Threat Identification, Hazard Pathway Analysis and Assessment of the Key Risks to the Sustainability of Endangered, Threatened and Protected Fish Populations at the Abrolhos Islands, presented by the establishment of the Mid West Aquaculture Development Zone, Western Australia

Prepared by

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Summary of the risk level

Risk	**Inherent Risk** (no management measures)	**Residual Risk** (based on implementation of identified management measures)
Aquaculture activity in the zone will potentially have a significant impact on endangered, threatened or protected (shark and ray) species within the Abrolhos Islands Fish Habitat Protection Area, either from a sustainability or social acceptability perspective.	**Moderate**	**Low**

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1. Context and Scope

The ecological risk assessment presented in this report has been undertaken to assist in identifying and assessing the potential impacts of finfish aquaculture associated with a Department of Fisheries proposal to establish an aquaculture development zone in the Mid West of Western Australia (referred to hereafter as the Mid West Aquaculture Development Zone or MWADZ), on the sustainability of endangered, threatened and protected fish species.

An environmental management objective of the MWADZ proposal is to ensure the establishment and operation of the MWADZ without significantly impacting on marine ecosystem functions, habitats and endangered, threatened and protected species which depend on these. This assessment does not seek to replicate previously conducted generic aquaculture risk assessments that are relevant to the MWADZ proposal, including the following:

- Marine Finfish Environmental Risk Assessment (de Jong &Tanner, FRDC Project 2003/223)
- National ESD Reporting Framework: The “How to” Guide for Aquaculture. Version 1.1 FRDC, Canberra, Australia (Fletcher et al., 2004)
- Finfish Aquaculture in Western Australia: Final ESD Risk Assessment Report for Sea-Cage and Land-Based Finfish Aquaculture (Vom Berg, 2008; Fisheries Management Paper No 229, Department of Fisheries, Western Australia)
- Finfish Aquaculture in Western Australia: Final ESD Risk Assessment Report for Marine Finfish Aquaculture (Vom Berg, 2009; Fisheries Management Paper No 233, Department of Fisheries, Western Australia)

Instead, the current assessment has used these previous reports as a basis to identify the main broad areas of threat that are most relevant to the MWADZ proposal. These threats were further broken down through the consideration of the detailed hazard pathways that may lead to the realisation of these threats. Consideration of the threats facilitated the identification of key overarching risks to the identified objective of the assessment.

This document describes the assessment of one key risk presented by the establishment of the MWADZ to the sustainability of endangered, threatened and protected fish populations. Both the inherent risk (risk before application of management controls) coupled to the residual risk (following application of proposed management controls) were assessed in order to determine the nature and level of management controls required to bring the cumulative risks around sea-cage culture of finfish in the MWADZ to an acceptable level.

Using this methodology, the current assessment sought to clearly identify the current risk management measures in place and assess their adequacy in bringing identified risks to ecosystem sustainability associated with the MWADZ proposal to an acceptable level.

An aquaculture development zone is a designated area of water selected for its suitability for a specific aquaculture sector (in this case marine finfish). Designating areas as aquaculture development zones is a result of Departmental policy aimed at stimulating aquaculture investment through providing an ‘investment ready’ platform for organisations that wish to set up commercial aquaculture operations.

More streamlined approvals processes are in place for organisations that want to establish aquaculture operations within these zones. Extensive studies and modelling underpins the approval of a zone to ensure its potential effects are identified, well understood and managed. Establishing new aquaculture operations, or expanding existing ones, will provide significant economic benefits to the local community through the creation of job opportunities and regional economic diversification

A Kimberley Aquaculture Development Zone (KADZ) in WA’s northern waters has already been declared by the Minister for Fisheries. Covering a total area of almost 2,000 hectares, the zone is located within Cone Bay approximately 215 kilometres northeast of Broome. Extensive environmental studies completed for the zone indicate its capacity to support 20,000 tonnes of finfish without any significant environmental impact. An existing barramundi farm operates within the boundaries of the KADZ. The establishment of the zone has enabled the operator, Marine Produce Australia Pty Ltd, to secure environmental approval to increase its production capability from 2,000 to nearly 7,000 tonnes per annum.

This assessment relates to a second planned aquaculture development in the Mid West region of Western Australia (WA). The MWADZ will be located within the State waters of the Abrolhos Islands Fish Habitat Protection Area (FHPA), north of the Pelsaert Group, about 60 kilometres west of Geraldton. The exact site will be determined after evaluating the results of environmental and technical studies.

The zone is being established through a process that primarily involves environmental assessment of the zone as a strategic proposal under Part IV of the *Environmental Protection Act 1986*. Approval of this strategic proposal will create opportunities for existing and future aquaculture operators to refer their proposals to the Environmental Protection Authority (EPA) as ‘derived proposals’. The aim of the zone concept is a more efficient assessment and regulation process due to early consideration of potential environmental impacts and cumulative impacts identified during the assessment process for the zone.

The Department surveyed and sampled a study area of 4,740 hectares in two locations within the FHPA. This process identified 2,200 hectares in the Northern Area and 800 hectares in the Southern Area (see Figure 1) as the most suitable areas for finfish aquaculture. Technical environmental studies of these locations helped determine the delineation of the zone. The proposed zone is situated away from areas of highest conservation value and is subject to considerable water flushing driven by prevailing winds, waves and currents. Good water flow through the sea-cages in which the fish are grown is essential for high productivity and to minimise environmental impact.

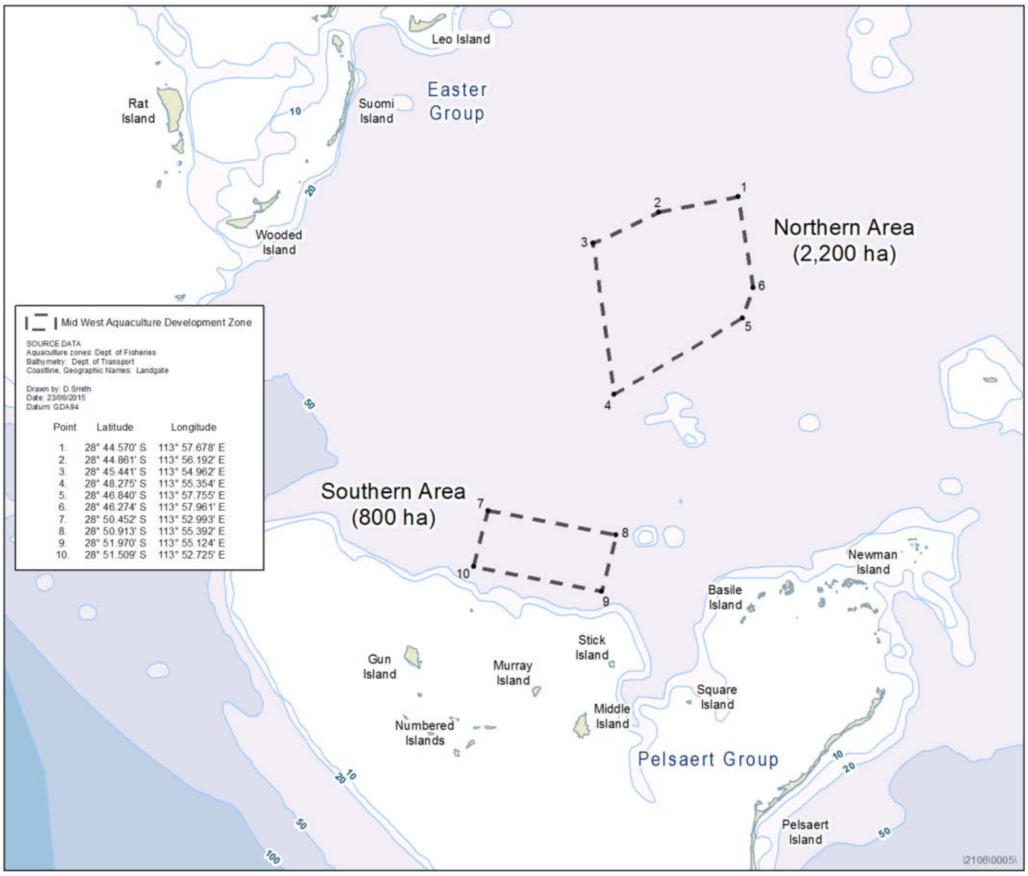

Figure 1: Proposed Mid West Aquaculture Development Zone

The Department will manage aquaculture operations in the MWADZ within an integrated management framework. This framework will be similar to that developed for the Kimberley Aquaculture Development Zone. Its purpose is to:

- establish an overarching, integrated structure for managing the aquaculture activities within the zone;
- provide clear, efficient and effective processes for monitoring, evaluating and reporting;
- guide the development of marine finfish aquaculture;
- implement the monitoring and reporting processes; and

- ensure adaptive management occurs as part of a process of continuous improvement.

The zone management framework will incorporate:

- a zone Management Policy;
- an Environmental Monitoring and Management Plan (EMMP);
- a Ministerial Statement/Notice;
- Aquaculture Licences;
- Management and Environmental Monitoring Plans (MEMPs); and
- Aquaculture Leases.

The selection of suitable species for aquaculture in WA is managed through the requirement for commercial aquaculture operators to obtain an aquaculture licence which is assessed with regard to the Department’s Translocation Policy. Likely suitable fish species to be cultured in the zone, based on existing commercial aquaculture interest, the positive outcome of previous research trials, their suitability for aquaculture in WA and/or ability to meet Departmental licensing and biosecurity requirements (e.g. being native species and suited to feeding with a formulated, pathogen-free diet) include the following:

- Yellowtail kingfish (*Seriola lalandi*)
- Mulloway (*Argyrosomus japonicus*)
- Dolphin fish (*Coryphaena hippurus*)

Based on this context, the current threat identification, hazard pathway analysis and risk assessment was conducted to identify and assess the potential impacts of finfish aquaculture on endangered, threatened and protected species of fish (ETP species) within the MWADZ.

ETP species of fish comprise sharks, rays, Queensland grouper, and syngnathids (pipefish, seahorses and seadragons). Most syngnathid species inhabit shallow, sheltered coastal waters. This assessment has not included sygnathids because there are no factors linked to the proposed aquaculture that are likely to influence sygnathids or habitats they are reliant on.

This assessment has also not included Queensland grouper. Queensland grouper is occasionally recorded in temperate waters; however, it is usually found in tropical waters throughout the Indo-Pacific. While Queensland grouper possibly exist at the Abrolhos Islands and may potentially be influenced by finfish aquaculture, the likelihood of an interaction is considered extremely remote.

From this point in the assessment onwards, “ETP species” refers to ETP species of sharks and rays (listed in Table 1).

This ecological risk assessment is generic in nature, but is knowledge-based on the limited records relating to interactions between sharks/rays and culture of marine finfish. The assessment has also considered all available relevant information relating to the:

- proposed location within the Abrolhos Islands Fish habitat Protection Area (FHPA);
- ETP species known to inhabit the FHPA in the vicinity of the MWADZ and (in particular) the behavioural biology of white shark (*Carcharodon carcharias*) as a representative species;
- likely characteristics of yellowtail kingfish aquaculture (proposed aquaculture); and
- proposed management framework and options for minimising interactions between ETP species and the proposed aquaculture.

Information on interactions between sharks/rays and aquaculture is limited. Almost all of the available data are focused on white shark and shark species other than ETP species (i.e. tiger shark).

Given the lack of information on ETP species-aquaculture interactions, the information known on the interactions of white shark/tiger shark/similar species with finfish aquaculture was used for the purposes of this assessment. It is acknowledged that while there could be different types of interactions between other ETP species (e.g. sawfish and whale shark) and finfish aquaculture, the behavioural characteristics of the iconic white shark/tiger shark/similar species could be reasonably considered indicative of the wider ETP species group. Therefore, this iconic suite of species was used to assess the overall potential impacts of the proposal on ETP species. A list of the endangered, threatened and protected species (ETPs) that could potentially be affected by the MWADZ proposal has been provided in Table 1.

Table 1: Endangered, threatened and protected species of fish (ETP species) potentially affected by the proposal

Common name	Family	Species
White shark	Lamnidae	*Carcharodon carcharias*
Shortfin mako		*Isurus oxyrinchus*
Longfin mako		*Isurus paucus*
Grey Nurse shark	Odontaspididae	*Carcharias taurus*
Tiger shark[1]	Sphyrnidae	*Galeocerdo cuvier*
Smooth hammerhead		*Sphyrna zygaena*
Scalloped hammerhead		*Sphyrna lewini*
Great hammerhead		*Sphyrna mokarran*
Green sawfish	Pristiophoridae	*Pritis zijsron*
Whale shark	Rhincodontidae	*Rhincodon typus*
Manta ray	Mobulidae	*Manta birostris*

[1] Tiger shark is not considered to be an ETP species, however, as an iconic marine species is considered to be representative of many of the ETP species of fish listed above.

2. Assessment Methodology

The identification of threats, analysis of hazard pathways and assessment of risks that may be generated by the proposal to develop an aquaculture zone in the Mid West region of WA was completed using methods that are consistent with the international standards for risk management and assessment (ISO 31000, 2009; IEC/ISO; 2009; SA-HB89; 2012). The process for assessment included three components – threat identification, hazard pathway analysis, identification of overarching risks, assessment of the contribution of hazards and factors, and the overarching risk assessment (see Figure 2).

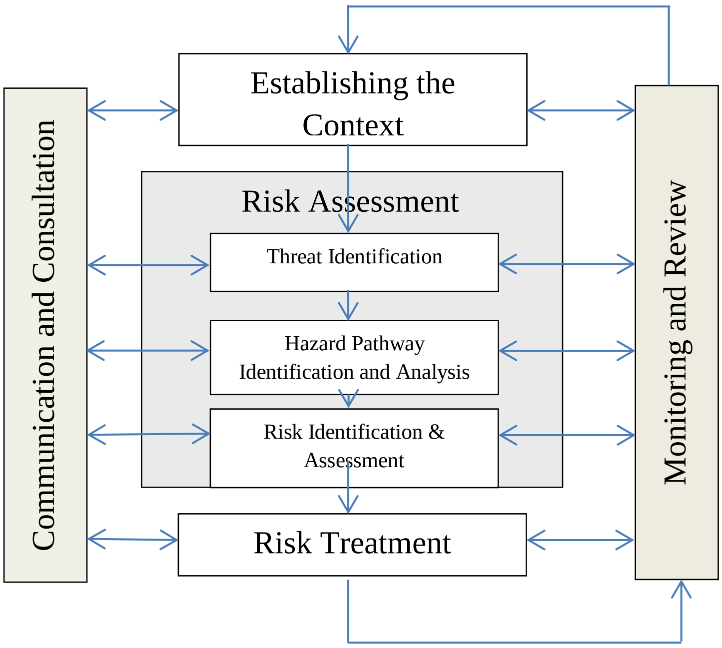

Figure 2: Description of risk assessment within the risk management process (modified from SA, 2012)

The specific protocols to complete each of these steps have been specifically tailored and extensively applied across a number of different aquatic management situations in Australia (Fletcher 2005, Fletcher et al. 2002, Jones and Fletcher 2012). Moreover this methodology has now been widely applied in many other locations in the world (Cochrane et al. 2008, FAO 2012, Fletcher 2008, Fletcher and Bianchi 2014) and is considered one of the 'must be read' methods supporting the implementation of the ecosystem approach (Cochrane 2013).

2.1. Threat Identification

Threat identification was based on a review of the following previously conducted assessments and consideration of specific information associated with the MWADZ proposal:

- Marine Finfish Environmental Risk Assessment (de Jong & Tanner, FRDC Project 2003/223)
- National ESD Reporting Framework: The "How to" Guide for Aquaculture. Version 1.1 FRDC, Canberra, Australia (Fletcher et al., 2004)
- Finfish Aquaculture in Western Australia: Final ESD Risk Assessment Report for Sea-Cage and Land-Based Finfish Aquaculture (Vom Berg, 2008; Fisheries Management Paper No 229, Department of Fisheries, Western Australia)
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2.2. Hazard Pathway Identification

The identification of hazard pathways associated with the broad threat identified within the scope of the current assessment was accomplished using 'Failure Mode Analysis'. Failure Mode Analysis is an engineering technique used to identify critical steps or hazard pathways that can lead to systems failure or the realisation of threats (in this case, the effects of interactions between ETP species and aquaculture operations in the MWADZ). This process was conducted in order to assist with the orderly identification of issues relevant to assessment. The generated hazard pathways were used to assist with the identification of critical steps that may result in threats that need to be considered as a result of undertaking aquaculture activity in the MWADZ (Figure 3).

2.3. Hazard Pathway Analysis

Individual hazards in each pathway were individually assessed according to their risk (Table 6); with respect to both inherent risk (i.e. baseline risk if no management measures aimed at mitigating the risk were in place) and residual risk (i.e. remaining risk once one or more of proposed management controls have been effected). This process was undertaken to both understand the individual inherent hazards as well as to provide clarity as to the specific hazard or risk that a particular management activity is targeted at mitigating. This, in turn, assists in assessing whether management controls are adequate to manage risk of the entire pathway to an acceptable level and to identify any additional management actions required to address specific unacceptable risks.

The Consequence–Likelihood method was used to assess the level of the identified hazard pathway components associated with the key identified threats. The broad approach applied is a widely used method (SA, 2012) that is applied by many WA Government Agencies through WA RiskCover.

Undertaking hazard or risk analysis using the Consequence-Likelihood (CxL) methodology involves selecting the most appropriate combination of consequence (levels of impact; Table 2) and the likelihood (levels of probability; Table 3) of this consequence actually occurring. The combination of these scores is then used to determine the risk rating (Table 4; IEC/ISO, 2009, SA, 2012). In considering the hazard pathways associated with an impact on the sustainability of ETP species, consequence (as described in Table 2) was determined against achievement of the corresponding objective.

The International standards definition of risk is "*the effect of uncertainty on objectives*" (ISO, 2009). This definition of risk makes it clear that examining risk will inherently include the level of uncertainty generated from having incomplete information (SA, 2012).

In the context of assessing the threats and risk associated with this proposal, the objective is to ensure ETP species are not significantly impacted by aquaculture operations and infrastructure in the MWADZ. Accordingly, a "significant impact" that would result in a high risk would be one for which there was a reasonable likelihood that the number of individuals of a ETP species affected by aquaculture operations and infrastructure would materially alter the longer-term sustainability of that species at the population level, thereby resulting in a significant community concern.

Table 2: Levels of consequence relating to the environmental management objectives of the MWADZ proposal (modified from Fletcher, 2015)

Objective	Minor (1)	Moderate (2)	Major (3)	Severe (4)
Sustainability of endangered, threatened and protected (ETP) species (including the impacts on social acceptability)	Few individuals directly impacted in most years (i.e. no impact on sustainability) and well below that which will generate public concern.	Catch or impact at the maximum level that will not impact on recovery or cause unacceptable public concern.	Recovery of a vulnerable population may be impeded and/or some clear (but short term) public concern is generated.	Further decline of a vulnerable population and/or significant, widespread and ongoing public concern generated.
Maintenance of Ecosystem Structure and Function	Measurable but minor changes to ecosystem structure, but no measurable change to function.	Maximum acceptable level of change in the ecosystem structure with no material change in function.	Ecosystem function now altered with some function or major components now missing and/or new species are prevalent.	Extreme change to structure and function. Complete species shifts in capture or prevalence in system.

Conservation of Habitat	Measurable impacts very localised. Area directly affected well below maximum accepted.	Maximum acceptable level of impact to habitat with no long-term impacts on region-wide habitat dynamics.	Above acceptable level of loss/impact with region-wide dynamics or related systems may begin to be impacted.	Level of habitat loss clearly generating region-wide effects on dynamics and related systems.

Table 3: Levels of likelihood for each of the main risks analysed in this assessment (modified from Fletcher, 2015)

Level	Descriptor
Remote (1)	The consequence not heard of in these circumstances, but still plausible within the time frame (indicative probability 1-2%)
Unlikely (2)	The consequence is not expected to occur in the time frame but some evidence that it could occur under special circumstances (indicative probability of 3-9%)
Possible (3)	Evidence to suggest this consequence level may occur in some circumstances within the time frame (indicative probability of 10 to 39%)
Likely (4)	A particular consequence is expected to occur in the timeframe (indicative probability of 40 to 100%)

Table 4: Hazard/Risk Analysis Matrix. The numbers in each cell indicate the Hazard/Risk Score, the colour indicates the Hazard/Risk Rankings (see Table 6)

		Likelihood Level			
Consequence level		Remote	Unlikely	Possible	Likely
		1	2	3	4
Minor	1	1	2	3	4
Moderate	2	2	4	6	8
Major	3	3	6	9	12
Severe	4	4	8	12	16

The residual consequences, likelihoods and resultant levels of hazard or risk are all dependent upon the effectiveness of the risk mitigation controls that are in place (SA, 2012). Determining the most appropriate combinations of consequence and likelihood scores therefore involves the collation and analysis of all information available on an issue.

The best-practice technique for applying this method now makes use of all available lines of evidence for an issue and is effectively a risk-based variation of the 'weight of evidence' approach that has been adopted for many assessments (Linkov et al. 2009, Wise et al. 2007, Fletcher in press).

The hazard evaluation step uses the outcomes of the risk analysis to help make decisions about which hazards need treatment, the level of treatment, and the priority for action. The different levels of management action can be determined by having the hazard or risk scores separated into different categories of hazard (Table 6).

Table 5: Risk Evaluation, Rankings and Outcomes [modified from Fletcher et al. (2002, 2005, 2015)]

Risk Level	Hazard/Risk Score (C x L)	Description	Likely Management Response
Negligible	0-2	Acceptable with no management actions or regular monitoring.	Brief justification
Low	3-4	Acceptable with no direct management actions and monitoring at specific intervals.	Full justification and periodic reports
Moderate	6-8	Acceptable with specific, direct management and regular monitoring.	Full regular performance report
High	9-16	Unacceptable unless additional management actions are undertaken. This may involve a recovery strategy with increased monitoring or even complete cessation of the activity.	Frequent and detailed performance reporting

<u>Information Utilised</u>

The key information used to generate the hazard and risk scores included:

- Broad knowledge of the aquaculture proposal as provided in its application;
- A previous high-level generic risk assessment conducted for marine finfish aquaculture in Australia (FRDC project 2003/223); and
- Relevant scientific studies and publications on finfish aquaculture, ETP species of fish, and interactions between aquaculture and wildlife, for example, sharks (see references).

2.4. Risk Identification and Assessment

Based on consideration of the identified broad areas of threat and constituent hazard pathways, an overarching risk was identified associated with the MWADZ proposal. Assessment of this overarching risk was conducted as described for the hazard pathway assessment described above. Once again, the inherent hazard or risk was assessed in the absence of any management control measures. The residual risk following application of the identified management controls was then assessed.

While this assessment is focused upon ecological risk, social acceptability is also a primary risk consideration in relation to aquaculture-ETP species interaction risks.

The assessment of economic impact on the aquaculture industry resulting from such risk was not considered within the scope of this assessment.

3. Threat Identification, Hazard Pathway Identification and Hazard Pathway Analysis

3.1. Threat Identification

The identification of risks utilised a component-tree approach (Fletcher et al., 2004). This approach assists with the orderly identification of issues (components) for an assessment by providing a standardised starting point and framework to structure components in a consistent and hierarchical manner. Threats to ETP species were identified that were considered both most relevant to the MWADZ proposal and within the scope of the current assessment. The key threat that was identified was:

> *The proposed aquaculture activity could have a significant impact on ETP (shark and ray) species in the vicinity of the Abrolhos Islands FHPA, from an ecological sustainability and social acceptability perspective.*

3.2. Hazard Pathway Identification

Key threats were identified by linking various hazards, via probable pathways of cause-effect, to contributing factors leading to a potential detrimental effect on the sustainability of one or more ETP species (Figure 3). This process facilitated the identification of management measures that could mitigate risks by reducing or eliminating the consequences and by minimising probability of occurrences.

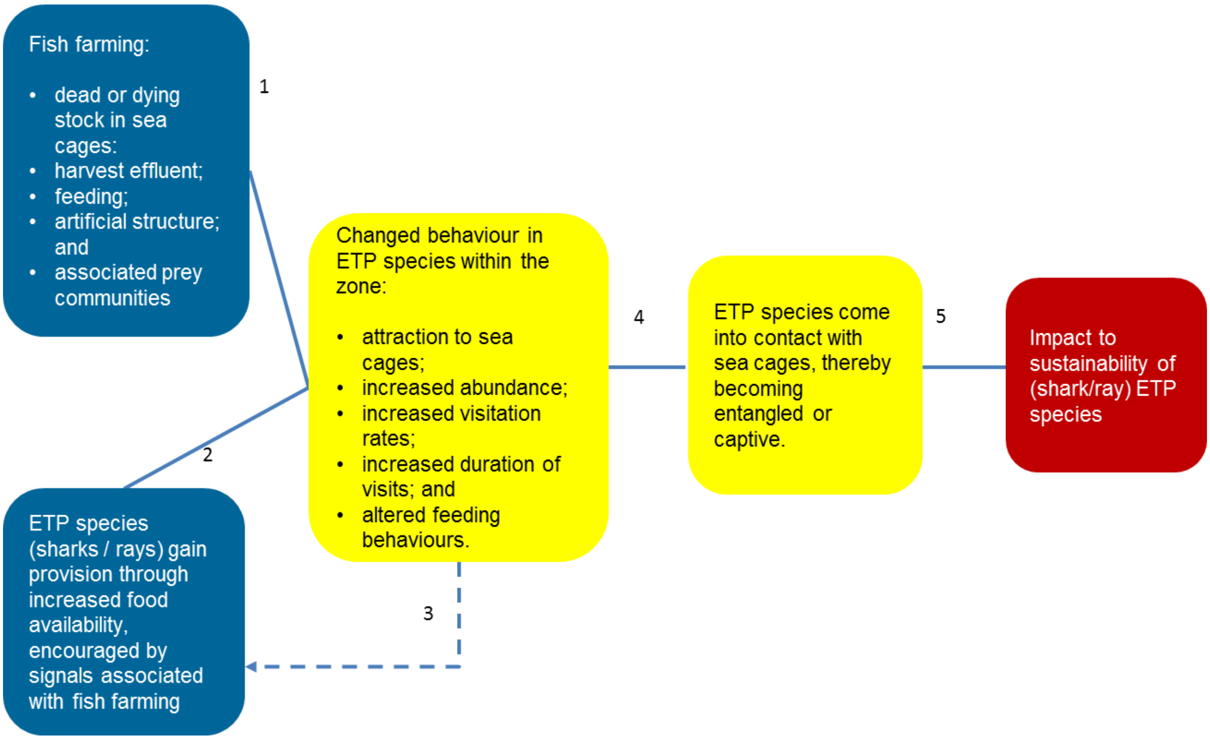

Figure 3: Conceptual model of hazards associated with aquaculture and the potential cause-effect pathways leading from hazards to factors which could impact on the ecological sustainability of threatened, endangered or protected species of fish (sharks and rays). Numbers refer to hazard pathways reviewed in Table 6.

3.3. Hazard Pathway Analysis

For the purpose of hazard pathway analysis, hazards were considered based on the direct and indirect consequences to ETP species as detailed in Table 6. Whilst significant ecological consequences are generally a prerequisite that may lead to subsequent social consequences (e.g. economic and reputational costs via loss of market access resulting from a non-sustainable status that has resulted in trade issues and social amenity impact) these aspects are not comprehensively evaluated in the current assessment.

3.4. Potential negative effects of aquaculture on the sustainability of endangered, threatened and protected species of sharks and rays

3.4.1. Overview of potential impacts of aquaculture on the sustainability of an endangered, threatened or protected species of shark/ray

Marine sea-cage farming has the potential to have negative effects on ETP shark and rays species, primarily through interactions of these species with aquaculture gear. The opportunity for interaction may be increased due to a positive attraction of such species to sea-cages for reasons relating to food and habitat provision as a result of aquaculture activity within the MWADZ.

The risks to ETP species were assessed based on potential socio-political and/or sustainability concerns. The key risks that were identified in the assessment process were:

- fish farming activities leads to the attraction of ETP species to the MWADZ;
- ETP species (sharks and rays) gain provision through increased food availability, encouraged by signals associated with fish farming;
- changes in the behaviour of ETP species (i.e. shark and rays) within the MWADZ;
- entanglement or mortality of ETP species in aquaculture infrastructure; and
- impact to sustainability of ETP species (shark/ray species) caused by mortalities resulting from entanglements or captures in sea-cages.

Information is limited on the interactions between ETP shark and ray species and marine finfish aquaculture. All available relevant information is predominantly focused on aquaculture interactions with white sharks and non-ETP shark species such as tiger sharks. Consequently, information from the relevant research studies on these species was used to assess the potential negative effects of the proposal on shark and ray ETP species.

3.4.2. Hazard Analysis: Potential negative effects of aquaculture on endangered, threatened and protected species

Table 6: Assessment of hazards identified in Figure 3 *Hazards were individually analysed with respect to both the inherent hazard (i.e. baseline hazard if no management measures aimed at mitigating the hazard were in place) and their residual hazard (i.e. remaining hazard once one or more of the proposed management controls have been implemented)*

Hazard	Inherent Hazard Assuming No Management Controls	Justification	Residual Hazard Following Implementation of Management Controls	Justification and Identified Management Controls
1. Fish farming activities leads to the attraction of ETP species to the MWADZ	**Consequence: Moderate (2)** **Likelihood: Likely (4)** **Hazard score: (8)** **Risk level: Moderate**	**Consequence** While attraction cues are important for bringing sharks into contact with aquaculture cages, significant populations of sharks currently reside in the vicinity of the proposed zone. A discrete consequence of attracting sharks closer to the sea-cages may be significant, but is not well understood and (at present) unquantified. An increased presence of sharks and rays in the proposed zone is likely to increase the probability that an individual shark or ray will come into contact with aquaculture. The consequence of an increased presence of sharks and rays is linked to other hazards, which are discussed in sections 2-5 of this table. Consequence is assessed as **Moderate (2)**. **Likelihood** There are four primary signals that are **Likely (4)** to attract sharks to the zone:	**Consequence: Minor (1)** **Likelihood: Possible (3)** **Hazard score: (3)** **Risk level: Low**	**Consequence** Consequence of any attraction could be reduced to **Minor (1)** by reducing the consequence on threatened species through elimination of the opportunity to interact negatively with aquaculture gear. Appropriate management measures include: • use of appropriate anti-predator netting materials; and • prevention of food provision, through regular removal of dead and moribund stock and aiming for less than 1% wastage of feed. **Likelihood** Likelihood of positive attraction can be reduced to **Possible (3)** based on a removal of as many of the potential sources of attractants as practical through actively

		• cultured stock (fish at high densities); • dead or moribund stock; • harvest activities (stress responses of the stock, and biological residues, such as blood etc.); and • plumes of minute traces of fish oils (contained in the pelletised feed) created when feeding the stock [2]. Only sharks and rays that are already in the near vicinity of the cultured fish the signals could detect signals likely to attract them to the source.[3] Similarly, only on small spatial and temporal scales is 'berleying' known to influence specific sites occupied by sharks[4]. <u>Cultured stock:</u> The long-term presence of high densities of cultured stock in the upper water column is likely to be a continuous, low-level source of biological residue (oil, scales, faeces, blood etc.) which could attract sharks to the proposed zone. <u>Dead or moribund stock:</u> Stock mortality is an inevitable factor in aquaculture and occasionally dead stock could be present in sea-cages for a number of hours or even days. Anecdotally, this potentially available source of food is reported to be the most		managing their levels of accumulation. Specific management mechanisms include the following: Development and compliance with a Management and Environmental Monitoring Plan (MEMP) and best-practices in aquaculture that include the following requirements: 1. Removal of dead and moribund stock on a daily basis; 3. Moderate stocking levels; 4. Humane harvesting methods; 5. Containment of all post-harvest blood water; and 6. Use of a high quality pellet feed. Modern feed for culturing fin-fish contains less fish meal and fish oil that traditional aquaculture feeds and can be designed to sink at rates which optimise consumption by stock; 7. Real-time monitoring of environmental conditions and stock responses during feeding.

[2] Bruce, 1998.
[3] Ibid.
[4] Price and Morris, 2013.

		significant signal for attracting white sharks to fish farms[5]. Harvest activities: It is not common practice in the industry to purposely discard harvest by-products on site. However, it is reasonable to expect that there is a variety of other cues associated with harvesting cultured fish that could attract sharks. Harvest activities could introduce fish blood to the environment and bring about stress behaviours in cultured stock. During a workshop on shark-aquaculture interactions, it was documented that dead and dying stock in a sea-cage is the most important attractant of sharks to fish farms. For example, the tuna farming industry in South Australia reported that a single, freshly-dead or dying fish was enough to bring about a shark interaction[6]. Feed: Aquaculture stock feed consists of fish meal and fish oil - known attractants to sharks and rays. It is plausible that the daily release of substantial quantities of feed to the water column within the proposed zone will have an influence on particular species of sharks. The tuna farming industry in South Australia reported that farm infrastructure alone does not appear to attract white sharks. However, while there is no evidence that the presence of		

[5]MurrayJones, 2004.
[6]Ibid.

		aquaculture structure alone will directly attract sharks and rays, the habitat structure provided by aquaculture infrastructure could attract natural prey species of finfish that (in turn) attract sharks. The scenario where the input of stock feed could influence shark behaviour relies on at least one of two major factors: 1. A substantial quantity of uneaten stock feed would need to build up in the local environment to a level which could influence shark behaviour; or 2. A concentration of uneaten feed would need to drive growth in populations of prey species within the proposed zone[7]. Additional food could build up in the local environment, thereby facilitating the growth of populations of prey species. An increase in the abundance of prey species could subsequently influence shark behaviour in the proposed zone. Sharks can be conditioned to stay around a source of food for periods longer than they otherwise would[8,3]. Sea-cage clusters provide additional three-dimensional structures to the marine environment. Given artificial reefs are known to attract fish communities[9], it is reasonable to expect that prey species will utilise this artificial habitat and wild predators will be among the various species that will spend time around these structures.		

[7]Price and Morris, 2013.
[8]Godvin, 2005.
[9]Machias, Karakassis and Giannoulaki, 2005.

2. ETP species (sharks and rays) gain provision through increased food availability, encouraged by signals associated with fish farming	**Consequence: Moderate (2)** **Likelihood: Likely (4)** **Hazard score: (8)** **Risk level: Moderate**	**Consequence** Success in gaining provision (food) from the fish farm will increase the rate at which individual sharks attempt to gain reward from the sea-cages. It is well-established in the literature that (generally) wildlife that are exposed to unnatural provisioning tend to change their feeding behaviours to maximise potential advantages. It is therefore reasonable to expect that any provisioning by a fish farm would be linked to increases in visitation rates, duration of visits, or abundance of sharks and rays at the sea-cages. In turn this could result in increased rates of attempted predation on the stock. Consequence is assessed as **Moderate (2)**. There are flow-on consequences associated with this hazard. These are discussed in sections 3-5 of this table. **Likelihood** Section 1 above has established that sharks are likely to be attracted to sea-cage aquaculture. Stock mortality is an inevitable factor in aquaculture and there are numerous examples from around the world of sharks biting through sea-cage netting to access dead stock. Although it is common practice in the industry to remove dead and moribund stock from cages on a daily basis (weather permitting) occasionally dead stock could be present in sea-cages for a number of hours or even days.	**Consequence: Minor (1)** **Likelihood: Possible (3)** **Hazard score: (3)** **Risk level: Low**	**Consequence** Consequence of any attraction could be reduced to **Minor (1)** by reducing the consequence on threatened species by preventing their opportunity to interact negatively with aquaculture gear. Appropriate management measures include: • use of appropriate anti-predator netting materials; and • prevention of food provision through regular removal of dead and moribund stock and aiming for less than 1% wastage of feed. **Likelihood** Likelihood can be reduced to **Possible (3)** by the measures outlined above. Reducing the likelihood of negative interactions with farming equipment can be achieved through use of appropriate predator exclusion controls. Development and compliance with a Management and Environmental Monitoring Plan (MEMP) and best-practices in aquaculture, including the requirement to remove dead and moribund stock on a daily basis should also occur.

		Given that sharks are likely to be present in the proposed zone regardless of the presence of aquaculture, it is reasonable to expect that (by chance alone) sharks will occasionally come into contact with the aquaculture infrastructure and attempt to access the stock behind the barriers. This hazard is dependent on a range of factors not limited to the species of shark and stock species, density and condition. Most of the shark species listed in Table 1 could be susceptible to provisioning and fish farming could facilitate this. Provisioning can be a powerful stimulus in changing feeding behaviour in wildlife. Given that some species of shark have been recorded staying longer than they otherwise would in fish farm areas, the effects of increased provisioning of sharks/rays could increase the rate at which sharks/rays attempt to gain food from behind sea-cage barriers. Likelihood is assessed as **Likely (4)**.		
3. Changes in the behaviours of ETP species (sharks and rays) in the zone: • **Attraction to the zone;**	**Consequence: Moderate (2)** **Likelihood: Likely (4)** **Hazard score: (8)** **Risk level:**	**Consequence** Provisioning is known to affect the behaviour of sharks and other species at local scales[10]. However, Laroche et. al. 2009 indicated that moderate levels of provisioning are unlikely to affect the behaviour of White sharks at the ecosystem level.	**Consequence: Minor (1)** **Likelihood: Unlikely (2)** **Hazard score: (2)** **Risk level:**	**Consequence** Consequence of any attraction, increased visitation rates, duration of visits, abundance or altered feeding behaviours could be reduced to **Minor (1)** by preventing the opportunity for ETP species to interact negatively with aquaculture gear.

[10] Ibid.

• **Increased visitation rates;** • **Increased duration of visits;** • **Increased abundance; or** • **Altered feeding behaviours**	**Moderate**	At a local scale, increased presence of sharks in the proposed zone increases the potential for entanglement or capture (as discussed in section 5 of this table). Consequence is assessed as **Moderate (2)**. **Likelihood** There are numerous records from Australia and other parts of the world of sharks accessing stock from fish farms. This may be driven by signals from aquaculture that attracts sharks and rays. However, it is important to note that provisioning itself can be a powerful stimulus in changing feeding behaviour. Consequently, there is a two-way link between changed behaviour in shark and ray and provisioning. For example, the residence times of white sharks at a site is influenced by whether or not an individual gains a 'reward' at that site (i.e. a feed).[11] 'Provisioning' of wildlife has been linked to changes in animal behaviour that can manifest over different time scales and with impacts on other species within the surrounding area[12]. Conversely, the ability of a shark to gain a reward from a fish farm will depend on the duration of its visit to the farm. The frequency of entanglement or capture will be influenced by the behaviour of sharks. Given that some species of shark have been recorded staying longer than they otherwise would in fish farm areas,[13] the effects of increased provisioning of sharks/rays could increase the rate at which	**Negligible**	Appropriate management measures include: • use of robust sea-cages with appropriate anti-predator netting materials; • industry benchmark of less than 1% wastage of feed; and • prevention of food provision through regular removal of dead and moribund stock. **Likelihood** Long term changes in behaviours can be minimised to **Unlikely (2)** through reducing the level of attraction for threatened species and which is also potentially related to minimising opportunity for rewarding that changed behavior. Management mechanisms to achieve this include: • review the management arrangement in relation to the removal of dead and moribund stock, and make required modifications to the requirements; • regulation of the density of sea-cage operations,[15] in addition to limiting the stocking density per hectare of lease;

[11]McAuley pers. com.
[12]Orams, 2002.
[13]Ibid.
[15]Papastamatiouet. al. 2010.

		sharks/rays attempt to gain food from behind sea-cage barriers. If sharks and rays spend extra time around the sea-cages, there is a greater probability that these individuals will make contact with the cages when presented with opportunities to feed on stock. Therefore, the risk of entanglement is escalated. In principle, aquaculture could elevate levels of dissolved nutrients in the water column surrounding the cages, thereby stimulating plankton growth. Research on the environmental factors important to whale sharks is lacking. However, given that whale sharks and manta rays are active pelagic filter-feeders targeting concentrations of plankton or fish, it is plausible that in certain situations aquaculture could indirectly attract these planktivorous fish. Whale sharks and manta rays are known to be attracted to areas that offer large concentrations of zooplankton and have been reported to visit seasonal shrimp blooms. They have also been known to aggregate in nutrient-rich feeding areas. In much of their range, there are a limited number of sites containing nutrient-rich waters associated with elevated abundance of zooplankton[14]. The scenario whereby sharks and rays are influenced by the presence of aquaculture through a provisioning mechanism can include a wide variety of species. Any increase in visitation rates, duration of visits or abundance of sharks or rays could increase the probability of entanglement or capture (as discussed in section 4 of this table). The likelihood of this scenario manifesting is dependent on the species. Given that the likelihood of entanglement is dependent on		• (in relation to planktivorous species) development and compliance with a Management and Environmental Monitoring Plan and best-practices in aquaculture, including the requirement to manage the levels of dissolved nutrients and chlorophyll-a. Chlorophyll-a is a proxy for phytoplankton levels. Median dissolved inorganic nitrogen levels must remain less than 500 µg/L. Median Chlorophyll-a levels must remain less than two-fold that at the Reference sites. Whale sharks and manta rays are rarely observed as far south as the Abrolhos Islands FHPA. However, future visitation to the Abrolhos Islands is possible. Providing phytoplankton levels remain at background levels, it is unlikely that the fish farms could affect the behaviour of whale sharks and manta rays.

[14] Froese and Pauly, 2015.

		species, an elevated level of uncertainty has necessitated a likelihood rating of **Likely (4)**.		
4. Entanglement and mortality of ETP species in aquaculture infrastructure	**Consequence: Major (3)** **Likelihood: Likely (4)** **Hazard score: High (12)** **Risk level: High**	**Consequence** Consequence is assessed as **Major (3)** given the social risks associated with the entanglement of protected species. Sustainability risks may also be a valid argument, dependent on the species and the level of knowledge regarding its population status in the wild. The global experience is that attempts by sharks to prey upon stock behind a netted barrier have resulted in sharks becoming entangled in the netting or caught within the cage [4]. Provisioning could negatively affect a target species through incidental mishap resulting in injury[16]. Changes in behaviour (including increased predation effort) have been known to result in the entanglement or capture of sharks in aquaculture netting, with fatal consequences [3,4,11]. It is hypothesised that white sharks are impacted by the Port Lincoln tuna industry through capture in sea-cages and, or, subsequent destruction by operators. This hazard is linked to potential impacts on the sustainability of shark / ray species, depending on the rate of shark and ray mortalities. Refer to section 5 below. **Likelihood** The literature suggests that there are several factors that could influence the visitation rates and	**Consequence: Major (3)** **Likelihood: Unlikely (2)** **Hazard score: (6)** **Risk level: Moderate**	**Consequence** Consequence remains **Major (3)** due to the social consequences of capturing and/or entangling any threatened species. **Likelihood** Likelihood may be reduced to **Unlikely (2)** based on the following management controls: Compliance around Management and Environmental Monitoring Plan (MEMP) and best practices in aquaculture, including requirements to: 1. minimise all attractant signals, e.g. keep stocking densities at low to moderate levels; 2. minimise opportunities for provisioning, e.g. the immediate or early removal of any dead and moribund stock; 3. use fit-for-purpose, well-designed sea-cages suited to the environmental conditions; 4. maintain the integrity of infrastructure; 5. use anti-predator nets to deny sharks access to the grow net (typically, ultra-high-molecular weight polyethylene fibre

[16] Orams, 2002.

		duration of visits by sharks to an area: • distance from shore; • depth of water; • mobility of the species; and • 'reward' provided in the area[17]. Any of the species listed in Table 1 could already be present in the proposed zone. Alternatively, these species could move into it as a response to an attraction signal or previous provisioning. The literature suggests that there are several factors that could influence the probability of a shark being captured or entangled in a sea-cage: • species of shark; • size of the individual; • design of the sea-cage; • maintenance of the sea-cage; • stocking density; and • presence of dead stock. Considering: • all of the species listed in Table 1, may already exist in the proposed area;		nets); 6. use mesh or netting less than 6 cm bar width; and 7. conduct regular, thorough inspections (e.g. using submerged cameras) to detect any damage to the mesh. While it is not possible to eliminate signals that could attract sharks and rays to the sea-cages, the management measures (above) make it unlikely that sharks and rays would become entangled or captured.

[17] Ibid.

		• stocking densities could be relatively high; • design and maintenance of sea-cages is the responsibility of the industry; and • dead and moribund stock could be present in the sea-cages, it is **Likely (4)** sharks will attempt to access stock behind sea-cage barriers. Due to their morphology, it is considered unlikely that rays would become entangled in sea-cage mesh or captured within the cages.		
5. Impact to sustainability of ETP species (shark / ray species) caused by mortalities resulting from entanglements or captures in sea-cages	**Consequence: Severe (4)** **Likelihood: Unlikely (2)** **Hazard score: (8)** **Risk level: Moderate**	**Consequence** Deaths of ETP species must be recorded, and could have consequences for the industry. For example, white sharks are protected under the FRMA, *Wildlife Conservation Act 1950* and the EPBC Act. If the rate of entanglement or capture increases beyond that of natural mortality rates, the sustainability of a ETP species of shark or ray could be threatened. The contribution aquaculture could make to anthropogenic mortality rates represents a potentially significant contribution in relation to anthropogenic pressure on particular ETP species. Consequences relating to a decline in the ecological sustainability of ETP species are confounded by secondary consequences associated with a high degree of public concern around ETP species. Such consequences are	**Consequence: Severe (4)** **Likelihood: Remote (1)** **Hazard score: (4)** **Risk level: Low**	**Consequence** The consequence assessment of **Severe (4)** would remain unchanged if sustainability issues were to occur. **Likelihood** Likelihood of sustainability impacts can be further reduced to **Remote (1)** based on implementation of management measures aimed at reducing interactions of endangered species with aquaculture operations (refer to sections 1-4 of this table). Operators within the MWADZ will be required to develop and implement an individual Management and Environmental Monitoring Plan (MEMP) that corresponds to an overarching zone *Environmental Monitoring*

		considered **Severe (4)**. **Likelihood** It is considered **Unlikely (2)** that in the absence of controls the interaction of threatened species with aquaculture operations could cause sustainability concerns, where population sizes of a certain species are very low and/or specific local populations exist. The Commonwealth's Marine Bioregional Plans assessed the risk of collision or entanglement of white sharks with aquaculture infrastructure (e.g. ropes and nets) as being of 'potential concern' in the *South-west Marine Region* of Australia. Such interactions could result in entanglement and drowning.[18] The probability of an impact on the sustainability of ETP species is dependent on the mortality rates for each species. For example, a risk assessment undertaken as part of the Western Australian Shark Hazard Mitigation Drum Line Program 2014-17 in relation to the tiger shark stocks off the west coast of WA states that the number of sharks that would need to be removed before even a measurable change in their population would occur is likely to be in the order of hundreds. However, it should be noted that other species of sharks and rays may mature later and therefore be more vulnerable to anthropogenic population depletion (i.e. low levels of mortality could contribute to impact on the sustainability of particular ETP species).[19]		*and Management Plan* (EMMP). The EMMP needs to be approved by the Western Australian Minister for Environment. The document, *inter alia*, describes strategies for minimising and avoiding interactions with significant marine vertebrates and also requires reporting of any interactions that occur. The Department of Fisheries will support or endorse best management practices for aquaculture and manage compliance around *Management and Environmental Monitoring Plans* (MEMPs) of individual operators, including mandatory reporting of interactions with ETP species. Failure to comply with the MEMP may result in suspension or cancellation of an offending licence. The industry could collect data on the rate of visitation of tagged sharks prior to starting-up aquaculture operations. Baseline data may be useful to quantify any changes in visitation rates of tagged sharks at aquaculture sites, after the introduction of stock and feed. This would be useful to provide an early warning to aquaculture managers if the rates of shark visitation or duration of visits increase in the vicinity of the fish farms. Collectively, the management framework (comprising the aforementioned mitigating and ameliorating mechanisms) significantly reduces the likelihood of ETP species mortalities caused by aquaculture

[18] Australian Government, 2013.
[19] DotPaC (2014)

		As stated in section 4 of this table, the morphology of ray species are such that it is considered unlikely rays would become entangled in sea-cage mesh or captured within the cages. Anecdotal records of sharks becoming entangled in aquaculture nets and subsequently being killed by the operators of the farms have been reported worldwide. For example, the aquaculture industry out of Port Lincoln was estimated to be responsible for up to 20 white shark deaths per year prior to a review by Malcolm et al. (2001). Modern fish farms alone are unlikely to be a major cause of mortality rates that could impact the sustainability of ETP species of sharks or rays. However, fish farms could contribute, by way of a small number of deaths, to the total number of anthropogenic shark mortalities within the region. Although fish farms are associated with a number of factors that could negatively affect shark and ray ETP species, it is considered Unlikely (Likelihood Score 2) that the proposed aquaculture could affect the sustainability of shark or ray ETP species in the MWADZ proposal area.		infrastructure or activity to be remote.

4. Risk Identification, Analysis and Assessment

4.1. Risk Identification

The key risk to local populations of ETP species was identified from detailed analysis of hazard pathways linked to the proposed activities associated with the MWADZ. This key risk was considered to be:

The proposed aquaculture activity could have a significant impact on ETP (shark and ray) species in the vicinity of the Abrolhos Islands FHPA, from an ecological sustainability and social acceptability perspective.

This risk was assessed with a consideration of potential cumulative impact using the precautionary approach described in the methodology. This process investigated pathways or cause-effect linkages between environmental hazards and key factors that contribute to a broad risk category.

4.2. Risk Analysis

Nature of Risk

The assessment considers the biological characteristics of species such as white sharks and tiger sharks to represent broad categories of protected fish taxa found in the area that have the potential to interact with aquaculture cages. Mortalities associated with marine finfish aquaculture worldwide typically result from entanglement or capture of individual animals (e.g. sharks) in the sea-cage mesh or within the cage itself which can lead to those individuals drowning or being destroyed by farm operators.

4.2.1. Inherent Risk Analysis

Likelihood

ETP species of concern (Table 1) are known to be present or migrate within the MWADZ general area and may be attracted to the zone based on a number of cues associated with aquaculture. These include:

- stock at high densities;
- dead or moribund stock;
- harvest activities (e.g. stress responses of the cultured fish and biological residues, such as blood, generated during harvest etc.);
- plumes of minute traces of fish oils (contained in the pelletised feed) created when feeding the stock; [20] and
- increased wild fish availability through their local attraction to sea cages.

[20] Bruce, 1998.

The degree to which these sources of attraction are managed will influence the likely visitation rates of shark and ray species and thus the likelihood of interacting with aquaculture gear.

In addition, the degree to which shark and ray species are rewarded though these encounters will also influence the likelihood of increased visitation and interactions with aquaculture gear. This so-called provisioning effect (access to an unnatural reward of food) is thought to be a powerful stimulus in changing the feeding behaviour of sharks and rays, including the white shark[21], black ray and eagle ray.[22]

Provisioning could:

- attract sharks and rays to the zone;
- increase visitation rates;
- increase duration of visits;
- increase localised abundance; and
- alter feeding behaviours.

Previous success in gaining provision from a fish farm will increase the likelihood that individuals (ETP species of sharks/rays) will continually attempt to gain reward from the sea-cages. Changes in feeding behaviour and effort have been known to result in the entanglement or capture of sharks and rays in aquaculture netting, with fatal consequences[23],[24].

Modern fish farms alone are unlikely to result in mortality rates that would threaten the sustainability of shark or ray ETP species. However, fish farming could potentially be one of several anthropogenic mechanisms which are contributing to a population decline in ETP species. In isolation, the proposed MWADZ is not considered a significant threat to ETP species sustainability. However, there may be social risks, relating to concerns for ETP species sustainability or with any potential capture of a ETP species.

Globally, there are clear records of sharks becoming entangled in aquaculture nets and subsequently being killed by the operators of aquaculture farms. In Port Lincoln, South Australia, the aquaculture industry was estimated to be responsible for up to 20 white shark deaths per year, prior to a review by Malcolm et al. (2001).

[21]Bruce and Bradford, 2011.
[22]Newsome, Lewis and Moncrieff, 2004.
[23]Australian Government (SEWPaC) 2013.
[24]Price and Morris, 2013.

However, the rate of interaction of shark species with aquaculture cages in Australia has been reduced in recent years, coinciding with increased public scrutiny, tighter regulations, and better reporting associated with third party accreditation of particular companies. The inherent likelihood of the MWADZ having a significant effect on the sustainability of these species is considered **Unlikely (2)**

Consequence

The ecological consequence of aquaculture activity in the MWADZ having a significant impact on ETP species was assessed from both, sustainability and social acceptability, perspectives. Any threat to the ecological sustainability of ETP species is confounded by consequences associated with a high degree of public concern around ETP species, and as such was assessed as **Severe (4)**. This consequence is deemed primarily to be social in nature. However, impacts on certain species could contribute to consequences in relation to ecological sustainability. The white shark, grey nurse, hammerhead, mako, sawfish and whale shark are protected under the FRMA, *Wildlife Conservation Act 1950* and EPBC Act. Deaths of EPBC listed species must be recorded, and the industry operating within the MWADZ is likely to seek to minimise rates of mortality in ETP species to avoid negative consequences, such as non-compliance related penalties under the FRMA and other legal implications relating to non-compliance with the *Wildlife Conservation Act 1950* and, or, EPBC Act.

4.2.2. Overall Inherent Risk

Using Table 4, the Hazard/Risk Score (C x L) for the overall inherent risk is 8 and the **inherent risk level is Moderate**.

4.2.3. Residual Risk Analysis

Likelihood

When a combination of management measures are put in place to reduce the likelihood in the hazard pathways identified in Figure 3, the likelihood of MWADZ activities having a significant impact on ETP species, either from a sustainability or social acceptability perspective, is reduced. These management measures include those highlighted below:

Control category	Management Control	DoF Control Mechanism
1. Reducing the strength of signals that may attract sharks/rays	• Removal of dead and moribund stock on a daily basis • Containment of all stock • Containment of all post-harvest by-products • Humane harvest methods • Appropriate stocking densities [i.e. stocking densities kept at levels below or equal to industry-best-practice bench marks (e.g. 10-25 kg/m^2)] • Minimisation of feed wastage (e.g. through setting a benchmark of less than 2% wastage, achieved by using efficient delivery systems and real-time monitoring of environmental conditions and stock feeding responses) • Use of a high-quality pellet feed, noting: ➢ increasing knowledge on nutritional needs of particular finfish species in aquaculture is leading to improved quality of feed and is responsible for significant improvements in feed conversion ratios ➢ modern feed for culturing fin-fish contains less fish meal and fish oil that traditional aquaculture feeds ➢ modern high-quality feed can be designed to sink at rates which optimise consumption by stock	Monitoring and enforcement of compliance with: ➢ Management and Environmental Monitoring Plans (MEMPs); and ➢ Licence conditions, to achieve best management practices, in accordance with the zone Environmental Monitoring and Management Plan (EMMP) and the zone Management Policy. Encouraging industry adoption of the Aquaculture Council of Western Australia Environmental Code of Practice.
2. Reducing opportunity for interactions between ETP species of sharks/rays and aquaculture	• Immediate or early removal of any dead and moribund stock (i.e. remove the most significant shark attractant signal) • Use of effective predator barriers, including: ➢ fit-for-purpose sea-cages suited to the environmental conditions ➢ durable, high tensile strength sea-cage mesh (e.g. made from ultra-high molecular weight, polyethylene fibre) ➢ highly-visible mesh (to reduce the likelihood of ETPs accidentally colliding with the sea-cages)	Monitoring and enforcement of compliance with: ➢ Management and Environmental Monitoring Plans (MEMPs); and ➢ Licence conditions, to achieve best management practices, in accordance with the zone Environmental Monitoring and Management Plan (EMMP) and the zone Management Policy.

Control category	Management Control	DoF Control Mechanism
	• regular, thorough inspections of sea-cages to detect any tears in the mesh (e.g. using submerged cameras)	Encouraging industry adoption of the Aquaculture Council of Western Australia Environmental Code of Practice.
3. Prevention of predators breaching the sea-cage netting	Use of best management practices in aquaculture (i.e. guided by the Norwegian Standards and the Aquaculture Council of Western Australia Environmental Code of Practice for marine finfish aquaculture) including: • sea-cage design and installation • sea-cage mesh that is durable, of suitable bar width (size) and having high-tensile-strength (e.g. ultra-high molecular weight, polyethylene fibre) • anti-predator nets (e.g. 'armour' nets external to the sea-cage net) • removal of dead and moribund stock on a daily basis • appropriate stocking densities [i.e. stocking densities kept at levels below or equal to industry-best-practice bench marks (e.g. 10-25 kg m^3)] • humane harvest methods • containment of all post-harvest blood water • real-time monitoring of environmental conditions and stock responses during feeding • regular, thorough inspections of sea-cages to detect any tears in the mesh (e.g. using submerged cameras)	Monitoring and enforcement of compliance with: ➢ MEMPs; and ➢ Licence conditions, to achieve best management practices, in accordance with the zone Environmental Monitoring and Management Plan (EMMP) and the zone Management Policy. Encouraging industry adoption of the Aquaculture Council of Western Australia Environmental Code of Practice.

Control category	Management Control	DoF Control Mechanism
4. Reducing impacts of potential interactions	• Industry adoption of the Aquaculture Council of Western Australia Environmental Code of Practice • Implementation of the Marine Fauna Interaction Plan • Mandatory training for workers responsible for maintaining the aquaculture infrastructure • Sea-cage design to facilitate release of captured ETP species • Adequate anchoring systems to correctly tension sea-cage clusters • Sea-cage nets correctly tensioned to minimise the impacts of predators and reduce the risk of the net wearing or tearing • Regular, thorough inspections (e.g. using submerged cameras) of sea-cages and associated aquaculture infrastructure to detect any entanglements, damage or weaknesses	Monitoring and enforcement of compliance with: ➢ MEMPs (incorporating Marine Fauna Interaction Plans); and ➢ Licence conditions, to achieve best management practices, in accordance with the zone Environmental Monitoring and Management Plan (EMMP) and the zone Management Policy. Encouraging industry adoption of the Aquaculture Council of Western Australia Environmental Code of Practice.
5. Reduced uncertainties in relation to how sharks/rays interact with offshore finfish aquaculture	• Mandatory recording and reporting of interactions with ETP species • Monitoring and scientific research in relation to shark behaviours within the proposed MWADZ • Adaptation of management arrangements to take advantage of new data/information as it becomes available	As above, plus annual review of ETP species interactions records and reports. In-kind support for industry to commission monitoring and research on ETP species-aquaculture interactions.

An overarching Environmental Management and Monitoring Plan (EMMP) has been developed which provides strategies to minimise the rate of interactions between aquaculture and ETP species.

Operators within the zone are also required to comply with individual MEMPs that require (*inter alia*) operators within the proposed zone to comply with the overarching EMMP. Additionally, a MEMP requires the adoption of best-practices in aquaculture. There are several factors which are important in reducing signals that may attract sharks and rays to the proposed zone. These include:

- removal of dead and moribund stock on a daily basis;
- moderate stocking levels;
- humane harvest methods;
- containment of all post-harvest blood-water; and
- use of a high-quality pellet feed.

The industry has the ability to collect data on the rate of visitation by tagged sharks prior to starting-up aquaculture operations. Baseline data may be useful to check that visitation rates and the duration of visits by tagged sharks at aquaculture sites are not increased after the introduction of stock and feed. This would be useful to provide an early warning to aquaculture managers, in case the presence of sharks and, or rays, significantly increase near sea-cages in the proposed zone.

A MEMP will also require operators to monitor the levels of dissolved nutrients and chlorophyll-a, which is a proxy for phytoplankton levels. Median concentrations of dissolved inorganic nitrogen must remain less than 500 µg/L. Median concentrations of Chlorophyll-a must remain less than two-fold that at the Reference sites. These requirements will ensure that phytoplankton levels remain at background levels. Therefore, it is unlikely that outputs of the proposed aquaculture could affect the behaviours of Whale sharks and Manta rays.

Overall, industry's compliance around MEMPs and the zone EMMP, which include best-management practices, should result in:

- significant reductions in levels of attractant signals to minimise the likelihood of ETP species making contact with sea-cages;
- significant reductions in opportunities for provisioning of ETP species by aquaculture to prevent behavioural changes;
- use of anti-predator nets to deny ETP species access to cages (a potential food source);
- use of mesh or netting of an appropriate mesh size (e.g. less than 4cm in bar width), tear-resistant and tangle-resistant to minimise the probability of ETP species becoming entangled in, or entrapped within, the sea-cages; and

- tensioning of aquaculture infrastructure to eliminate the possibility of entanglement of ETP species.

Collectively, these factors significantly reduce the likelihood of ETP species mortalities caused by aquaculture infrastructure or activity to **Remote (1)**.

Consequence

An impact to sustainability of ETP species caused by the proposed aquaculture is considered from both an ecological and social perspective, and did not change from being a **Severe (4)** consequence**.**

4.2.4. Overall Residual Risk

The overall residual risk of an impact to sustainability of ETP species caused by the proposed aquaculture zone is considered low and acceptable.

Using Table 4, the Hazard/Risk Score (C x L) for the overall residual risk is 4 and the **residual risk level is Low**.

5. Summary

The broad risk to ETP species presented by the proposal to develop marine finfish aquaculture associated with the MWADZ was identified as:

The proposed aquaculture activity could have a significant impact on ETP (shark and ray) species in the vicinity of the Abrolhos Islands FHPA, from an ecological sustainability and social acceptability perspective.

Critical pathways that could collectively lead to the realisation of this risk were identified (hazards) and reviewed systematically. The residual risk has taken into account the management measures associated with development of the MWADZ to address the hazards. Low risks suggest that current risk control measures are adequate in reducing the levels of identified risks to acceptable levels.

A primary hazard is the attraction of sharks to sea-cage aquaculture within the zone, through four primary signals:

- cultured stock;
- dead or moribund stock;
- harvest activities; and
- feed.

Sharks and rays that are already in the vicinity of the cultured fish could detect signals (associated with food and habitat) that are likely to attract them to the source. It is well established that sharks and rays are attracted to aquaculture by the presence of cultured stock at high densities and the act of feeding the stock.

Fish cage clusters are artificial three-dimensional structures that function as additional habitats within the existing marine environment. Given artificial reefs are known to attract fish communities[25], it is reasonable to expect that prey species will utilise this artificial habitat and wild predators will be among the various species that will spend time around these structures. An increased presence of sharks and rays in the proposed zone is likely to increase the probability that an individual shark or ray will come into contact with aquaculture.

The probability of positive attraction can be reduced by limiting the potential sources of attractants as much as possible. The overarching EMMP and individual operator MEMPs require all potential sources of attractants associated with aquaculture activity are reduced to the greatest extent practicable.

The consequences of changed behaviour in ETP species due to the proposed aquaculture can be significantly reduced by eliminating opportunities for ETP species to interact negatively with aquaculture gear through a number of practical management measures (set out in the zone EMMP and MEMPs). However, given that sharks are likely to be present in the proposed zone, regardless of the presence of aquaculture, it is reasonable to expect that sharks will occasionally come into contact with the aquaculture structures and attempt to access the stock behind the barriers.

Provisioning can be a powerful stimulus in changing feeding behaviours in wildlife. The provision of reward or advantage to wild animals has been shown to perpetuate the behaviours that contribute to the reward. If aquaculture facilitates provisioning of food or habitat to ETP species, it could increase the rates at which ETP species make contact with the sea-cages.

Aquaculture could elevate levels of dissolved nutrients in the water column surrounding the cages, thereby stimulating plankton growth in the water column. This, theoretically, could provision planktivorous species. Although this pathway of cause-effect is considered unlikely, the theory highlights the level of uncertainty associated with the potential for a wide variety of species to be influenced by aquaculture through factors such as provisioning.

Providing phytoplankton levels remain in the vicinity of background levels, it is unlikely that the fish farms could affect the behaviours of whale sharks and manta rays.

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[25]Machias, Karakassis and Giannoulaki, 2005.

The consequence of altered feeding behaviours can be reduced by preventing the provisioning of ETP species. This can be achieved through appropriate management measures such as:

- use of robust sea-cages with appropriate anti-predator netting materials;
- adopting an industry benchmark of less than 1% wastage of feed; and
- regular removal of dead and moribund stock from sea-cages.

Due to their morphology, it is considered unlikely that rays would become entangled in sea-cage mesh or captured within the cages. However, attempts by sharks to access stock are likely in the absence of such control measures. It is also possible that large individuals of particular species will breach the barriers containing the cultured stock. The Commonwealth's Marine Bioregional Plans assessed the risk of collision or entanglement of white sharks with infrastructure as being of 'potential concern' in the South-west Marine Region of Australia in relation to interactions with aquaculture ropes and nets, which could result in entanglement and drowning.

The available literature suggests that there are several factors that could influence the probability of a shark being captured or entangled in a sea-cage. These include:

- the species of shark/ray ETP species;
- size of the individual shark/ray;
- design of the sea-cage;
- maintenance of the sea-cage;
- density of the stock in culture; and
- presence of dead/moribund stock.

The last four factors (of the six above) can be controlled to substantially reduce the risk of ETP species mortalities due to aquaculture.

While it is not possible to eliminate signals that could attract sharks and rays to the sea-cages, the likelihood that sharks and rays would become entangled or captured is considered remote. Operators must comply with mitigating management measures set-out in the zone EMMP and MEMPs and failure to comply could result in the suspension or cancellation of the offending aquaculture licence.

Throughout the world, there is anecdotal evidence that fish farms could contribute, by way of a small number of deaths, to the total number of anthropogenic shark mortalities. The contribution aquaculture could make to mortality rates could be significant in relation to the various pressures on particular ETP species. However, modern aquaculture operations (with high-tech infrastructure and industry best-practices) are unlikely to cause mortality rates in shark and ray ETP species that would threaten ecological sustainability of a species.

Residual risk analysis (from an ecological sustainability or social perspective) considered the potential consequences of the proposed aquaculture impacting on biological sustainability of ETP species to be Severe; however the likelihood of occurrence was Remote. Therefore, the overall risk of an impact to sustainability of ETP species of shark or rays caused by the proposed MWADZ is considered low and acceptable. The Department of Fisheries will promote best-management practices for aquaculture and regulate compliance around the implementation of MEMPs for individual operators, including mandatory reporting of interactions with all ETP species.

In addition to their responsibilities under the *Environment Protection and Biodiversity Conservation Act 1999*, *Fish Resources Management Act 1994*, *Wildlife Conservation Act 1950*, and *Environmental Protection Act 1986*, the industry is likely to adhere to the marine finfish aquaculture Environmental Code of Practice developed by the Aquaculture Council of WA.

The risk of impact to biological sustainability of ETP species could be further reduced by the aquaculture industry participating in the collection of data on visitation rates of tagged ETP species. For example, operators within the zone could deploy acoustic receivers at their fish farms to record data on the behaviour of tagged sharks before and after the introduction of stock and feed to sea-cages. This would reduce some of the uncertainties surrounding shark-aquaculture interactions. It would also benefit the industry to provide an early warning to aquaculture managers if the rates of shark visitation or duration of visits to fish farms increases over time.

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