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**WESTERN AUSTRALIAN
SILVER-LIPPED PEARL OYSTER
(*PINCTADA MAXIMA*) RESOURCE**

HARVEST STRATEGY

2016 – 2021

Version 1.0

PEARL OYSTER FISHERY

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Western Australian silver-lipped pearl oyster (*Pinctada maxima*) resource
harvest strategy 2016 – 2021
Version 1.0
Pearl Oyster Fishery

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TABLE OF CONTENTS

1 INTRODUCTION	1
1.1 Review Process	1
2 SCOPE	2
2.1 Environmental Context	3
2.2 Target Species – <i>Pinctada maxima</i>	3
2.3 Fishing Activities	4
2.3.1 Governance	4
2.3.2 Commercial Fishing	5
2.3.3 Recreational Fishing	7
2.3.4 Customary Fishing	7
3 HARVEST STRATEGY	8
3.1 Harvesting and Management Approach	8
3.2 Long-Term Objectives	8
3.2.1 Ecological Sustainability (all sectors):	8
3.2.2 Social Objective (POF):	9
3.2.3 Economic Objective (POF):	9
3.3 Operational Objectives	9
3.4 Performance Indicators, Reference Levels and Control Rules	9
3.4.1 Identifying Performance Indicators, Reference Levels, and Tolerance Levels	10
3.4.1.1 <i>Pinctada maxima</i>	10
3.4.1.1.1 Reference periods	10
3.4.1.1.2 Culture pearl oysters (120 to 175 mm shell length)	10
3.4.1.1.3 Larger pearl oysters (> 175 mm shell length)	11
3.4.1.1.4 Tolerance Levels	12
3.4.1.2 Other Ecological Assets	12
3.4.1.3 Social and Economic Objectives	13
3.5 Monitoring and Assessment Procedures	18
3.5.1 Information and Monitoring	18
3.5.1.1 Fishery-Dependent Information	18
3.5.1.1.1 Commercial Catch and Effort Reporting	18

3.5.1.2	Fishery-Independent Information	18
3.5.1.2.1	Recruitment Monitoring	18
3.5.1.2.2	Population Surveys	18
3.5.2	Assessing Fishery Impacts	19
3.5.2.1	<i>Pinctada maxima</i>	19
3.5.2.1.1	Standardisation of Catch Rates and Recruitment Indices	19
3.5.2.2	Risk Assessments	19
4	MANAGEMENT MEASURES AND IMPLEMENTATION	20
4.1	Management Measures	20
4.2	Implementing Changes to the Management Arrangements	21
4.2.1	Consultation	21
4.2.1.1	Commercial Sector Consultation	21
4.2.1.1.1	TAC Setting Process	22
4.2.1.2	Consultation with Other Groups	23
4.3	Compliance and Enforcement	23
4.3.1	Operational Compliance Plan	24
4.3.1.1	Compliance Strategies	24
4.3.1.2	Vessel Monitoring System (VMS)	24
5	REFERENCES	25
6	APPENDIX I.	27

1 INTRODUCTION

Harvest strategies for aquatic resources managed by the Western Australian Department of Fisheries (the Department) are formal documents prepared to support decision-making processes and ensure these processes are consistent with the principles of Ecologically Sustainable Development (ESD; DoF 2002) and Ecosystem Based Fisheries Management (EBFM; DoF 2010; Fletcher et al. 2012). The principles of ESD are reflected within the Pearling legislative framework and the draft *Aquatic Resources Management Bill 2015*, Clause 9, which will replace the *Pearling Act 1990* (PA) once enacted.

The publication of these strategies is intended to make the decision-making considerations and processes for the management of specified aquatic resources publicly transparent and provide a basis for informed dialogue on management actions with resource users and other stakeholders.

These strategies provide guidance for decision-makers, but do not derogate from or limit the exercise of discretion required for independent decision-making under the PA by either the Minister for Fisheries, the Chief Executive Officer of the Department or other delegated decision-makers in order to meet the objects of the PA.

Harvest strategies make explicit the objectives, performance indicators, reference levels, and harvest control rules for each defined ecological resource taken into consideration by the Department when preparing advice for the Minister for Fisheries (DoF 2015). They also indicate the scope of management actions required in relation to the status of each resource in order to meet the specific long- and short-term management objectives and the broader goals of ESD and EBFM.

1.1 Review Process

The harvest strategy policy (DoF 2015) recognises that fisheries change over time and that a review period should be built into each harvest strategy to ensure that it remains relevant. This harvest strategy will remain in place for a period of five (5) years, after which time it will be fully reviewed; however, given that this is the first formal harvest strategy for this resource, this document may be subject to further review and amended as appropriate within the five year period.

2 SCOPE

This harvest strategy has been developed for the Western Australian (WA) silver-lipped pearl oyster (*Pinctada maxima*: *P. maxima*) resource (wildstock only¹). The Pearl Oyster Fishery (POF) is the only fishery that commercially targets *P. maxima* in WA waters. The POF boundaries encompass the northern coastal waters from the North West Cape (114° 10' E longitude), including Exmouth Gulf, northeast to the Northern Territory border (Figure 1). *P. maxima* are principally used for the culture of South Sea pearls and to a lesser extent, for mother-of-pearl (MOP) nacre and pearl oyster meat.

This strategy has been developed in line with the Department's over-arching *Harvest Strategy Policy for Aquatic Resources* (DoF 2015) and relevant national policies (ESD Steering Committee 1992) and guidelines (e.g. Sloan et al. 2014). In addition to considering fishing impacts on the target species (*P. maxima*), it also considers impacts on bycatch², endangered, threatened and protected (ETP) species, benthic habitats, and broader ecosystem processes to ensure the risks to these elements are managed effectively.

This strategy also sets out and summarises matters relevant to the independent, third-party assessment of the fishery against the Marine Stewardship Council (MSC) sustainability standard and should be read in conjunction with the MSC Assessment Report for this resource (Hart et al. in prep).

This document has been developed via a consultative process with industry members and has been approved by the Director General of the Department of Fisheries and the Minister for Fisheries.

¹ Note, activity related to pearl culture and the hatchery-production of *P. maxima* that occur in conjunction with the collection of wild pearl oysters is beyond the scope of this harvest strategy. The management strategies for these aspects are encompassed in the Pearling legislation, the Pearl Oyster Translocation Protocol and pearling industry Codes of Conduct.

² *Bycatch* is described as the part of the catch which is returned to the sea (usually referred to as non-retained or discarded) either because it has no commercial value or because legislative requirements preclude it being retained.

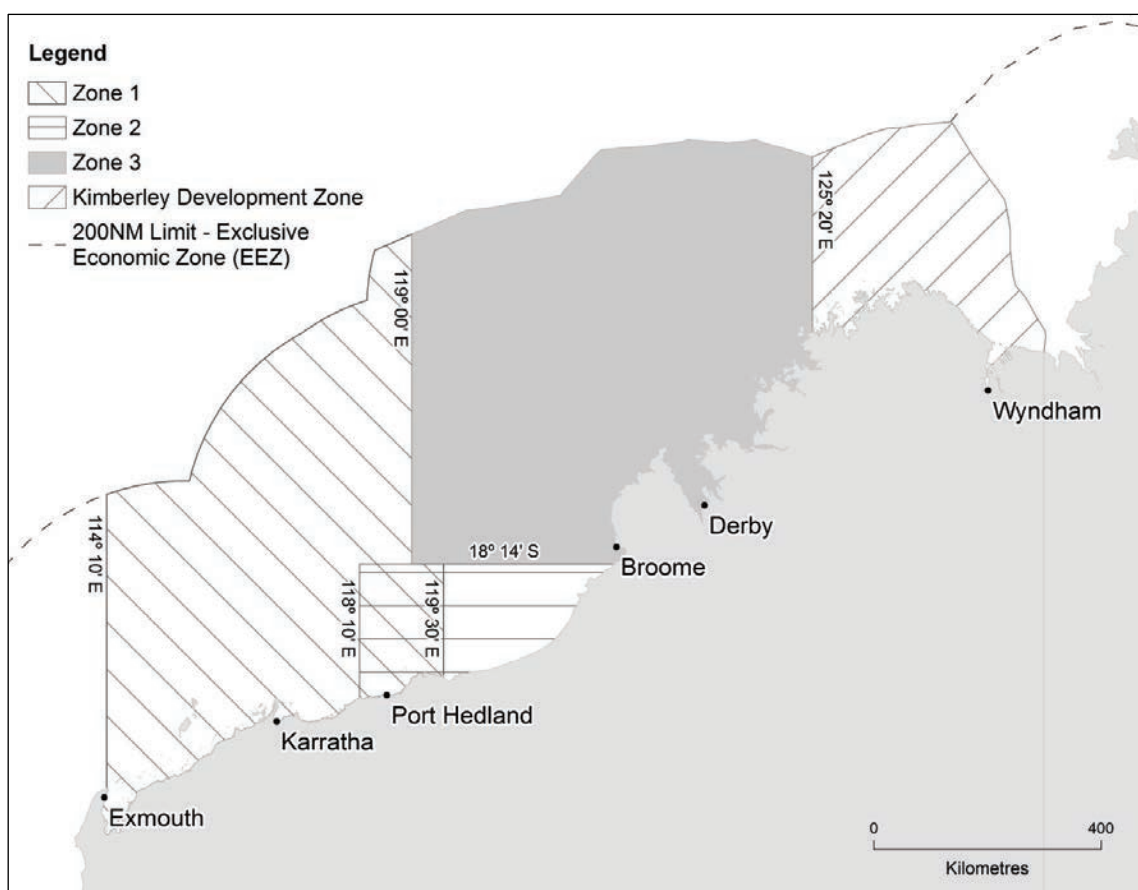


Figure 1. Location and boundaries of the Western Australian Pearl Oyster Fishery

2.1 Environmental Context

The POF is located on the North West Shelf of Australia. Harvesting of *P. maxima* primarily occurs in water depths of 10 – 35 metres off the southern Kimberly Coast, at Eighty Mile Beach and the Lacepede Islands, although a small amount of fishing has historically occurred in Exmouth Gulf. This region has a semi-arid, tropical climate with rainfall mainly occurring during the November to March monsoonal season. The occurrence of cyclones during this time can have major localised effects including high seas, large waves and storm surges. The wide continental shelf in the region results in large tidal amplitudes of up to 11 metres, and strong tidal currents produce a range of ecologically diverse filter-feeding communities. The region also has a number of ETP species, including cetaceans, dugong, marine turtles, sea snakes, crocodiles, syngnathids (seahorses and pipefish), sharks, rays and sea and shore birds.

2.2 Target Species – *Pinctada maxima*

The silver-lipped pearl oyster, *P. maxima*, is a filter-feeding bivalve mollusc and is the largest of four *Pinctada* species found in WA. The species has an Indo-Pacific distribution and is found in coastal waters north of Exmouth across northern Australia to Cooktown, Queensland. It occurs in shallow, subtidal habitats characterised by strong tidal currents in five to >50 metres depth. *P. maxima* is a broadcast spawner, and its life cycle includes a planktonic egg and larval stage of 28 to 35 days. Initial genetic analyses (using allozymes)

indicated high levels of connectivity between populations (Johnson and Joll 1993); however, more recent analyses (using microsatellite markers) have found differentiation between stocks in WA, the Northern Territory (NT) and Indonesia. Within WA, low levels of differentiation were also identified between geographically-distant populations in Exmouth Gulf and the northern Kimberley region (Benzie and Smith-Keune 2006). For management purposes *P. maxima* in WA are considered a single stock.

P. maxima is a protandrous hermaphrodite; animals mature first as males around three to four years of age (110 – 120 mm shell length¹), after which they undergo a sex change and become females. By 170 mm shell length, half of the animals are females, and by 190 mm shell length, the majority of the population is female (Hart and Joll 2006). Since animals can spawn every year, each individual can function as both a male and then a female for several spawning seasons. Very few animals are both male and female simultaneously. Spawning occurs between September and May each year, with a peak from October to December and a smaller, secondary spawning event in February and March (Rose et al. 1990; Rose and Baker 1994). Egg production by *P. maxima* is high, and mature female gonads contain between 20 and 50 million eggs. Recruitment of juveniles appears to be driven primarily by environmental conditions including sea surface temperature, rainfall and wind conditions (Hart et al. 2011), and *P. maxima* are commonly found in areas where the seabed has crevices that allow the young animals to settle into a protected environment. Large *P. maxima* individuals (> 200 mm shell length) have been estimated to be 15 to 20 years old. The instantaneous rate of natural mortality is relatively low and varies between 0.1 and 0.18 yr⁻¹, depending on habitat; this corresponds to a mortality of 10 to 16.5 % annually (Hart and Friedman 2004).

2.3 Fishing Activities

2.3.1 Governance

The POF is primarily managed via the PA, subsidiary instruments and policy guidelines, including:

- the *Pearling (General) Regulations 1991* (PR);
- the *Pearling (Declaration of Pearl Oysters) Notice 1995*;
- the *Pearling (Pearl Oyster Shell Size) Notice 1997*;
- the *Pearling (Declaration of Zones) Notice 1995* and *Pearling (Declaration of Zones) Amendment Notice 1997*;
- Ministerial Policy Guidelines (No. 17); and

¹ All measurements referring to shell size are dorso-ventral measurements

- pearling leases and licences (and associated conditions).

Licence holders and fishers operating within the POF must also comply with the requirements of the:

- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC);
- Western Australian *Fish Resources Management Act 1994* (Part 3 and Division 1 of Part 11);
- Western Australian *Fish Resources Management Regulations 1995* (Part 13A);
- *Western Australian Marine Act 1982*;
- Western Australian *Wildlife Conservation Act 1950*;
- Western Australian *Conservation and Land Management Act 1984*;
- Western Australian *Environmental Protection Act 1986*; and
- Any other legislation governing the use of the marine environment in which activities occur.

It should also be noted that the *Aquatic Resource Management Bill 2015* is currently before Parliament. Subject to Parliamentary ascension and proclamation of the Bill, when the new Aquatic Resources Management Act (ARMA) comes into force, it will repeal the PA. From that point the POF will be managed under the provisions of the new ARMA.

2.3.2 Commercial Fishing

Commercial fishing for pearl oysters in Western Australia began in Shark Bay in 1850, where the smaller *Pinctada albina* pearl oyster formed the basis of the fishery (Southgate and Lucas 2008). The fleet gradually moved northwards along the coast through Cossack to Eighty Mile Beach, where plentiful stocks of *P. maxima* were discovered near Nickol Bay in the 1860s. Over the next few decades, a series of regulations were introduced, including the *Pearl Fishing Act 1886* and the *Pearling Act 1912*. This legislation created the management framework for the commercial pearl oyster fishery.

Initially, the pearling industry harvested *P. maxima* pearl oysters (pearl oysters) of all sizes but favoured the larger oysters which were used for the production of MOP for buttons and inlays in furniture and watches. By 1910 there were nearly 400 luggers and 3500 people in the pearling industry. At its peak, around 2000 tonnes (approx. 2 million pearl oysters) was harvested annually, supplying up to 75 % of global MOP production. The mass production of synthetic buttons and economic factors relating to the Great Depression led to the decline in fishing and MOP production, and pearling activities almost entirely ceased during World War II.

In 1949 the *Pearling Act Amendment Act 1922*, which prohibited the culture of pearls, was repealed, and the pearl culture phase of the pearling industry began to develop and replace the MOP fishery. *P. maxima* pearl culture activities began in Kuri Bay in the Kimberley region

during the 1950s, and by the end of the 1970s, most of the pearling industry had moved into cultured pearl production. The annual catch of *P. maxima* used for MOP declined to between 200 to 300 tonnes, however the catch of *P. maxima* used to culture pearls (between 120 and 175 mm shell length) increased to around 400 000 in the same period (Wells & Jernakoff 2006, Malone et al. 1988). This shift towards pearl culture saw a change in the location of fishing and decrease in the number of pearling vessels to 12, as well as the voluntary protection of larger oysters (>175 mm shell length) to ensure continuity of high levels of recruitment considered necessary for adequate culture pearl oyster abundance.

During the 1990s hatchery techniques for *P. maxima* were pioneered by Rose & Baker (1994). In 1992, the WA Government granted hatchery options to licensees enabling production of pearls from hatchery-reared pearl oysters and reducing the reliance on wildstock pearl oysters. Hatchery bred pearl oysters now supplement an important component of pearl production in WA (DoF 2001).

The POF is a dive-based hand collection fishery; highly trained divers collect individual pearl oysters while being towed behind large (~ 35 metres long) tender vessels, typically in depths of 10 to 35 metres. Collection of wild *P. maxima* generally occurs for three to four months of the year, between March and July, during the neap phase of the tidal cycle when currents are reduced. Divers operate on hookah, with air supplied from a surface compressor. The present day fishery is a 'gauntlet fishery' focused on the collection of smaller pearl oysters (100 to 175 mm shell length) that are optimal for pearl culture.

In addition to the collection of pearl oysters for culture purposes, the harvest of a specific number of pearl oysters larger than 175 mm shell length is allowed under a co-management arrangement between the Department and licence holders. A baseline harvest of up to 53 000 larger pearl oysters is allowed; however, this number can be increased during periods of strong recruitment, subject to information on recruitment strength and consultation with licence holders. Increased harvest of larger pearl oysters has occurred since 2011, in response to an exceptional settlement event in 2005 that resulted in a stock abundance well in excess of both the fleet's fishing capacity and the potential market capacity. Fishing of the 2005 cohort has provided the Department with a valuable research opportunity and has also provided the industry with an opportunity to increase production of MOP and pearl oyster meat. The collection of larger pearl oysters will be reduced in forthcoming years as the abundance returns to normal levels.

The POF is managed primarily through output controls in the form of a Total Allowable Commercial Catch (TAC) that is divided into Individual Transferable Quotas (ITQs). There are 572 total quota units, across management Zones 1 – 3 (Figure 2). One quota unit equates to a particular number of pearl oysters and varies from year to year. The value of a quota unit depends on the status of pearl oyster stocks and the annual TAC as set by the CEO of the Department, based on advice from a Stock Assessment Working Group (SAWG) and the Pearl Producers Association (PPA). The 2015 TAC for all fished Zones (1–3) was 667 350 pearl oysters comprising 54 970 pearl oysters in Zone 1 and 612 380 (with an agreement that 502 700 pearl oysters between 100–175mm shell length could be taken and 109 680 pearl

oysters greater than 175mm shell length could be taken) in Zone 2/3. Noting transferability of quota units, the TAC is currently fished by 6 to 10 vessels.

The total annual catch of *P. maxima* since 1979 has oscillated between 330 000 and 830 000 pearl oysters, with an overall average of 530 000 (\pm 120 000 SD). The POF is primarily based on *P. maxima* from Zone 2, which has supplied 70 % of the total harvest in the past 30 years, and close to 100% in recent years. Since its introduction in 1982 the TAC has generally been caught, although since 2008 a combination of exceptionally high recruitment and economic factors have resulted in the TAC not being caught. Total annual effort in Zone 2/3 since 1979 has oscillated between 3000 and 23 000 dive hours, with a stable trend and overall average of 14 400 (\pm 4000 SD).

Divers are able to specifically target pearl oysters of choice (size and quality), and no other species are retained. Although not directly targeted, commensal biofouling organisms that encrust the pearl oyster shells are collected; however, the harvested pearl oysters are young and generally have relatively little epiphytic growth (Daume et al. 2009).

The selective nature of the fishing method (hand collection by divers) minimises the risk of interactions with ETP species. There have been no interactions with any ETP species reported in the POF.

Habitat interactions in the POF are minimal. Divers swim about 1.5 metres off the seabed and are not in contact with the substrate. Since water clarity is paramount to divers being able to identify the appropriate sized pearl oysters, significant effort is put in place to ensure they do not strike the sea floor while collecting pearl oysters.

A large proportion of pearls are sold to overseas markets. Fluctuations in the value of the Australian dollar and other macroeconomic factors can have a large influence on the POF. The pearling industry suffered a major economic downturn from the Global Financial Crisis (GFC) in 2008, which had an impact on luxury goods including pearls. In 2013, the value of cultured pearls and other related products (MOP and pearl oyster meat) was considered to be AUD \$61 million (Hart et al. 2014a), compared with AUD \$120 to 180 million prior to the GFC.

2.3.3 Recreational Fishing

No authorised recreational fishing has taken place under the PA.

2.3.4 Customary Fishing

Pearl oyster shell is an important resource of cultural significance to the Indigenous people of Australia and has been harvested for at least 20 000 years (Yu and Brisbourn 2011). Aboriginal Australians of the West Kimberley harvested pearl oyster shells from shallow waters and had well established traditional trading networks that extended throughout Australia (Akerman and Stanton 1994). The *P. maxima* pearling industry was initiated in 1861 through trade between early explorers and Aboriginal Australians (Southgate and Lucas 2008).

3 HARVEST STRATEGY

3.1 Harvesting and Management Approach

The harvest strategy for *P. maxima* is a *constant exploitation approach* whereby the same proportion of the stock is harvested each year. Since 1985 this approach has been operationalised through an annual TAC, divided into ITQs, which is set in proportion to overall stock abundance.

The harvesting approach accounts for this species being long-lived, with effort being focused primarily on the young, fast-growing males that are the optimal size for pearl culture. The bases of this approach are spat settlement surveys, which are used to calculate an index of abundance of 0+ and 1+ pearl oysters, and the standardised commercial catch per unit effort (SCPUE) of culture pearl oysters (120 – 175 mm shell length), which is used as an index of abundance. These indices have been used to develop two strongly-predictive relationships: firstly between spat abundance and culture pearl oyster SCPUE four years into the future and secondly, between the current season's sustainable harvest level (SHL) and culture pearl oyster SCPUE. As the catch of culture pearl oysters is comprised mainly of two age classes (4+ and 5+ pearl oysters), these relationships allow recommendations on a SHL to be made up to three years in advance based on the spat settlement surveys (see Appendix I). The numbers of pearl oysters larger than 175 mm shell length that may be collected is currently co-managed through a voluntary agreement between the Department and licence holders.

The control rules in place ensure that the catch is reduced when predicted recruitment is low, in order to provide increased protection to the stock, but also allows the catch to be raised in years when predicted abundance is high.

3.2 Long-Term Objectives

The short title of the PA is “An Act to regulate pearling and pearl oyster hatchery activities, to provide for the conservation and management of pearl oyster fisheries, to repeal the *Pearling Act 1912* and for connected purposes”. The species declared under the PA is *P. maxima*. Fishery-specific objectives are provided below. In addition to ensuring the biological sustainability of all captured aquatic resources, this harvest strategy also includes broader ecological objectives for each ecosystem component, as well as social and economic objectives for the POF as a whole, which are applied within the context of ESD.

3.2.1 Ecological Sustainability (all sectors):

- 1) To maintain spawning stock biomass of the target species (i.e. *P. maxima*) at a level where the main factor affecting recruitment is the environment;

- 2) To ensure fishing impacts do not result in serious or irreversible harm¹ to bycatch species populations;
- 3) To ensure fishing impacts do not result in serious or irreversible harm to ETP species populations;
- 4) To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function; and
- 5) To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes.

3.2.2 Social Objective (POF):

- 1) To provide flexible opportunities to ensure licence holders and fishers within the POF can maintain or enhance their livelihood, within the constraints of ecological sustainability.

3.2.3 Economic Objective (POF):

- 1) To optimise economic returns to the State through the production of pearls from the pearl oyster (*P. maxima*) resource.

3.3 Operational Objectives

Long-term management objectives are typically operationalised as short-term (e.g. annual), fishery-specific objectives through one or more performance indicators that can be measured and assessed against pre-defined reference levels so as to ascertain actual performance. Thus, within the context of the long-term objectives provided above, the POF has operational objectives to maintain each resource / component above the threshold level (and, where relevant, close to the target level), or rebuild the resource if it has fallen below the threshold or limit levels.

3.4 Performance Indicators, Reference Levels and Control Rules

Suitable indicators have been selected to describe performance of the POF in relation to each management objective, with a set of reference levels established to separate acceptable from unacceptable performance. Where relevant, these levels include:

- A target level (where you want the indicator to be);
- A threshold level (where you review your position); and

¹ Serious or irreversible harm relates to a change caused by the fishery that fundamentally alters the capacity of the component (e.g. bycatch population, ETP species population) to maintain its function or to recover from the impact.

- A limit level (where you do not want the indicator to be).

The associated control rules define what management actions should occur in relation to each indicator approaching or crossing the limit, threshold or target levels. Summaries of the management objectives, performance indicators, reference levels and control rules for each component of the POF are provided in Table 2.

Note the ability and timeframe to implement the required management changes depends on the legal instrument under which the management measure occurs. Further information on the management measures in place for the POF is provided in Section 4.

3.4.1 Identifying Performance Indicators, Reference Levels, and Tolerance Levels

3.4.1.1 *Pinctada maxima*

3.4.1.1.1 Reference periods

Reference levels for the assessment of the *P. maxima* resource have been established based on a range of information and monitoring data that has been collected since 1979 (see Section 3.5.1). Different reference periods have been used for setting the reference levels depending on the information available (Table 1).

Table 1. Reference periods used for setting reference levels

Assessment	Performance indicator	Reference Period(s)
Culture pearl oyster abundance (120 – 175 mm)	Fishery-dependent SCPUE	2003 – 2014
Culture pearl oyster abundance (120 – 175 mm)	Fishery-dependent CPUE	1979 – 2014
0+ and 1+ spat abundance	Spat settlement index	1990 – 2014
Larger pearl oyster abundance (> 175 mm)	Fishery-independent SCPUE	2007 – 2014
Larger pearl oyster abundance (> 175 mm)	Population surveys	1999 – 2001 2012 – 2013

3.4.1.1.2 Culture pearl oysters (120 to 175 mm shell length)

The primary performance indicator for the *P. maxima* resource is the SCPUE of culture pearl oysters (120 to 175 mm shell length). The SCPUE is the mean annual number of culture pearl oysters caught per hour within Zone 2/3 of the POF. The SCPUE index is available from 2003 onwards, during which time it has been highly correlated with the unstandardised CPUE ($r^2 = 0.98$; Table 1; Figure A-1.). The high correlation between SCPUE and the 0+ spat index from 4 to 5 years previous ($r^2 = 0.96$) confirms that the catch rates are indicative of culture pearl oyster abundance.

The limit reference level for *P. maxima* is a predicted SCPUE of 15 culture pearl oysters per hour (Table 2). This level coincides with a recruitment failure as estimated by the current predictive model for SCPUE (16.7 ± 3.3 SD) when settlement is 0 (Figure A-2.). This level is also close to the lowest value recorded in 1981 of 16 pearl oysters per hour. The ongoing

sustainability of the stock over the last 36 years indicates that this limit reference level is set above the level where there is a substantial risk of recruitment impairment.

The threshold reference level is a predicted SCPUE of 20 culture pearl oysters per hour (Table 2). This level is 33 % above the limit reference level and is used to provide an early warning that stock abundance is declining, enabling management action to be taken to reduce exploitation before the limit reference level is reached.

The target reference level is a predicted SCPUE of 25 culture pearl oysters per hour (Table 2). This level has been set well-above the limit and threshold reference levels, with the intention of maintaining the stock at levels of production consistent with B_{MSY} .

In line with a constant exploitation harvesting approach, control rules calculate a SHL in Zone 2/3 of the POF each year based on the SCPUE (Table 2, Figure A-3.). When the SCPUE is predicted to be at or above target levels, the harvest control rule is to calculate the Zone 2/3 SHL as a function of stock abundance (based on SCPUE) using a linear regression model that is updated annually (2014 Model: $SHL = 13.7 \times SCPUE + 85.3$). There has been relatively little or no catch and effort in Zone 1 of the POF in recent years. Consequently, a fixed SHL of 54 970 pearl oysters is currently recommended for Zone 1.

When the stock is predicted to be below target levels, harvest control rules adjust the total SHL against a ‘baseline’ of 457 000 pearl oysters for Zone 2/3 and 54 970 for Zone 1 (Table 2, Figure A-3.). These are the lowest values of the SHL since 2003 when the SCPUE index began. A range of fixed and variable reductions to the baseline SHL are made to ensure that exploitation is reduced as the stock abundance decreases and the limit reference level is approached. This approach is used since the stock has not previously been below the point where recruitment is impaired, and consequently, the relationship between spat abundance and legal-sized abundance at low population sizes is not known.

3.4.1.1.3 Larger pearl oysters (> 175 mm shell length)

Following a 15 year voluntary cessation of harvest of larger pearl oysters, fishery-independent population surveys were undertaken between 1999 and 2001 to estimate the biomass build-up and SHL for this component of the stock (Hart and Friedman 2004). Based on results from these surveys, it was determined that a SHL of up to 53 000 larger pearl oysters could be taken within the overall Zone 2/3 SHL each year. In good recruitment years a greater harvest of larger pearl oysters could be sustained if information on recruitment strength was available.

Although catch of larger pearl oysters remained negligible in the immediate following years, a combination of changing economic conditions and greatly increased pearl oyster abundance (see Section 2.3.2 for details) led to the recommencement of fishing for larger pearl oysters in 2011, after 25 years of little to no fishing. Fishery-dependent population surveys in 2012-2013 confirmed that the predicted high abundance of the 2005 cohort had been realised, and the SHL of larger pearl oysters was estimated at 190 000 to 300 000 (Hart et al. 2014b). This figure, equivalent to 10 % of the Zone 2/3 population, was based on an approximate

exploitation level equivalent to two-thirds natural mortality ($2/3M$) and assuming $M = 0.15 \text{ yr}^{-1}$ (Hart and Friedman 2004).

It is important to note that in recent years, due to the temporarily high abundance of larger pearl oysters, the increased SHL for this component of the stock has resulted in an additional catch component being allocated separate to the SHL for culture pearl oysters. This differs from the previous process whereby a SHL for larger oysters was specified within the culture SHL. In the future, as the stock returns to normal levels of abundance, it is intended that the previous SHL of 53 000 larger pearl oysters (as described above) will apply. In coming years it is also envisioned that an SCPUE-based harvest control rule will be implemented for larger pearl oysters (as occurs currently for culture pearl oysters), consistent with a constant exploitation harvesting approach.

The performance indicator for implementing this control rule is the annual fishery-independent SCPUE of larger pearl oysters in Zone 2/3 (Table 2). Preliminary reference levels have been set based on the reference period from 2007 to 2014 (Table 1). This is when routine monitoring of larger pearl oysters commenced and is a period when the stock is known to have been above the point of recruitment impairment (PRI). Nominal limit, threshold and target reference levels have been set at a SCPUE of 5, 10, and 15 larger pearl oysters per hour in Zone 2/3, respectively (Table 2). The limit reference point is slightly below the lowest SCPUE of 6.6 pearl oysters per hour observed during the reference period (Hart et al. 2014b). Reference points will be refined as more information is collected.

When the stock is above target levels, harvest control rules will recommend a SHL proportional to stock abundance. Below target levels, harvest control rules will adjust the SHL against the previous ‘baseline’ level of 53 000 pearl oysters (Hart and Friedman 2004).

3.4.1.1.4 Tolerance Levels

Given the highly dynamic nature of fisheries it is often not possible to predict precisely what the catch will be each year. To minimise unnecessary management intervention it may be important to define the level of tolerance in the control rules before management adjustments are made (DoF 2015). Specific tolerance levels are not required for the POF since the performance indicator for culture pearl oysters allows accurate predictions of abundance and SHL four years in advance. This provides a medium-term outlook on the status of the stock that allows research and management staff to discriminate between minor or ‘technical breaches’ of control rules and genuine trends in abundance requiring management intervention.

3.4.1.2 Other Ecological Assets

Other ecological assets incorporated in this harvest strategy include bycatch, ETP species, habitats and ecosystem processes. Reference levels for these performance indicators have been set to differentiate acceptable fishery impacts (target levels) from unacceptable fishery impacts (limit levels) according to the risk levels defined in Fletcher (2005).

3.4.1.3 Social and Economic Objectives

In line with the Department's *Harvest Strategy Policy* and the principles of ESD, this harvest strategy also includes social and economic objectives. It is important to note that management actions relating to these objectives are applied within the constraints of ecological sustainability.

Performance against the social objective is assessed by determining whether livelihood opportunities are provided to licence holders and fishers within the POF and whether they are able to access these opportunities (e.g. maintaining access to a resource, use of transferrable use rights), identifying any constraints on livelihood opportunities imposed by the management system (e.g. high entry costs) and evaluating their satisfaction with the management system (based on Triantafillos et al. 2014).

Performance against the economic objective is assessed by monitoring changes in the annual Gross Value of Production (GVP) of the industry.

Explicit reference levels and control rules are not currently defined for these objectives. Rather, it is through the formal consultation process that occurs as part of annual management activities whereby regulatory impediments to maintaining social and economic returns, or opportunities for enhancing these, are discussed with the pearling industry (see Section 4.2.1 for more information on consultation processes within the POF).

It is important to note that fisheries managers cannot always address the causes of constraints on access to fishing activities, as these may be due to environmental or other factors, or may compromise ecological sustainability. Where possible, and in due consideration of ecological sustainability, fisheries management arrangements may be adjusted or reformed to help meet these objectives.

Table 2. Summary of the harvest strategy for the Pearl Oyster Fishery. Note the reference levels essentially prescribe the operational objective which is to maintain each resource above the threshold level and near the target level.

Management Objectives	Resource/Asset	Assessment	Performance Indicators	Reference Levels	Control Rules
Ecological Aspects					
To maintain spawning stock biomass of the target species at a level where the main factor affecting recruitment is the environment.	Silver-lipped pearl oyster (<i>Pinctada maxima</i>)	Level 4 stock assessment incorporating standardised fishery-dependent relative abundance and fishery-independent recruitment surveys.	Annual standardised commercial catch rate (SCPUE) of culture pearl oysters (120 – 175 mm) in Zone 2/3 of the POF	<p>Target: SCPUE is 25 pearl oysters per hour</p> <p>Threshold: SCPUE is 20 pearl oysters per hour</p> <p>Limit: SCPUE is 15 pearl oysters per hour</p>	<p>Baseline SHL of 54 970 oysters set for Zone 1.</p> <p>SHL for Zone 2/3 calculated a function of stock abundance using predictive model.</p> <p>(a) If predicted SCPUE is between the target and threshold level, reduce SHL by 30% below baseline levels: Zone 1 SHL = 38 479; Zone 2/3 SHL = 319 900 oysters.</p> <p>(b) If predicted SCPUE is between the threshold and the limit level, reduce SHL by 40 to 50 % below baseline levels: Zone 1 SHL = 32 982 – 27 485; Zone 2/3 SHL = 274 200 – 228 500 oysters.</p> <p>If predicted SCPUE is below the limit level, reduce SHL by 50 to 100 % below baseline levels: Zone 1 SHL is < 27 485; Zone 2/3 SHL is < 228 500 oysters.</p>
		Level 4 stock assessment incorporating fishery-independent surveys	Annual standardised fishery-independent catch rate (SCPUE) of larger pearl oysters (> 175 mm) in Zone 2/3 of the POF	<p>Target: SCPUE is 15 pearl oysters per hour</p> <p>Threshold: SCPUE is 10 pearl oysters per hour</p> <p>Limit: SCPUE is 5 pearl oysters per hour</p>	<p>Baseline SHL of up to 53 000 larger (>175 mm) oysters for Zone 2/3 to be taken within the SHL for culture pearl oysters</p> <p>(a) If SCPUE is between the target and threshold level, reduce SHL of larger oysters (>175 mm) by 30% below baseline level: Zone 2/3 SHL = 37 100 oysters.</p> <p>(b) If SCPUE is between the threshold and the limit level reduce SHL of larger oysters (>175 mm) by 40 to 50 % below baseline level: Zone 2/3 SHL = 31 800 – 26 500 oysters.</p> <p>If SCPUE is below the limit level reduce SHL of larger oysters (>175 mm) by 50 to 100 % below baseline level: Zone 2/3 SHL < 26 500 oysters.</p>

To ensure fishing impacts do not result in serious or irreversible harm to bycatch species populations.	All (non-ETP) bycatch species	Periodic risk assessments incorporating current management arrangements, catch levels, species information and available research.	Assessed level of risk for each bycatch species/group from fishery activities	<p>Target: Fishing impacts are considered to generate an acceptable level of risk to all bycatch species' populations, i.e. moderate risk or lower.</p> <p>Threshold: Fishing impacts are considered to generate an undesirable level of risk to any bycatch species' populations, i.e. high risk.</p> <p>Limit: Fishing impacts are considered to generate an unacceptable level of risk to any bycatch species' populations, i.e. severe risk.</p>	<p>Maintain current management arrangements.</p> <p>A review is triggered to investigate the reasons for the variation. If sustainability is considered to be at risk, appropriate management action will be taken to reduce the risk to an acceptable level.</p> <p>Implement management strategies to reduce the risk to an acceptable level.</p>
To ensure fishing impacts do not result in serious or irreversible harm to endangered, threatened and protected (ETP) species populations.	All ETP species	Periodic risk assessments incorporating current management arrangements, number of reported interactions, species information and available research.	Assessed level of risk for each ETP species/group from fishery activities	<p>Target: Fishing impacts are considered to generate an acceptable level of risk to all ETP species' populations, i.e. moderate risk or lower.</p> <p>Threshold: Fishing impacts are considered to generate an undesirable level of risk to any ETP species' populations, i.e. high risk.</p> <p>Limit: Fishing impacts are considered to generate an unacceptable level of risk to any ETP species' populations, i.e. severe risk.</p>	<p>Maintain current management arrangements.</p> <p>A review is triggered to investigate the reasons for the variation. If sustainability is considered to be at risk, appropriate management action will be taken to reduce the risk to an acceptable level.</p> <p>Implement management strategies to reduce the risk to an acceptable level.</p>
To ensure the effects of fishing do not result in serious or irreversible harm to habitat structure and function.	Benthic habitats	Periodic risk assessments incorporating current management arrangements, extent of fishing activities, habitat	Assessed level of risk for benthic habitats from fishery activities	<p>Target: Fishing impacts are considered to generate an acceptable level of risk to all benthic habitats, i.e. moderate risk or lower.</p>	Maintain current management arrangements.

		distribution and available research.		<p>Threshold: Fishing impacts are considered to generate an undesirable level of risk to any benthic habitats, i.e. high risk.</p> <p>Limit: Fishing impacts are considered to generate an unacceptable level of risk to any benthic habitats, i.e. severe risk.</p>	<p>A review is triggered to investigate the reasons for the variation. If sustainability is considered to be at risk, appropriate management action will be taken to reduce the risk to an acceptable level.</p> <p>Implement management strategies to reduce the risk to an acceptable level.</p>
To ensure the effects of fishing do not result in serious or irreversible harm to ecological processes.	Northwest Shelf Ecosystem	Periodic risk assessments incorporating current management arrangements, catch levels, extent of fishing activities, ecosystem information and available research.	Assessed level of risk for ecosystem processes from fishery activities	<p>Target: Fishing impacts are considered to generate an acceptable level of risk to ecological processes within the ecosystem, i.e. moderate risk or lower; and</p> <p>Fishing impacts on each ecological resource / asset impacts are considered to generate an acceptable level of risk, i.e. moderate risk or lower.</p> <p>Threshold: Fishing impacts are considered to generate an undesirable level of risk to any ecological processes within the ecosystem, i.e. high risk.</p> <p>Limit: Fishing impacts are considered to generate an unacceptable level of risk to any ecological processes within the ecosystem, i.e. severe risk; or</p> <p>Fishing impacts are considered to generate an unacceptable level of risk, i.e. severe risk, to the majority of ecological resources / assets within the ecosystem.</p>	<p>Maintain current management arrangements.</p> <p>A review is triggered to investigate the reasons for the variation. If sustainability is considered to be at risk, appropriate management action will be taken to reduce the risk to an acceptable level.</p> <p>Implement management strategies to reduce the risk to an acceptable level.</p>

Social and Economic Aspects					
To provide flexible opportunities to ensure licence holders and fishers within the POF can maintain or enhance their livelihood, within the constraints of ecological sustainability	NA	Undertaken as part of formal consultation processes with Industry	<ul style="list-style-type: none"> • Provision of livelihood opportunities • Constraints on livelihood opportunities • Licence holders and fisher satisfaction 	NA	NA
To optimise economic returns to the State through the production of pearls.	NA	Undertaken as part of formal consultation processes with the pearling industry	Annual Gross Value of Production (GVP) of the pearling industry	NA	NA

3.5 Monitoring and Assessment Procedures

3.5.1 Information and Monitoring

3.5.1.1 Fishery-Dependent Information

3.5.1.1.1 Commercial Catch and Effort Reporting

Since 1979 there has been a statutory obligation to provide records of daily catch and effort in 10 x 10 nautical mile statistical reporting blocks. Information recorded includes catch by numbers, effort in dive hours, depth fished, statistical reporting block, visibility, quota record, and tag numbers for the panels where pearl oysters are stored. As a result of the constraints of diving to avoid decompression illness, the estimates of effort derived from the daily catch and effort logbook are highly accurate as they are dependent on pre-determined depth/time profiles that are consistent between pearl divers and from year to year. These commercial catch rates are used in the assessment of *P. maxima* stocks.

3.5.1.2 Fishery-Independent Information

3.5.1.2.1 Recruitment Monitoring

Recruitment is monitored using a unique settlement index (the “piggyback” spat index; as described by Hart and Joll 2006). The piggyback spat index is derived by counting juvenile spat that settle onto adult oysters as part of the commercial monitoring program. 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 SHL. Spat samples are obtained from 30 000 to 155 000 adult pearl oysters each fishing year from individuals inspected on 200 to 800 dives. Spat are counted, measured and separated into two age classes based on their size frequency. The age classes are newly settled spat (age 0+) between 5 and 35 mm shell length (4 – 7 months old), and age 1+ between 35 and 75 mm length (16 – 19 months old).

3.5.1.2.2 Population Surveys

Population surveys have been undertaken on a periodic basis over the history of the POF and have been incorporated into the annual monitoring for Zone 2/3 since 2007. Research personnel design the sampling regime at specified fixed sites each year and also several random sites within the POF. The Department hires highly experienced commercial divers to sample the target areas, capturing all observed pearl oysters. Research personnel record all measurements. Between 3000 and 5000 pearl oysters are measured from 30 to 150 sites per year. SCPUE of larger pearl oysters (> 175 mm shell length) during the surveys provide an index of spawning stock abundance and are used for stock assessment.

In addition to annual monitoring that now takes place, two scientifically designed surveys to quantify the absolute abundance and SHL of larger pearl oysters within Zone 2/3 were also undertake between 1999 and 2001 (Hart and Friedman 2004) and between 2012 and 2013 (Hart et al. 2014b).

3.5.2 Assessing Fishery Impacts

3.5.2.1 *Pinctada maxima*

The WA *P. maxima* stock is assessed using standardised catch rates as indices of abundance for culture and larger pearl oysters. In addition, a relationship between catch rates and previous recruitment is used to predict future catch rates (abundance) and determine the SHL of culture pearl oysters in Zone 2/3 of the POF.

3.5.2.1.1 Standardisation of Catch Rates and Recruitment Indices

Commercial catch rate data are standardised using a generalised linear model to account for the effects of year, visibility, vessel, neap, grid, depth, and experience (of pearl divers). The resultant model is applied to the individual pearl drift (dive) catch rate data. Each pearl drift is undertaken by between four and eight pearl divers of varying experience for a period of 30 to 60 minutes, depending on depth. The piggyback spat index of *P. maxima* recruitment is also standardised using a generalised linear model accounting for year, neap, patch and depth.

3.5.2.2 Risk Assessments

The Department uses a risk-based EBFM framework to assess the impacts of fishing on all parts of the marine environment, including target species, bycatch, ETP species, habitats and the ecosystem. In line with this framework, periodic risk assessments are conducted for the POF. These assessments are used to prioritise research, data collection and monitoring needs, as well as management actions for the POF to ensure that fishing activities are managed both sustainably and efficiently.

In August 2015, an ecological risk assessment (ERA) workshop was held to assess the impacts of the WA *P. maxima* pearling industry, including the wild capture, hatchery and pearl culture operations (Travaille et al. in prep). The workshop participants included representatives from the 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. The risk assessment framework applied during the workshop was 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, 2015).

Four aspects were considered for the assessment: ecological sustainability, community well-being, external factors and governance (note only ecological sustainability is currently considered as part of this harvest strategy). Fourteen ecological components were identified as potentially impacted by the WA *P. maxima* Pearling Industry's operations, with 31 possible associated issues (Travaille et al. in prep).

Risk assessments will be undertaken periodically (every 3 – 5 years) to reassess any current or new issues that may arise in the POF; however, a risk assessment can also be triggered if there are significant changes identified in fishing operations or management activities or controls that may change current risk levels.

4 MANAGEMENT MEASURES AND IMPLEMENTATION

4.1 Management Measures

The PA provides the overarching legislative framework to implement the management arrangements for the WA pearling industry. There are a number of management measures in place in the POF (Table 3) that are used to help achieve the management objectives. These measures can be amended as needed to ensure the POF is achieving management objectives; however, these do not preclude the consideration of other options.

Table 3. Current management measures and instrument of implementation for the Pearl Oyster Fishery

Measure/Control	Description	Instrument
Species Restrictions	The pearling industry is limited to the collection, seeding and grow-out of <i>P. maxima</i> .	<i>Pearling (Declaration of Pearl Oysters) Notice 1995</i>
Size limits	<p>The minimum size for <i>P. maxima</i> is a shell length of 120 mm shell length.</p> <p>Note: a new minimum legal size of 100 mm shell width is being trialled from 2011 through 2016 (restricted to 15 % of the total catch). The 100 mm trial was approved by the CEO at the request of the pearling industry to ascertain the suitability of smaller wild pearl oysters for seeding, noting that the 120 mm size had been in place for many years and that seeding techniques had progressed over time. The trial began in 2011 for 3 years and has now been approved for a further 3 years 2015-2016.</p> <p>There is a maximum size limit of 160 mm shell width in the waters of the Exmouth Gulf.</p>	<p><i>Pearling (Pearl Oyster Shell Size) Notice 1997</i> Letter from CEO</p> <p><i>Pearling (Pearl Oyster Shell Size) Notice 1997</i></p>
Method Restrictions	Pearl oysters can only be taken by means of diving and by hand.	<i>Pearling (General) Regulations 1991</i>
Quota system	<p>The POF is managed via output controls in the form of a total allowable commercial catch (TAC), which is divided into individually-transferable quota units as conditions on Pearling (Wildstock) Licences.</p> <p>The total number of permanent wildstock quota units in the POF is 572, with the unit value determined annually based on stock assessment advice.</p>	<i>MPG No. 17</i> ; Licence condition; Wildstock TAC determined annually by CEO
Licence Requirements	<p>Operators must hold an appropriate licence to undertake wild collection, hatchery or seeding operations. Licences are renewed annually.</p> <p>Pearling (Wildstock) Licence holders are required to hold a minimum of 15 quota units.</p> <p>Pearling (Wildstock) Licences allow for the take of pearl oysters from the wild, transport or holding and the practice of pearl culture (seeding) techniques on wildstock pearl oysters.</p>	<p><i>Pearling Act 1990</i> (Section 23)</p> <p><i>MGP No. 17</i></p>

Spatial Restrictions — Zoning	The POF is divided into four Zones.	<i>Pearling (Declaration of Zones) Notice 1995 and Pearling (Declaration of Zones) Amendment Notice 1997</i>
	Wildstock quota units are currently distributed across Zones 1 – 3.	<i>Pearling (Wildstock) Licence Conditions</i>

4.2 Implementing Changes to the Management Arrangements

Decision-making processes can be triggered following the identification of new or potential issues as part of an ecological risk assessment (generally reviewed every 3 – 5 years), results of research, management or compliance projects or investigations, monitoring or assessment outcomes (including those assessed as part of the Harvest Strategy) and / or expert workshops and peer review of aspects of research and management.

There are two main processes for making decisions about the implementation of management measures and strategies in the POF:

- Annual decision-making processes that may result in measures to meet the operational objectives (driven by the control rules, see Section 4.2.1.1.1 below); and
- Longer-term decision-making processes that result in new measures and / or strategies to achieve the long-term objectives (i.e. changes to the management system).

If there is an urgent issue, stakeholder meetings may be called on an as-needed basis to determine appropriate management action.

4.2.1 Consultation

Management changes are generally given effect through amendments to legislation, such as the PA, PR, notices and Ministerial Policy Guidelines, as well as licence conditions. These changes generally require the approval of the Minister for Fisheries and/or the CEO of the Department (or appropriate delegates). In making decisions relevant to fisheries, the Minister for Fisheries may choose to receive advice from any source, but has indicated that:

1. The Department is the primary source of management advice; and
2. The peak body (in this case, the Western Australian Fishing Industry Council [WAFIC]) is the primary source of industry advice and representation. In accordance with WAFIC's operating principles, the Department will consult directly with the recognised sector body, the PPA, for matters solely affecting the pearling industry.

4.2.1.1 Commercial Sector Consultation

Under a Service Level Agreement (SLA) with the Department, WAFIC has been funded to undertake statutory consultation functions related to fisheries management and the facilitation of annual management meetings for licensed fisheries.

Departmental Annual Management Meetings (AMMs) between the Department, WAFIC, the PPA and the pearling industry are used as the main forum to consult with stakeholders and licence holders on the management of the POF. During the AMMs, current and future management issues that may have arisen during the previous fishing season, and any proposed changes to the management structure, are discussed. Follow-up meetings may be held as required.

4.2.1.1.1 TAC Setting Process

The annual TAC is determined by the CEO of the Department through a consultative process that occurs from October to December each year. Results from the annual stock assessment, monitoring and research are presented by Departmental research staff to the Stock Assessment Working Group (SAWG), which is considered as the key source of advice in respect to setting the TAC. The SAWG comprises Departmental staff, pearling industry members and the PPA and meets as required to discuss recommendations relating to the sustainable management of the POF. The SAWG's harvest level (HL) recommendations are considered more broadly at the AMM, along with co-management arrangements, such as voluntary size limits and the number of larger pearl oysters that can be collected. Final recommendations on the HL (from the SAWG), along with the AMM and PPA positions on the recommendations, are then provided to the CEO of the Department for consideration and a final determination. Once the final determination is made, licence renewals and season arrangements commence for the following year.

The 2015 TAC for all fished Zones (1 – 3) was 667 350 pearl oysters comprising 54 970 pearl oysters in Zone 1 and 612 380 pearl oysters in Zone 2/3. As part of the Zone 2/3 TAC determination an allowance was included for the harvest of up to 109 680 large pearl oysters (> 175 mm). The substantial additional numbers of larger-sized pearl oysters above the 'baseline' level was due to the high abundance of the 2005 cohort (see Section 2.3.2) and will be reduced in forthcoming years. The 100 mm minimum shell length trial continued during 2015 on the basis that no more than 15% of culture pearl oysters taken would be < 120 mm shell length (see Table 3 above).

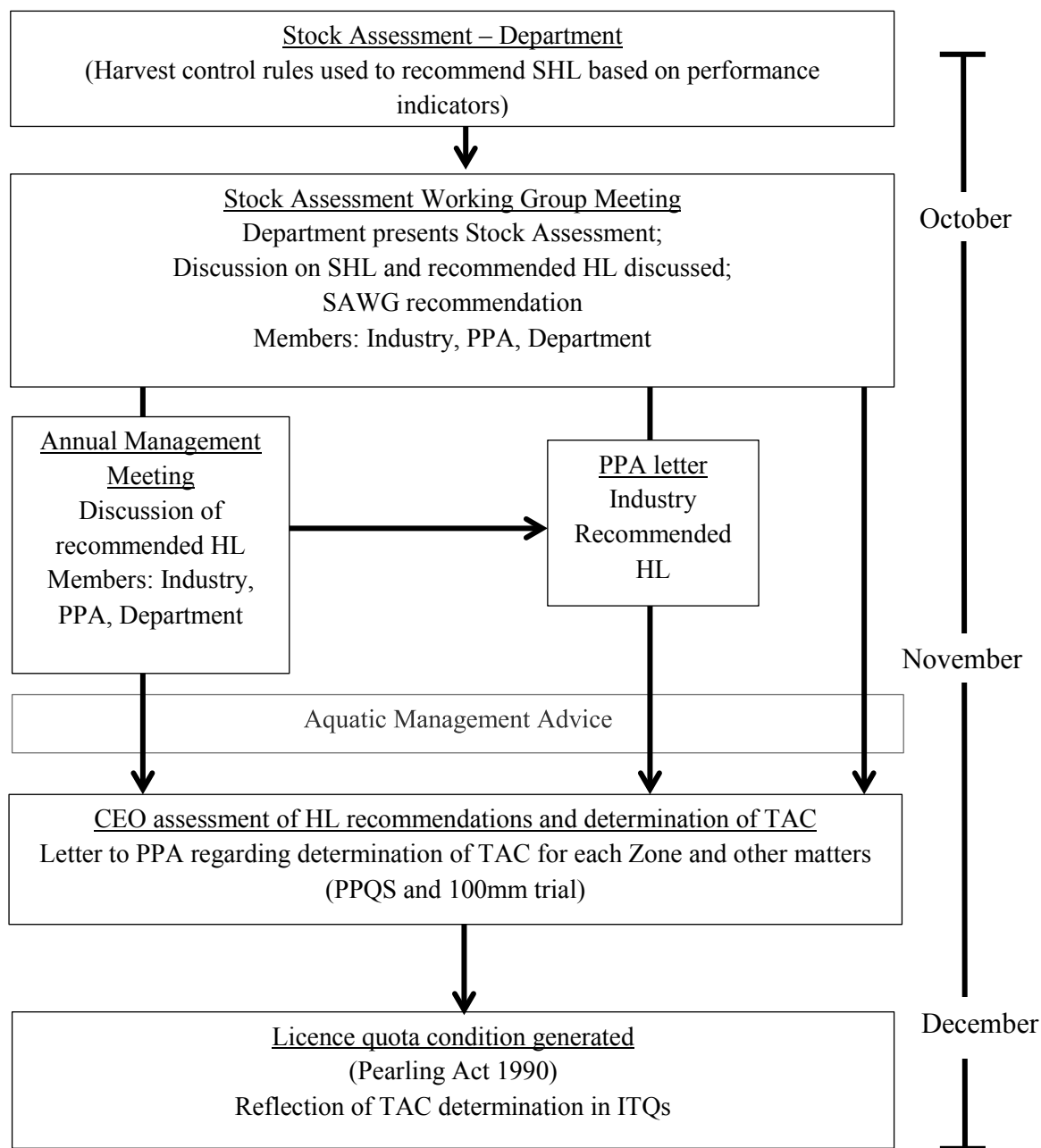


Figure 2. Annual Total Allowable Catch setting process for the Pearl Oyster Fishery

4.2.1.2 Consultation with Other Groups

Consultation with the broader public, other Government agencies, marine users, Native Title parties and environmental groups is undertaken by the Department on an as needed basis.

4.3 Compliance and Enforcement

A primary objective of the Department is to encourage voluntary compliance through education, awareness and consultation activities.

4.3.1 Operational Compliance Plan

Compliance arrangements are delivered under a Pearling Operational Compliance Plan (OCP) for the Northern Region of Western Australia. OCPs are informed and underpinned by compliance risk assessments conducted for each fishery. Annual planning meetings are held for OCPs, with regular specific planning of day-to-day targeted and non-targeted patrols linked to the OCP based on available resources and competing priorities.

The Pearling OCP has the following objectives:

- To provide clear direction and guidance to officers regarding compliance activities that are required to support effective management of the POF;
- To provide a mechanism that aids the identification of future and current priorities; and
- To review compliance strategies and their effective implementation.

The OCP is generally reviewed every 2 – 3 years.

4.3.1.1 Compliance Strategies

Compliance strategies and activities that are used in the POF include:

- Pre-season briefings of pearling company staff and pearling vessel crews;
- In port inspections of pearling vessels; and
- At sea inspections of pearling vessels, pearl oyster farm leases and pearling equipment.

Inspections may involve:

- Inspection of vessel log books and pearling tags;
- Inspection of pearling equipment including long lines;
- Inspections of licences; and
- Inspection of holding tanks, freezers and fish (including pearl oysters) on-board the vessels.

4.3.1.2 Vessel Monitoring System (VMS)

Some vessels operating within the POF are currently fitted with Automatic Location Communicators (ALCs) on a voluntary basis. The ALC is used to track the location of a vessel by transmitting information as geographical position, course and speed of the vessel to 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. It is expected that VMS will become compulsory in the POF when it is transitioned to the ARMA.

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6 APPENDIX I

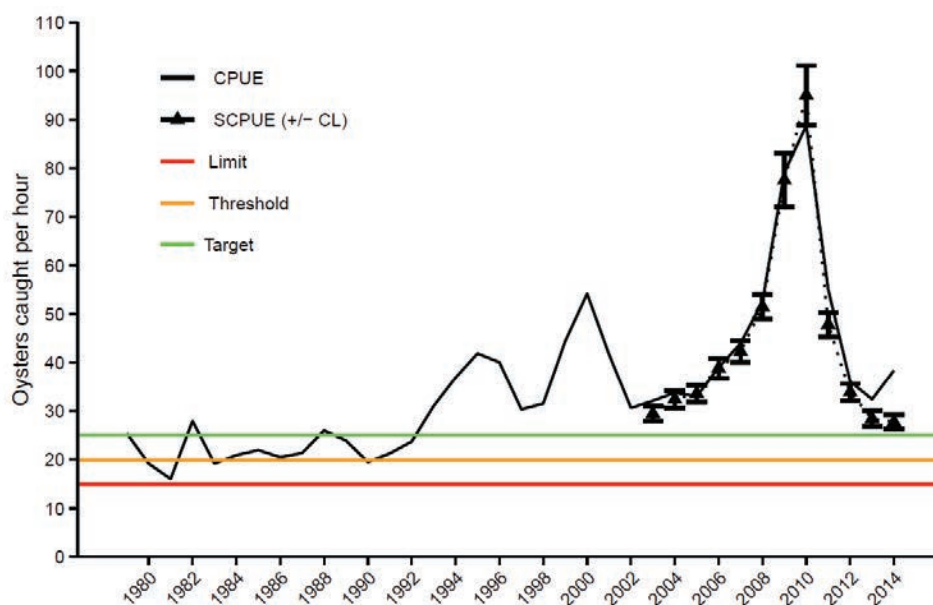


Figure A-1. Standardised catch rate (SCPUE) performance measure, and associated target, threshold and limit levels of culture pearl oysters (120 to 175 mm shell length). Unstandardised CPUE is shown for comparison.

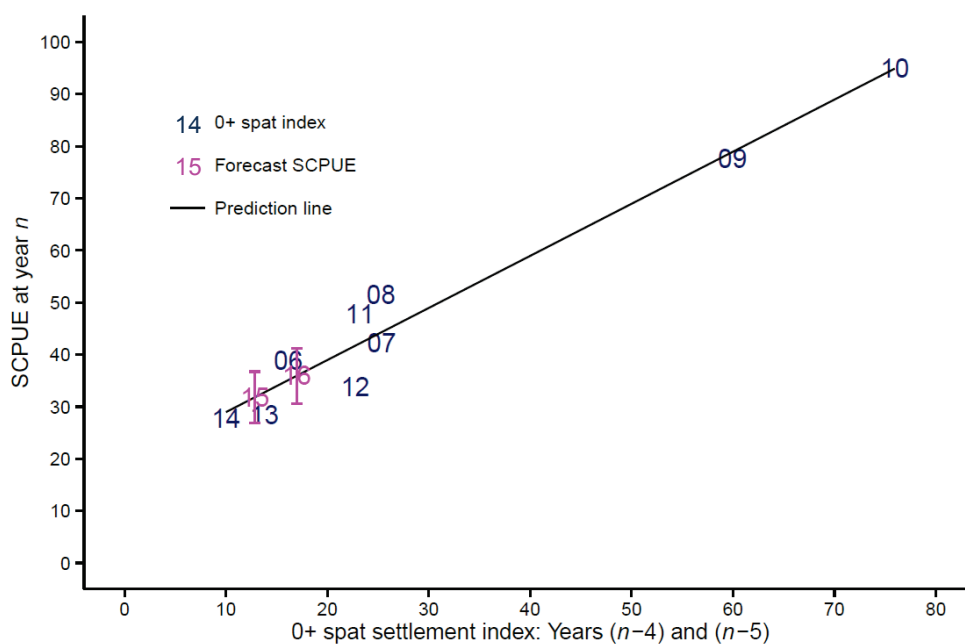


Figure A-2. Multiple regression model used to predict SCPUE of culture pearl oysters in year n as a function of 0+ spat settlement index in years $n - 4$ and $n - 5$. Forecast values of SCPUE are used to calculate the sustainable harvest level (SHL), shown for 2015 and 2016.

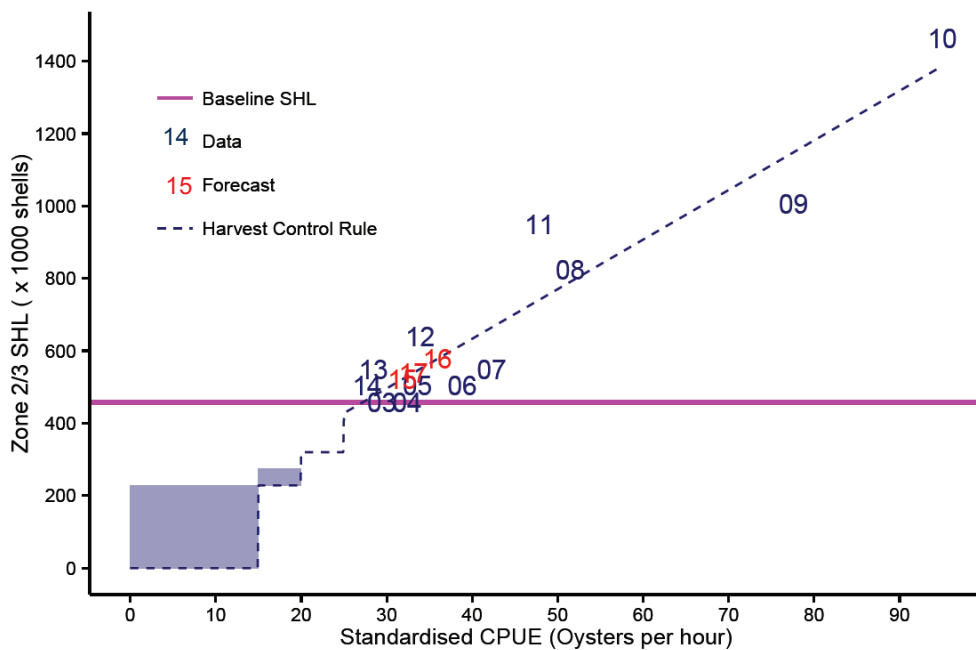


Figure A-3. The harvest control rule used for calculating the Zone 2/3 SHL is based on forecast values of SCPUE from the spat settlement index. When forecast SCPUE is above target levels, the SHL is proportional to SCPUE. Blue numbers compare the SHL against the achieved SCPUE between 2003 and 2014. Red numbers are forecast values of the SHL. Below target levels the reductions are made relative to a baseline SHL. Blue shaded zones indicate range of values allowed under the harvest control rules when SCPUE is below threshold and limit levels.