — management processes and arrangements that impact the WA pearling industry's performance.

Scoping work to identify components and sub-components within each of these four areas was undertaken by Departmental research and management staff and the pearling industry in August 2015 prior to the stakeholder's workshop. Issues were identified using the assistance of the component tree approach (Fletcher et al. 2002). The identification of issues was guided by the generic ESD component trees to include issues that were applicable to the pearling industry. Industry-specific issues were determined based on previous risk assessments undertaken for the industry and identified gaps in the Marine Stewardship Council (MSC) performance indicators (as identified during a pre-assessment of the industry against the MSC Fisheries Standards in 2014).

4.4 Risk Analysis and Scoring

After all the components and issues were identified, a risk analysis process to prioritise each of these issues was completed using the formal ISO 31000-based qualitative risk assessment methodology. This methodology utilises a consequence-likelihood analysis, which involves the examination of the magnitude of potential consequences from fishing activities and the likelihood that those consequences will occur given current management controls (Fletcher 2015).

The analysis used a set of pre-defined consequence and likelihood levels (see Appendix B). Consequence and likelihood analyses range in complexity; here, we applied a 5 x 5 level system, with the consequence levels ranging from 1 (e.g. minor impact/consequence to fish stocks) to 5 (e.g. catastrophic consequences for fish stocks) and likelihood levels ranging from 1 ('remote', i.e. < 5 % probability) to 5 ('certain', i.e. > 90 % probability). Scoring involved assessing the likelihood that each level of consequence is actually occurring or is likely to occur within the next five years. Note that if an issue was not considered to have any measurable impact, it was considered to be a 0 consequence; however, this was only permitted where the likelihood of each other consequence level occurring was 0 (i.e. so remote that it is considered essentially impossible in the next five years). The scores for each of the consequence and likelihood levels were then multiplied to determine the risk score, i.e. Risk = the highest Consequence × Likelihood (Figure 11).

The formal risk analysis was conducted at a stakeholder workshop held on 27 August 2015 in Broome, WA. Stakeholders present during the workshop included the commercial pearling industry, the Western Australian Fishing Industry Council (WAFIC), environmental groups, the WA Department of Fisheries and the NT Department of Primary Industry and Fisheries (full attendance and participant list provided in Appendix A). The group at the workshop made a realistic estimate of the risk level for each issue, based on the combined judgement of the participants at the workshop, who collectively were considered to have appropriate expertise on the areas examined.

The level of consequence was determined at the appropriate scale for the issue, i.e. for the retained, non-retained and endangered, threatened and protected (ETP) species, the consequence of the pearling industry was based at the stock / population level; habitats were considered in relation to the entire extent of the habitat and the ecosystem / environment was considered at a whole-of-system scale. Community wellbeing and economic issues were scored at the appropriate scale, e.g. the pearling industry, the local community (Broome and surrounding areas) and / or the broader community (Australia-wide and internationally).

Based on the calculated score, each issue was assigned a Risk Rating within one of five categories: Negligible, Low, Medium, High or Severe (Table 1). The rationale for classifying issues at each risk level was documented at the workshop and forms the majority of this report. This allows all stakeholders and interested parties to see the rationale and justification for the final risk ratings.

		Likelihood				
		Remote (1)	Unlikely (2)	Possible (3)	Likely (4)	Certain (5)
Consequence	Minimal (1)	1	2	3	4	5
	Moderate (2)	2	4	6	8	10
	High (3)	3	6	9	12	15
	Major (4)	4	8	12	16	20
	Catastrophic (5)	5	10	15	20	25

Figure 11. 5 x 5 Consequence — Likelihood Risk Matrix (based on AS 4360 / ISO 31000) used for the risk analysis (from Department of Fisheries 2015)

Table 1. Risk levels applied to all resources/assets by the Department of Fisheries WA (modified from Fletcher 2005)

Risk Category / Level	Description	Likely Reporting & Monitoring Requirements	Likely Management Action
1 Negligible	Acceptable; Not an issue	Brief justification – no monitoring	Nil
2 Low	Acceptable; No specific control measures needed	Full justification needed – periodic monitoring	None specific
3 Medium	Acceptable; With current risk control measures in place (no new management required)	Full Performance Report – regular monitoring	Specific management and/or monitoring required
4 High	Not desirable; Continue strong management actions OR new / further risk control measures to be introduced in the near future	Full Performance Report – regular monitoring	Increased management activities needed
5 Severe	Unacceptable; Major changes required to management in immediate future	Recovery strategy and detailed monitoring	Increased management activities needed urgently

5. Risk Assessment Results

The majority of issues identified for the pearling industry were considered to be a low or negligible risk (Table 2), and no issues related to ecological sustainability were considered to be medium or high risk. Specific issues are presented below, along with a brief justification for the final scoring. Note the risk justifications include comments from individual stakeholders at the workshop; these comments are a summary of individual views and may not be representative of every stakeholder at the workshop; however, the risk scores are reflective of the group consensus at the workshop, as well as follow-up discussions between the Department, industry and workshop participants. Where discrepancies in risk levels occurred, all risk ratings are provided, along with the justification for any differences.

Table 2. Summary of risk scores across each aspect considered in the 2015 risk assessment of the pearling industry

	Component	Risk Score				Total
		Negligible	Low	Medium	High	
Ecological Sustainability	Retained Species	4	3	0	0	**7**
	Non-retained Species	1	0	0	0	**1**
	ETP species	11	0	0	0	**11**
	Habitats	4	0	0	0	**4**
	Ecosystem Structure	3	0	0	0	**3**
	Broader Environment	4	0	0	0	**4**
External Factors	Environment: Natural Changes	4	2	0	0	**6**
	Environment: Human-induced Changes	0	3	0	1	**4**
	Social Drivers	1	0	0	0	**1**
	Economic Drivers	0	4	2	0	**6**
	Access	2	1	1	2	**6**
Comm. Well-being	Fishing Industry	1	0	1	3	**5**
	Local Community	0	0	3	1	**4**
	Broader Community	2	1	0	0	**3**
Governance	Government: Department of Fisheries	0	1	1	2	**4**
	Government: Other Agencies	0	0	0	1	**1**
	Industry	0	0	3	0	**3**
	Other Stakeholders	0	2	2	0	**4**
Total		**37**	**17**	**13**	**10**	**77**

5.1 Ecological Sustainability

Fourteen ecological sub-components were identified as potentially impacted by the pearling industry's operations (Figure 12), with 30 associated issues (Table 3). All issues were considered to be a low or negligible risk.

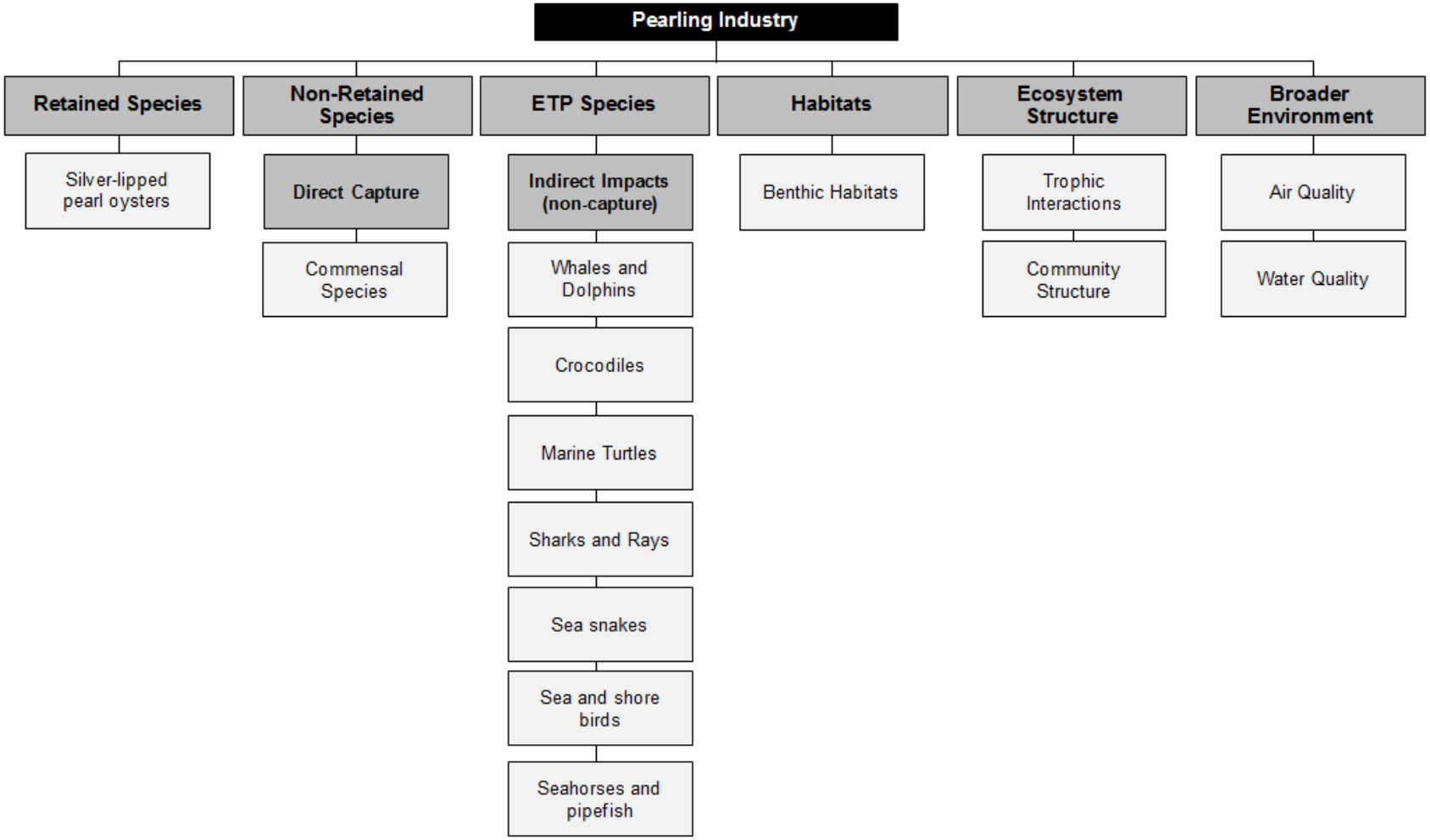

Figure 12. Component tree for ecological sustainability aspects of the pearling industry

Table 3. Overview Table of Identified Components, Objectives, Sub-Components, Issues assessed risk ratings related to the Ecological Sustainability of the pearling industry

Component	Industry Objective	Sub-Component	Issue	Risk Rating
Retained Species	To maintain spawning stock biomass of *P. maxima* at a level where the main factor affecting recruitment is the environment	Silver-lipped pearl oyster, *P. maxima*	Collection of pearl oysters from the wild (WA specific)	**LOW**
			Collection of pearl oyster from the wild (NT specific)	**NEGLIGIBLE**
			Translocation: impact on genetic structure of pearl oyster populations	**NEGLIGIBLE**
			Translocation: transfer of diseases between pearl oyster populations (all Zones)	**LOW**
			Hatchery propagation: impact on genetic structure of pearl oyster populations	**NEGLIGIBLE**
			Hatchery propagation: transfer of diseases between wild pearl oyster populations	**NEGLIGIBLE**
			Hatchery propagation: transfer of diseases between hatchery populations	**LOW**
Non-retained Species	To ensure fishing impacts do not result in serious or irreversible harm to bycatch (non-retained) species' populations	Commensal / Fouling ('Piggyback') Species	Loss of habitat for fouling / commensal species populations from pearl oyster collection	**NEGLIGIBLE**
ETP Species	To ensure fishing impacts do not result in serious or irreversible harm to ETP species' populations	Whales and Dolphins	Boat strike	**NEGLIGIBLE**
			Entanglement in culture lines	**NEGLIGIBLE**
		Crocodiles	Boat strike	**NEGLIGIBLE**
			Entanglement in culture lines	**NEGLIGIBLE**
		Marine Turtles	Boat strike	**NEGLIGIBLE**
			Entanglement in culture lines	**NEGLIGIBLE**
		Sharks and Rays	Entanglement in culture lines	**NEGLIGIBLE**
		Sea snakes	Entanglement in culture lines	**NEGLIGIBLE**
		Sea birds	Disturbance from industry activities	**NEGLIGIBLE**

		Shore birds ('waders')	Disturbance from industry activities	**NEGLIGIBLE**
		Seahorses and Pipefish	Entanglement in culture lines	**NEGLIGIBLE**
Habitats	To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function	Benthic Habitats	Diver activities	**NEGLIGIBLE**
			Anchoring	**NEGLIGIBLE**
			Holding and Dump Sites	**NEGLIGIBLE**
			Farm Leases	**NEGLIGIBLE**
Ecosystem Structure	To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes	Trophic Interactions	Removal / Addition of materials to the ecosystem	**NEGLIGIBLE**
		Community Structure	Depletion of phytoplankton at farm sites	**NEGLIGIBLE**
			Introduction of diseases, pests or invasive species	**NEGLIGIBLE**
Broader Environment	To ensure the effects of fishing do not result in serious or irreversible harm to the broader environment	Air Quality	Fuel usage / Exhaust fumes	**NEGLIGIBLE**
			Greenhouse gas emissions	**NEGLIGIBLE**
		Water Quality	Debris / Litter	**NEGLIGIBLE**
			Oil discharge	**NEGLIGIBLE**

5.1.1 Retained Species

5.1.1.1 Silver-lipped pearl oyster (*Pinctada maxima*)

5.1.1.1.1 Collection of pearl oysters from the wild

Rationale for Inclusion: The silver-lipped pearl oyster, *P. maxima*, is the only species targeted in the POF. It is fished commercially on the northwest coast of WA from Exmouth Gulf in the south to the Lacepede Islands in the north. These pearl oysters are used for pearl cultivation, MOP and pearl oyster meat. Pearl oysters have historically been fished in Northern Territory waters; however, only a small amount of pearl oysters have been collected in the NT over the last few years. These oysters are primarily used for MOP production.

There is some evidence of genetic differentiation between Exmouth Gulf and the more northern pearl oyster populations, as well as between Darwin (NT) and WA populations (Benzie & Smith-Keune 2006). Impacts from wild collection on pearl oyster stocks in WA and the NT have therefore been assessed separately.

Risk Rating: Impact of wild collection on spawning stocks of silver-lipped pearl oysters in Western Australia — C2, L3 = 6; LOW

Risk Rating: Impact of wild collection on spawning stocks of silver-lipped pearl oysters in the Northern Territory — C1, L1 = 1; NEGLIGIBLE

Justification:

Western Australian stock:

- Catch and effort are reported at a high level of accuracy by fishers in daily logbooks, which include catch by numbers of the two size classes of oysters (100 – 175 mm SL and greater than 175 mm SL), effort in dive hours, depth fished, statistical reporting block (10 x 10 nm), visibility, quota record and tag numbers for the panels where the pearl oysters are stored.
- Total catch of pearl oysters has been successfully controlled by the TAC for over 30 years. The current system of adjusting the TAC in response to predicted abundance will continue to be applied into the future.
- Effort is tightly controlled and has remained relatively stable, excepting 2009 and 2010, when it fell substantially due to economic conditions (following the global financial crisis).
- Catch rates in recent years have been exceptionally high due to good recruitment in 2005 and, while returning to normal levels, are still within the target catch rate range.
- Although variable, there has been consistent recruitment of pearl oysters since monitoring of 0+ spat began. Variation in recruitment has been well-explained by environmental factors.
- A relationship between catch rates and previous recruitment has been found to be highly informative for predicting future abundance, allowing for pre-emptive

management. The catch rates for 2013 and 2014 occurred as predicted, and predictions for 2015 and 2016 indicate as small increase in catch rates for these years.

- Between 1987 and 2009, little to no fishing occurred on the breeding stock (i.e. pearl oysters greater than 175 mm SL), thus providing a very high level of protection to the overall stock. Since that time, limited and tightly-controlled fishing for these larger pearl oysters has taken place.

Northern Territory stock:

- Pearl oysters have been fished in NT waters since the late 1880s, primarily for MOP production. In general, the fishing grounds in the NT are deeper, more-isolated and patchier and have a higher proportion of pearl oysters not suitable for round pearl culture than the areas fished off WA.
- Currently only a very small amount of pearl oysters are collected for MOP shell annually — approximately 5000 oysters over the last 2 – 3 years (M. Barton, NT Dept. of Primary Industries and Fisheries, pers. comm. 2015).
- The NT fishery has historically supported much higher catches than current levels, with production peaking in the 1950s at around 1100 tonnes. In the 1970s, the industry started using culture stock from WA, reducing the reliance on local pearl oyster collection. From 1987 to 1993, there was renewed interest in harvesting pearl oysters from NT waters, with average yields during this period of 40 tonnes per year (NT Government 2012).
- Since 1994, there has been very limited harvesting of pearl oysters due to a reliable supply of hatchery reared oysters, combined with poor yields of good culture stock from the local pearling grounds (NT Government 2012).

5.1.1.1.2 Translocation of pearl oysters

Rationale for Inclusion: As part of industry operations, pearl oysters are moved from fishing areas in WA to dump/holding sites and farm leases in WA and farm leases in the NT. The translocation of a species among different geographic areas may pose a risk to the genetic diversity of wild populations.

Additionally, the movement of oysters from one area to another may also result in the transfer of diseases between populations via contaminated diving equipment, vessel biofouling, contaminated water, pearling equipment and infrastructure, the cleaning of pearl oysters and the movement of pearl oysters themselves.

Risk Rating: Impact of translocation on genetic structure of silver-lipped pearl oysters populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Restrictions are imposed on the transport of *P. maxima* under the WA *Pearling Act 1990* and the *Pearling (General) Regulations 1991*. Regulation 42 of the *Pearling*

(General) Regulations 1991 outlines when transport approvals and health certificates are required.

- The *Pearl Oyster Translocation Protocol* is utilised in decision making related to the application for pearl oyster transport approvals. The Protocol is reflective of the current legislation and governs the movement of hatchery-produced pearl oysters and the movement of oysters between farms. It also applies to the movement of pearl oysters into WA.
- Part 13A of the FRMR also regulates the control of disease within pearl oysters.
- Restrictions are also imposed on the translocation of pearl oysters under the *NT Fisheries Act* and the *NT Fisheries Regulations* (Regulation 16). The Zoning strategy for Disease Control in the NT is utilised in decision making related to the application for pearl oyster translocation approvals.
- Studies undertaken by Johnson & Joll (1983) and by Benzie & Smith-Keune (2006) found WA and NT populations of *P. maxima* to be genetically different. Thus, despite substantial historical translocation of *P. maxima* from WA into NT, the regional population structure has been maintained (i.e. is not genetically homogenous), suggesting that pearl culturing has had minimal (if any) genetic impacts on wild stocks.
- A study on the impacts of cultured stock on the genetic structure of wild black-lipped pearl oyster (*P. margaritifera*) populations showed no impact of extensive pearl farming on the genetic structure of wild populations (Arnaud-Haond et al. 2003).

Risk Rating: Impact of translocation on transfer of diseases between silver-lipped pearl oyster populations — C3, L2 = 6; LOW

Justification:

- All pearl oyster shells collected from the wild are cleaned at the fishing area prior to being moved to dump or holding sites. This practice helps to prevent the spread of diseases or pests between fishing and holding areas.
- Restrictions are imposed on the transport of *P. maxima* under the *Pearling Act 1990* and the *Pearling (General) Regulations 1991* and the FRMR (Part 13A only). Additionally, the *Pearl Oyster Translocation Protocol* is utilised in decision making related to the application for pearl oyster transport approvals. The Protocol reflects the pearling legislation and provides guidance on the movement of hatchery-produced pearl oysters and the movement of pearl oysters between farms. Although the *Translocation Protocol* is not a statutory document, there is a high level of compliance with the recommended procedures, as any deviation may delay or cause the refusal of translocation approvals by the Department.
- Transports require application by the pearling company for prior approval (Form P2) from a pearling inspector, with some transports requiring a health certificate. If a health certificate is required, significant quantities of samples from the batch to be transported are to be submitted to the government fish health division for health

clearance. This approval will be denied if there are disease concerns about a particular lease, hatchery or area. The Department maintains a passive surveillance program in this area, actively investigating any reports of abnormal mortalities, which are backed up by emergency response capability in the areas of both aquatic pests and diseases.

- A Departmental incident management protocol has been developed, which details protocols associated with emergency biosecurity response. The development of an industry specific rapid response plan would further improve management. The Department is equipped with state-of-the-art diagnostic laboratories and capability. It participates in nationally-coordinated proficiency testing programs and is accredited to ISO17025 for both pest identification and pathogen identification.
- The pearling industry has also developed a *Pearling Environmental Code of Conduct*, which outlines the environmental responsibilities of license holders. This Code of Conduct includes general practices for disease management (e.g. water quality management, hygiene and post seeding/harvest health).
- There have been minor problems with the introduction and transfer of diseases in the past; however, since the 1970's the only known disease is the spread of OOD in the Exmouth Gulf (Zone 1). This is thought to have occurred partly due to the boat movements, indicating that the disease was likely to be transferred between areas via boats or diving equipment.
- No wild collection has occurred in Exmouth Gulf in recent years.
- There is an ongoing research program in place which includes efforts to identify and develop tools to better understand the pathology and cause of OOD in pearl oysters. This information will help to inform disease protocols in the future.
- The FRDC project "Pearl Oyster (*Pinctada maxima*) Aquaculture: Health Survey of Northern Territory, Western Australia and Queensland Pearl Oyster Beds and Farms" (Humphrey et al. 1998) showed that there was no difference in the health status of NT and WA oyster beds and farms. Continued pre-movement testing of pearl oysters from both jurisdictions supports these findings.
- Fishing and farm leases overlap in Exmouth Gulf (Zone 1), although they are spatially separated by large distances in Zones 2/3 (fishing and farming) and 4 (farming only); however, as the same restrictions are utilised regardless of the distance transported.
- While pearl oyster diseases may have significant impacts at the farm level, the regulation and policies in place limit the likelihood of industry-wide impacts occurring.
- It was noted, however, that the introduction of some invasive species (e.g. *Didemnum*) would be harmful to nursery areas. This species could potentially be spread by pearling boats or other vessels operating in the region. Vessels operating in the industry are encouraged to comply with state-wide biofouling management guidance, including in-water cleaning guidance; however, no industry-specific protocols are currently in place for boats.

- Restrictions are also imposed on the translocation of *P. maxima* under the *NT Fisheries Act* and the *NT Fisheries Regulations* (Regulation 16). The Zoning strategy for Disease Control in the NT is utilised in decision making related to the application for pearl oyster translocation approvals.
- The NT Department of Primary Industries and Fisheries has developed protocols associated with emergency biosecurity responses. The Department of Primary Industries and Fisheries' Veterinary Laboratory is NATA accredited with specialists in pearl oyster diagnostic pathology.

5.1.1.1.3 Hatchery propagation of pearl oysters

Rationale for Inclusion: Hatchery-based enhancement may reduce the genetic diversity of wild stocks through intentional or unintentional artificial selection in the hatchery environment. Additionally, hatchery production of pearl oysters may also result in the introduction of new diseases in the wild populations.

In the POF, local pearl oyster broodstock are reared in a hatchery environment, with the hatcheries providing culture pearl oyster spat or pearl oysters to the WA pearling industry.

Risk Rating: Impact of hatchery propagation on genetic structure of silver-lipped pearl oysters populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Broodstock used in a hatchery must be produced in a hatchery or taken from Zones 1, 2 or 3 of the POF (i.e. all broodstock is derived from the wild WA pearl oyster stock). Thus, pearl oysters produced in hatcheries are genetically similar or the same as wild pearl oysters.
- Hatchery-reared pearl oysters are not used to enhance wild stocks.
- There are limits in place on the amount of hatchery-produced pearl oysters that can be seeded annually.
- Hatchery-bred pearl oysters are currently the minority of stock on WA pearl farms.
- The situation is different in the NT where the majority of stock are from hatchery bred oysters.
- The majority of the farms are situated a significant distance from the WA pearl oyster fishing grounds.

Risk Rating: Impact of hatchery propagation on the transfer of diseases in wild silver-lipped pearl oysters populations — C2, L1 = 2; NEGLIGIBLE

Justification:

- There are number of controls in place under the *Pearling Act 1990*, the *Pearling (General) Regulations 1991* (movement of all pearl oysters [including spat]), and the FRMR, with additional guidance provided in the *Pearl Oyster Translocation Protocol*

(pearl oyster [including spat] movement from hatcheries to farm leases and farm lease to farm lease movement), which reduce the likelihood of disease transfer between hatcheries and farm leases.

- All transports of pearl oysters produced from a hatchery require application by the pearling company for prior approval from a pearling inspector (Form P2), including a health certificate. All oysters leave the hatchery 'healthy' and are transported to farm areas. Once the pearl oysters arrive at the farm areas, however, they may be more vulnerable to disease than the wild pearl oysters until they acclimatise to the environment.
- Farm leases for grow-out of pearl oysters (both hatchery and wild caught pearl oysters) are spatially separated from the main fishing grounds by ~ 200 – 600 km, thus there is a low chance of hatchery-reared larvae reaching fishing grounds and settling. However, as previously discussed the Exmouth Gulf (Zone 1) is an area where fishing could occur in closer proximity to farm leases. A very small amount of fishing has been undertaken in Zone 1 in the last few years, with all fishing activity currently been within the Zone 1/2 border (outside Exmouth Gulf waters). Additionally, there are no longer any hatcheries located in the Exmouth Gulf (i.e. no hatchery activity is occurring).
- There has been no evidence of the introduction of diseases into wild populations or onto farm leases from hatchery-reared pearl oysters since the start of hatchery activities in WA and the NT.
- Translocation health testing is required on pearl oysters coming into the NT which minimises the risk of disease spread.

Risk Rating: Impact of hatchery propagation on the transfer of diseases between hatchery populations — C2, L2 = 4; LOW

Justification:

- The industry has experienced diseases issues on farms in the past (e.g. OOD); however, these diseases are not thought to have been introduced from hatchery-reared oysters.
- It is possible that a disease outbreak could occur in a hatchery, although it is considered unlikely due to the health protocols in place (under the FRMR, e.g. statutory health testing of spat after settlement and requirement of health certificates for movement of pearl oysters (including spat).

5.1.2 Non-Retained Species

5.1.2.1 Fouling or Commensal ('Piggyback') Species

5.1.2.1.1 Removal of pearl oyster substrate from environment

Rationale for Inclusion: Pearl oyster shells are encrusted with fouling / commensal organisms that use the shell of pearl oysters as substrate. These organisms are harvested together with the pearl oyster and are then scraped off the pearl oyster shell and discarded overboard.

Within WA and the NT, the primary pearl oyster fouling organisms include coralline algae and sponges, as well as ascidians, fire coral and other algae. Predatory sponges, boring annelids, gastropods and algae can also infest pearl oysters.

Risk Rating: Impact of pearl oyster collection and associated loss of habitat for fouling or commensal species' populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Biofouling organisms found on pearl oyster shells in WA and the NT are considered to be widespread and can live on a variety of substrates.
- The limited harvest of pearl oysters ensures an adequate level of shells remain within the fishing grounds to provide substrate for any organisms that may show a preference for shells as habitat.
- Most harvested pearl oysters are young and contain a smaller amount of biofouling compared to larger, older pearl oysters.
- Only a small proportion of the total abundance of commensal species found in the fishing areas are actually brought on board (with the collected pearl oyster) and subsequently discarded.

5.1.3 Endangered, Threatened and Protected (ETP) Species

5.1.3.1 Whales and Dolphins

Rationale for Inclusion: Over thirty species of whales and dolphins have been recorded along the Gascoyne, Pilbara and Kimberley coasts. This area is considered to be an important migratory pathway for several species including fin (*Balaenoptera physalus*), minke (*B. acutorostrata*) and pygmy blue whales (*B. musculus brevicauda*). The region is particularly important for the WA population of humpback whales (*Megaptera novaeangliae*), which have known breeding and calving grounds in the area between Broome and the northern end of Camden Sound (DEH 2005; Jenner et al. 2001).

Dolphins regularly seen in the inshore waters of the region include Australian snubfin dolphins (*Orcaella heinsohni*), Indo-Pacific humpback dolphins (*Sousa chinensis*), common bottlenose dolphins (*Tursiops truncatus*), Indo-Pacific bottlenose dolphins (*Tursiops adunctus*) and spinner dolphins (*Stenella* spp.). The distribution of each species varies, but all have localised and fragmented populations reflecting the scarcity of appropriate habitat and prey throughout the bioregion (SEWPaC 2012a).

5.1.3.1.1 Boat strike

Risk Rating: Impact of boat strikes on whale and dolphin populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Humpback whales considered likely to have highest amount of interactions due to their migration patterns and overlapping fishing activities. Only one boat strike is known to have occurred over the past few decades, with the whale surviving the encounter and swimming away.
- Whale interaction very uncommon in the NT as not a known breeding and calving area.
- Although inshore dolphins (e.g. Australian snubfin dolphins) have been shown to be vulnerable to boat strikes in Roebuck Bay (Thiele 2010), it is unlikely that pearl fishing vessels would hit a whale or dolphin. Pearl vessel skippers have higher level of boat handling skills and experience than recreational vessel users (e.g. tourists) and would be able to avoid a collision with any large megafauna species.
- There are a small number of boats operating in the POF, which each tow up to six divers at a time. While fishing, the boats travel at relatively slow speeds to allow divers to move across the beds and collect pearl oysters. This fishing method and small number of boats in the water reduces the likelihood of any interactions with protected species.

5.1.3.1.2 Entanglement in culture lines

Risk Rating: Impact of entanglements in culture lines on whale and dolphin populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Unlike fish farms that are netted at the periphery, the pearl farms have large open areas that small cetaceans can swim through, although some individuals may simply avoid the farm areas all together because of the equipment, human activities or other factors (Watson-Capp & Mann 2005).
- The majority of farm leases are situated in sheltered waters along the Kimberley coast north of Broome and the NT coast. These sites do not overlap normal migration paths of whales along the NT and WA coastlines, which are generally further offshore.
- The layout of the farms and use of surface longlines reduces the number of lines in the water and thus, the potential for whale entanglements.
- In the more than five decades of the Australian *P. maxima* pearling industry, there have been only two known humpback whale entanglement with farmleases. On both occasions the whale was successfully released.
- The pearling industry has implemented a *Whale Management Policy and Protocol* (PPA 2008b), which includes an overview of industry instructions for preventing whale entanglements and interactions and a response protocol should an interaction or entanglement occur.

5.1.3.2 Crocodiles

Rationale for Inclusion: Both saltwater (*Crocodilus porosus*) and freshwater crocodiles (*C. johnsoni*) can be found in the northern coastal waters of WA and the NT. Saltwater crocodiles are natural inhabitants of coastal waters and estuaries of the Kimberley, and can be found in tidal rivers, coastal floodplains and channels, billabongs and swamps up to 150 km inland from the coast (Webb et al. 1987). Freshwater crocodiles are endemic to Australia and only occur in the tropics (Webb and Manolis 1989). They prefer upstream freshwater areas and can be found in lakes, rivers and billabongs.

5.1.3.2.1 Boat strike

Risk Rating: Impact of boat strikes on crocodile populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- There are a small number of boats operating in the POF, which each tow up to six divers at a time. While fishing, the boats travel at relatively slow speeds to allow divers to move across the beds and collect pearl oysters. This fishing method and small number of boats in the water reduces the likelihood of any interactions with protected species.
- There have been no known boat strikes involving crocodiles or reported concerns about this occurring in the history of the pearling industry.

5.1.3.2.2 Entanglement in culture lines

Risk Rating: Impact of entanglements in culture lines on crocodile populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- There have been no known crocodile entanglements in culture lines or reported concerns about this occurring in the history of the pearling industry.

5.1.3.3 Marine turtles

Rationale for Inclusion: Six species of marine turtles have been reported in the waters along the north coast of WA and the NT: green (*Chelonia mydas*), loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), flatback (*Natator depressus*), leatherback (*Dermochelus coriacea*), and the occasional olive ridley (*Lepidochelys olivacea*). Turtle breeding areas throughout the region include Ashmore Reef (green, hawksbill and loggerheads), Browse Island, the Lacepede Islands, the North West Cape, Barrow Island, Muiron Islands and the Montebello Islands (Prince 1994). Turtle nesting occurs from October to February each year, and large turtle rookeries in the region include the Dampier Archipelago, Port Hedland's Cemetery Beach, Eighty Mile Beach, Broome's Reddell Beach and Eco Beach in the Kimberley.

The 6 species mentioned above also occur in the NT with the most important nesting areas located at Turtle Point in Joseph Bonaparte Gulf, Bare Sand and Quail Islands near Darwin, the south west of Bathurst Island, a number of beaches along the northern coastline of Melville Island, the Smith Point area of Cobourg Peninsula, the islands to the north and east of Croker Island, the Goulburn Islands, NW Crocodile Island, many of the outer islands of the numerous island chains off north eastern Arnhem Land, the mainland coast and islands between Cape Arnhem and Blue Mud Bay, the eastern part of Groote Eylandt and its associated islands and some of the outer islands in the Sir Edward Pellew Group. (Chatto et al 2008).

Individual turtles are likely to move through pearl farms from time to time, and as turtles are known to occasionally become entangled in other fisheries trap lines, it is also possible that they may become entangled in lines on pearl farms.

5.1.3.3.1 Boat strike

Risk Rating: Impact of boat strikes on marine turtle populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- There are a small number of boats operating in the POF, which each tow up to six divers at a time. While fishing, the boats travel at relatively slow speeds to allow divers to move across the beds and collect pearl oysters. This fishing method and small number of boats in the water reduces the likelihood of any interactions with ETP species.
- There have been no known boat strikes involving marine turtles in the history of the pearling industry.

5.1.3.3.2 Entanglement in culture lines

Risk Rating: Impact of entanglements in culture lines on marine turtle populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Turtles have been known to become entangled in trap lines in other fisheries; however, there have been no recorded entanglements of marine turtles in pearl culture lines in WA or the NT.

5.1.3.4 Sharks and Rays

Rationale for Inclusion: Elasmobranch species found in the north coast region include grey nurse sharks (*Carcharias taurus*), whale sharks (*Rhincodon typus*), mako sharks (*Isurus* spp.), *Glyphis* sharks and sawfish (*Pristis* and *Anoxypristis* spp.).

5.1.3.4.1 Entanglement in culture lines

Risk Rating: Impact of entanglements in culture lines on shark and ray populations — C0, L1 = 0; NEGLIGIBLE

Justification:

- There have been no recorded entanglements of sharks or rays (including sawfish) in pearl oyster culture lines in WA or the NT, There is a remote chance of an entanglement occurring.

5.1.3.5 Sea snakes

Rationale for Inclusion: A number of sea snake species are found in the area where fishing operations occur. Sea snakes are generally long-lived and slow-growing, with small broods and high juvenile mortality (DEWHA 2008). Sea snakes in the region occupy three broad habitat types: shallow water coral reef and seagrass habitats, deepwater soft bottom habitats away from reefs and surface water pelagic habitats (Guniea 2007).

Areas in the North Coast Bioregion that are particularly important for some species include the Sahul Shelf (for short-nosed, leaf-scaled, turtle-headed and slender-necked sea snakes); the Pilbara coast (for brown-lined and north-western mangrove sea snakes) and the Kimberley coast (for brown-lined, Stokes', black-ringed and northern mangrove sea snakes). Most species in the bioregion are not considered to be threatened, with the exception of the short-nosed sea snake (*A. apraefrontalis*), which has recently become scarce, and the leaf-scaled sea snake (*A. foliosquama*).

5.1.3.5.1 Entanglement in culture lines

Risk Rating: Impact of entanglements in culture lines on sea snake populations — C0, L1 = 0; NEGLIGIBLE

Justification:

- There have been no recorded entanglements of sea snakes in pearl oyster culture lines in WA or the NT.

5.1.3.6 Sea and shore birds

Rationale for Inclusion: The pearling industry area has two coastal areas of international significance, both covered by the Ramsar Convention: Roebuck Bay and 80 Mile Beach. Both sites have large intertidal mudflats, containing a high density of invertebrates and are the primary feeding grounds and over-wintering areas for Palaearctic shorebirds on their annual southwards migrations. The region is also important for many seabird species including terns, petrels, shearwaters, tropic birds, frigatebirds and boobies.

5.1.3.6.1 Disturbance from industry activities

Risk Rating: Impact of industry activities (disturbance) on sea bird populations — C1, L1 = 1; NEGLIGIBLE

Justification:

- Seabirds can be found feeding on and around pearl farms; however, there have been no known entanglements or interactions with seabirds in the pearling industry.

Risk Rating: Impact of industry activities (disturbance) on shore bird ('waders') populations — C0, L0 = 0; NEGLIGIBLE

Justification:

- Pearl oyster fishing and farming activities do not operate in nearshore, shallow areas where shorebird populations occur (leases at minimum of 10 m mark low tide).
- There have been no recorded entanglements or interactions with shorebirds in the pearling industry.

5.1.3.7 Seahorses and Pipefish

Rationale for Inclusion: A number syngnathids and solenostomids (seahorses, pipefish and ghost pipefish) can be found throughout the North West Shelf region. Syngnathids generally have diverse characteristics, ranging from rare and localised species to widely distributed and very common. Syngnathids are usually found in shallow, coastal waters living among seagrasses, mangroves, coral reefs, macroalgae-dominated reefs and sand / rubble habitats (Dawson 1985; Vincent 1996; Lourie et al. 1999, 2004).

5.1.3.7.1 Entanglement in culture lines

Risk Rating: Impact of entanglements in culture lines on seahorse and pipefish populations — C0, L0 = 0; NEGLIGIBLE

Justification:

- There have been no recorded entanglements or interactions with seahorses or pipefish in the pearling industry.

5.1.4 Habitats

5.1.4.1 Benthic Habitats

5.1.4.1.1 Diver activities

Rationale for Inclusion: Pearl oyster divers carry several pieces of equipment with them for safety and pearl oyster collection purposes, including an underwater breathing apparatus and large mesh bag to store the pearl oyster. Both the divers and their equipment may come into contact with benthic habitats while collecting pearl oysters.

Risk Rating: Impact of diver activities on benthic habitats — C1, L1 = 1; NEGLIGIBLE

Justification:

- The main habitats where fishing occurs are soft sediment 'garden' and 'potato' bottoms.
- While pearl oysters may occur in ecologically-sensitive areas, such as seagrasses, coral reefs or mangroves, fishing activities do not generally occur in these areas as pearl oyster densities are too low to be commercially-viable.

- Fishing for pearl oysters generally involves the extension of booms outwards from each side of the vessel, with a number of weighted ropes hung vertically from each boom to a height of approximately one to two metres from the seabed. Since water clarity is paramount to divers being able to capture the pearl oysters efficiently (i.e. identify the appropriate sized oysters), significant effort is put in place to ensure the weights do not strike the sea floor. The divers will signal to the vessel to raise the weights according to the sea floor height, thus preventing the weights from striking the bottom, preventing damage to the sea floor.
- The hand collection methods result in minimal disturbance to benthic habitats.

5.1.4.1.2 Anchoring

Rationale for Inclusion: Pearl oyster vessels do not anchor in the course of daily fishing but need to anchor at night when the crew and skipper are on standby. Anchors may physically alter or damage the benthic habitats where they are set.

Risk Rating: Impact of vessel anchoring on benthic habitats (fishing) — C1, L1 = 1; NEGLIGIBLE

Justification:

- Most anchoring occurs just outside fishing patches or holding sites in muddy, sandy bottom areas.
- Pearl oyster vessels operating at remote fishing locations cannot afford to lose fishing time over the neap period. Therefore, they will avoid anchoring in complex habitat for fear of fouling the anchor and prefer to anchor over sand.
- Although some level of impacts occurs with anchoring activities, anchoring impacts are ephemeral in their nature allowing habitats to recover. Anchoring impacts are not noticeable from year-to-year.
- There is minimal diving activity conducted by the pearling industry in the NT.

5.1.4.1.3 Holding and Dump Sites

Rationale for Inclusion: Once pearl oysters have been collected, cleaned, and placed in tagged panels they are stored on dump and/or holding sites.

Risk Rating: Impact of pearl oyster holding and dump sites on benthic habitats — C1, L2 = 2; NEGLIGIBLE

Justification:

- 105 km^2 were used as holding sites in WA in 2013 and 2014; 95 km^2 were used in 2015. The actual seabed space used at each of these sites, however, is only a few hectares.
- All holding sites are in depths of less than 30 metres.

- Benthic habitats of dump/holding sites are generally similar to those on the fishing grounds, e.g. 'garden' or 'potato' bottom. The seafloors in the area must be sufficiently hard that the panels do not sink into the mud.
- Dump sites are used on a temporary basis only and are marked with surface buoys so they can be relocated.
- Holding site locations are gazetted for the specified company to use for three years.
- The same areas have been used as holding sites across years, with no noticeable impacts over multiple year use.
- Holding sites are temporary in nature; all shell must be removed from the holding sites by 31 December each year (unless otherwise specified) and anchoring material is removable.
- Holding sites were considered to be a higher risk than vessel anchoring activities primarily because holding sites are re-used each year, while vessel anchoring occurs across entire fishing area and vessels are generally anchored in different areas each trip.
- Holding and dump sites are not used in the NT as there is no collection, via diving, of culture-sized pearl oysters.

5.1.4.1.4 Farm Leases

Rationale for Inclusion: Suspended bivalve culture can impact the environment by increasing the amount of organic material that settles on the seabed. Shellfish feed by filtering organic matter from the water column and release faster-sinking (pseudo) faecal particles, which are deposited on the seafloor under the pearl oyster culture lines. As this organic sediment builds up underneath the farm leases, changes to benthic habitats and communities may occur.

Pearl oysters produce biodeposits in the form of faeces and pseudofaecal pellets as a waste product. These biodeposits are thought to be similar in composition to the natural sediments because they are derived from phytoplankton and suspended particles (Grant et al. 1995). However, these biodeposits and shell debris can accumulate in the sediments below the oyster longlines and potentially lead to localised organic enrichment and eutrophication. This process can be intensified through the cleaning of biofouling organisms from the pearl oyster shells, which also accumulate beneath the farm lease.

Risk Rating: Impact of farm leases on benthic habitats — C1, L2 = 2; NEGLIGIBLE

Justification:

- Pearl oyster farm leases are located throughout the northwest region and the NT, with a number of farms in Exmouth Gulf, Barrow and the Montebello Islands, the Dampier Peninsula, King Sound, the northern Kimberley coast and in the NT, the Darwin area, Cobourg peninsular and around the English Company Islands.
- The area of seabed leased for pearl oyster cultivation is matched to the area required to cultivate the quota units allocated and/or pearl oyster stock holdings to each

company. Therefore, the company's total leased areas need to be within this requirement.

- There are anchoring requirements for farm leases and industry reports on anchoring methods and substrate (to the WA Department of Parks and Wildlife) at the site prior to installing farm structures.
- No chemicals or feed are used in the pearl oyster cultivation process. On the farm leases, pearl oyster shells are cleaned approximately every four weeks.
- Potential interactions between pearl oyster farms and marine habitats, particularly seabed communities, have been studied at several locations around Asia and Australia. A brief summary of these studies is provided below:
    - Beagle Bay, WA — survey of the seabed beneath longlines conducted by the WA museum and found no measurable impact (WA Museum 1997);
    - Montebellos Islands, WA — sampling program inside and outside a pearl *P. maxima* lease found no impact of pearl farms on abundance and diversity of the benthic macrofauna community (Prince 1999);
    - Gokasho Bay, Japan — compared impacts of raft pearl farming (*P. martensii*) and fish cages by measuring macrobenthic fauna and sediment nutrient loads (carbon, nitrogen, sulphur and dissolved oxygen) and found that fish farming created a large impact on macrobenthic fauna and sediments, whereas the pearl farming caused fewer effects. The community structure at the farm lease was similar to that of the control site, although there were lower densities and species diversity at the farm lease (Yokoyama 2002);
    - Port Stephens, New South Wales, Australia — environmental impacts of pearl farming (*P. imbricata*) investigated using sediment samples with results indicating no significant changes in the sediments underneath the experimental farm lease over time relative to the control sites (O'Connor et al. 2003) and an environmental impact assessment, which found no impact of a pearl longline farm on sediment chemistry (Gifford 2004);
    - Within the Kimberley region of WA, the impacts of pearl farming on benthic assemblages and the physico-chemistry of sediments have been investigated in a comprehensive study conducted over multiple years at three farm sites (McCallum & Prince 2009; Jelbart et al. 2011). At all three pearl farms there was no indication of eutrophication (nutrient enrichment), nor was there evidence of any consistent change in the total number of benthic macrofauna taxa or individuals within soft sediments that may be directly attributed to pearl oyster longline compared to reference locations. There was considerable natural variability of the benthic macrofauna among all locations but especially among the reference locations, indicating the diversity of taxa and their relative abundances within the sediments underlying the farms fell within the range of natural variability found at these spatial scales (Jelbart et al. 2011).

- McCallum & Prince (2009) also studied the effects of removing a pearl farm (Otama pearl oyster farm, near Kuri Bay, WA) on the benthic conditions under the farm compared to nearby reference locations. The results from this study suggested that the farm lease had no impact on the sediments or benthic fauna.
- There are similar environmental conditions on the NT farm leases. No detectable benthic change is also expected.

5.1.5 Ecosystem Structure

5.1.5.1 Trophic Interactions

5.1.5.1.1 Removal / Addition of material from the environment

Rationale for Inclusion: The removal or addition of a species may alter the key elements of the local ecosystem including trophic structure and function.

The only species retained by the WA pearling industry is *P. maxima*.

Although not directly targeted, commensal biofouling organisms that encrust the pearl oyster shells are collected with the pearl oysters. After the pearl oysters have been collected, fouling organisms are cleaned off the shell surface by a combination of mechanical scraping with a knife, followed by washing with high pressure seawater (no chemicals are used in the procedure). This material is then discarded back into the ocean.

Risk Rating: Impact of removal/addition of materials on the ecosystem — C1, L1 = 1; NEGLIGIBLE

Justification:

- Pearl oysters are found throughout the northwest region where there is suitable habitat, which includes most habitats apart from muddy substrate (Hart & Freidman 2004).
- In the wild, pearl oysters comprise a small proportion of filter-feeders present in the ecosystem. Additionally, there are no known obligate predators of pearl oysters. Therefore, removing pearl oysters at the current level is unlikely to results in significant trophic impacts.
- Divers target specific size ranges of the pearl oysters available on the fishing grounds, and total catch is limited by the annual TAC.
- Pearl divers are limited to shallower areas and calmer-weather seasons for safety reasons, providing areas and times of refuge from fishing activities for pearl oysters populations (Fletcher et al. 2006).
- There may be some impact from the discarding of commensal/fouling species into the water column following pearl oyster shell cleaning (through provisioning throughout the water column); however, the harvested oysters are young and generally have relatively little epiphytic growth and low infestation rates (Daume et al. 2009). Thus, any provisioning impact from discarding this small amount of organisms is likely to be negligible.

- Additionally, the boat is constantly moving during shell cleaning, and all discards are dispersed over a wide area and rapidly dissipated in the open ocean.
- Negligible effect in the NT as only very small number of pearl oysters harvested.

5.1.5.2 Community Structure

5.1.5.2.1 Depletion of phytoplankton from pearl oyster filtration at farm sites

Rationale for Inclusion: Bivalves such as pearl oysters gain nourishment by filtering suspended particles, such as phytoplankton and detritus, from the water column. If phytoplankton consumption due to culture activities exceeds the combined reproduction rate and tidal replenishment rate of phytoplankton to a system (termed 'ecological carrying capacity'), changes to local ecological processes, species, populations or communities may occur.

Risk Rating: Impact of pearl oyster cultivation on phytoplankton abundance — C1, L1 = 1; NEGLIGIBLE

Justification:

- The extensive amount of research conducted on bivalve and oyster culture indicates that while farms have the capacity to alter ecosystem structure, impacts vary depending on factors such as farm size, oyster density, water depth, currents and season. Large-scale effects have only been documented in situations with high densities of oysters in water bodies with limited water exchange (Forrest et al. 2009). For example, where pearl oysters are held in high densities in lower-nutrient environments (lagoonal pearl farms), studies have shown that pearl oysters have a very low consumption of plankton compared to planktonic fluxes and that their filter feeding activity does not markedly impact on primary productivity (e.g. Niquil et al. 2001; Souchou et al. 2001).
- The northwest coast of WA is known for its high tidal regimes (high levels of water exchange) and seasonal productivity cycles (CoA 2007a).
- A reduction in phytoplankton abundance would reduce the quality of the pearls being cultured; therefore, any reductions in phytoplankton at the farm leases are avoided. For example, the pearling industry standard for the stocking density of pearl oysters is no more than 16250 shells per square nautical mile. This density is much lower than densities used in other bivalve aquaculture activities where significant ecosystem impacts have been reported (Jelbart et al. 2011).
- Farm leases are located throughout the northwest region, although the lease size and total area that a company can use is restricted. Farm leases must be a minimum distance of 5 nm from other farm sites (unless there is mutual consent with the pre-existing farm lease owners or if the farm leases are owned by the same legal entity).
- The total area of seabed that can be used for pearl oyster cultivation in WA is generally limited by the companies' quota and stock holdings. In 2013, 675 km^2 were used as pearl farm areas in WA. This was reduced to 655 km^2 and 650 km^2 in 2014

and 2015, respectively. The majority of pearl farms are located in less than 30 m depth, with all farms located in less than 40 m depth.

- The total area of shallow seabed (< 20 m depth) from Exmouth Gulf to the NT border leased for pearl oyster farms over the last five years is ~ 780 km^2.
- The total area that is available to pearling in the NT issued under Crown Leases is 9213 hectares however approximately only 3000 hectares is currently in use. Stocking densities follow the industry standard.

5.1.5.2.2 Introduction of diseases, pests, pathogens or non-native species

Rationale for Inclusion: The main threat associated with the translocation of pearl oysters is the introduction of diseases, pests or invasive species. In some cases, the introduction of diseases or invasive species have resulted in mass mortalities of native species and severely disrupted ecosystems.

Risk Rating: Impact of pearl oyster translocation on the surrounding ecosystem from the introduction of diseases, pests, pathogens or non-native species — C2, L1 = 2; NEGLIGIBLE

Justification:

- Past experience has indicated that diseases are specific to one species. There are number of industry and management protocols in place to reduce the risk of introduction, including:
    - Restrictions are imposed on the transport of *P. maxima* under the WA *Pearling Act 1990*, the *Pearling (General) Regulations 1991* (Part 7) and the FRMR (Part 13A).
    - The *Pearl Oyster Translocation Protocol* reflects this legislation and is utilised in decision making related to the application for pearl oyster transport approvals. The Protocol governs the movement of hatchery-produced pearl oysters and the movement of pearl oysters between pearl oyster farms. It also applies to the movement of pearl oysters into and out of WA.
    - All transports require application by the pearling company for prior approval from a pearling inspector (Form P2) and may require a health certificate. If a health certificate is required, significant quantities of samples from the batch to be transported are required to be submitted to the government fish health division (NT and/or WA) for health testing. This approval will be denied if there are disease concerns about a particular lease, hatchery or area.
- The Department maintains a passive surveillance program in this area, actively investigating any reports of abnormal mortalities, which are backed up by emergency response capability in the areas of both aquatic pests and diseases.
- A Departmental incident management protocol has been developed, which details protocol associated with emergency biosecurity response. The Department is also

equipped with state-of-the-art diagnostic laboratories and capability. It participates in nationally-coordinated proficiency testing programs and is accredited to ISO17025 for both pest identification and pathogen identification.

- It was noted that the development of an industry-specific rapid response plan would further improve management of this issue.
- Restrictions are also imposed on the translocation of *P. maxima* under the *NT Fisheries Act* and the *NT Fisheries Regulations* (Regulation 16). The Zoning strategy for Disease Control in the NT is utilised in decision making related to the application for pearl oyster translocation approvals.
- The NT Department of Primary Industries and Fisheries has developed protocols associated with emergency biosecurity responses. The Department of Primary Industries and Fisheries' Veterinary Laboratory is NATA accredited with specialists in pearl oyster diagnostic pathology.

5.1.6 Broader Environment

Rationale for Inclusion: Pearl oysters are collected from fishing boats operating between Exmouth Gulf and the Northern Territory. In any given year, there can be six to 10 vessels fishing for pearl oysters. Many of these boats have been custom designed for the WA pearling industry and have a total crew of 10 – 12 people (Fletcher et al. 2006).

5.1.6.1 Air quality

5.1.6.1.1 Fuel usage / Exhaust fumes

Risk Rating: Impact of fuel use and/or exhaust from fishing vessels on regional air quality — C1, L1 = 1; NEGLIGIBLE

Justification:

- There are few boats operating in the pearling industry, and activities are widespread over a large geographical area.

5.1.6.1.2 Greenhouse gas emissions

Risk Rating: Impact of greenhouse gas emissions from fishing vessels on regional air quality — C1, L1 = 1; NEGLIGIBLE

Justification:

- There may be some minor impacts at industry level (one company reported burning approximately three million litres of greenhouse gasses per year); however, the pearl oyster farm leases act as carbon sinks and offset some greenhouse gas emissions.

5.1.6.2 Water quality

5.1.6.2.1 Debris / Litter

Risk Rating: Impact of litter from fishing activities on regional water quality — C1, L1 = 1; NEGLIGIBLE

Justification:

- There are specific controls in place to reduce litter from fishing and cultivation activities, which are monitored by WAPOL.
- Very little amounts of floats or other gear escapes from pearl leases.
- Any impacts would be localised and would not affect regional water quality.

5.1.6.2.2 Oil discharge

Risk Rating: Impact of litter from fishing activities on regional water quality — C1, L1 = 1; NEGLIGIBLE

Justification:

- There are few boats operating in the WA pearling industry, and activities are widespread over large geographical area. Thus, any impacts would be localised and would not affect regional water quality.

5.2 External (Environmental) Factors

Twenty-three external factor sub-components and associated issues were identified as potentially impacting the WA pearling industry's performance (Figure 12, Table 4). Seventeen issues were assessed as a low or negligible risk, three were medium risk and three were high risk.

Impacts from climate change were originally included in the component tree; however, it was decided to remove this component at the risk assessment workshop. The primary reasons for its removal were a lack of clarity on the definition and aspects of climate change that were being assessed and the feeling by participants that the impacts from climate change over the next five years were captured in the separate natural environment components assessed, such as rainfall, water temperature, cyclones, wind, etc.

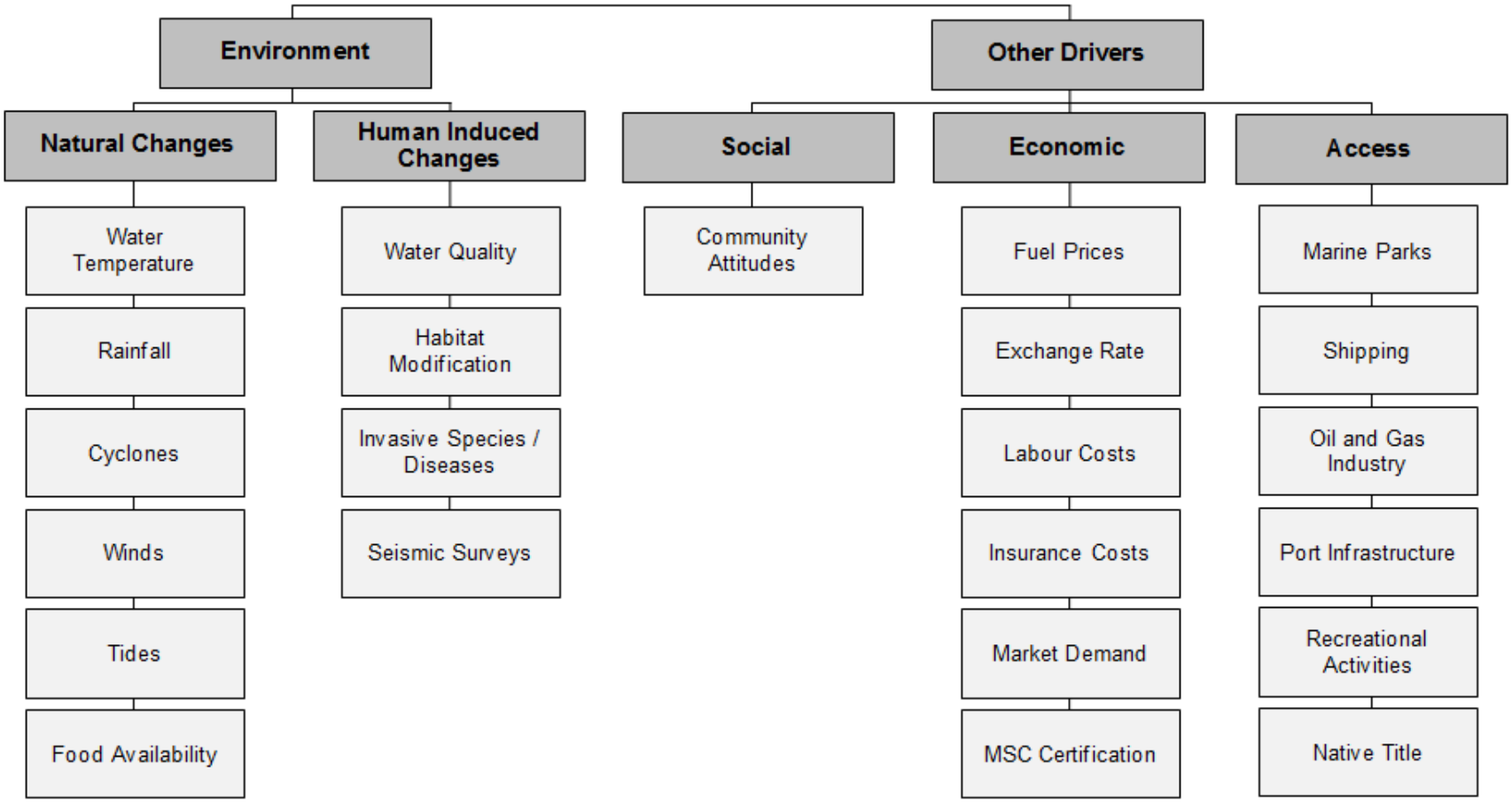

Figure 13. Component tree for external factors that potential affect the WA pearling industry's performance

Table 4. Overview Table of Identified Components, Sub-Components, Issues and assessed risk ratings related to the External Factors that may impact the activities of the WA pearling industry

Component	Sub-Component	Issue	Risk Rating
Environment: Natural Changes	Water temperature	Impact of water temperature on industry performance	LOW
	Rainfall	Impact of annual rainfall on industry performance	NEGLIGIBLE
	Cyclones	Impact of cyclones on industry performance	LOW
	Seasonal winds / wind direction	Impact of winds on industry performance	NEGLIGIBLE
	Tides	Impact of tides on industry performance	NEGLIGIBLE
	Food availability	Impact of food availability on industry performance	NEGLIGIBLE
Environment: Human-Induced Changes	Water quality	Impact of water quality on industry performance	LOW
	Habitat modification	Impact of habitat modification on industry performance	LOW
	Invasive species / Diseases	Impact of introduction of invasive species or diseases on industry performance	LOW
	Seismic surveys	Impact of seismic surveys on industry performance	HIGH
Social Drivers	Community attitudes	Impact of community attitudes on industry performance	NEGLIGIBLE
Economic Drivers	Fuel Prices	Impact of fuel prices on industry performance	LOW
	Currency	Impact of currency exchange rates on industry performance	LOW
	Labour costs	Impact of labour costs on industry performance	LOW
	Insurance	Impact of insurance costs on industry performance	MEDIUM
	Market demand	Impact of market demand on industry performance	LOW
	MSC Certification	Impact of MSC certification on industry performance	MEDIUM
Access	Marine Parks	Impact of marine parks on industry performance	HIGH
	Shipping	Impact of shipping activities on industry performance	NEGLIGIBLE
	Port Infrastructure	Impact of port infrastructure on industry performance	MEDIUM
	Oil and Gas Industry	Impact of oil and gas industry activities on industry performance	HIGH
	Recreational fishing activities	Impact of recreational fishing activities on industry performance	NEGLIGIBLE
	Native Title	Impact of Native Title on industry performance	LOW

5.2.1 Environment: Natural Changes

5.2.1.1 El Niño / Southern Oscillation (ENSO)-Related Changes

Rationale for Inclusion: Environmental variables such as water temperature, winds, rainfall and cyclones can have significant effects on the recruitment, settlement and growth of marine organisms.

While each of these variables was assessed separately at the ERA workshop, it was decided that they could be grouped under the broader heading of El Niño / Southern Oscillation (ENSO) related changes. The dominant influence on coastal hydrology in WA is the Leeuwin Current, which itself is influenced by the El Niño / Southern Oscillation (ENSO). Environmental variables related to ENSO include the Southern Oscillation Index (SOI), water temperature, rainfall, wind strength and the frequency of cyclones. The impacts of these variables may influence pearl oyster settlement and recruitment, as well as abundance and health, either directly or indirectly through impacts on habitats or food availability.

Separate risk levels are provided below for each of the aspects assessed, with a combined justification provided.

5.2.1.1.1 Water Temperature

Risk Rating: Impact of water temperature on industry performance — C1, L3 = 3; LOW

5.2.1.1.2 Rainfall

Risk Rating: Impact of amount of annual rainfall on industry performance — C1, L1 = 1; NEGLIGIBLE

5.2.1.1.3 Cyclones

Rationale for Inclusion: Severe tropical cyclones seasonally occur within the area of the pearling industries operations, and historically have severely impacted on both pearl farms and the habitat of the pearl oyster beds of the POF. Cyclones can shift sand over fishing patches and farm lease, resulting in significant losses of wild and hatchery pearl oysters.

Risk Rating: Impact of cyclones on industry performance — C2, L2 = 4; LOW

Justification:

- Although cyclones are common within the area where industry operates, they generally only cause localised impacts on pearl oyster stocks and habitats. Thus, the effect on industry performance would be dependent on the category and specific location of the cyclone. Historically, there have been many cyclones within the area, but these have not had an ongoing impact on industry performance or pearl oyster stock abundance.

5.2.1.1.4 Winds

Risk Rating: Impact of seasonal winds and wind direction on industry performance — C0, L0 = 0; NEGIGIBLE

5.2.1.1.5 Tides

Risk Rating: Impact of tides on industry performance — C0, L0 = 0; NEGIGIBLE

5.2.1.1.6 Food Availability

Risk Rating: Impact of pearl oyster food availability on industry performance — C0, L0 = 0; NEGIGIBLE

Justification:

- Water temperatures in northern WA and the NT are close to the maximum water temperatures tolerated by *P. maxima*, so any significant increase in temperature could result in reduced pearl oyster health. Concerns about the impacts of even small increases in temperature on pearl oysters have also been noted elsewhere in the world, e.g. the Philippines.
- Industry attempts to minimise changes in pearl oyster environments (maintain oyster homeostasis) to reduce stress levels in individuals, which is important for maintaining production of a high-quality product and reducing the likelihood of disease, etc.
- Environmental variables, such as SST, rainfall, wind strength, and cyclones, have been shown to influence WA pearl oyster stocks, with a negative relationship between abundance and rainfall and a positive relationship between abundance and temperature (both spat settlement and stock abundance). Northerly winds from December to February significantly enhance settlement, but easterly winds in the main fishing month of May have a positive influence fishing power (Hart et al. 2011).
- An environmental monitoring program is undertaken in the POF, which includes monitoring of SST, rainfall, frequency of cyclones, wind components and SOI, and analysis of environmental effects is routinely carried out during stock assessments.

5.2.2 Environment: Human-Induced Changes

5.2.2.1 Water Quality

Rationale for Inclusion: There are examples from elsewhere, e.g. the Torres Strait Fishery, where reduced water quality has led to the closure of the fishery.

Risk Rating: Impact of water quality on industry performance — C3, L1 = 3; LOW

Justification:

- Impacts from reduced water quality would likely be localised, with specific pearl farms or areas impacted, but with minimal impacts on the pearling industry overall.

- Reduced water quality could potentially impact the industry more broadly if it affected a 'source' population, which supplies a high number of new recruits into the fishery.

5.2.2.2 Habitat Modification

Risk Rating: Impact of human-induced habitat modification on industry performance — C3, L1 = 3; LOW

Justification:

- Impacts from habitat modification (e.g. due to coastal development) would likely be localised, with specific pearl farms or areas impacted but minimal impacts on the industry overall.
- Similar to water quality impacts, habitat modification could potentially impact the industry more broadly if affected a 'source' population.

5.2.2.3 Invasive Species / Diseases

Rationale for Inclusion: Non-pearling industry vessels that travel and work in the area that the pearling industry operates in may inadvertently introduce an exotic species or disease into the surrounding waters.

Risk Rating: Impact of the introduction of invasive species / disease on industry performance — C3, L2 = 6; LOW

Justification:

- There are high levels of foreign, long-distance and local boat traffic in northern WA and the NT due to industrial activities (e.g. oil and gas, international shipping).
- There are few known invasive species or diseases in the Kimberley region and across northern Australia compared to the southwest regions of WA; however, the remoteness of the Kimberley region makes it difficult to detect the introduction of invasive species or diseases.
- In addition to ecological implications, pest introductions (e.g. *Didemnum*) may also impact pearling industry activities / protocols, such as increasing the frequency needed of cleaning or vessel disinfection, which may impact operational costs (e.g. if black-striped mussels were introduced they would heavily foul pearling infrastructure).

5.2.2.4 Seismic Surveys

Rationale for Inclusion: Oil and gas exploration (using seismic surveys) occurs off the North West Shelf in areas that the pearling industry operates.

Risk Rating: Impact of seismic surveys on industry performance — C4 L3 = 12; HIGH

Justification:

- Impacts from seismic surveys were of high concern for pearling industry members.
- The impacts of seismic surveys on pearl oysters are unknown; however, there are concerns that seismic surveys would impact on all life-history stages of pearl oysters (spat, pre-recruits, juveniles and adults). Seismic surveys may also impact the availability of food for pearl oysters (e.g. planktonic impacts).
- Seismic surveys are already occurring on the North West Shelf, and it is considered highly likely that exploration activities will continue to expand into pearl oyster fishing areas over the next few years.

5.2.3 Social Drivers

5.2.3.1 Community Attitudes

Risk Rating: Impact of local community attitudes on industry performance — C1, L4 = 4; NEGLIGIBLE

Justification:

- The local community generally has positive views about the pearling industry; no public concerns have been brought to the Department. Traditional Owners may have slightly more-negative views than the broader community; however, in general, the pearling industry is well-regarded.

5.2.4 Economic Drivers

A number of factors impact the cost of operation and subsequently, the amount of pearling industry activities that occur. Economic drivers identified at the workshop include fuel prices, currency exchange rates, labour costs, insurance and market demand.

5.2.4.1 Fuel Prices

Risk Rating: Impact of fuel prices on industry performance — C2, L3 = 6; LOW

Justification:

- Ongoing fuel costs considered to possibly have a minor, ongoing impact on economic sustainability of individuals involved in the pearling industry over the next five years.

5.2.4.2 Currency Exchange Rates

Risk Rating: Impact of currency exchange rates on industry performance — C2, L3 = 6; LOW

Justification:

- Changes in the currency exchange rate considered to possibly have a minor, ongoing impact on economic sustainability of individuals involved in pearling industry over the next five years.

5.2.4.3 Labour Costs

Risk Rating: Impact of currency exchange rates on industry performance — C2, L3 = 6; LOW

Justification:

- Ongoing labour costs considered to possibly have a minor, ongoing impact on economic sustainability of individuals involved in pearling industry over the next five years.

5.2.4.4 Insurance Costs

Risk Rating: Impact of insurance costs on industry performance — C2, L4 = 8; MEDIUM

Justification:

- Insurance costs considered to likely have a minor, ongoing impact on economic sustainability of individuals involved in pearling industry in next five years. Insurance costs are very high, and many within the pearling industry continuing pearling activities despite having no insurance on their products.

5.2.4.5 Market Demand

Risk Rating: Impact of global market demand on industry performance — C2, L3 = 6; LOW

Justification:

- The global financial crisis, as well as the Asian bird flu, had a major impact on the WA pearling industry due to reductions in demand for pearls around the world. This resulted in a reduction in pearl production, partial use of wildstock quotas, rationalisation and consolidation of pearl leases and a significant reduction in the gross value of the pearling industry. Similarly, changes in the global economy (and/or consumer confidence) could impact pearling activities in the next few years.

5.2.4.6 Marine Stewardship Council (MSC) Certification

Risk Rating: Impact of MSC certification on industry performance — C3, L3 = 9; MEDIUM

Justification:

- The pearling industry will likely be required to make some changes to operations based on the results of the MSC assessment process (possible conditions imposed by MSC).
- Additional ongoing costs will be associated with maintaining certification into the future.

5.2.5 Access

5.2.5.1 Marine Parks

Rationale for Inclusion: There are a number of marine protected areas in the North Coast Bioregion that have been proclaimed under the *Conservation and Land Management Act 1984* (CALM Act), including the Montebello and Barrow Islands Marine Conservation Reserves, the Rowley Shoals Marine Park, Eighty Mile Beach Marine Park and the Lalang-garram / Camden Sound Marine Park (Figure 14). Additionally, there are total fishing closures (under Section 43 of the *Fish Resources Management Act 1994*) at Point Samson and the Kunmunya and Samson II wreck at Delambre Reef.

There are also three Commonwealth marine reserves in place in the North Coast Bioregion at Mermaid Reef, Ashmore Reef, and Cartier Island. The Federal Minister has also recently announced a reserve network for the North West region, which will include marine reserves at Ashmore and Cartier Islands, the Montebello Islands, Dampier Archipelago, Eighty Mile Beach, Roebuck Bay, the Argo-Rowley Terrace and the western Kimberley Coast (Figure 15).

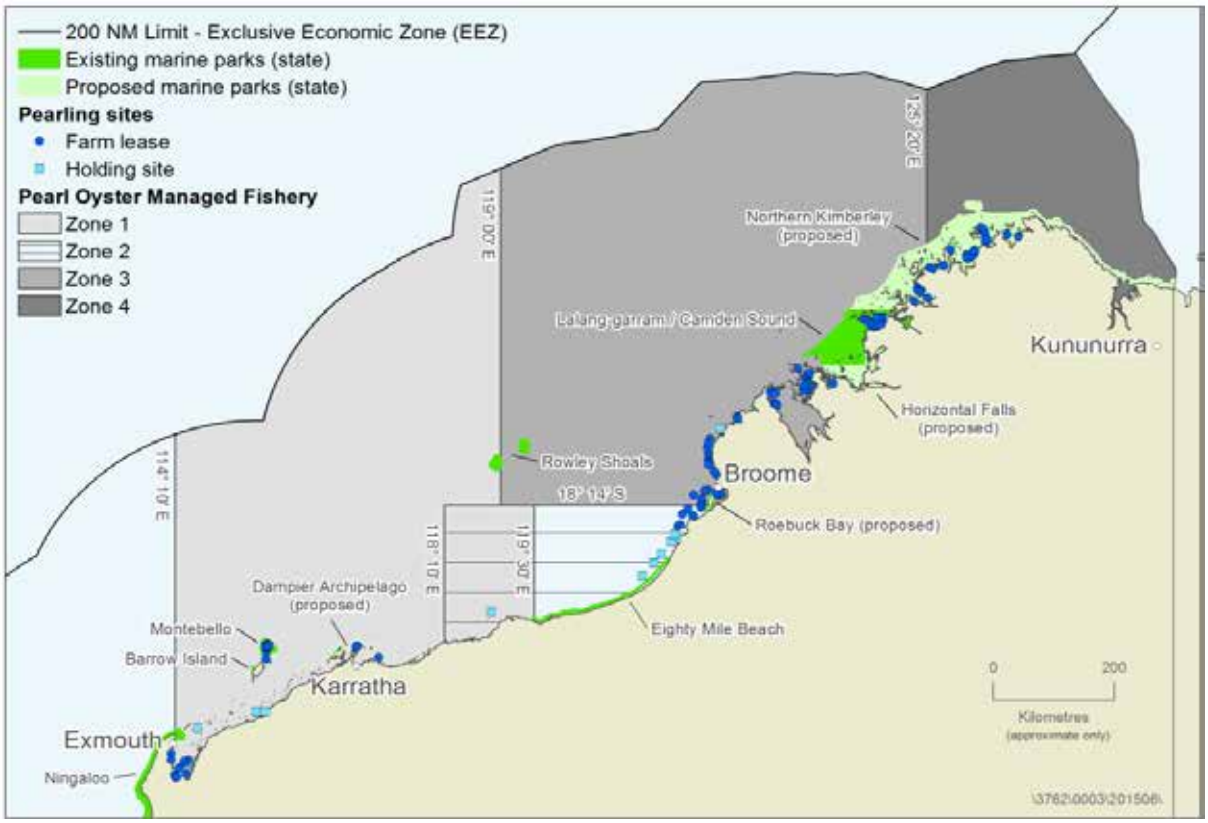

Figure 14. Existing and proposed State marine parks that overlap with Western Australian pearling industry activities

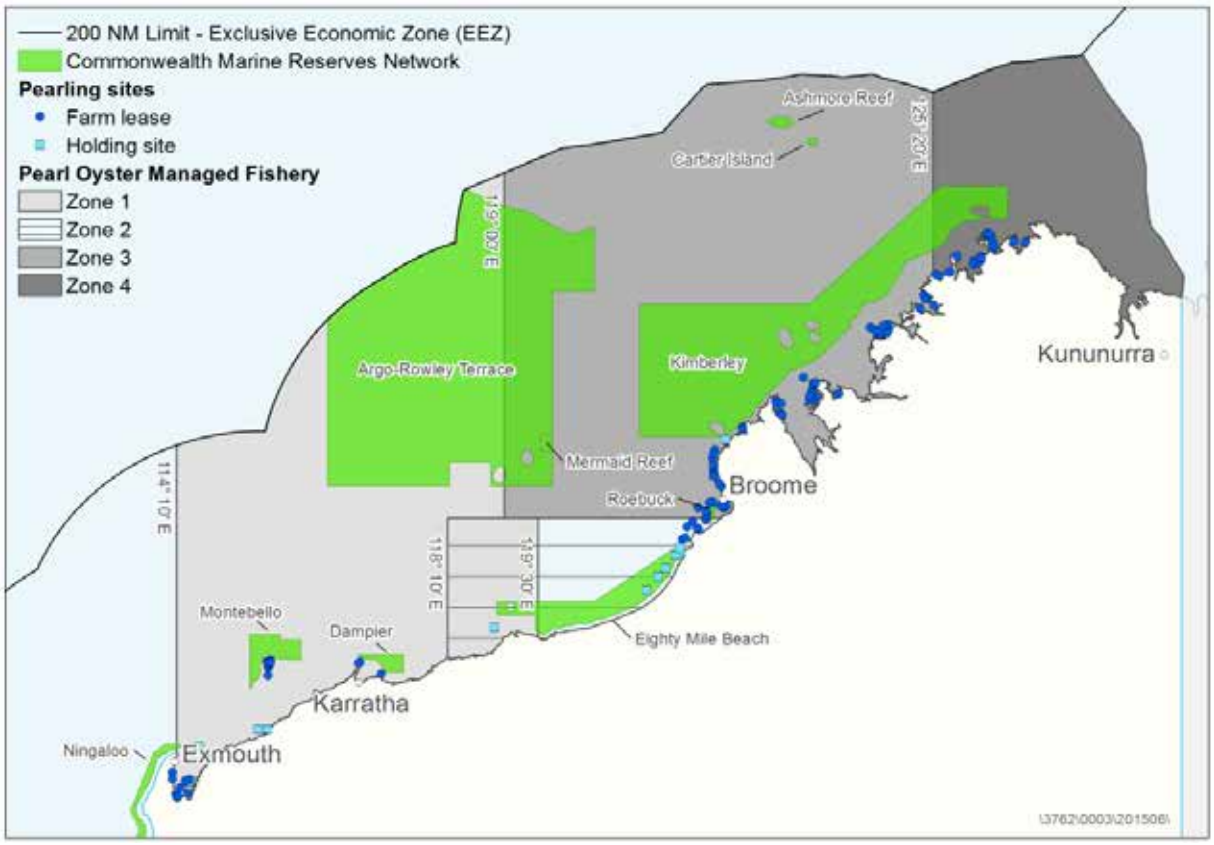

Figure 15. Commonwealth marine reserve network in the north-west region of WA and overlap with Western Australian pearling industry activities

Risk Rating: Impact of marine parks on industry performance — C3, L4 = 12; HIGH

Justification:

- Environmental offsets have been set on an *ad hoc* basis with the creation of new marine parks, leading to a high level of uncertainty among industry about the impacts of the creation and zoning of marine parks on access to fishing grounds and farm leases.
- It was considered likely that loss of access to fishing grounds from marine parks would have ongoing moderate impacts on the pearling industry.

5.2.5.2 Shipping and Port Infrastructure

Rationale for Inclusion: Shipping activity is high along the northwest coast of WA, primarily due to mining activities. An increase in shipping and port expansion associated with growth of the resources sector has potential implications for the marine environment. Potential threats include loss or contamination of marine habitats as a result of dredging, sea dumping, oil spills, interactions between vessels and protected species and the introduction of marine pests.

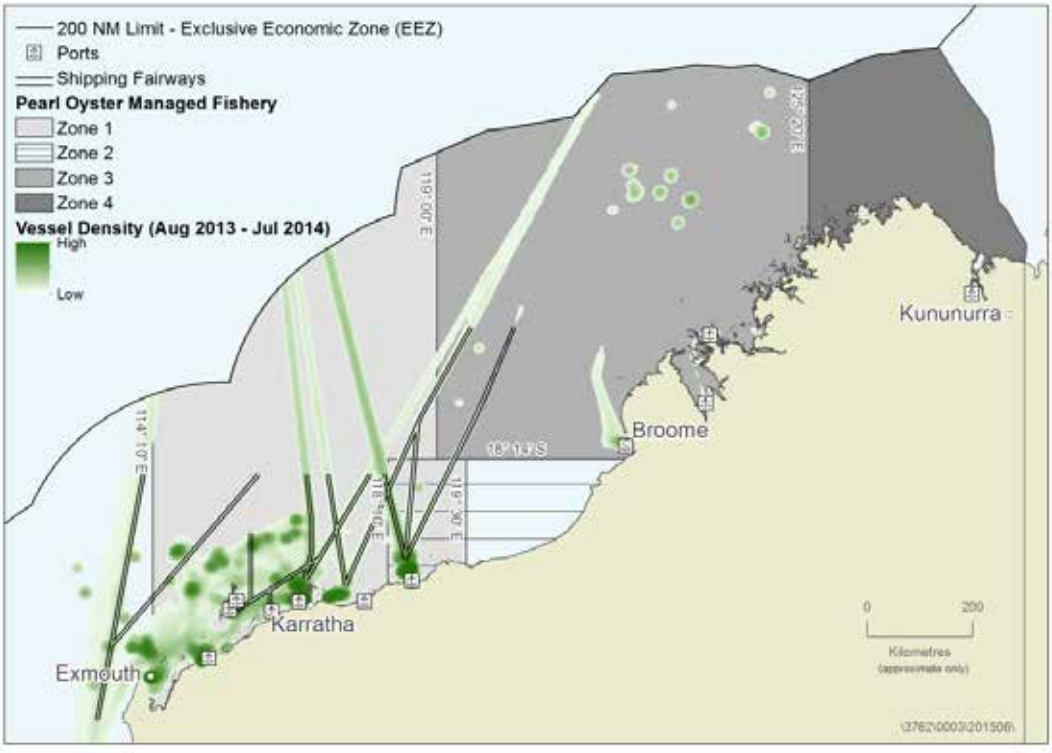

Figure 16. Major ports and shipping activity on the North West Shelf of Western Australia

Risk Rating: Impact of shipping activities on industry performance — C1, L4 = 4; NEGLIGIBLE

Justification:

- No impacts on industry access have been identified.

Risk Rating: Impact of port infrastructure development on industry performance — C3, L3 = 9; MEDIUM

Justification:

- The development of ports is tied to the exploration and development activities of the oil and gas industry;
- Pearling vessels must pay to use ports and are in competition with other industries to use the ports;

5.2.5.3 Oil and Gas Industry Development

Rational for Inclusion: The majority of the offshore oil and gas industry in WA is focused in the northern part of the state. The main disturbances associated with oil and gas exploration and production include noise pollution from seismic surveys, potential for fish movement / impact arising from seismic surveys, disturbance to the marine habitat through drilling and/or dredging activities, release of produced formation water, shipping and transport activities and oil spill accidents.

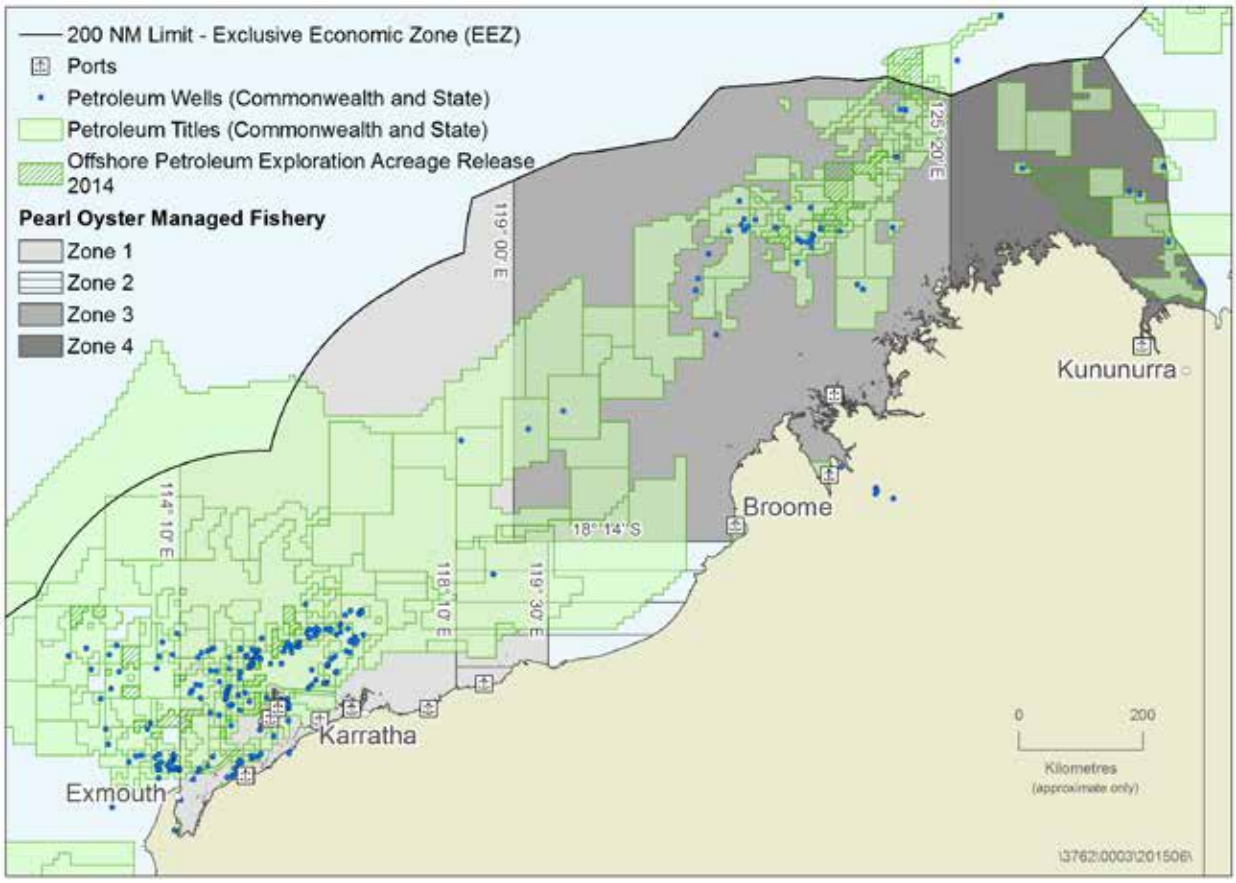

Figure 17. Oil and gas industry wells and exploration areas in the Western Australian pearling industry area

Risk Rating: Impacts of oil and gas industry activities on industry performance — C4, L3 = 12; HIGH

Justification:

- Currently the pearling industry considers that there is no mechanism for the protection of industry activities from oil and gas exploration and development; therefore, impacts from these activities are uncertain.
- There has been increased interest in exploration in inshore areas around Eighty Mile beach, and ongoing access to these important fishing areas is uncertain.
- There are significant costs to industry to undertake engagement with the oil and gas sector currently.

5.2.5.4 Recreational Fishing Activities

Rationale for Inclusion: Areas that the pearling industry currently operates within maybe closed or there may be more limited pearling activities to allow for recreational fishing.

Risk Rating: Impact of recreational fishing-associated access constraints on industry performance — C0, L0 = 0; NEGLIGIBLE

Justification:

- Currently, no significant impacts on access have been identified for the pearling industry.

5.2.5.5 Native Title

Rationale for Inclusion: Areas that the pearling industry currently operates within may be closed or there may be more limited pearling activities under Native Title rights.

Risk Rating: Impact of Native Title on industry performance — C1, L3 = 3; LOW

Justification:

- The WA pearling industry does not have exclusive access rights, and pearling activities may interact with customary activities.
- There is a high level of uncertainty about access in co-managed areas (e.g. new marine parks in the Kimberley region that are co-managed between government and customary owners).
- It was noted that the risks associated with Native Title are likely to be higher in the NT.

5.3 Community Wellbeing

Ten community wellbeing components were identified as potentially impacted by the WA pearling industry's operations (Figure 18), with 12 associated issues scored (Table 5). Four issues were a low or negligible risk, four were medium risk and four were high risk.

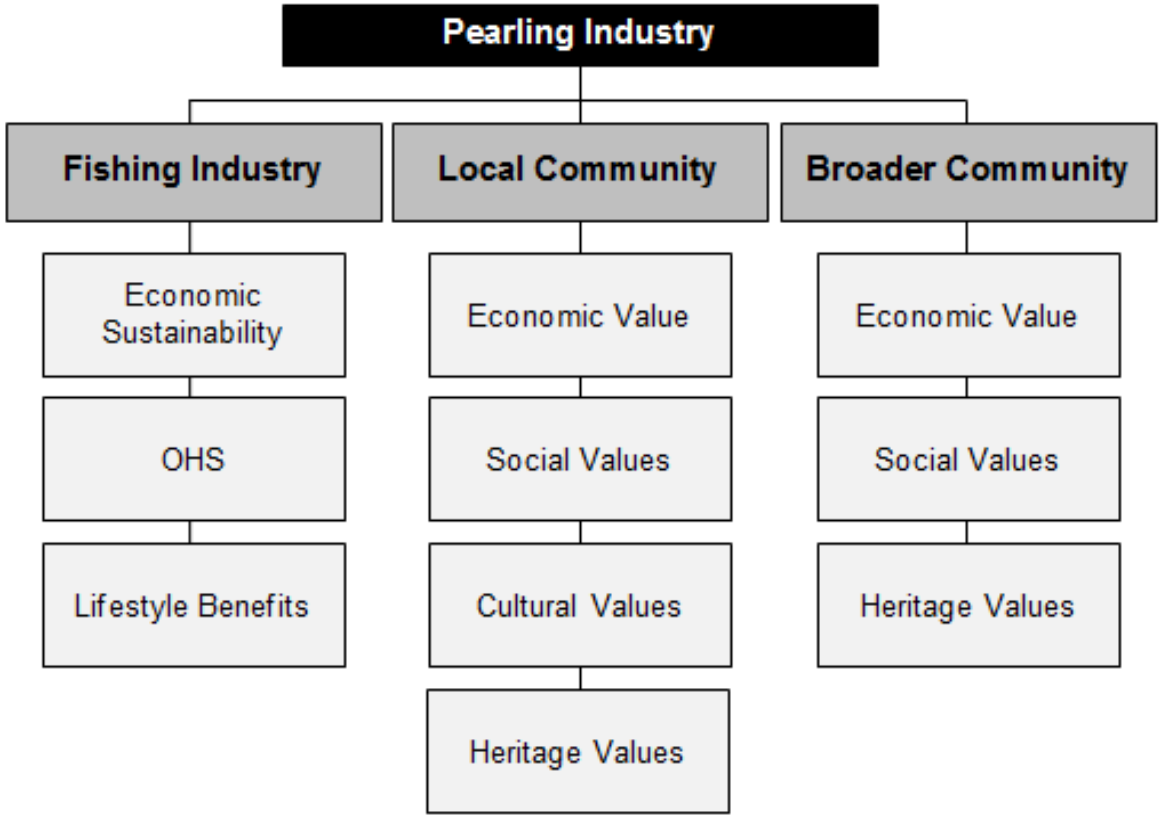

Figure 18. Component tree for community wellbeing aspects of the WA pearling industry

Table 5. Overview Table of Identified Components, Sub-Components, Issues and assessed risk ratings related to Community Wellbeing aspects of the WA pearling industry

Aspect	Industry Objective	Component	Issue	Risk Rating
Fishing Industry	To provide flexible opportunities to ensure fishers can maintain or enhance their livelihood, within the constraints of ecological sustainability	Economic Sustainability	Contribution of the industry to competition among fishers	**HIGH**
			Contribution of the industry to fisher income	**HIGH**
			Contribution of the industry to fisher employment	**HIGH**
		Occupational Health and Safety (OHS)	Contribution of the industry to a safe working environment	**MEDIUM**
		Lifestyle Benefits	Contribution of the industry to lifestyle benefits	**NEGLIGIBLE**
Local Community	To contribute to local community well-being, lifestyle and cultural needs	Economic Value	Contribution of the industry to the economic value of the local community	**MEDIUM**
		Social Values	Contribution of the industry to the social values of the local community	**MEDIUM**
		Cultural Values	Contribution of the industry to the cultural values of the local community	**MEDIUM**
		Heritage Values	Contribution of the industry to the heritage values of the local community	**HIGH**
Broader Community	To contribute to regional, national and international community well-being, lifestyle and cultural needs	Economic Value	Contribution of the industry to the economic value of the broader community	**NEGLIGIBLE**
		Social Values	Contribution of the industry to the social values of the broader community	**NEGLIGIBLE**
		Heritage Values	Contribution of the industry to the heritage values of the broader community	**LOW**

5.3.1 Fishing Industry

5.3.1.1 Economic Sustainability

Three aspects of economic sustainability in the WA pearling industry were scored: the contribution of the industry to competition among fishers, fisher income and fisher employment.

Risk Rating: 4.3.2.1.3 Contribution of the industry to competition among fishers — C4, L4 = 16; HIGH

Risk Rating: Contribution of the industry to fisher income — C3, L4 = 12; HIGH

Risk Rating: Contribution of the industry to fisher employment — C3, L4 = 12; HIGH

Justification:

- Competition between licences holders and companies within the industry is one of the main drivers of industry activities and innovation.
- The majority of licences holders are reliant on this industry for the majority of their income and employment.
- In years when market demand has been severely reduced (e.g. during the global financial crisis), the industry reduced fishing activities, using less boats with only the best divers to collect pearl oysters. This resulted in unemployment for a number of skippers and pearl oyster divers, who are usually reliant on the industry for their income.

5.3.1.2 Occupational Health and Safety (OHS)

5.3.1.2.1 Contribution of the industry to a safe working environment

Risk Rating: Contribution of the industry to a safe working environment — C2, L4 = 8; MEDIUM

Justification:

- Historically, the diving practices in the POF have resulted in a number of injuries (from decompression sickness) to pearl divers and in some cases resulted in more serious injuries and death.
- A Code of Practice for diving in the industry has been developed, and the industry has appointed both a dive safety officer and a specialist dive doctor to reduce the likelihood of diving-related injuries.
- Currently, the majority of injuries require minor medical treatment (by doctors) and there have not been many hospitalisations.

5.3.1.3 Lifestyle Benefits

5.3.1.3.1 Contribution of the industry to lifestyle benefits

Risk Rating: Contribution of the industry to lifestyle benefits — C1, L1 = 1; NEGLIGIBLE

5.3.2 Local Community

5.3.2.1 Economic Value

5.3.2.1.1 Contribution of the industry to economic value of the local community

Risk Rating: Contribution of the industry to economic value of the local community — C2, L5 = 10; MEDIUM

Justification:

- Each year, around 30 000 people visit Broome and the Kimberley region. A large attraction for tourists is the WA pearling industry with interest in both the history of pearling and present day operations. To accommodate the large number of tourists, there are numerous caravan parks, hotels and restaurants. Additionally, there are many other activities for tourists in the Kimberley and Broome region that support the local economy, with the most common including charter boat fishing tours, whale watching, scenic flights, indigenous and cultural tours and Kimberley cruises on live-aboard vessels.

5.3.2.2 Social Values

5.3.2.2.1 Contribution of the industry to social values of the local community

Risk Rating: Contribution of the industry to social values of the local community — C2, L5 = 10; MEDIUM

Justification:

- The week-long Festival of the Pearl (also known as Shinju Matsuri) is held in Broome each year and provides an opportunity for the community to learn about the industry and engage with both pearling industry and management representatives. The WA pearling industry, as well as the PPA, is involved in the organisation and promotion of the Festival.
- There are currently two pearl farms which offer tours, where tourists can learn about the history of the WA pearling industry, the pearling culture process, farm operations and gain an appreciation of early grading. Other tours related to the pearling industry offered in Broome include tours of luggers and old China town.
- The ongoing community outreach and engagement by the pearling industry has resulted in high levels of community support and generally positive feeling towards the industry.

5.3.2.3 Cultural Values

5.3.2.3.1 Contribution of the industry to cultural values of the local community

Risk Rating: Contribution of the industry to cultural values of the local community — C2, L5 = 10; MEDIUM

Justification:

- As a result of the pearling industry, the architecture and population of Broome is very multicultural. Broome has a China town with a number of Chinese buildings and a local cemetery with both Japanese and Chinese sections. Additionally with the decline of the pearling industry in the Torres Strait, many people moved to Broome in search of work (CoA 2007b).

5.3.2.4 Heritage Values

5.3.2.4.1 Contribution of the industry to heritage values of the local community

Risk Rating: Contribution of the industry to heritage values of the local community — C3, L4 = 12; HIGH

Justification:

- The town of Broome is characterized by the WA pearling industry, with a rich cultural heritage related to the development and continuation of the pearling industry.

5.3.3 Broader Community

5.3.3.1 Economic Value

5.3.3.1.1 Contribution of the industry to economic value of the broader community

Risk Rating: Contribution of the industry to economic value of the broader community — C2, L1 = 2; NEGLIGIBLE

Justification:

- The WA pearling industry is the world's top producer of the highly-prized South Sea Pearls; the industry is well regarded worldwide, with the value of cultured pearls and other related products considered to be approximately AUD $61 million in 2013.

5.3.3.2 Social Values

5.3.3.2.1 Contribution of the industry to social values of the broader community

Risk Rating: Contribution of the industry to social values of the broader community — C2, L1 = 2; NEGLIGIBLE

Justification:

- The WA pearling industry provides a number of opportunities for the broader community to learn and become involved with the pearling industry. For example, a display, which included aquaria with live pearl oysters and other general information on the pearling industry, was exhibited at the Perth Royal Show in 2014 attracting hundreds of enquiries and questions.

- Broome based Departmental staff also often discuss pearling at regional shows, expos and events.

5.3.3.3 Heritage Values

5.3.3.3.1 Contribution of the industry to heritage values of the broader community

Risk Rating: Contribution of the industry to heritage values of the broader community — C2, L3 = 6; LOW

Justification:

- In 2011, the Australian Government added the West Kimberley to its National Heritage List, in recognition of the significance of the region's pearling heritage to the country's history, culture and indigenous community.

5.4 Governance

Three main aspects of governance were identified as potentially impacting the WA pearling industry's performance: government agencies, industry and other stakeholders (Figure 19). A number of sub-components were identified within each of these three areas, with 12 issues assessed (Table 6). Three issues were a low risk, six were medium risk and three were high risk.

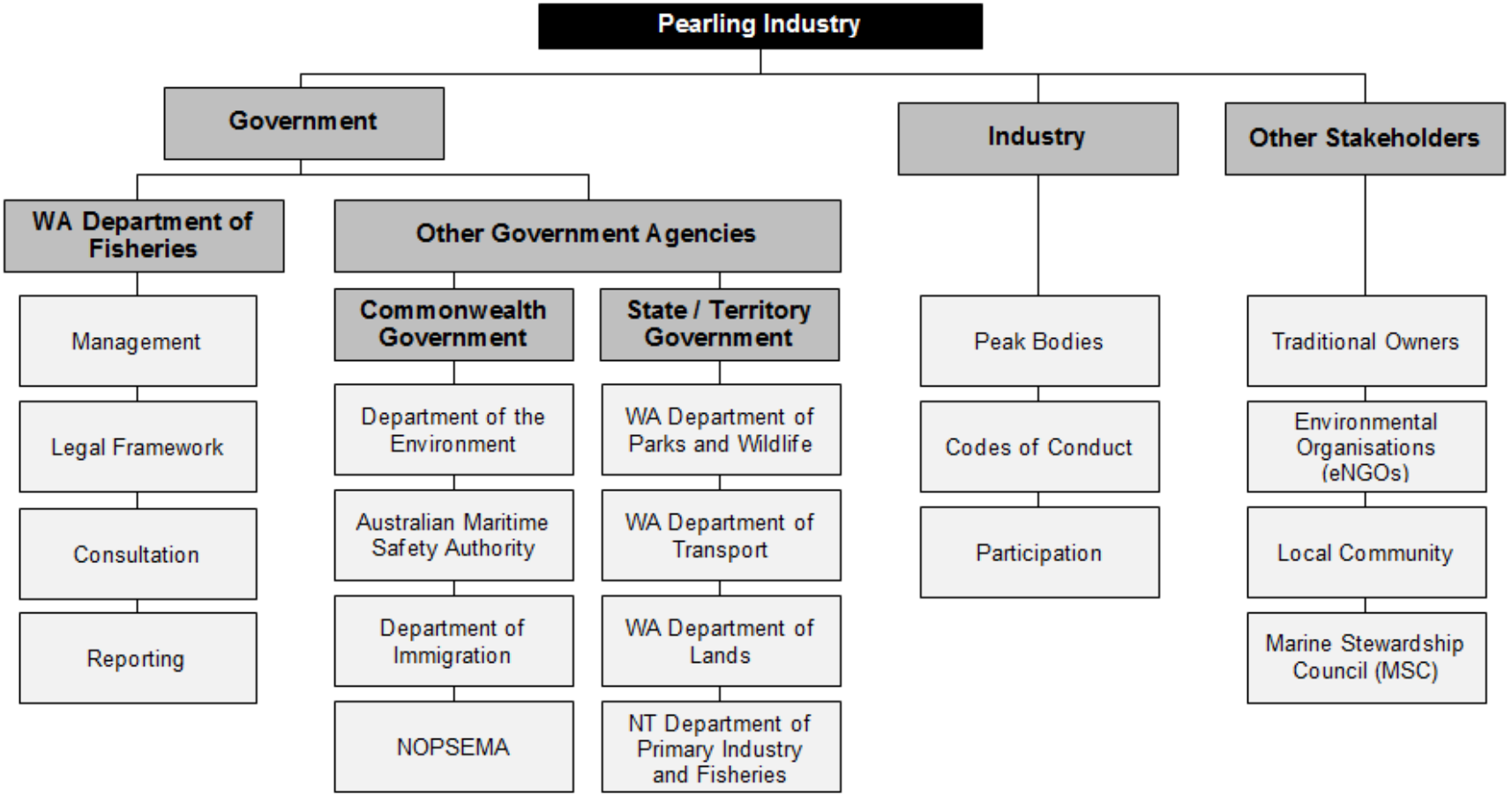

Figure 19. Component tree for Governance aspects of the WA pearling industry

Table 6. Overview Table of Objectives, Identified Components, Sub-Components, Issues and assessed risk ratings related to Governance aspects of the WA pearling industry

Industry Objective	Component	Sub-Component	Issue	Risk Rating
To ensure ESD principles are underpinned by legal, institutional, economic and policy frameworks capable of responding and taking appropriate peremptory and remedial actions.	Government: WA Dept. of Fisheries	Management	Effectiveness of Management System	HIGH
		Legal Framework	Effectiveness of Legal Framework	HIGH
		Consultation	Effectiveness of Consultation Processes	MEDIUM
		Reporting	Effectiveness of Reporting	LOW
	Government: Other Agencies	Commonwealth and State Departments / Agencies	Effectiveness of Consultation Processes	HIGH
	Industry	Peak Bodies	Effectiveness of Peak Bodies	MEDIUM
		Codes of Conduct	Effectiveness of Codes of Conduct	MEDIUM
		Participation	Level of Participation	MEDIUM
	Other Stakeholders	Traditional Owners	Effectiveness of Consultation Processes	MEDIUM
		Environmental Organisations	Effectiveness of Consultation Processes	LOW
		Local Community	Effectiveness of Consultation Processes	LOW
		Marine Stewardship Council (MSC)	Effectiveness of Consultation Processes	MEDIUM

5.4.1 Government: WA Department of Fisheries

5.4.1.1 Management System

The *Pealing Act 1990* and *Pearling (General) Regulations 1991*, together with *Ministerial Policy Guidelines 8* and *17* (MPG 8 and 17, respectively) are the primary instruments for management of the pearling industry in WA. The *Pealing Act 1990* provides for the creation of subsidiary legislation, in the forms of regulations, MPGs, notices, leases and licences (with conditions).

In 2010, the (then) Minster for Fisheries directed the Department to review the existing legislation and scope the requirements for a new WA Act of Parliament to ensure the sustainable development and conservation of the state's aquatic resources into the future. As a result the Aquatic Resource Management Act (currently before parliament as the *Aquatic Resource Management Bill 2015*[5]) was drafted and provides an innovative legislative and administrative framework for the future management of the State's fish and aquatic resources, based on the principles of ESD and EBFM.

Risk Rating: Effectiveness of Management System — C4, L3 = 12; HIGH

Justification:

- The pearling legislation and management arrangements are currently being reviewed to transition into the *Aquatic Resource Management Act* (currently before Parliament as the *Aquatic Resource Management Bill 2015*); however, no significant changes to the management regime are anticipated as part of this process.

5.4.1.2 Legal Framework

The current legal framework includes the Pearling legislation (as detailed above), annual licences, access rights and quota allocation among licence holders. Additionally, the pearling industry is subject to the Offshore Constitutional Settlement (OCS) arrangements (Commonwealth government).

Risk Rating: Effectiveness of Legal Framework — C4, L3 = 12; HIGH

Justification:

- The pearling legislation and management arrangements will transition into the *Aquatic Resource Management Act* (subject to Parliamentary ascent and proclamation); however, no significant changes to the management regime are anticipated as part of this process.

[5] The Bill can be viewed on the Parliamentary website http://www.parliament.wa.gov.au/parliament/bills.nsf/BillProgressPopup?openForm&ParentUNID=1D103914B411A4CF48257DF6001BBD6B

- There is a MoU in place between the WA Minister for Fisheries and NT Minister for Primary Industry and Fisheries regarding the management of the *P. maxima* pearling industry.

5.4.1.3 Consultation Processes

Consultation includes the participation of various stakeholder groups in management processes and the level of communication between the Department, industry and broader stakeholders. This is also dependent on the consultation requirements within the current legislative framework.

Risk Rating: Effectiveness of Consultation Processes — C2, L4 = 8; MEDIUM

Justification:

- MPG No. 8 (issued pursuant to section 24 of the *Pearling Act 1990*) sets out the issues to be taken into consideration by the CEO regarding the assessment and community consultation procedure when considering pearl lease applications for pearling in coastal waters in WA. The decision making authorities, other involved agencies, representative community and interest groups are identified in MPG No. 8 and are to be engaged with as part of the consultation process.
- There is collaboration and communication between the Department and the PPA throughout the year, with the annual management meeting (AMM) being the key forum for discussion of management matters (although additional meetings and communications occur).
- The Department has a general practice of holding an AMM with licensees to discuss research, management, compliance and other specific issues affecting the industry (e.g. marine park planning). These management meetings underpin the decision-making process at the fishery-specific level. Departmental AMMs are coordinated by Industry Consultation Unit (established by WAFIC under the Service Level Agreement [SLA] with the Department), in discussion with the relevant Departmental staff in terms of location, timing and priority of the AMM.

5.4.1.4 Reporting

Reporting takes into account the level of internal and external reviews of the management system or audits of the industry, such as against the MSC standards.

Risk Rating: Effectiveness of Reporting — C2, L3 = 6; LOW

Justification:

- The management system has been the subject of periodic external review as part of the process undertaken to achieve accreditation by the Commonwealth Department of the Environment against the *Guidelines for the Ecologically Sustainable Management of Fisheries – V2* (CoA 2007c). The industry has also undergone an independent pre-

assessment against the MSC fishery standard (Intertek Fishery Certification [IFC] 2014) and is currently pursuing MSC certification[6].

- There is effective reporting in place. The wild collection POF performance outcomes for target and retained non-target species, bycatch, ETP species, habitats and ecosystems are also made publically-available in the annual *Status Report of the Fisheries and Aquatic Resources of Western Australia: the state of the fisheries.*

5.4.2 Government: Other Agencies

A number of other government agencies that influence industry activities were identified at the workshop including the Department of the Environment, Australian Maritime Safety Authority, Department of Immigration, NOPSEMA, WA Department of Parks and Wildlife, WA Department of Transport, WA Department of Lands and the NT Department of Primary Industry and Fisheries.

Risk Rating: Effectiveness of Consultation Processes — C4, L3 = 12; HIGH

Justification:

- MPG No. 8 (issued pursuant to section 24 of the *Pearling Act 1990*) sets out the issues to be taken into consideration by the CEO regarding the assessment and community consultation procedure when considering pearl lease applications for pearling in coastal waters in WA. The decision making authorities, other involved agencies, representative community and interest groups are identified in MPG No. 8 and are to be engaged with as part of the consultation process.
- Departmental AMMs are attended by Department staff, WAFIC, the PPA and licence holders but can also be open to other stakeholder groups, e.g. Recfishwest, processors, universities, other Government departments and the conservation sector.
- The Department is currently working to improve consultation process with the non-fishing sector and has recently introduced changes to provide more opportunities for public and stakeholder involvement in fisheries management processes. Other opportunities may include public forums, targeted consultation with key interest groups or a regional approach depending on the fishery or issues under consideration.

5.4.3 Industry

5.4.3.1 Peak Bodies

The primary peak body for commercial fishing operations in WA is the WAFIC. The PPA is the primary association for the WA and NT pearling industry.

Risk Rating: Effectiveness of Peak Bodies — C3, L3 = 9; MEDIUM

[6] More information on the MSC assessment process for the Australian Silver-lipped Pearl Oyster Fishery is available at: https://www.msc.org/track-a-fishery/fisheries-in-the-program/in-assessment/Indian-ocean/Australia-pearl-oyster

Justification:

- The Department has a general practice of holding an annual management meeting with licensees to discuss research, management, compliance and other specific issues affecting the industry (e.g. Marine Park planning). These management meetings underpin the decision-making process at the fishery-specific level. These meetings are generally coordinated by WAFIC.
- The POF has a SAWG that includes Department staff, the PPA and pearling industry members, which meets annually to review scientific data from monitoring programs and to propose management measures, such as the Sustainable Harvest Levels for the following season (that will be considered by the CEO of the Department when setting the TAC) and any other potential changes.
- The PPA is the main forum for communication between the pearling industry and the Department. The PPA will consult with industry on any required issues; for example, the PPA is responsible for writing to the Department to formally communicate the industry's position on the recommended Harvest Levels and annual access fees.

5.4.3.2 Codes of Conduct

Industry Codes of Conduct outline industry initiatives, viewpoints and activities that are undertaken voluntarily to improve industry outcomes.

Risk Rating: Effectiveness of Codes of Conduct — C2, L4 = 8; MEDIUM

Justification:

- Both the NT and WA pearling industries have adopted a *Pearling Environmental Code of Conduct* (PPA 2008a), which outlines environmental responsibilities of license holders. The Code stipulates that industry will work in conjunction with government and other stakeholders to ensure that the pearling industry is managed sustainably (ecologically and economically) and that the pearling industry's social, economic and environmental benefits are maintained.
- The *Whale Management Policy and Protocol* (PPA 2008b) was developed by PPA in conjunction with the Department of Environment and Conservation (currently the WA Department of Parks and Wildlife) and Seanet Environmental Extension Service to establish a policy and response protocol to deal with a whale interaction, in the rare event that one should occur.

5.4.3.3 Participation

Risk Rating: Level of Participation — C2, L4 = 8; MEDIUM

Justification:

- There is a high level of industry participation in management activities, including discussion of recommended harvest levels (which may influence the annual TAC),

changes to management measures and industry initiatives, such as the pursuit of MSC certification.

5.4.4 Other Stakeholders

5.4.4.1 Traditional Owners

Risk Rating: Effectiveness of Consultation Processes — C3, L3 = 9; MEDIUM

Justification:

- MPG No. 8 (issued pursuant to section 24 of the *Pearling Act 1990*) sets out the issues to be taken into consideration by the CEO regarding the assessment and community consultation procedure when considering pearl lease applications for pearling in coastal waters in WA. The decision making authorities, other involved agencies, representative community and interest groups (including Indigenous groups) are identified in MPG No. 8 and are to be engaged with as part of the consultation process.
- It is currently unclear how Departmental and industry consultation with Indigenous Australians occurs on other issues.
- The Department is currently reviewing its consultation processes to provide greater opportunity for other stakeholder involvement. This may include public forums, targeted consultation with key interest groups or a regional approach depending on the fishery or issues under consideration.

5.4.4.2 Environmental Organisations

Risk Rating: Effectiveness of Consultation Processes — C3, L2 = 6; LOW

Justification:

- There are some clear consultation processes in place, e.g. multiple environmental groups were present at the risk assessment workshop in August 2015, and the Department is currently working to improve consultation processes with the non-fishing sector. This may include public forums, targeted consultation with key interest groups or a regional approach depending on the fishery or issues under consideration.
- Departmental AMMs are attended by Department staff, WAFIC and licence holders, but can also be open to other stakeholder groups, e.g. Recfishwest, processors, universities, other Government departments and the conservation sector.
- MPG No. 8 (issued pursuant to section 24 of the *Pearling Act 1990*) sets out the issues to be taken into consideration by the CEO regarding the assessment and community consultation procedure when considering pearl lease applications for pearling in coastal waters in WA. The decision making authorities, other involved agencies, representative community and interest groups are identified in MPG No. 8 and are to be engaged with as part of the consultation process.

5.4.4.3 Local Community

Risk Rating: Effectiveness of Consultation Processes — C3, L2 = 6; LOW

Justification:

- Industry members are a prominent part of the local community.

5.4.4.4 MSC

Risk Rating: Effectiveness of Consultation Processes — C2, L4 = 9; MEDIUM

Justification:

- Clear consultation processes and governance system are in place as part of the MSC assessment and certification process; however, the WA pearling industry operates differently to other fisheries that have been certified by the MSC as it is a combination of wild stock fishing, hatchery production and aquaculture to primarily produce a luxury product, not food source. Therefore, there has been a need to further discuss the MSC processes and standards.

6. Discussion

This risk assessment of the WA pearling industry has provided a comprehensive overview of the ecological, social, governance and external issues associated with the WA pearling industry. These issues have been prioritised for management using a qualitative risk analysis based on the global standard for risk assessment and management (AS/NZS ISO 31000), which have been adopted for use in a fisheries context (see Fletcher et al. 2002; Fletcher 2005; Fletcher 2014).

Multiple risk assessments have been undertaken previously for the WA pearling industry, with the cultivation aspects assessed in 2001 (Jernakoff 2002) and 2004 (PPA 2004) and the wild collection and hatchery aspects (as part of the POF) assessed at a stakeholder workshop in 2001 (Fletcher et al. 2006) and subsequently internally reviewed by the Department and the PPA in 2008 (Department of Fisheries 2008) and 2013 (Department of Fisheries 2013)[7]. Summaries of the previous risk assessment outcomes are provided in Table 7 and Table 8 below; however, due to differences in the methodology and issues identified and assessed between these previous assessments and the current assessment, a detailed comparison of outcomes over time cannot be completed.

Table 7. Summary of previous risk assessment outcomes for the Western Australian pearling industry: cultivation aspects (Jernakoff 2002; PPA 2004)

Year	Issue	Risk Rating
2001	Introduction of disease from translocation	LOW
	Introduction of disease from hatchery	MED
	Introduction of disease from seeding	MED
	Spread of disease	MED
	Attraction of other fauna (farm leases)	MED
	Impact of entanglement of protected/endangered species	LOW
	Impact of farm lighting on protected/endangered species	LOW
	Impact on habitat	LOW
	Potential for litter	LOW
	Perceived change in water quality	LOW
	Nutrient impacts in sediment	LOW
	Reduction in primary productivity	LOW
	Introduction of exotic organisms	MED
2004	Introduction of disease from hatchery	LOW
	Introduction of disease via technicians	MED

[7] All previous wild-fishery POF risk assessment outcomes (wild collection and hatchery activities only) are available at: http://www.environment.gov.au/system/files/pages/489e726d-1763-4007-8139-32d824d5b55d/files/application-2013.pdf

Spread of disease from translocation of shell	LOW
Spread of endemic disease across bivalve populations	LOW
Impact on wildlife, endangered species and pearl oysters	LOW
Entanglement in longlines	LOW
Panel impact on habitats	LOW
Damage to benthic biota	LOW
Litter (e.g. plastic tags, bags) in the water	LOW
Reduction in water quality (filtering by oysters)	LOW
Nutrient addition	LOW
Alienation of water areas from other users	LOW
Water quality loss (hydrocarbon spill approx. 80 L)	LOW
Groundwater quality loss (diesel 50 000 on land)	MED
Water quality loss (aviation fuel 35 000 L)	MED
Water quality loss (chemical treatment of sewage)	MED

Table 8. Summary of previous risk assessment outcomes for the Western Australian pearling industry: wild collection and hatchery aspects. N/A indicated 'Not Assessed'. (Fletcher et al. 2006; Dept. of Fisheries 2008, 2013)

Issue	2002 Rating	2008 Rating	2013 Rating
Impact on spawning stock of *P. maxima* oysters	LOW	LOW	LOW
Impact of movement on genetic disruption to *P. maxima* oyster populations	NEG	N/A	N/A
Impact of removing pearl oysters – Loss of habitat for fouling or commensal species	NEG	NEG	NEG
Impact of recreational take of specimen shells on species populations	N/A	N/A	LOW
Impact of removing pearl oysters – Trophic interactions	NEG	NEG	NEG
Impact on *P. maxima* stock – Discarding shells	NEG	N/A	N/A
Impact on benthic habitats – Diver activities	NEG	NEG	NEG
Impact on benthic habitats – Anchoring	NEG	NEG	NEG
Impact on benthic habitats – Fish holding sites	NEG	NEG	NEG

The majority of issues in the 2015 risk assessment were considered to be of negligible or low risk, and therefore do not require specific control measures (as per Fletcher et al. 2002). Table identifies those issues scored as a medium or high risk. Although a medium risk is considered an acceptable level of risk, some specific management measures and/or monitoring may be required for these issues. Where an issue is considered to be a high risk, managers will need to continue strong management action or introduce new or additional measure to reduce the risk to an acceptable level (in line with the Department's EBFM

approach and the *POF Harvest Strategy* (draft, 2016). Appropriate management actions for medium and high risk issues are discussed in the risk treatment section below (Section 6.1). Further should any additional management measures be required these will be developed through a consultative process between the Department, the pearling industry and other agencies, as required.

Table 9. Summary of issues identified as medium or high risk in the 2015 risk assessment of WA pearling industry

Issue	Risk Score
External (Environmental) Factors	
Impact of seismic surveys on fishery performance	HIGH
Impact of insurance costs on fishery performance	MEDIUM
Impact of MSC certification on fishery performance	MEDIUM
Impact of marine parks on fishery performance	HIGH
Impact of port infrastructure development on fishery performance	MEDIUM
Impact of oil and gas industry activities on fishery performance	HIGH
Community Wellbeing	
Contribution of the industry to competition among fishers	HIGH
Contribution of the industry to fisher income	HIGH
Contribution of the industry to fisher employment	HIGH
Contribution of the industry to a safe working environment	MEDIUM
Contribution of the industry to the economic value of the local community	MEDIUM
Contribution of the industry to the social values of the local community	MEDIUM
Contribution of the industry to the cultural values of the local community	MEDIUM
Contribution of the industry to the heritage values of the local community	HIGH
Governance	
Effectiveness of Management System (Dept. of Fisheries)	HIGH
Effectiveness of Legal Framework (Dept. of Fisheries)	HIGH
Effectiveness of Consultation Processes (Dept. of Fisheries)	MEDIUM
Effectiveness of Consultation Processes (Other Government Agencies)	HIGH
Effectiveness of Peak Bodies (WAFIC and PPA)	MEDIUM
Effectiveness of (Industry) Codes of Conduct	MEDIUM
Level of Participation (Industry)	MEDIUM
Effectiveness of Consultation Processes (Traditional Owners)	MEDIUM
Effectiveness of Consultation Processes (Marine Stewardship Council)	MEDIUM

In line with the adaptive nature of EBFM, ecological risk assessments will continue to be undertaken periodically (approx. every five years) for the Western Australian Pearling Industry. The broad nature of the 2015 assessment, including all wild-collection, hatchery and cultivation activities as well as associated external factors, community well-being and governance aspects, has provided a standardised, comprehensive report against which these

future assessments can be compared in order to monitor changes in risk over time. This information will be useful for fisheries managers, researchers and the pearling industry in evaluating management arrangements and strategies, prioritising research and identifying industry opportunities.

6.1 Risk treatment

This risk assessment has assisted in the identification and filtering of the different types of ecological risks associated with the pearling industry. Different levels of risk have different levels of acceptability, with different requirements for monitoring and reporting and management actions (See Table 1 for a summary). Issued identified as medium risk are considered acceptable providing there is specific monitoring, reporting and management measures implemented. Risks identified as high are considered 'not desirable', requiring management actions or new control measures to be introduced in the near future. Severe risks are considered 'unacceptable' with major changes to management required in the immediate future (Fletcher et al. 2002).

A summary of issues identified as medium risk or higher with associated monitoring, reporting and management actions is provided Table 10. Note that whilst risks identified as medium are considered acceptable and not requiring additional treatment, they are documented in Table 10 to provide clarity in relation to current reporting and management arrangements. Some of issues identified in the ERA as high risk are outside of the Departments direct influence or jurisdiction. However, whilst the Department cannot directly influence these issues, the risks can be mitigated by ensuring that *P. maxima* stocks are sustainably managed through regular monitoring, targeted research and best management practices.

Table 10. Risk Treatment: Specification of probable reporting and monitoring requirements and management actions for medium and high risk

Issue	Risk Score	Reporting and monitoring requirements	Management action
External (Environmental) Factors			
Impact of seismic surveys on fishery performance	HIGH	The Department is not the relevant agency in terms of direct reporting and monitoring. Continue with current monitoring and reporting on *P.maxima* stocks.	Continue to provide advice to NOPSEMA and companies completing seismic surveys on requirement to consult with the pearling industry. Ensure sustainable management of *P.maxima* stocks to assist in the mitigation of external impacts.
Impact of insurance costs on fishery performance	MEDIUM	Mainly influenced by factors external to the Department. Continue with current monitoring and reporting on *P.maxima* stocks.	Ensure sustainable management of *P.maxima* stocks to assist in the mitigation of external impacts.
Impact of MSC certification on fishery performance	MEDIUM	Continue with current monitoring and reporting on *P.maxima* stocks.	Ensure sustainable management of *P.maxima* stocks to meet MSC standards. Ensure the pearling industry meets the MSC standards by implementing required changes identified during the assessment
Impact of marine parks on fishery performance	HIGH	The Department is not the relevant agency in terms of direct reporting and monitoring. The responsible agency for state marine park is DPaW and for commonwealth marine parks is DoTE. Provide scientific advice to DPaW and DoTE regarding the impact of marine parks as required. Continue with current monitoring and reporting on *P.maxima* stocks.	Provide management advice to DPaW and DoTE regarding the impact of marine parks as required.
Impact of port infrastructure development on fishery performance	MEDIUM	The Department is not the relevant agency in terms of direct reporting and monitoring. Continue with current monitoring and reporting on *P.maxima* stocks.	Provide general information to the relevant agencies/companies on the pearling industry. Ensure sustainable management of *P.maxima* stocks to assist in the mitigation of external impacts.
Impact of oil and gas industry activities on fishery performance	HIGH	The Department is not the relevant agency in terms of direct reporting and monitoring. Continue with current monitoring and reporting on *P.maxima* stocks.	Continue to provide advice to NOPSEMA and oil and gas companies on the requirement to consult with the pearling industry. Ensure sustainable management of *P.maxima* stocks to assist in the mitigation of external impacts.

Issue	Risk Score	Reporting and monitoring requirements	Management action
Community Wellbeing			
Contribution of the industry to competition among fishers	HIGH	Mainly influenced by factors external to the Department. Continue to monitor and report on *P.maxima* stocks.	Maintain current management practises to ensure *P.maxima* stocks are sustainably managed to ensure that individuals and companies in the pearling industry can maintain and enhance economic benefits, within the constraints of ecological sustainability.
Contribution of the industry to fisher income	HIGH	Mainly influenced by factors external to the Department. Continue to monitor and report on *P.maxima* stocks.	Maintain current management practises to ensure *P.maxima* stocks are maintained to ensure individuals involved in the pearling industry can maintain and enhance their livelihood, within the constraints of ecological sustainability.
Contribution of the industry to fisher employment	HIGH	Mainly influenced by factors external to the Department. Continue to monitor and report on *P.maxima* stocks.	Maintain current management practises to ensure *P.maxima* stocks are maintained to ensure individuals involved in the Pearling Industry can maintain and enhance their livelihood, within the constraints of ecological sustainability.
Contribution of the industry to a safe working environment	MEDIUM	The Department is not the relevant agency in terms of direct reporting and monitoring.	Be aware of the current practices of the pearling industry and codes developed by the PPA. Assist in providing information to the Occupational Diving Working Party established by the Commission for Occupation Safety and Health.
Contribution of the industry to the economic value of the local community	MEDIUM	Mainly influenced by factors external to the Department. Continue to monitor and report on *P.maxima* stocks.	Maintain current management practises to ensure the sustainability of *P.maxima* stocks so that the pearling industry can maintain its position in the local community. Engage with and provide general information to the local community on the management of the pearling industry.
Contribution of the industry to the social values of the local community	MEDIUM		
Contribution of the industry to the cultural values of the local community	MEDIUM		
Contribution of the industry to the heritage values of the local community	HIGH	Mainly influenced by factors external to the Department. Continue to monitor and report on *P.maxima* stocks.	Maintain current management practises to ensure the sustainability of *P.maxima* stocks so that the pearling industry can maintain its position in the local community. Engage with and provide general information to the local community on the management of the pearling industry.

Issue	Risk Score	Reporting and monitoring requirements	Management action
Governance			
Effectiveness of Management System (Dept. of Fisheries)	HIGH[8]	Summary of management arrangements is reported within the State of the Fisheries annually. As required, the Department will publish relevant policy statements and draft legislation for comment by the pearling industry and broader community.	Continue to consult with the pearling industry and other relevant stakeholders on management systems and process. The Department will work closely with the PPA and pearling industry to effect a smooth transition into the ARMA.
Effectiveness of Legal Framework (Dept. of Fisheries)	HIGH[9]	Summary of management arrangements is reported within the State of the Fisheries annually. As required, the Department will publish relevant policy statements and draft legislation for comment by the pearling industry and broader community.	Continue to consult with the pearling industry and other relevant stakeholders on management systems and process. The Department will work closely with the PPA and pearling industry to effect a smooth transition into the ARMA.
Effectiveness of Consultation Processes (Dept. of Fisheries)	MEDIUM	Maintain current reporting and monitoring of consultation processes.	The Department is currently working to improve consultation processes with the non-fishing stakeholders.
Effectiveness of Consultation Processes (Other Government Agencies)	HIGH	The Department is not the relevant agency in terms of direct reporting and monitoring. When consultation is completed by the Department this will be recorded.	The Department to continue to provide information and advice to other government agencies regarding consultation with the pearling industry.
Effectiveness of Peak Bodies (WAFIC and PPA)	MEDIUM	Maintain current reporting and monitoring of consultation processes and peak body requirements.	Maintain current peak body arrangements. Maintain current Service Level Agreement with WAFIC. Maintain effective relationships with WAFIC and the PPA.
Effectiveness of (Industry) Codes of Conduct	MEDIUM	Mainly influenced by factors external to the Department.	Be aware of the current practices of the pearling industry and codes of conduct developed by the PPA. Continue to provide information and assist in the development of codes of conduct as required.

[8] Note the risk rating of high was due to current discussions with the pearling industry on the transition of the PA into the ARMA framework.
[9] Note the risk rating of high was due to current discussions with the pearling industry on the transition of the PA into the ARMA framework.

Issue	Risk Score	Reporting and monitoring requirements	Management action
Governance continued			
Level of Participation (Industry)	MEDIUM	Mainly influenced by factors external to the Department. Maintain current reporting and monitoring on the *P.maxima* resource.	Continue to encourage industry participation in the management of the *P.maxima* resource.
Effectiveness of Consultation Processes (Traditional Owners)	MEDIUM	Maintain current reporting and monitoring of consultation processes.	The Department is currently reviewing its consultation processes to provide greater opportunity for other stakeholder involvement.
Effectiveness of Consultation Processes (Marine Stewardship Council)	MEDIUM	Continue with current monitoring and reporting on *P.maxima* stocks.	Ensure sustainable management of *P.maxima* stocks to meet MSC standards. Ensure the pearling industry meets the MSC standards by implementing required changes identified during the assessment

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8. Appendices

Appendix A. Stakeholder workshop participants and reviewers

Attendees	Representative Body
Facilitators	
Dr Brent Wise	Department of Fisheries WA
Kendra Travaille	Department of Fisheries WA
Participants	
Aaron Irving	Pearl Producers Association (PPA)
Guy Leland	Western Australian Fishing Industry Council (WAFIC)
James Brown	Cygnet Bay Pearls
Bruce Brown	Cygnet Bay Pearls
Peter Carrington	Maxima Pearls
Melanie Carrington	Maxima Pearls
Patrick Moase	Clipper Pearls
Kym Coffey	Paspaley Pearls
Tony Thiel	Paspaley Pearls
Jason Fowler	Environs Kimberley
Alexander Watson	World Wildlife Fund (WWF)
Murray Barton	NT D**e**partment of Primary Industries and Fisheries
Peter Godfrey	Department of Fisheries WA (Compliance)
Shane O'Donoghue	Department of Fisheries WA (Aquatic Management)
Rhiannon Jones	Department of Fisheries WA (Aquatic Management)
Andrew Cribb	Department of Fisheries WA
Observers	
Matt Watson	Marine Stewardship Council (MSC)
Dr Sabine Daume	Global SCS – Australia
Apologies	
Alan Kendrick	WA Department of Parks and Wildlife
Additional Reviewers of Risk Assessment Report	
Dr Rick Fletcher	WA Department of Fisheries (Executive Director, Research)
Dr Lynda Bellchambers	WA Department of Fisheries (Biodiversity and Biosecurity)
Dr Anthony Hart	Department of Fisheries WA (Invertebrates)
Rae Burrows	WA Department of Fisheries (Aquatic Environment)
Marion Massam	WA Department of Fisheries (Aquatic Environment)
Victoria Aitken	WA Department of Fisheries (Aquatic Environment)
Fran Stephens	WA Department of Agriculture (Fish Health)

Appendix B. Risk assessment likelihood and consequence levels

Standard Consequence — Likelihood Risk Matrix

		Likelihood				
		Remote (1)	Unlikely (2)	Possible (3)	Likely (4)	Certain (5)
Consequence	Minimal (1)	1	2	3	4	5
	Moderate (2)	2	4	6	8	10
	High (3)	3	6	9	12	15
	Major (4)	4	8	12	16	20
	Catastrophic (5)	5	10	15	20	25

Risk Levels applied by the Department of Fisheries

Risk Category / Level	Description	Likely Reporting & Monitoring Requirements	Likely Management Action
1 Negligible	Acceptable; Not an issue	Brief justification – no monitoring	Nil
2 Low	Acceptable; No specific control measures needed	Full justification needed – periodic monitoring	None specific
3 Medium	Acceptable; With current risk control measures in place (no new management required)	Full Performance Report – regular monitoring	Specific management and/or monitoring required
4 High	Not desirable; Continue strong management actions OR new / further risk control measures to be introduced in the near future	Full Performance Report – regular monitoring	Increased management activities needed
5 Severe	Unacceptable; Major changes required to management in immediate future	Recovery strategy and detailed monitoring	Increased management activities needed urgently

LIKELIHOOD LEVELS

(Note: If not measurable, Likelihood Level was scored as 0)

1. Remote – Never heard of but not impossible here (< 5 % probability)
2. Unlikely – May occur here but only in exceptional circumstances (> 5 %)
3. Possible – Clear evidence to suggest this is possible in this situation (> 30 %)
4. Likely – It is likely, but not certain, to occur here (> 50 %)
5. Certain – It is almost certain to occur here (> 90 %)

CONSEQUENCE LEVELS

Note: if not measurable Consequence Level is essentially 0

FISH STOCKS (retained / non-retained species) – measured at a stock level

1. Measurable but minor levels of depletion of fish stock
2. Maximum acceptable level of depletion of stock
3. Level of depletion of stock unacceptable but still not affecting recruitment level of the stock
4. Level of depletion of stock are already (or will definitely) affect future recruitment potential / level of the stock
5. Permanent or widespread and long-term depletion of key fish stock, close to extinction levels

ETP SPECIES – measured at a population or regional level

1. Level of capture is common but will not further impact on stock and is well below that which will generate public concern
2. Level of capture is the maximum that will not impact on recovery or cause unacceptable public concern
3. Recovery may be being affected and/or some clear, but short-term public concern will be generated
4. Recover times are clearly being impacted and/or public concern is widespread
5. Further declines in ETP species stocks are occurring or major public concern is ongoing

HABITATS – measured at a regional level

1. Measurable impacts to habitats but still not considered to impact on habitat dynamics or system
2. Maximum acceptable level of impact to habitat with no long-term impacts on region-wide habitat dynamics
3. Above acceptable level of loss / impact with region-wide dynamics or related systems may begin to be impacted
4. Level of habitat loss clearly generating region-wide effects on dynamics and related systems
5. Total region-wide loss of habitat and associated systems

ECOSYSTEM / ENVIRONMENT – measured at a regional level

1. Measurable but minor change in the environment or ecosystem structure but no measurable change to function
2. Maximum acceptable level of change in the environment / ecosystem structure with no material change in function
3. Ecosystem function altered to an unacceptable level with some function or major components now missing and/or new species are prevalent
4. Long-term, significant impact with an extreme change to both ecosystem structure and function; different dynamics now occur with different species / groups now the major targets of capture or surveys
5. Permanent or widespread long-term damage to the environment; total collapse or complete shift in ecosystem processes

PUBLIC REPUTATION and IMAGE

1. Negligible negative impact and news profile
2. Low negative impact, low news profile
3. Some public embarrassment, moderate impact and news profile, minor Ministerial involvement
4. High public embarrassment, high impact and news profile, third-party actions, public and significant Ministerial involvement
5. Extreme public embarrassment, very high multiple impacts, high widespread news profile, third-party actions, public and prolonged Ministerial involvement, Government censure, Upper House enquiry

ECONOMIC – measured at a regional or entire fishery level

1. A small, measurable but temporary impact on economic sustainability of some fishers in relevant fisheries
2. A minor, ongoing impact on economic sustainability of all / most fishers in relevant fisheries
3. Temporary significant impact on economic sustainability or ongoing moderate impact on economic performance of the fishery
4. Long-term, major reduction in economic sustainability for relevant fisheries and their related industries
5. Permanent and widespread complete cessation of economic sustainability for the relevant fisheries and their related industries

SAFETY AND HEALTH

1. First Aid Only
2. Some minor medical treatment required, eg visit to doctor's surgery. Less than a week off work.
3. Hospitalisation and/or intensive and extended treatment period required.
4. Serious or extensive injuries / disease. Hospitalisation and extended recuperation period > 1 month
5. Death or multiple severe permanent disabilities.

SOCIAL

1. Temporary and minor additional stakeholder restrictions or expectations (< 1 year)
2. Some minor ongoing restrictions or loss of expectations
3. Some important expectations suspended or severely restricted in the medium term (> 2 years)
4. Long-term suspension or restriction of expectation in some key activities
5. Permanent loss of all key expectations for activities on this asset

COMMUNITY (Social Structures / Culture) – measured at a regional level

1. Some minor impacts may be measurable but minimal concerns
2. Clear impacts but no local communities threatened or social dislocations
3. Major impacts at least at local level, disruptions now evident
4. Impacts occurring at broader level or severe local impacts
5. Complete alteration to social structures across a region

OPERATIONAL EFFECTIVENESS

1. Minor delay in achievement of a key deliverable
2. Minor element of one key deliverable unable to be achieved on time
3. Significant delay in achievement of key deliverable
4. Non-achievement of more than one key deliverable or major delay to entire strategic directive
5. Non-achievement of an entire strategic directive