Threat Identification, Hazard Pathway Analysis and Assessment of the Key Risks to invertebrate and finfish species and fisheries at the Abrolhos Islands, presented by the establishment of the Mid West Aquaculture Development Zone in Western Australia

Prepared by

Department of Fisheries Western Australia

August 2015

Summary of the assessed risk level:

Risk	**Inherent Risk** (no management measures)	**Residual Risk** (based on implementation of identified management measures)
1. Aquaculture activity in the zone has a significant impact on the populations of invertebrate species (i.e. saucer scallop) in the Abrolhos Islands FHPA	**Negligible**	**Negligible**
2. Aquaculture activity in the zone has a significant impact on populations of finfish species in the Abrolhos Islands FHPA.	**Negligible**	**Negligible**
3. Aquaculture activity in the zone has a significant impact on the invertebrate fishery (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery).	**Low**	**Low**
4. Aquaculture activity in the zone has a significant impact on finfish fisheries in the Abrolhos Islands FHPA.	**Negligible**	**Negligible**

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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 region of Western Australia (referred to hereafter as the Mid West Aquaculture Development Zone or MWADZ) on the sustainability of ecosystems and their dependent extractive finfish fisheries. This assessment does not seek to replicate previously conducted generic aquaculture risk assessments which remain relevant to the MWADZ proposal and which include 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)

Instead, the current assessment has used these previous reports as a basis to identify the main 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, which was to ensure the establishment and operation of the MWADZ without significantly impacting the sustainability of ecosystems and their dependent fisheries. These risks were then assessed.

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 and economic 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 Department of Fisheries (Department) 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 wanting to establish aquaculture operations within these zones.

Extensive studies and modelling underpin 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) had already been officially declared by the Minister for Fisheries in WA’s northern waters. 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 the production of 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 zone in the Mid West region of Western Australia. The Mid West Aquaculture Development Zone (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 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 198*6. Approval of this strategic proposal will create opportunities for existing and future aquaculture operators to refer their proposals to the Environmental Protection Authority as ‘derived proposals’. The objective is a more streamlined 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 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 exact 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.

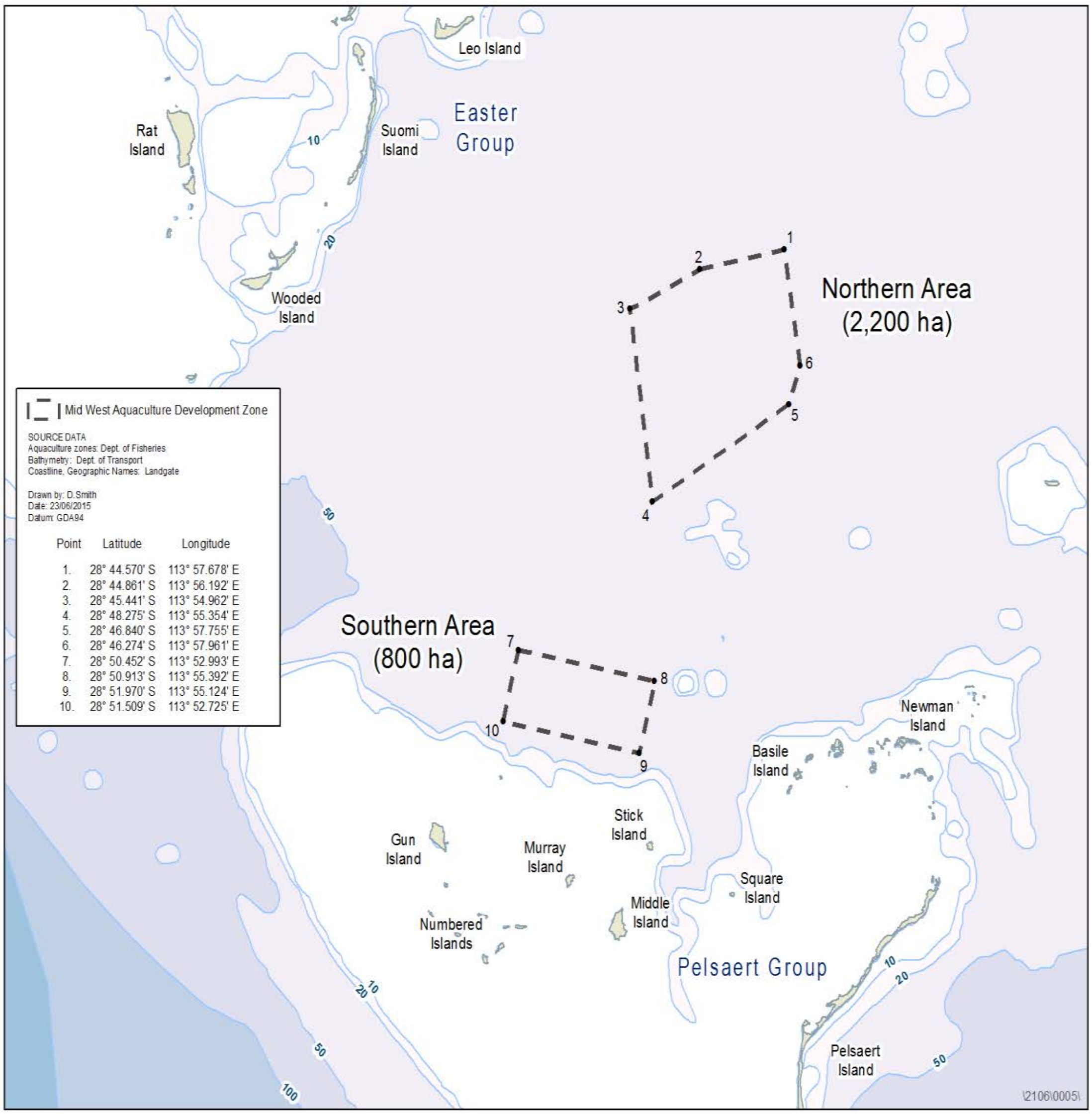

Figure 1: Proposed Mid West Aquaculture Development Zone

The Department will manage the proposed MWADZ within an integrated management framework that governs the workings of the zone. This will be similar to the framework 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.

Likely suitable fish species to be cultured in the zone, based on existing commercial aquaculture interest, their suitability for aquaculture in Western Australia 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 species:

- yellowtail kingfish (*Seriola lalandi*)
- mulloway (*Argyrosomus japonicus*)
- dolphin fish (*Coryphaena hippurus*)
- pink snapper (*Chrysophrys auratus*)

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 of these species associated with establishment and operation of the MWADZ on the sustainability of ecosystems, and their dependent fisheries. Both the inherent risk (risk before application of management controls) coupled to the residual risk (following application of proposed management controls) was 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.

The assessment is based on the current knowledge/literature of the potential impacts of sea cage finfish aquaculture on fish and invertebrate species and fisheries production. The assessment also considers all available relevant information relating to:

- the proposed location within the Abrolhos Islands Fish Habitat Protection Area (FHPA);
- fish and invertebrate species known to inhabit the FHPA in the vicinity of the MWADZ;
- key invertebrate and commercial fisheries which are permitted to currently operate within the strategic MWADZ area; and
- yellowtail kingfish as the proposed culture species for the MWADZ project.

2 Threat Identification, Hazard Pathway Analysis and Risk Identification and 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 of Western Australia 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 and their assessment (see Figure 2).

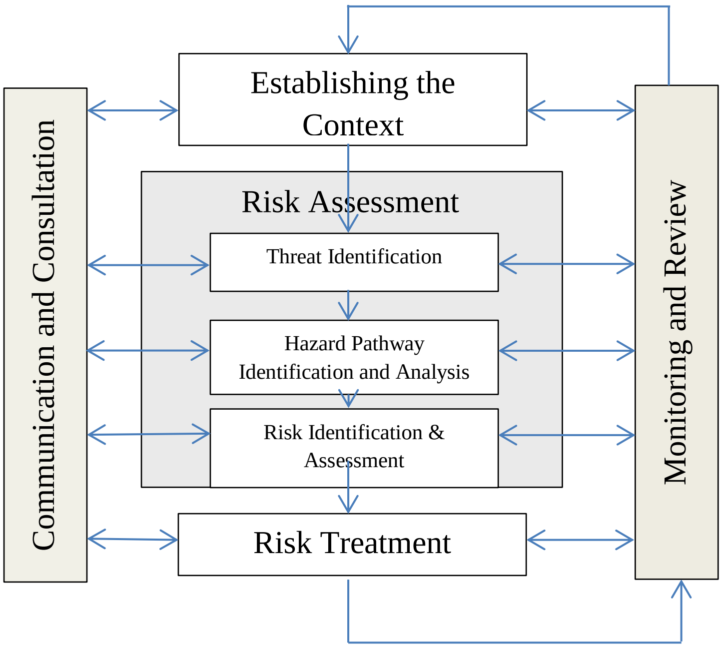

Figure 2: Description of risk assessment within the risk management process (modified from SA, 2012)

The specific protocols to complete each of these steps has 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 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)

2.2 Hazard Pathway Identification

The identification of hazard pathways associated with the four main threats 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, impacts on invertebrate and fish species and key commercial and recreational fisheries arising from an aquaculture facility 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 (Figures 3-6a).

2.3 Hazard Pathway Analysis

Individual hazards in each pathway were individually assessed (Tables 2-5a) 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 the proposed management controls have been implemented). 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 Western Australian Government Agencies through WA RiskCover.

Undertaking hazard or risk analysis using the Consequence-Likelihood (C x L) methodology involves selecting the most appropriate combination of consequence (levels of impact; Table 1a) and likelihood (levels of probability; Table 1b) of this consequence actually occurring. The combination of these scores is then used to determine the risk rating (Table 1c; IEC/ISO, 2009, SA, 2012).

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 risks associated with this proposal, the objective to be achieved is to ensure the maintenance of sustainable ecosystems, including fish and invertebrate species, (and any dependent fisheries) and that they are not significantly impacted by the establishment of aquaculture operations in the MWADZ. Consequently, a "significant impact" that would result in a high risk would be one for which there was a reasonable likelihood that either the sustainability of the species was at risk or it was likely to have a significant impact on a commercial or recreational fishery.

Table 1a: Qualitative levels of consequence for each of the main objectives relevant to the assessment (modified from Fletcher, 2015)

Objective	Minor (1)	Moderate (2)	Major (3)	Severe (4)
Sustainability of fish and invertebrate species	Measurable but minimal "impacts" of the potential aquaculture development on fish stocks that are highly acceptable and easily meet sustainability objectives.	Maximum acceptable level of "impact" of the potential aquaculture development on fish stocks that would still meet the sustainability objectives.	Above acceptable level of "impact" of the potential aquaculture development on fish stocks. Broad and/or long-term negative effects on sustainability objectives which may no longer be met. Restoration can be achieved within a short to moderate time frame.	Well above acceptable level of impact of the potential aquaculture development on fish stocks. Very serious effects on sustainability objectives that are clearly not being met and may require a long restoration time or may not be possible.
Ecosystem structure	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 prevalent.	Extreme change to structure and function. Complete species shifts in capture or prevalence in system.
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.

Economic	Detectable but no real impact on the economic pathways for the industry or the community.	Some level of reduction for a major fishery or a large reduction in a small fishery that community is not dependent upon.	Major sector decline and economic generation with clear flow on effects to the community.	Permanent and widespread collapse of economic activity for industry and the community including possible debts.

Table 1b: Generic levels of likelihood for each of the four 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 10–39%)
Likely (4)	A particular consequence level is expected to occur in the time frame (indicative probability of 40–100%)

Table 1c: Hazard/Risk Analysis Matrix. The numbers in each cell indicate the Hazard/Risk Score; the colour indicates the Hazard/Risk Rankings (see Table 2)

		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 2).

Table 1d: Risk Evaluation, Rankings and Outcomes (modified from Fletcher *et al.* (2002, 2005, 2014)

Risk Level	Hazard/Risk Score C x L	Probable management response	Expected reporting requirements
Negligible	0-2	Acceptable with no management actions or regular monitoring	Brief justification
Low	3-5	Acceptable with no direct management actions and monitoring at specified 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

Information Utilised

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

- Broad knowledge of the proposal as provided in its application.
- A previous high-level generic risk assessment conducted for marine finfish aquaculture in Australia (FRDC project 2003/223).
- An identified list of species likely to be under consideration for aquaculture in the MWADZ.
- Relevant scientific studies and publications (see references) and knowledge of the fish and invertebrate species within the vicinity of the proposed MWADZ area.
- Knowledge of the key fisheries within the vicinity of the proposed MWADZ area.
- Research survey information for the West Coast bioregion.

- Commercial catch and effort information for relevant WA fisheries within the vicinity of the MWADZ area.
- Relevant biological and behavioural information on finfish and invertebrates species.
- Other relevant scientific studies and publications (see references).

2.4 Risk Identification

Based on consideration of the identified broad areas of threat and their constituent hazard pathways, overarching risks were identified associated with the MWADZ proposal. Assessment of these overarching risks 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.

During the risk assessment process, the invertebrate fishery which was identified likely to be most significantly impacted by the MWADZ proposal was the Abrolhos Islands and Mid West Trawl Managed Fishery (AIMWTMF). Some areas of the strategic MWADZ proposal area (i.e. the southern area) are within historical scallop fishing grounds of the AIMWTMF. Therefore, the proposal is likely to limit the extent of available fishing ground in this fishery. Given these impacts, a specific risk assessment was conducted on the AIMWTMF. A separate risk assessment was also conducted on the saucer scallop (*Amusium balloti*) which is the key target species for the AIMWTMF.

The other invertebrate commercial fishery that was identified to potentially be impacted by the MWADZ proposal was the West Coast Rock Lobster Managed Fishery (WCRLMF). The waters around the Abrolhos Islands FHPA provide an important area for the fishery, with approximately 15% of the fishery's total average catch coming from this area (Department of Fisheries 2012). Commercial rock lobster fishing activity at the Abrolhos Islands predominantly occurs over reef habitat, with between 45 to 65 percent of fishing effort occurring in shallow waters (0 to 20 metres) near submerged platforms and exposed reefs (Webster, F *et al* 2002). These habitats tended to occur generally on the western and central parts of the islands groups where there is a high abundance of limestone reef and macroalgae habitat (Webster, F *et al* 2002). Previous research surveys conducted in the area have shown that the highest average number of fishing effort for the fishery occurs in the Wallabi/North Island area (273,000) pot lifts compared to the Easter Group (196,000) and the Southern Pelseart Group (98,300) (Webster, F *et al* 2002). Benthic habitat data collected in the strategic MWADZ proposal area indicates that the predominant habitat is sand, which does not represent a key habitat area for western rock lobster [pers comm De Lestang, S (DoF)].

While sandy benthic habitat can sometimes provide and important area for migrating lobster “whites run” at certain times of the year, the MWADZ proposal is not known to be an important area for migrating rock lobster.

Catch and effort information which has also been recorded from the WCRLMF indicates that the majority of historical effort at the Abrolhos Islands is conducted outside of the strategic proposal area. In addition, the MWADZ proposal area represents a very small proportion (i.e. 3,000 hectares) less than 0.1% of the overall area of the fishery.

As a result, it is unlikely that the MWADZ project will have a significant impact on the WCRLMF. Consequently, no further assessment was conducted in relation to this species or fishery.

During the risk identification process two commercial finfish fisheries were identified to be potentially impacted by the MWADZ proposal. These included the West Coast Demersal Scalefish (Interim) Managed Fishery and the Mackerel Managed Fishery. Catch and effort information reported for these fisheries indicates that the MWADZ proposal area does not represent a key fishing area for these fisheries at the Abrolhos Islands. The majority of the commercial fishing effort for these fisheries is conducted outside of the MWADZ proposal area [pers comm Fairclough, D (DoF)]. As a result, a more generic risk assessment was conducted for the key finfish fisheries.

Given that the proposed finfish aquaculture in the MWADZ has the potential to impact target and non-target finfish species, a generic risk assessment was also conducted for finfish species.

3 Threat Identification, Hazard Pathway Analysis and Risk Identification

3.1 Threat Identification

Using a component-tree based approach (Fletcher *et al.*, 2014) four broad areas of threats were identified that were considered both most relevant to the MWADZ proposal and within the scope of the current assessment. The key threats were as follows:

- Potential impacts on the populations of invertebrate species (i.e. saucer scallop) within the Abrolhos Islands FHPA.
- Potential impacts on the populations of finfish species within the Abrolhos Islands FHPA.
- Potential impacts on the invertebrate fisheries (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery) that operates in the Abrolhos Islands FHPA.

- Potential impacts on the finfish fisheries that operate in the Abrolhos Islands FHPA.

The qualitative component-tree structure (refer to Table 1 a) was used to assist with the identification of the environmental, ecological and biological components that needed to be assessed as part of the proposed MWADZ project.

3.2 Hazard Pathway Identification

Four hazard identification pathways associated with the key identified threats (Figures 3, 4, 5, 5a, 6 and 6a) were generated. These were pathways leading to potential impacts on:

- populations of invertebrate species (i.e. saucer scallops);
- populations of finfish species;
- invertebrate fisheries (Abrolhos Islands and Mid West Trawl Managed Fishery); and
- finfish fisheries.

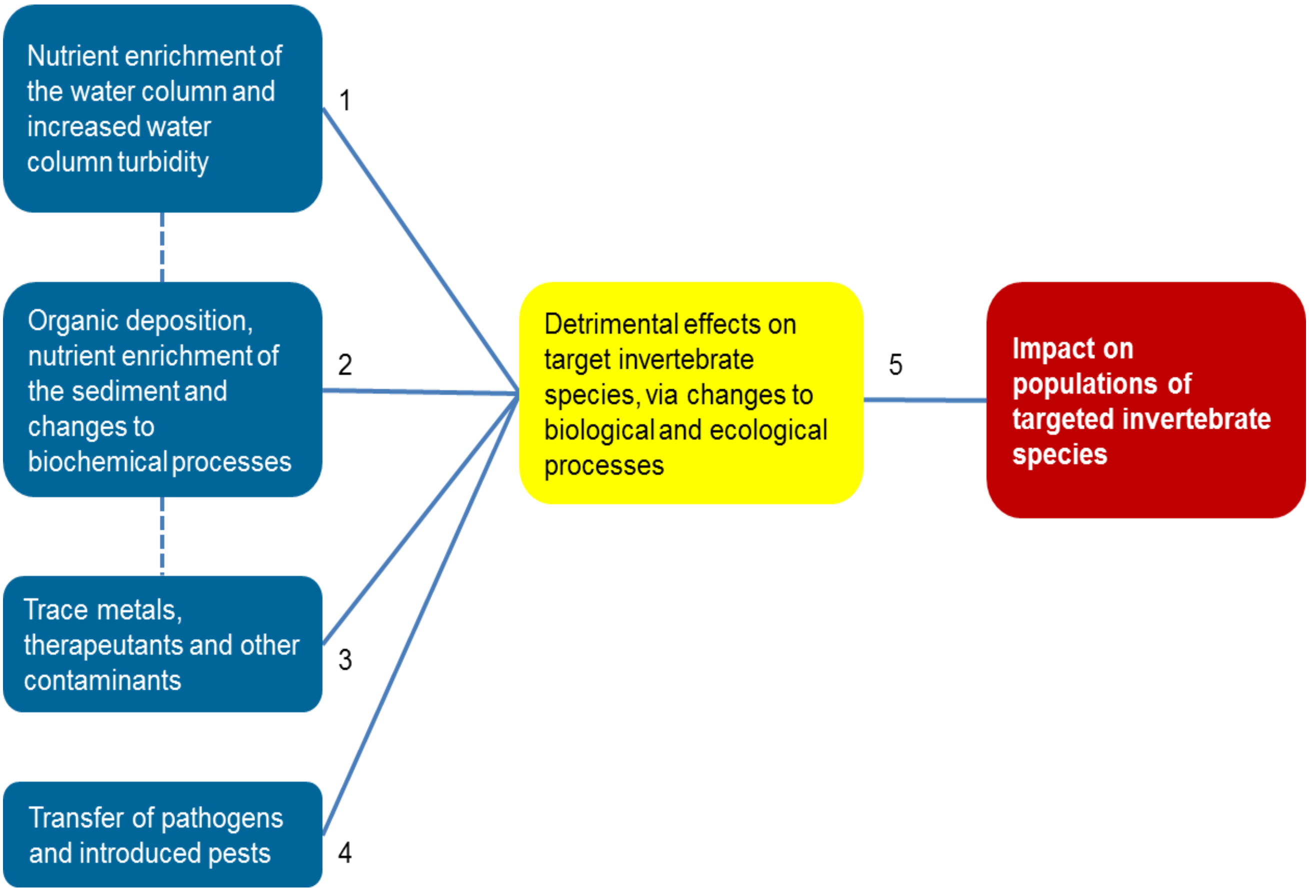

Figure 3: Conceptual model of ecological hazards associated with finfish aquaculture and the potential cause-effect pathways leading from the hazards to factors which could impact on the populations of invertebrate species (Saucer scallop). *Numbers refer to hazard pathways reviewed in Table 2.*

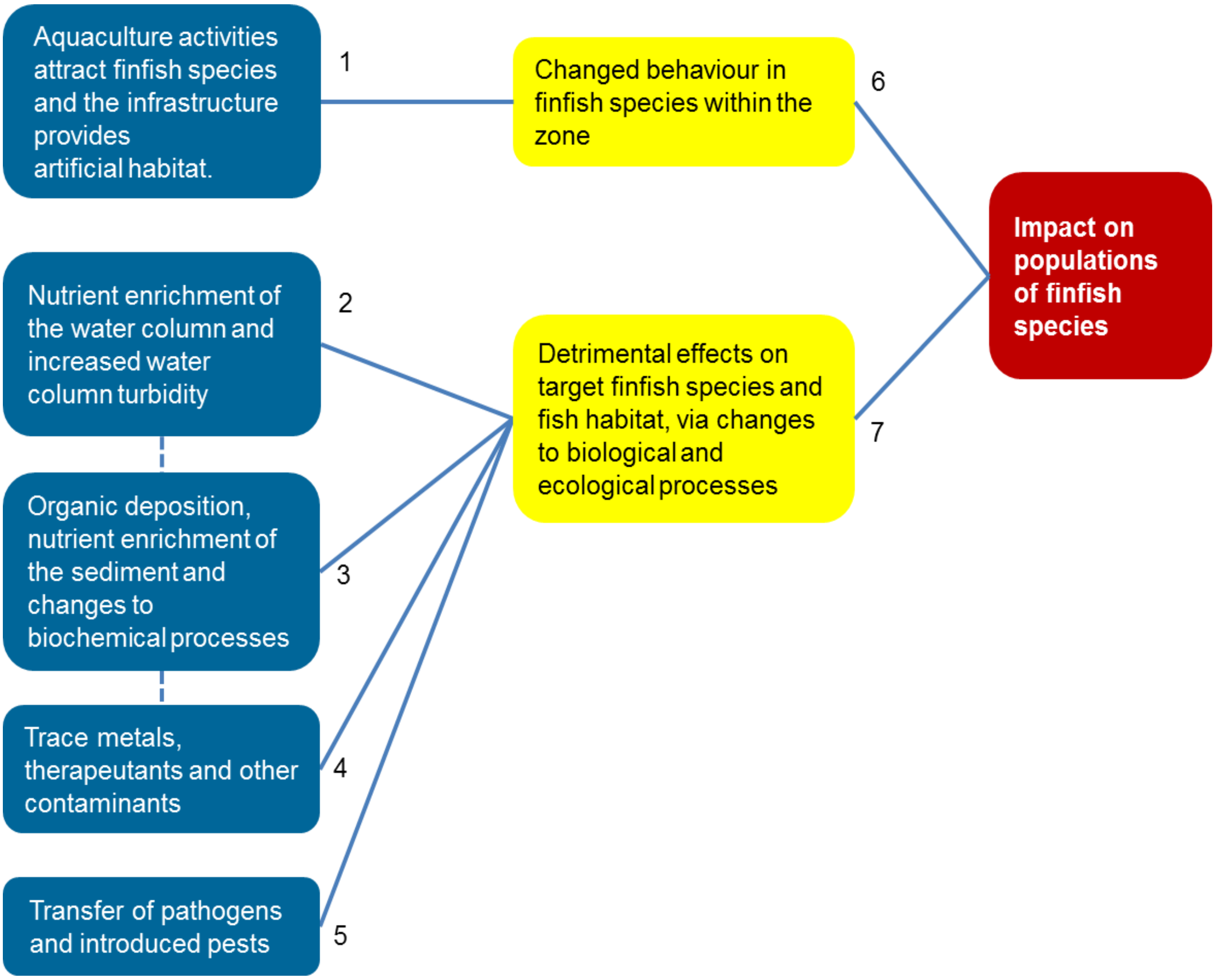

Figure 4: Conceptual model of ecological hazards associated with finfish aquaculture and the potential cause-effect pathways leading from the hazards to factors that could impact on populations of finfish species. *Numbers refer to hazard pathways reviewed in Table 3*

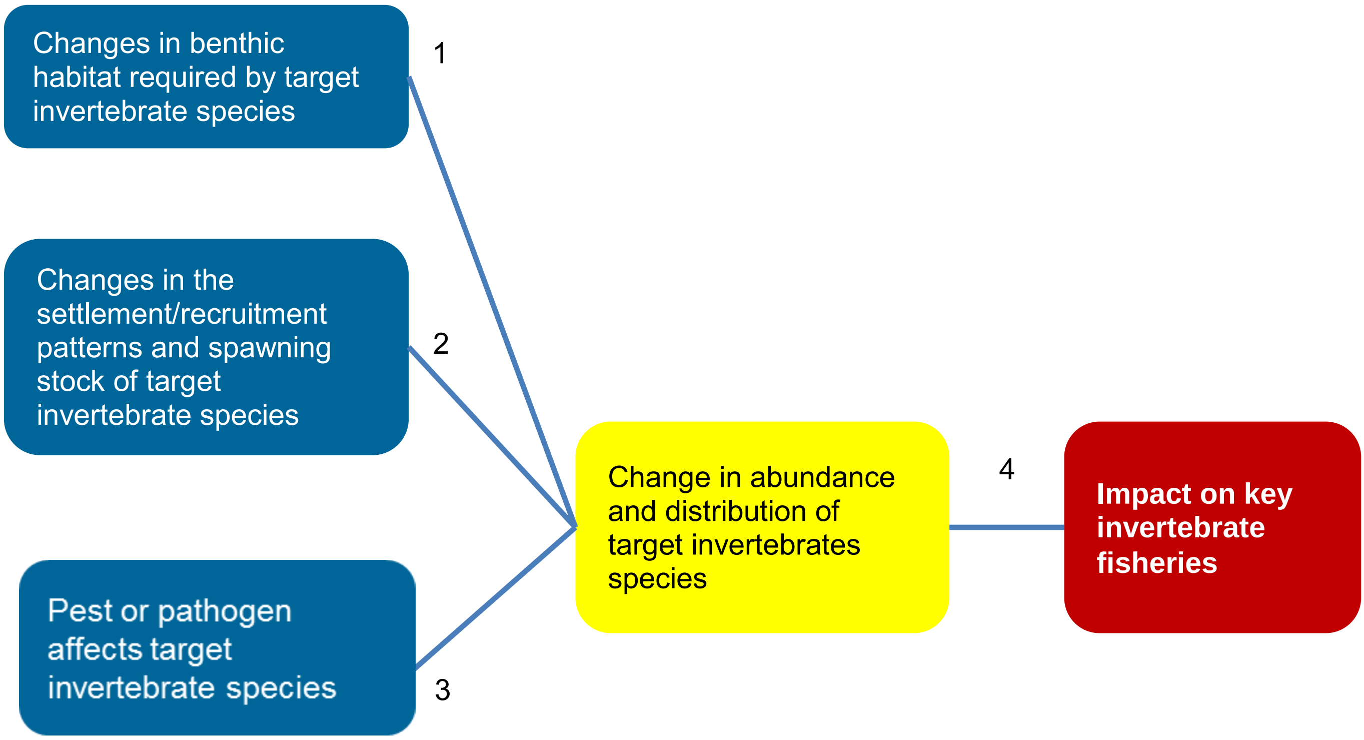

Figure 5: Conceptual model of ecological hazards associated with finfish aquaculture and the potential cause-effect pathways leading from the hazards to factors that could impact on the invertebrate fishery (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery). *Numbers refer to hazard pathways reviewed in Table 4*

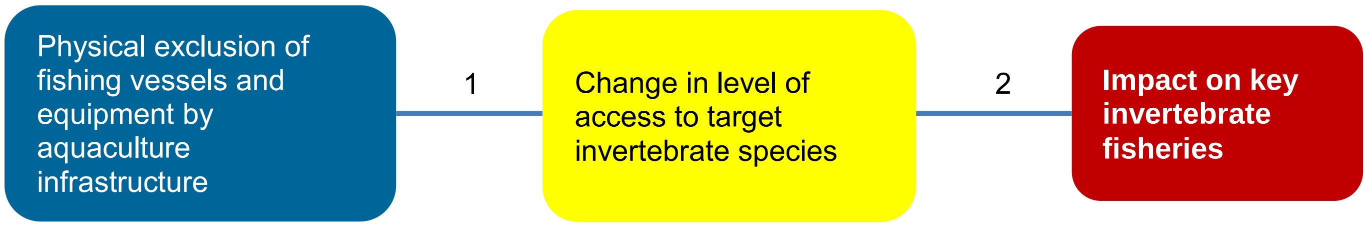

Figure 5a: Conceptual model of a resource access hazard associated with finfish aquaculture and the potential cause-effect pathways leading from the hazards to factors that could impact on the invertebrate fishery (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery). *Numbers refer to hazard pathways reviewed in Table 4a*

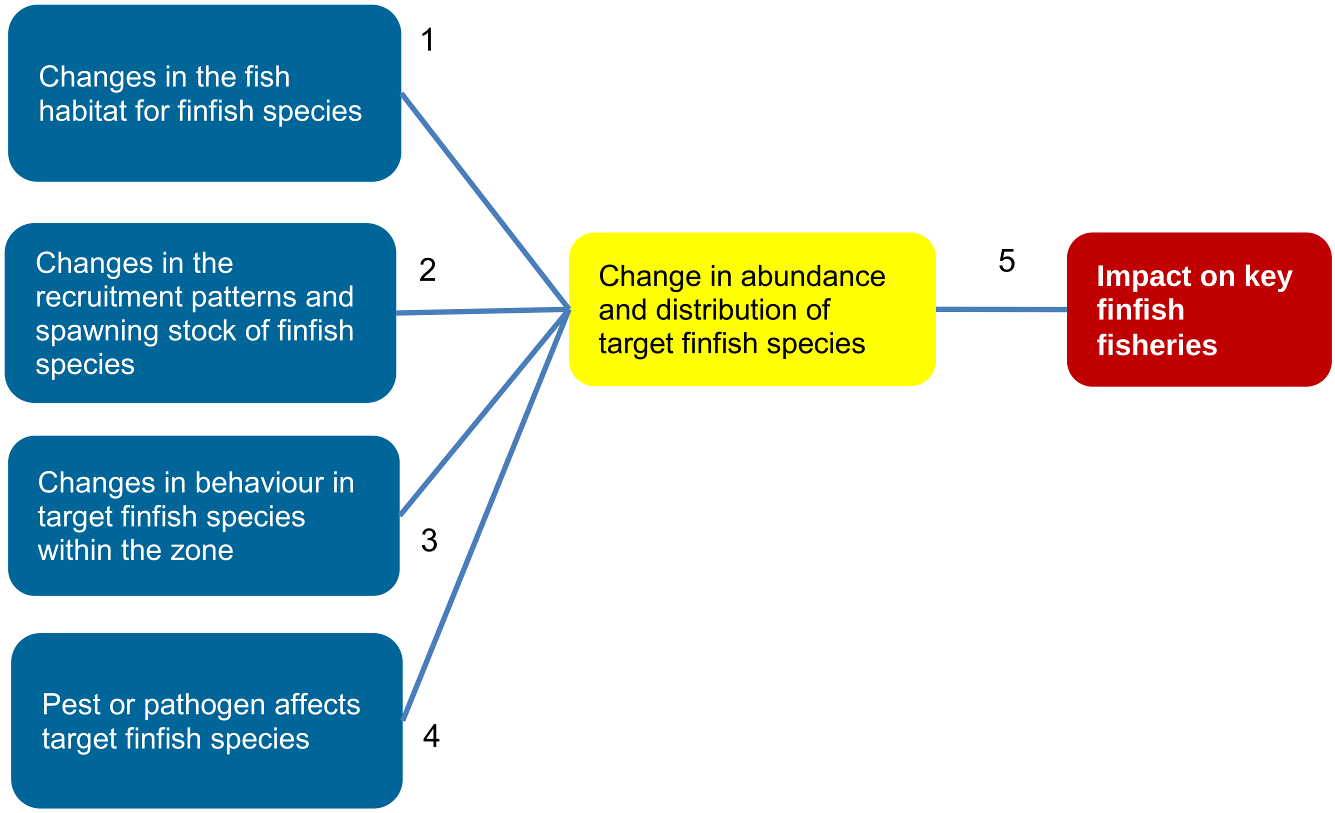

Figure 6: Conceptual model of ecological hazards associated with finfish aquaculture and the potential cause-effect pathways leading from the hazards to factors that could impact on finfish fisheries. *Numbers refer to hazard pathways reviewed in Table 5*

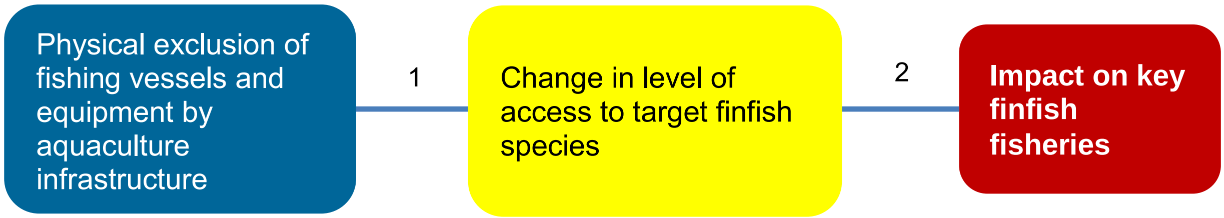

Figure 6a: Conceptual model of resource access hazard associated with finfish aquaculture and the potential cause-effect pathways leading from the hazards to factors that could impact on finfish fisheries. *Numbers refer to hazard pathways reviewed in Table 5a*

3.3 Hazard Pathway Analysis

The hazard pathway components identified in the conceptual diagrams of cause-effect pathways, detailed in Figures 3-6a, 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 effected) as indicated in Tables 2-5a.

Prior to conducting this exercise a review of relevant literature documenting the impacts of aquaculture on wild fish and fisheries was conducted, with a focus on yellowtail kingfish (YTK) as the cultured species in this case study. Consequence to invertebrate and finfish species and fisheries was specifically considered in developing this assessment based on a worst-case scenario model. This used relevant examples applicable to the culture of the proposed species, with a focus on YTK.

3.2.1 Hazard Pathway 1: Impact on populations of invertebrate species within the Abrolhos Islands FHPA

The primary potential impacts of the MWADZ proposal on invertebrate species that were identified during the risk assessment process were the following:

- Nutrient enrichment of the water column and increased turbidity;
- Organic deposition, nutrient enrichment of the sediment and changes to biochemical processes;
- Trace metals, therapeutants and other contaminants;
- Transfer of pathogens and introduced pests; and
- Impact on populations of invertebrate species, due to detrimental effects on biological and ecological processes from aquaculture.

During the risk assessment process, it was identified that saucer scallop (*Amusium balloti*) were one of key invertebrate species likely to be impacted by the sea cage finfish aquaculture. Previous research studies conducted within the proposed MWADZ area by the Department of Fisheries has shown that saucer scallops have been historically abundant within certain areas of the proposed aquaculture development zone. This species is also one of the key target species of the AIMWTMF. Given the availability of biological and ecological information on this species and its commercial importance in terms of the AIMWTMF, a specific assessment was conducted on this species.

Table 2: Assessment of hazards identified on the impact on targeted invertebrate species (i.e. saucer scallop). *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 the residual hazard (i.e. remaining hazard once one or a number 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. Nutrient enrichment of the water column and increased water turbidity **(Refer to Figure 3)**	**Likelihood: Possible (3)** **Consequence: Minor (1)** **Hazard score: (3)** **Risk: Low**	**Likelihood** *Nutrient enrichment* Marine cage aquaculture is a recognized source of nitrogenous and phosphorous discharge from uneaten food, faeces and metabolic wastes including ammonia and urea (Nash et al 2005). The level of nitrogen and phosphorous discharge is highly dependent on the types of feeds, feed conversion ratios and feeding efficiencies (of the cultured species), and other farm practices (e.g. stocking densities). Sea cage aquaculture could elevate levels of dissolved nutrients in the water column surrounding the cages, thereby stimulating phytoplankton productivity in the water column. *Increased Turbidity* Particulates from feed and fish faeces are likely to increase the turbidity within close proximity of the sea cages. These particulate will settle beneath the sea-cages, resulting in an increase in sedimentation beneath the sea cages or pens (Hargrave, B 2005).	**Likelihood: Possible (3)** **Consequence: Minor (1)** **Hazard score: (3)** **Risk: Low**	**Likelihood** *Nutrient enrichment* There is likely to be some level of nutrient enrichment in the water column in localised areas within the MWADZ. The **Possible (3)** ranking is unlikely to change in that some level of enrichment is almost inevitable. *Increased Turbidity* Likelihood ranking is unlikely to change as some degree of turbidity/ increased sedimentation is likely to occur underneath and within close proximity to the sea-cages. Most of the effects of organic deposition and smothering of the benthos are likely to be localised and within close proximity to the footprint

		Particular species of phytoplankton are known to cause shellfish poisoning; however the strong water currents in area and mixing of the water column reduce the likelihood of toxic algae blooms affecting any target benthic invertebrates. It is therefore **Possible (3)** that the MWADZ proposal could increase nutrient enrichment and turbidity within close proximity to the sea cages and potentially has an impact on target benthic invertebrates. **Consequence** *Nutrient enrichment* Elevated dissolved nitrogen in the water column is typically a localised effect (within hundreds of meters) of the sea cages. Increases in dissolved phosphorous, however, is generally not considered to be a primary concern (Nash et al 2005), and most marine waters are nitrogen limited. Nutrient enrichment can result in elevated levels of primary (i.e. phytoplankton) and macro algal production (Nash et al 2005), and thus eutrophication of the water column (and oxygen depletion of the water column). Any potential eutrophication as a consequence of nutrient enrichment in the water column in the localised area is likely to have negative impact on scallop populations. *Increased Turbidity* An increase in turbidity can lead to a decrease in light penetration within the water column, which can have negative impacts on photosynthetic organisms (like corals) directly underneath and in close proximity to the sea cages (Price and Morris, 2013).		of the sea cages (Hargrave, B 2005). **Consequence** The consequence remains unchanged as **Minor (1)**. *Nutrient enrichment* Consequences can be reduced through the adoption of good farming practices that maximize the feeding efficiency and reduce feed waste. Monitoring of nutrient levels under farm management practices, including direct measurement of the level of Chl-a at the farm and reference sites (e.g. Pittenger et al. 2007) will further reduce the level and thus consequence of water column nutrient enrichment. Chlorophyll-a is a proxy for phytoplankton levels. Median dissolved inorganic nitrogen levels must remain below 500µg/L. Median Chlorophyll-a levels must remain less than two-fold that at the Reference sites. Additionally, situating farms in well-flushed locations, and setting stocking densities of farms at conservative levels will help to minimise the likelihood of water column enrichment.

		An increase in sedimentation on the seabed can result in a potential loss or reduction in diversity of benthic invertebrates through smothering of benthic habitats and through oxygen depletion and hydrogen sulphide production during bacterial de-composition of organic matter. This could in turn lead to a dominance of small opportunistic benthic invertebrate species including capetellid worms and other scavengers and deposit feeding species (Hargrave, B 2005) Increased turbidity and sedimentation is likely to have a negative impact on scallop populations directly underneath the sea cages and in close proximity to the cage footprint. The risk of nutrient enrichment and increased turbidity causing detrimental effects on target invertebrate species in the overall Abrolhos Islands FHPA is, however, considered M**inor (1)**.		*Increased Turbidity* The consequence of increased turbidity and sedimentation can be reduced through the adoption of best practice arrangement. These include: • maximizing feeding efficiency and reducing feed waste; • situating sea cages within well-flushed locations; and • setting the stocking density of farms at conservative levels.
2. Organic deposition nutrient enrichment of the sediment and changes to biochemical processes **(Refer to Figure 3)**	**Likelihood: Possible (3)** **Consequence: Minor(1)** **Hazard score: (3)** **Risk level: Low**	**Likelihood** Globally sea cage aquaculture in known to have an impact on marine sediments (Price and Morris 2013).Research studies conducted by Price and Morris 2013 have shown that globally an average of 20-463kg of nitrogen and 5-80 kg of phosphorus are released into sediments (from fish farms) per metric ton of fish produced. Reviews conducted by Wu,R.S 1995, have shown that approximately 23% of the carbon from feed accumulates in sediments beneath cages; similarly, Pearson and Black (2001) report 4.1-78g carbon/m^2/day is input in to sediments. Nutrient enrichment, sedimentation and changes in sediment biogeochemistry are generally restricted to within 500 metres of culture cages (Price and Morris 2013).	**Likelihood: Unlikely (2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** Likelihood of the impacts can be further reduced to **Unlikely (2)** based on implementation of management measures outlined below: • Locating the sea cages in well flushed areas where there is an increased water depth below the sea cages • Feed Control- minimizing feed wastage can significantly reduce sediment enrichment effects which can help improve sediment conditions underneath the sea cages

		The level of nutrient enrichment (N,P,C) is highly dependent on the species being cultured, feed source and farm practices, and density of proximal farm sites. Additionally, the type of sediment found under the farm is a major contributing factor to the extent and severity impacts (Price and Morris 2013). Increased sedimentation beneath the sea cages or pens can result in a potential loss or reduction in diversity of benthic invertebrates through smothering of benthic habitats. Bacterial de-composition of the organic matter results in an increase in the biological oxygen demand of the sediment, leading to depletion of oxygen at the benthos. This could result in anoxic conditions at the sediment-water interface resulting in a sharp decline in populations of target invertebrates, and a dominance of small opportunistic benthic invertebrate, i.e. scavengers and deposit feeding species, e.g. capetellid worms. Anoxic conditions could also lead to elevated levels of nitrites and hydrogen sulphide, which are toxic to invertebrates (Hargrave, B 2005). Increased organic deposition nutrient enrichment of the sediment and changes to biochemical processes is likely to have an effect on target invertebrate species, via changes to biochemical properties of the benthic environment. This is likely to result in avoidance of the area by target invertebrates. Survival and recruitment of sessile target species beneath the sea-cages (and within 100 meters) is likely to be impacted. The likelihood as been rated as **Possible (3)**. **Consequence** The most significant impact of nutrient enrichment of sediments is changes to the biogeochemical parameters of the sediment. Alterations of sediment sulfide, redox		• The use of good quality feeding systems which minimize waste • The use of high quality feed and improvements in feed conversion ratios • Fallowing of sites to allow seabed recovery. The rotation of sea cages is likely to allow the recovery of nutrient enrichment in the sediments. • Consider cumulative impacts under management plans • Pre-stocking monitoring, and use of multiple biotic and abiotic indices to monitor any impacts • Encourage integrated multi-trophic aquaculture (Price and Morris 2013) • Regulation of the density of sea-cage operations, in addition to limiting the stocking density per hectare of lease • Development of and compliance with a Management and Environmental Monitoring Plan (MEMP) and best-practices in aquaculture, including the requirement to monitor the levels of dissolved nutrients and chlorophyll-a. **Consequence** Consequence would remain unchanged [i.e. **Minor (1)**].

		potential, sediment oxygen consumption and nitrogen mineralization are consistently reported to be sensitive to nutrient input. These biogeochemical changes can induce changes in micro and macrofauna that live on or in the sediments, due to the shift from aerobic to anoxic conditions (Hargrave, B 2005). Nitrate toxicosis of invertebrate species can also occur through metabolism of nitrate due to nitrite being an intermediate. This process generally leads to lack of oxygen in organ tissues of animals. Although metabolism of nitrite can convert it to ammonia, if there is more nitrite than can be converted, animals will be unable to respire. Nitrate is much less toxic than ammonia. However, levels over 30 ppm of nitrate can inhibit growth, impair the immune system and cause stress in some aquatic species[1]. Vezzulli et al 2004 found bacterial levels below a sea bream farm were up to three times higher than the reference site, with the bacterial community shifting toward gram-negative species and an occurrence of pathogenic *Vibrio* species. Decreased species diversity and richness and changes in biomass of macrofauna have been widely reported for sediments beneath cages compared to reference sites (Vezzulli et al 2002). Hydrodynamics of the farm site will tend to disperse organic wastes over larger areas, but also provide a mechanism for aerobic assimilation of waste nutrients within the marine environment (Price and Morris 2013). While impacts are generally reported to be localized (i.e. up to 500m from cages) far-field impacts have been recorded in terms of changes to benthic community structure (Wildish et al 2005).		

		Previous aquaculture research studies have demonstrated that the effects of sediment enrichment display a strong gradient of rapidly decreasing impact with increasing distance from the sea cages (Forrest, B et al 2007). Canadian studies indicate that impacts may take more than five years to manifest and may disrupt food webs at larger scales, impacting commercial fisheries (Price and Morris 2013, Wildish et al 2005). It is expected any decline in abundance of the target invertebrates would be restricted to the depositional area in close proximity (i.e. within 100 metres) and directly underneath the sea-cage infrastructure. Consequence **Minor (1)**.		
3. Trace metals, therapeutants, and other contaminants **(Refer to Figure 3)**	**Likelihood: Unlikely (2)** **Consequence: Moderate (2)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** Chemicals (antibiotics, therapeutants, antifoulants and heavy metals) used within marine cage farming practices may be released into the surrounding environment; through feed, faeces and directly in the water column (e.g. leaching from antifoulants or heavy metal release from feeds). The likelihood of a chemical impact is highly dependent on specific chemicals, the characteristics of the farm site (e.g. flushing rate, sediment type) and farm management practices (e.g. feeding rates, husbandry techniques etc.). Considering the uncertainty, the likelihood is rated as **Unlikely (2)**. **Consequence** Therapeutants can have toxic effects on invertebrates including commercially important species such as scallops	**Likelihood: Remote (1)** **Consequence: Minor (1)** **Hazard score: (1)** **Risk level: Negligible**	**Likelihood** Most therapeutants have limited environmental significance as they are usually highly water soluble and breakdown readily in the environment (Forrest B *et al* 2007). Given the high level of flushing and dispersion of organic deposition in the MWADZ area it is unlikely, that unacceptable levels of heavy metals will be present in the aquaculture zone. Any potential impacts on the scallop populations are likely to be localised and within close proximity to the sea cages. The likelihood can be reduced to **Remote (1)** by having strict controls

		and rock lobster (e.g. Haya et al. 2001). Heavy metals originating from feeds or from antifoulants used in aquaculture farming practices can accumulate in sediments below sea cages (reducing benthic colonization), and can have direct toxic effects of benthic invertebrates and can lead to bioaccumulation within the food chain (Forrest, B et al 2007). Therefore consequence is rated as **Moderate (2)**.		on the use of chemicals associated with aquaculture, and appropriate approval, licensing and compliance regime. **Consequence** Consequence can be reduced through the following practices: • Good husbandry and farming practices • Reducing the use of copper-based anti-foulant paints to structures which are essential and manual defouling used on other structures • Reducing the level of therapeutants in feed (e.g. zinc) Consequence of any attraction could be reduced to **Minor (1)** by reducing the extent and intensity of organic enrichment of the benthos.
4. Transfer of pathogens and introduced pests **(Refer to Figure 3)**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**
5. Impact on populations of a target invertebrate	**Likelihood: Unlikely (2)** **Consequence: Minor (1)**	**Likelihood** Increased organic deposition nutrient enrichment of the sediment and changes to biochemical processes is likely to have a detrimental effect on target invertebrate species,	**Likelihood: Remote (1)** **Consequence: Minor (1)**	**Likelihood** Likelihood of sustainability impacts can be further reduced based on implementation of management

species, due to detrimental effects on biological and ecological processes, resulting from aquaculture **(Refer to Figure 3)**	**Hazard score: (2)** **Risk level: Negligible**	via changes to biological and ecological processes. This is likely to result in avoidance of the area by target invertebrates. Survival and recruitment of sessile target species beneath the sea-cages (and within 100 metres) is likely to be impacted. However, such a decline in abundance of the target invertebrates would be restricted to the depositional area in close proximity (i.e. within 100 metres) and directly underneath a sea-cage. Given the area affected by a decline in abundance of the target invertebrates is a negligible proportion (much less than 1 percent) of its natural range, the contribution aquaculture could make to anthropogenic-caused mortality is not considered significant. Therefore, the likelihood that the proposed aquaculture will have an impact of the overall target invertebrate species populations in the Abrolhos FHPA is rated **Unlikely (2).** **Consequence** The consequences of the proposed aquaculture having an impact on the population of saucer scallops are rated as **Minor (1)**.	**Hazard score: (1)** **Risk level: Negligible**	measures aimed at reducing wastage of stock feed associated with the aquaculture. Operations will be required to comply with a Management and Environmental Monitoring Plan (MEMP), which requires operators to conduct water quality and sediment quality monitoring. Department of Fisheries will support or endorse best-practices in aquaculture. It will manage compliance around MEMP requirements including mandatory reporting on water and sediment quality. Failure to comply with the MEMP may result in suspension or cancellation of the offending licence. The industry will collect and report on water and sediment quality. This provides an early warning to aquaculture managers if the rates of organic enrichment increase beyond acceptable limits within the proposed zone. The management measures described above will ensure that the likelihood of the proposed aquaculture significantly impacting the target invertebrate species population is reduced to **Remote (1)**.

				Consequence Consequence would remain unchanged at **Minor (1)**.

3.2.2 Hazard Pathway 2: Impact on populations of finfish species within the Abrolhos Islands FHPA

The primary potential impacts of the MWADZ proposal that were identified during the risk assessment process on finfish species were the following:

- Aquaculture activities attract finfish species and provide additional food and artificial habitat;
- Nutrient enrichment of the water column and increased water column turbidity;
- Organic deposition nutrient enrichment of the sediment and changes to biochemical processes;
- Trace metals, therapeutants and other contaminants;
- Transfer of pathogens and introduced pests;
- Changes in behavior of finfish species within the aquaculture zone; and
- Impact on populations of finfish species, due to detrimental effects on biological and ecological processes, resulting from aquaculture.

Given the lack of available information on finfish species within the proposed MWADZ area, and the potential impacts finfish aquaculture could have on both target and non-target finfish species, a generic assessment on finfish species was conducted.

Table 3: Assessment of hazards identified on the potential impacts of the proposal on finfish species. *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 the residual hazard (i.e. remaining hazard once one or a number 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. Aquaculture activities attract finfish species to the sea-cages and provide additional food and artificial habitat **(Refer to Figure 4)**	**Likelihood: Likely (4)** **Consequence: Moderate (2)** **Hazard score: (8)** **Risk level: Moderate**	**Likelihood** Fish farming is associated with: • residue from cultured stock; • harvest activities and effluent; • artificial feed; • increased food availability; • artificial structure; and • attracted prey species. This could lead to changes in the behaviour of target species within the zone, including: • attraction to or avoidance of the fish farming area; • increased/decreased visitation rates;	**Likelihood: Possible (3)** **Consequence: Minor (1)** **Hazard score: (3)** **Risk level: Low**	**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 possible through actively 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, including the following requirements: • removal of dead and moribund stock on a daily basis; • moderate stocking levels; • containment of all post-harvest blood

		• increased duration of visits; • increased/decreased abundance; and • altered feeding behaviours. It is documented that marine cage culture can increase the abundances of fish at local scales (e.g. Machias et al 2005). This is primarily a result of the excess food and waste released from farming activities acting as a food source for wild fishes (Machias et al 2005). Aquaculture stock feed consists of fish meal and fish oil, which are known attractants to fish. The likelihood of attraction of finfish to sea-cage aquaculture is dependent on the species. Generally, the provision of food and habitat can lead to changed behaviour in wildlife including fish. Given that some species of finfish are attracted to fish farms, e.g. Pink snapper (*Chrysophrys auratus)*, it is **Likely (4)** that the effects of increased provisioning (food and habitat) could extend the residence time of some scalefish populations near the sea-cages. Other attraction signals include: *Stock* The long-term presence of high densities of aquaculture stocks in the upper water column is likely to produce a continuous, low-level source of biological residue (oil, scales, faeces, blood etc.) which may attract some species of finfish to the proposed zone. Some level of stock mortality is inevitable in aquaculture and occasional dead and		water; and • use of a high-quality pellet feed. **Consequence** Consequence of any attraction could be reduced to **Minor (1)** by eliminating some of the signals that attract target species to the sea-cages. Appropriate management measures include those that reduce or eliminate feed and biological residue being released to the ocean.

		decomposing stock in sea-cages could influence the presence of particular fish species. Additional food could facilitate the growth of populations of prey species. An increase in the abundance of prey species could, in turn, influence behaviour of predatory fish species (e.g. sharks and pelagic species such as Spanish mackerel and tuna) in the proposed zone. *Biological residue* 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 particular species of wild fish, e.g. faeces, blood, lipids, pheromones and scales from stock. *Artificial structure* Fish cage clusters can provide additional three dimensional structures to the marine environment. Mooring lines and anchors used to secure the sea cage infrastructure could be of advantage to particular finfish species or their prey by providing an artificial habitat. Given artificial reefs are known to attract fish species, it is reasonable to expect that these structures will increase complex benthic habitat in the area. The attraction of fish is likely to be restricted to those already known to occur in the vicinity of the aquaculture. The pathway of cause-effect assumes that the aquaculture facility acts as an attractant to small fish species on a spatial and temporal scale.		

		Consequence The discrete consequence of attracting finfish to aquaculture cages is the increased probability that finfish populations will reside in the area, utilising additional habitat and feeding opportunities provided (Price and Morris 2013). Generally, aquaculture is considered to positively influence the presence of finfish species in the vicinity of the sea-cages. However, the provision of food and habitat by aquaculture may extend the residence time of some finfish species around the sea-cages, making them more available and therefore vulnerable to fishing. The consequence of changed behaviour in finfish species is considered **Moderate (2)**, in relation to potentially higher levels of fishing. It should be noted that an increased presence of finfish in the zone could increase the probability that finfish species will also be exposed to other hazards, which are discussed in section 6 of this table.		
2. Nutrient enrichment of the water column and increased water column turbidity **(Refer to Figure 4)**	**Likelihood: Possible(3)** **Consequence: Minor (1)** **Hazard score: (3)** **Risk level: Low**	**Likelihood** *Nutrient enrichment* Marine sea-cage aquaculture is a recognised source of nitrogenous and phosphorous discharge from uneaten food, faeces and metabolic wastes, including ammonia and urea (Nash et al 2005). The level of nitrogen and phosphorous discharge is highly dependent on the types of feeds, feed conversion ratios and feeding efficiencies (of the cultured species) in addition to other farm practices (e.g. stocking densities). Sea-cage	**Likelihood: Possible (3)** **Consequence: Minor (1)** **Hazard score: (3)** **Risk level: Low**	**Likelihood** *Nutrient enrichment* There is likely to be some level of nutrient enrichment in the water column in localised areas within the MWADZ. The likelihood is unlikely to change in that some level of enrichment is almost inevitable. Likelihood **Possible (3)**. *Increased Turbidity*

		aquaculture could elevate levels of dissolved nutrients in the water column surrounding the cages, thereby stimulating phytoplankton production in the water column (Hargrave, B 2005). *Increased Turbidity* Fish waste, particulates from feed and increased phytoplankton levels are likely to increase the turbidity within close proximity of the sea-cages (Hargrave, B 2005). Particular species of phytoplankton are known to cause mortalities in finfish. However, the strong water currents in the area and mixing of the water column are likely to reduce, the probability of toxic algae blooms affecting fish. It is **Possible (3)** that aquaculture activities will result in nutrient enrichment of the water column and an increase in turbidity within close proximity to the sea-cages. **Consequence** *Nutrient enrichment* Elevated dissolved nitrogen in the water column is typically a localised effect (within hundreds of metres) of the sea-cages. Increases in dissolved phosphorous, however, are generally not considered to be a primary concern (Nash et al 2005, Costa-Pierce et al 2007). Most marine waters are nitrogen limited. Nutrient enrichment can result in elevated levels of primary (i.e. phytoplankton) and macro-algal production (Nash et al 2005) and thus eutrophication (and oxygen depletion) of the water column.		Likelihood is unlikely to change as some degree of turbidity/increased sedimentation is likely to occur underneath and within close proximity to the sea-cages. Most of the effects of organic deposition and smothering of the benthos are likely to be localised and within close proximity to the footprint of the sea-cages (Hargrave, B 2005). **Consequence** Remains unchanged at **Minor (1)**. *Nutrient enrichment* Consequences can be reduced through the adoption of good farming practices that maximise the feeding efficiency and reduce feed waste. Monitoring of nutrient levels under farm management practices, including direct measurement of the level of Chl-*a* at the farm and reference sites (e.g. Pittenger et al. 2007) will further reduce the level and thus consequence of water column nutrient enrichment. Additionally, situating farms in well-flushed locations, and setting of density of farms at conservative levels will help to minimise the consequence of water column enrichment.

		Any potential eutrophication as a consequence of nutrient enrichment in the water column may have a negative impact on finfish populations in the localised area. *Increased Turbidity* An increase in turbidity can lead to a decrease in light penetration within the water column. This can have negative impacts on photosynthetic organisms (like corals) directly underneath and in close proximity to the sea-cages (Price and Morris, 2013). Increases in turbidity will have a greater influence in nearshore sites compared to open ocean sites, especially in sites located close to critical habitats such as corals and seagrass beds. Given the proposed MWADZ is a deeper water environment (i.e. average depth 30 to 40 metres), nutrient enrichment and increases in turbidity are likely to be localised and have been rated as a **Minor (1)** consequence.		*Increased Turbidity* The consequence of increased turbidity and sedimentation can be reduced through the adoption of best practice arrangements. These include: • maximising feeding efficiency and reducing feed waste; • situating sea cages within well-flushed location; and • setting the stocking densities at conservative levels.
3. Organic deposition nutrient enrichment of the sediment and changes to biochemical processes **(Refer to Figure 4)**	**Likelihood: Possible (3)** **Consequence: Minor (1)** **Hazard score: (3)** **Risk level: Low**	**Likelihood** Increased sedimentation beneath the sea-cages or pens can result in a potential loss or reduction in diversity of finfish through smothering of benthic habitats. Bacterial de-composition of the organic matter results in an increase in the biological oxygen demand of the sediment, leading to depletion of oxygen at the benthos. This could result in anoxic conditions at the sediment-water interface resulting in a decline in populations of	**Likelihood: Unlikely (2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** The likelihood can be reduced to **Unlikely (2)** by regulating the density of sea-cage operations, in addition to limiting the stocking density per hectare of lease. Development and compliance with a MEMP and best-practices in aquaculture, including the requirement to monitor the

		finfish and a dominance of small opportunistic benthic invertebrates (i.e. scavengers and deposit-feeding species such as capetellid worms). Anoxic conditions could also lead to elevated levels of nitrites and hydrogen sulphide, which are toxic to biota (Hargrave, B 2005). Increased organic deposition nutrient enrichment of the sediment and changes to biochemical processes is likely to have a detrimental effect on finfish species, via changes to biochemical properties of the benthic environment. This is likely to result in avoidance of the area by finfish species. Survival and recruitment of fish species confined to habitats beneath the sea-cages and within close proximity are likely to be impacted. Likelihood is assessed as **Possible (3)**. **Consequence** The most significant impact of nutrient enrichment of sediments is changes to the biogeochemical parameters of the sediment. Alterations of sediment sulfide, redox potential, sediment oxygen consumption and nitrogen mineralization are consistently reported to be sensitive to nutrient input. These biogeochemical changes can induce changes in micro and macrofauna that live on or in the sediments, due to the shift from aerobic to anoxic conditions (Hargrave, B et al 2008). Decreased species diversity and richness and changes in biomass of macrofauna have been widely reported for sediments beneath cages compared to reference sites (Hargrave, B et al 2008). Hydrodynamics of the farm site will tend to disperse organic wastes over larger areas,		levels of dissolved nutrients and chlorophyll-a, would also assist. The likelihood could also be reduced by reducing feed waste improving feeding efficiency and adopting good husbandry and farming practices. **Consequence** Consequence remains at **Minor (1)**.

		however also provide a mechanism for aerobic assimilation of waste nutrients within the marine environment (Price and Morris 2013). Consequence **Minor (1)**. Any potential decline in abundance of finfish species is likely to be restricted to areas directly underneath the sea-cage and within the depositional area.		
4. Trace metals, therapeutants, and other contaminants **(Refer to Figure 4)**	**Likelihood: Unlikely (2)** **Consequence: Moderate (2)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** Chemicals (antibiotics, therapeutants, antifoulants and heavy metals) used within marine sea-cage farming practices may be released into the surrounding environment; through feed, faeces and directly to the water column (e.g. leaching from anti-foulants or heavy metal release from feeds). Improved regulation has seen a decline in the use of chemicals in marine fish aquaculture. The likelihood of a chemical impacts is highly dependent on the specific chemicals used, the characteristics of the farm site (e.g. flushing rate and sediment type) and farm management practices (e.g. feeding rates, husbandry techniques etc.). Likelihood rated as **Possible (2)**. **Consequence** Chemicals pose several environmental risks including the evolution of resistant strains of pathogenic organisms, non-lethal toxicity, direct mortality and bioaccumulation in the food chain (Price and Morris 2013). Laboratory and field studies have found the persistence of chemicals	**Likelihood: Remote (1)** **Consequence: Moderate (2)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** Likelihood can be reduced to **Remote (1)** by having strict controls on the use of chemicals associated with aquaculture and an appropriate approval, licensing and compliance regime. **Consequence** Consequence remains unchanged as **Moderate (2)**. Good husbandry and farm practices (e.g. removing sick or dead fish, reducing feed waste, conservative stocking densities etc.) can reduce the need for chemical use associated with marine sea-cage aquaculture within the MWADZ. Additionally, the location of the farm site and stringent environmental management protocols (e.g. monitoring of sediments for presence of chemicals used in aquaculture farms within the MWADZ) will further reduce the likelihood of

		(administered/used during marine sea-cage culture) from a few days to years depending on the chemical/metal in question and geophysical properties of the water or sediments at the farm site (Price and Morris 2013). Exposure to chemicals like antibiotics and therapeutants allows bacteria and other pathogenic organisms to adapt and become resistant (Price and Morris 2013). Direct toxicity is also a known consequence from chemicals originating from marine sea-cage aquaculture. Therapeutants can have toxic effects on finfish (e.g. Haya et al. 2001). Heavy metals originating from feeds or from antifoulants can also accumulate in sediments below farms (reducing benthic colonisation) with direct toxic effects and accumulation within the food chain (Pittenger et al 2007). Consequence rated as **Moderate (2)**.		chemical input consequences being realised.
5. Transfer of pathogens or introduced pests	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**
6. Changes in behaviour of finfish species within the aquaculture development zone **(Refer to Figure 4)**	**Likelihood: Possible (3)** **Consequence: Minor (1)** **Hazard score: (3)**	**Likelihood** It is **Possible (3)** that sea cage finfish aquaculture will result in potential changes in behaviour of finfish species within the vicinity of the proposed MWADZ area. Some finfish species have the potential to change their behaviour (i.e. higher visitation rates etc.) in the aquaculture zone given	**Likelihood: Possible: (3)** **Consequence: Minor (1)** **Hazard score: (3)**	**Likelihood** The likelihood is unlikely to change in that finfish species will have changed behaviour if there is an increase in food availability within the aquaculture development zone. The likelihood therefore remains **Possible (3)**.

	Risk level: Low	any increase in the availability of food from aquaculture feed. **Consequence** It has also been suggested that marine sea-cage culture has potential concentrating effects on finfish species. This may make some species more vulnerable to fishing pressure, with some authors recommending the prohibition of fishing in close proximity to sea-cages (e.g. Dempster et al 2006). Research studies conducted have also suggested that marine sea-cage culture may also have negative influences, such as the use of lights at night impacting on juvenile migratory fishes (Nash et al 2005). Other documented influences include entanglement of wild fishes (Huntington et al 2006), disease transfer and/or the consumption of medicated feeds by wild fishes (Braaten 2007). The overall consequences of changes in behavior of finfish species within the MWADZ has been rated as **Minor (1)**.	**Risk level: Low**	**Consequence** Consequence remains unchanged at **Minor (1)**. Consequence to fish communities, however, can be further reduced through implementation of the following management controls: • Good husbandry and farm practices (e.g. removing sick or dead fish, reducing feed waste, conservative stocking densities etc.) are likely to reduce negative influences of marine sea-cage aquaculture within the MWADZ; • Reducing the density of farms within the MWADZ would reduce the level of fish attraction to the area. These management practices would help reduce the secondary likelihood of impacts on Threatened Endangered Protected (TEP) species by helping reduce the attraction of potential wild food sources.
7. Impact on populations of finfish species due to detrimental effects on biological and ecological	**Likelihood: Unlikely(2)** **Consequence: Minor (1)** **Hazard score: (2)**	**Likelihood** Increased organic deposition nutrient enrichment of the sediment and changes to biochemical processes is likely to have a detrimental effect on finfish species, via changes to biological and ecological processes. This may result in	**Likelihood: Unlikely (2)** **Consequence: Minor(1)** **Hazard score: (2)**	**Likelihood** The management measures described in the above sections ensures that the likelihood the aquaculture proposal will have an impact on the populations of finfish species remains rated as **Unlikely**

processes resulting from aquaculture **(Refer to Figure 4)**	**Risk level: Negligible**	avoidance of the area by finfish. Survival and recruitment of finfish species beneath the sea-cages is likely to be negatively impacted. Any decline in abundance of the finfish would be restricted to the depositional area in close proximity and directly underneath a sea-cage. Given the area potentially affected by a decline in abundance of the target finfish is a negligible proportion (much less than 1 percent) of their natural range, the contribution aquaculture could make to anthropogenic-caused mortality is not considered significant. Therefore, the likelihood that the proposed aquaculture could have a significant impact on populations of finfish species is considered **Unlikely (2)**. **Consequence** The consequences of the proposed aquaculture having an impact on populations of finfish species is rated **Minor (1)**.	**Risk level: Negligible**	**(2)**. **Consequence** Consequence would remain unchanged at **Minor (1)**.

3.2.3 Hazard Pathway 3: Impacts on invertebrate fisheries (i.e. Abrolhos Islands Mid West Trawl Managed Fishery)

The primary potential ecological impacts of the MWADZ proposal on the AIMWTMF that were assessed in the hazard analysis were the following:

- Changes in benthic habitat of targeted invertebrate species;
- Changes in the sediment/recruitment patterns and spawning stock of target invertebrate species;
- Pest or pathogen affects wild populations; and
- Changes in the abundance and distribution of target invertebrate species, leads to a significant impact on the invertebrate fisheries.

In addition to these potential ecological hazards, a potential resource access impact was also identified and assessed in the hazard analysis. This was:

- Physical exclusion from fishing ground due to presence of equipment and sea cage infrastructure.

The consequence- likelihood method was used to assess the level of risk for each of the identified hazards for the AIMWTMF that could potentially be impacted by the finfish aquaculture proposal.

Table 4: Assessment of ecological hazards identified on the potential impacts on key of invertebrate fisheries (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery). *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 the residual hazard (i.e. remaining hazard once one or a number of the proposed management controls have been implemented). Note that no reference has been made to recreational invertebrate fisheries. Scallops are unlikely to be targeted by recreational fishers.*

Hazard	Inherent Hazard Assuming No Management Controls	Justification	Residual Hazard Following Implementation of Management Controls	Justification and Identified Management Controls
1. Changes in benthic habitat of target invertebrate species **(Refer to Figure 5)**	**Likelihood: Unlikely(2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** It is considered **Unlikely (2)** that the MWADZ proposal will have a significant effect on the benthic habitat of commercially-targeted scallop species in the Abrolhos Islands and Mid West Trawl Managed Fishery (AIMWTMF). The MWADZ proposal may have impact on the survival of settled juveniles and/or adult scallops within the vicinity of the sea-cages as scallops prefer sandy habitats, not mud or very fine sediments. The benthic habitat is likely to be modified directly underneath the sea-cages and within close proximity to these areas due to any increase in sedimentation/smothering and other impacts from aquaculture (Refer to Table 3). **Consequence** The consequence of the MWADZ proposal on the overall habitat for scallops in the AIMWTMF has	**Likelihood: Unlikely(2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** Likelihood remains unchanged at **Unlikely (2)** in that the MWADZ proposal is unlikely to have a significant impact on the overall benthic habitat for saucer scallops that are targeted by the AIMWTMF. Any impacts to benthic habitat are likely to be directly underneath the sea-cages and within close proximity to these areas. **Consequence** The consequences of the MWADZ proposal having a significant effect on benthic habitat for scallops in the AIMWTMF remain unchanged at **Minor (1)**.

		been deemed as **Minor (1)**. Any impacts on benthic habitat are likely to be small scale and directly within high-impact zone areas under the sea-cages. Scallops do have some capacity to move short distances (up to 10-100 metres) if disturbed or possibly if habitat becomes unsuitable.		
2. Changes in the settlement/ recruitment patterns and spawning stock of target invertebrate species **(Refer to Figure 5)**	**Likelihood: Unlikely (2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** It was considered **Unlikely (2)** that there will be any significant changes in settlement/recruitment patterns and spawning stock of target invertebrate species within the AIMWTMF in the absence of any control interactions. There may be some potential changes in the settlement patterns or survival of settling larvae and/or juveniles in a small localised area within the MWADZ. Scallops are known to have highly variable settlement/recruitment patterns on a very small-scale. However, the southern area of the proposed MWADZ is located within a broader area that has historically been a high-density scallop settlement area in the Abrolhos Islands. **Consequence** The consequences of any potential changes in the settlement/recruitment patterns and spawning stock of scallops have been deemed **Minor (1)**. Impacts are likely to be localised and within the footprint of the sea-cages within the MWADZ.	**Likelihood: Unlikely (2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** The likelihood remains unchanged as **Unlikely (2)** due to the inability to mitigate any potential localised impacts of the proposal on settlement/recruitment and spawning stock. **Consequence** Consequence remains unchanged at **Minor (1)**. Due to variable settlement patterns and abundance in any one year, the quantification of impacts is relatively complex. In some years the specific areas under sea-cages may be important for the saucer scallops, while in other years they could be less so.

3. Pest or pathogen effects on invertebrate fisheries **(Refer to Figure 5)**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**
4. Changes in the abundance and distribution of target invertebrate species, leads to a significant impact on the invertebrate fisheries **(Refer to Figure 5)**	**Likelihood:** **Likely(4)** **Consequence: Minor (1)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** It has been considered **Likely (4)** that there will be some minor changes in the abundance and distribution of saucer scallops within the AIMWTMF in the absence of any control interactions. The distribution of scallops will primarily be dependent of larval settlement patterns associated with hydrodynamic processes and spawning stock distribution and abundance. The southern area of the proposed MWADZ is located within a broader area that has historically been a high-density scallop settlement area in the Abrolhos Islands. Small-scale changes in the distribution of scallops could potentially occur in close vicinity of sea-cages if unfavorable conditions prevail directly below them. Scallops do have a limited capacity to move (swim) away (i.e. 10 to 100 metres) from these impacted areas. **Consequence** The overall consequences of any potential changes in the distribution and abundance patterns of scallops within the Abrolhos Islands FHPA have been deemed as **Minor (1)**. Any impacts are likely to be localised and within the footprint of the sea-cages within the MWADZ area.	**Likelihood: Likely(4)** **Consequence: Minor (1)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** The likelihood remains unchanged at **Likely (4)** due to the inability to mitigate any potential localised impacts of the proposal on scallop distribution and abundance patterns. **Consequence** Consequence remains unchanged at **Minor (1)**. Due to variable settlement patterns and abundance in any one year and subsequent abundance and distribution of adult (harvestable) scallops, the quantification of impacts is relatively complex. In some years the specific areas under sea-cages may be quite important for the saucer scallops, while in other years they could be less so.

		The MWADZ proposal area represents less than 0.2 % (i.e. 3,000 hectares) of the overall available AIMWTMF fishing ground (1,309,740 hectares) and 1.3% of the historically fished scallop grounds. Any impacts to the scallop abundance and distribution are not likely to have a significant impact on the fishery. Historically, commercial fishing effort information collected from the AIMWTMF indicates that the southern area of the MWADZ is located within a broader area that has been a key scallop fishing area in the past. However, the same fishing effort information demonstrates that northern area in the MWADZ area does not represent a key fishing area for the AIMWTMF.		

Table 4a: Assessment of resource access hazard identified on the potential impacts on key invertebrate fisheries. *Hazard was 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 the residual hazard (i.e. remaining hazard once one or a number 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. Physical exclusion of the fishing vessels and associated equipment by aquaculture infrastructure **(Refer to Figure 5a)**	**Likelihood: Likely (4)** **Consequence: Minor (1)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** The physical presence of aquaculture infrastructure including sea-cages, anchoring and feeding systems is **Likely (4)** to directly exclude AIMWTMF commercial scallop fishing vessels from fishing where the sea-cage clusters are located. The presence of this infrastructure is therefore likely to effectively create an 'exclusion zone' to fishing wherever the aquaculture infrastructure is located within the MWADZ. In some years, these locations will be within areas that have historically been shown to produce significant quantities of scallops. **Consequence** The physical presence of aquaculture infrastructure is likely to limit the extent of the available fishing ground within the AIMWTMF. However, access arrangements to the MWADZ proposal area will be non-exclusive; meaning commercial fishers (and others) will still be permitted to travel through and fish within the aquaculture development area. Commercial fishers	**Likelihood: Likely (4)** **Consequence: Minor (1)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** As the physical presence of aquaculture infrastructure in the MWADZ remains the same, the likelihood of it directly excluding AIMWTMF commercial scallop fishing vessels from fishing where the sea-cage clusters are located remains **Likely (4).** **Consequence** If timely information is provided to the commercial fishing industry (particularly the AIMWTMF) of the locations of mooring/anchoring systems and sea-cage infrastructure within the MWADZ, commercial fishers will then be able to fish areas within the MWADZ while avoiding those areas where trawl gear could potentially get hooked up on aquaculture infrastructure. Such notifications could be incorporated in the management arrangements for the MWADZ.

		(and others) who fish within the MWADZ will not be permitted to interfere with the aquaculture infrastructure. The consequence of this hazard is difficult to determine due to the highly variable nature of the recruitment and settlement of scallops within the AIMWTMF from year to year. In recent (4-5) years, there has been no consequence whatsoever as there has not been any commercial scallop fishing in the area of the proposed MWADZ. It is acknowledged there is no certainty this trend will continue into the future. On balance, the consequence has been rated as **Minor (1)**.		The consequence of an impact on the AIMWTMF could therefore be reduced by this arrangement. Nevertheless, it is not possible to guarantee a zero consequence and so the consequence rating must remain **Minor (1)**.

3.2.4 Hazard Pathway 4: Impact on sustainability on finfish fisheries

The primary potential ecological impacts of the MWADZ proposal on the finfish fisheries that were assessed in the hazard analysis were the following:

- Changes in the fish habitat for finfish species;
- Changes in the recruitment patterns and spawning stock of finfish species;
- Pest or pathogen affects finfish fisheries; and
- Changes in the abundance and distribution of finish species, leads to a significant impact on key finfish fisheries.

In addition to these potential ecological hazards, a potential resource access impact was also identified and assessed in the hazard analysis. This was:

- Physical exclusion from fishing ground due to presence of equipment and sea cage infrastructure.

The consequence-likelihood method was used to assess the level of risk for each of the identified hazards for the finfish fisheries that could be potentially impacted by the finfish aquaculture proposal.

Table 5. Assessment of hazards identified on the potential impacts on key finfish fisheries. *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 the residual hazard (i.e. remaining hazard once one or a number 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. Changes in the fish habitat for finfish species **(Refer to Figure 6)**	**Likelihood: Unlikely (2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** It is **Unlikely (2)** that the MWADZ proposal will have a significant effect on fish habitat required by targeted commercial finfish species such as baldchin groper, snapper, West Australian dhufish, spangled emperor, coral trout and other demersal scalefish species. The MWADZ proposal may have impact on the fish habitat for non-target species which may inhabit sandy areas directly underneath the sea-cages and within the close proximity to these areas. Impacts are, however, likely to be localised. Baseline habitat surveys conducted in the MWADZ area indicate that the majority of the habitat is comprised of sandy bottom with some areas of mixed assemblages and isolated patches of reef. In the northern area of the MWADZ 47.1 % of the habitat comprised of bare sand, 34.9% of mixed assemblages and 8.5% of reef habitat. While in the southern area 91.6% of the habitat comprised of bare sand and 5.2% of mixed assemblage (BMT Oceanica 2015). Mixed assemblage substrate, comprising rubble, low platform reef, algae and/or sponges, are often	**Likelihood: Remote (1)** **Consequence: Minor (1)** **Hazard score: (1)** **Risk level: Negligible**	**Likelihood** Likelihood may be reduced to **Remote (1)** based on management controls including: • situating sea cages in areas of sand and away from any potential fish habitat; and • fallowing of sea cages (i.e. rotation and movement of sea-cages to enable any fish habitat impacted to recover. **Consequence** The consequence of the MWADZ proposal having a significant effect on fish habitat remains unchanged with a ranking of **Minor (1)**.

		used by juvenile stages of species such as Baldchin groper and Redthroat emperor. Low platform reef is used by adults of the target species and may be used during spawning periods. However, the ‘footprint’ of the sea-cage clusters within the proposed MWADZ and the potential area affected by nutrient dispersal represents a very small part of the distribution area of these species. Consequently, the proposed aquaculture activities are unlikely to have a significant impact on the broader finfish stocks. It is unknown if the MWADZ is likely to have an impact on known spawning areas and nursery areas for key target demersal scalefish species (e.g. coral trout, Baldchin groper, etc.). However, given the small spatial extent of the proposal and the large range of most species, the likelihood of significantly impacting habitats is low. The fish habitat is likely to be modified directly underneath the sea-cages and within close proximity to these areas due to increased sedimentation/smothering and other impacts of aquaculture (Refer to Table 3). **Consequence** The consequence of the MWADZ proposal has been deemed **Minor (1).** Any potential impacts on fish habitats are likely to be relatively small-scale impacts directly within high impact zone areas. If fish habitat is affected, the potential consequences on the broader stocks of target species are likely to be low.		

2. Changes in the recruitment patterns and spawning stock of finfish species **(Refer to Figure 6)**	**Likelihood: Remote (1)** **Consequence: Minor (1)** **Hazard score: (1)** **Risk level: Negligible**	**Likelihood** The area proposed for the MWADZ, the cage clusters and the potential zone affected by nutrient dispersal, represents a very small component of the distribution of these species and the proposed aquaculture activities are unlikely to have significant impact on their broader stocks. The likelihood of the MWADZ proposal having an impact on the recruitment patterns and spawning stock of finfish species is rated as **Remote (1)**. **Consequence** The habitat of the proposed area comprises sandy substrate with some areas of mixed assemblages. Mixed assemblage substrate (comprising rubble, low platform reef, algae and/or sponges), for example, are often used by juvenile stages (recruits) of species such as Baldchin groper and Redthroat emperor. Low platform reef is used by adults of the target species and may be used during spawning periods. Given that the MWADZ proposal area does not represent a key recruitment area for finfish species, the consequence has be rated as **Minor (1)**.	**Likelihood: Remote (1)** **Consequence: Minor (1)** **Hazard score: (1)** **Risk level: Negligible**	**Likelihood** The likelihood remains unchanged at **Remote (1)** due to the inability to mitigate any potential localised impacts of the proposal on settlement/recruitment and spawning stock. **Consequence** Remains unchanged as **Minor (1)**.
3. Pest or pathogen affects finfish fisheries **(Refer to Figure 6)**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**	***See biosecurity risk assessment**

4. Changes in the abundance and distribution of finfish species leads to a significant impact on key finfish fisheries **(Refer to Figure 6)**	**Likelihood: Unlikely (2)** **Consequence: Minor (1)** **Hazard score: (2)** **Risk level: Negligible**	**Likelihood** It was considered **Unlikely (2)** that there will be any significant changes in the abundance and distribution of finfish species within the Abrolhos Islands FHPA. Although there may be some localised changes in abundance, resulting from either increases associated with increased production or decreases associated with affected habitat/nutrient enrichment around the proposed MWADZ, it is unlikely these will result in large-scale changes in the abundance or distribution of the targeted species at a whole of stock level. Thus, there is **Unlikely (2)** to be any significant impact on the line fisheries for these finfish species. **Consequence** The consequences of any potential changes in the distribution and abundance finfish species have been deemed as **Minor (1)**. Impacts are likely to be localised and within the footprint of the sea-cages within the MWADZ.	**Likelihood: Remote (1)** **Consequence: Minor (1)** **Hazard score: (1)** **Risk level: Negligible**	**Likelihood** Likelihood of changes in the abundance and distribution of finfish species could be further reduced to **Remote (1)** based on implementation of management measures aimed at reducing the (low) level of stock feed wastage associated with the aquaculture. **Consequence** The consequence will remain unchanged at **Minor (1)**.

Table 5a: Assessment of resource access hazard identified on the potential impacts on key finfish fisheries. *Hazard was 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 the residual hazard (i.e. remaining hazard once one or a number 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. Physical exclusion of the fishing vessels and associated equipment by aquaculture infrastructure **(Refer to Figure 6a)**	**Likelihood: Likely (4)** **Consequence: Minor (1)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** The physical presence of aquaculture infrastructure including sea-cages, anchoring and feeding systems is **Likely (4)** to directly exclude commercial and recreational fishers from fishing within the immediate area where the sea-cage clusters are located. Under the proposed management arrangements, both commercial and recreational fishers will be permitted to fish within the MWADZ provided they do not interfere with the aquaculture infrastructure. Sea-cages and their associated infrastructure are likely to aggregate some species of finfish and may potentially attract to the area predatory fish (large and small) including pelagic species. This may result in increased numbers of predatory fishes remaining in the vicinity of cages that may be attractive to recreational and commercial fishes (e.g. mackerel, tuna etc.). Consequently, such aggregations could potentially increase both recreational and commercial fishing activity within the area.	**Likelihood: Likely (4)** **Consequence: Minor (1)** **Hazard score: (4)** **Risk level: Low**	**Likelihood** The likelihood remains unchanged at **Likely (4)** due to the inability to mitigate any direct loss of available fishing ground. The number of sea-cage clusters permitted to be deployed within the MWADZ will have a bearing on the degree to which this likelihood will be realised. Ultimately, this aspect will largely be determined by the environmental carrying capacity of the MWADZ. **Consequence** Consequence will remain unchanged at **Minor (1)**.

		Consequence The physical presence of aquaculture infrastructure is likely to limit access to the fishing grounds currently available to both commercial and recreational fisheries. However, this limitation is largely restricted to those areas under the sea-cage clusters. The proposed access arrangements to the proposed MWADZ area will be non-exclusive, meaning both commercial and recreational fishers will otherwise still be permitted to fish within the MWADZ to the extent they are currently permitted. It should be noted that the current extent of commercial (and recreational) line fishing in the MWADZ area is relatively **Minor (1)**.		

4 Risk Assessment

Following the identification of key threats and detailed analysis of hazard pathways leading to potential realisation of these threats, four overarching risks of most relevance to the activities proposed in association with the MWADZ were identified as follows:

1. Aquaculture activity in the zone has a significant impact on the populations of invertebrate species (i.e. saucer scallop) in the Abrolhos Islands FHPA.
2. Aquaculture activity in the zone has a significant impact on the populations of finfish species in the Abrolhos Islands FHPA.
3. Aquaculture activity in the zone has a significant impact on the invertebrate fishery (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery).
4. That aquaculture activity in the zone has a significant impact on finfish fisheries in the Abrolhos Islands FHPA.

Overarching risks 1 and 2 are risks associated with potential ecological impacts on the species populations. By comparison, overarching risks 3 and 4 are risks that essentially comprise the effects of overarching risks 1 and 2 (i.e. the **ecological impacts**) in addition to the potential **resource access impacts** resulting from the physical presence of aquaculture infrastructure within the MWADZ.

All the above risks were 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 hazards and key factors that contribute to a broad risk category.

5 Risk Analysis Results

5.1 Risk 1 - Impact on the populations of invertebrate species (i.e. saucer scallop) within the Abrolhos Islands FHPA

5.1.1 Inherent Risk Analysis

5.1.1.1 Likelihood

Aquaculture activity will almost inevitably result in some degree of nutrient enrichment of the water column based on discharge from uneaten feed, faeces and metabolic wastes. Finfish aquaculture is also likely to result in increased organic deposition, nutrient enrichment of the sediment and changes to biochemical processes. This is likely to result in some changes in the behaviour, abundance and distribution of the saucer scallop within the area. Survival and recruitment of this species beneath the sea-cages is also likely to be impacted. Given the area likely to be affected by a MWADZ, is a negligible proportion (much less than 1 percent) of the saucer scallop natural range, the likelihood that the proposed aquaculture could impact the populations of the target invertebrate species within the Abrolhos Islands FHPA was rated as **Unlikely (2).**

5.1.1.2 Consequence

The consequence of aquaculture activity in the MWADZ proposal area having a significant impact on the populations of the target invertebrate species i.e. saucer scallop was assessed based on the known biological information on the species and the literature collected on the known impacts of aquaculture on invertebrate species. Whilst the aquaculture activity may have an impact on the abundance and distribution of the saucer scallop within the MWADZ area, the consequence has been rated as **Minor (1)** in terms of its impact on the overall populations of this species at the Abrolhos Islands FHPA.

5.1.1.3 Overall Inherent Risk

Inherent Risk level is Negligible

5.1.2 Residual Risk Analysis

5.1.2.1 Likelihood

The likelihood that the MWADZ proposal will have an impact on the invertebrate species saucer scallop can further be reduced through the implementation of management measures. Management controls that can mitigate potential effects from the proposal include those detailed in table below:

Control Category	Management Control	DoF Control Mechanism
1. Restricting the amount of biomass held in the aquaculture zone	• Limiting maximum biomass to be held on the farm.	Licensing conditions. Mechanism to ensure compliance with biomass conditions and accurate reporting of stock levels.
2. Reducing feed wastage and improvements in feeding efficiency	• Measures to govern feed type and usage. • Good husbandry practices to ensure high food conversion ratios and appropriate feeding regime.	Development and compliance with a Management and Environmental Monitoring Plan and best management practices in aquaculture.
3. Reducing the release of therapeutants and other contaminants into the environment	• Regulation of chemicals used for aquaculture and reduced requirements through good husbandry practices. • Reducing the level of therapeutants in feed.	Development and compliance with a Management and Environmental Monitoring Plan and best management practices in aquaculture.

4. Reducing the level of nutrient enrichment in the water column and turbidity	• Regular monitoring of nutrient levels within the vicinity of sea cages. • Situating sea cages in well flushed areas. • Maximising feeding efficiency and reducing fish waste. • Setting the stock densities at conservative levels.	Development and compliance with a Management and Environmental Monitoring Plan and best management practices in aquaculture.
5. Reducing impacts on sediment and changes in biochemical processes	• As per above	As per above

Based on implementation of these measures, the residual likelihood of aquaculture operations having an impact on populations of saucer scallops in the Abrolhos Islands FHPA is considered to be **Remote (1)**.

5.1.2.2 Consequence

Residual Consequence remains unchanged at **Minor (1).**

5.1.2.3 Overall Residual Risk

Residual Risk level is Negligible

5.2 Risk 2 - Impact on populations of finfish species within the Abrolhos Islands FHPA

5.2.1 Inherent Risk Analysis

5.2.1.1 Likelihood

It has been identified through aquaculture literature reviews, baseline water and sediment quality data that sea cage aquaculture is likely have some potential impacts on finfish species. The majority of the risks identified during the assessment relate to the potential changes in localised environmental conditions within the MWADZ area. These changes are likely to occur due to the nutrient enrichment of the water column, increased turbidity, organic deposition and nutrient enrichment of sediments and potential release of trace metals, therapeutants and other contaminants. Information obtained from previous environmental assessments of sea cage aquaculture indicates that any changes to environmental conditions are likely to be localised and either directly underneath or within close proximity to the sea cages.

Feed from aquaculture activities, residue from cultured stock and harvesting activities and effluent from the operations is also likely to have a potential impact on finfish species. An increase in the availability of food sources from fish feed, residue from cultured stock, or effluent from harvest activities has the potential to increase or decrease the visitation and or potential abundance of some finfish species within the MWADZ area. The physical presence of sea cage infrastructure is also likely to have Fish Aggregation Device (FAD) effects which may also increase or decrease the abundance of abundance of predatory and opportunistic finfish species within the aquaculture development zone.

An increase in the abundance of these species has the potential to influence the behaviour of other finfish species within the vicinity of the MWADZ proposal area. However, whilst there are likely to be some localised environmental impacts, potential changes in fish abundance and fish behaviour near the sea cages, the inherent likelihood the MWADZ proposal would have a significant impact on the overall populations of finfish species within the Abrolhos Islands FHPA was rated as **Unlikely (2).**

5.2.1.2 Consequence

The consequence of the proposed aquaculture having an impact on populations of finfish species within the Abrolhos Islands FHPA was rated as **Minor (1).**

5.2.1.3 Overall Inherent Risk

Inherent Risk level is Negligible

5.2.2 Residual Risk Analysis

5.2.2.1 Likelihood

The likelihood that the MWADZ proposal will have a significant impact on the finfish species can be further reduced through the implementation of management measures. Management controls that can mitigate potential effects from the proposal include those detailed in table below:

Control Category	Management Control	DoF Control Mechanism
1. Reducing the positive attraction of finfish species to the sea cages due to availability of additional food	• Limiting maximum biomass to be held on farm. • Maximising feeding efficiency and reducing fish waste. • Removal of dead and moribund stock on a daily basis. • Use of high-quality pellet feed.	Development of and compliance with a Management and Environmental Monitoring Plan (MEMP) and best-management practices in aquaculture.
2. Reducing the level of nutrient enrichment in the water column and turbidity	• Regular monitoring of nutrient levels within the vicinity of sea cages. • Situating sea cages in well flushed areas. • Maximising feeding efficiency and reducing fish waste. • Setting the stock densities at conservative levels. • Regular monitoring of levels of dissolved nutrients and	Development of and compliance with a Management and Environmental Monitoring Plan (MEMP) and best-management practices in aquaculture.
3. Reducing the release of therapeutants and other contaminants into the environment	• Regulation of chemicals used for aquaculture and reduced requirements through good husbandry practices • Reducing the level of therapeutants in feed	As per above

Based on implementation of these measures, the residual likelihood of aquaculture operations having an impact on the populations of finfish species at the Abrolhos Islands FHPA is considered to be **Remote (1)**.

5.2.2.2 Consequence

Residual Consequence remains unchanged at **Minor (1).**

5.2.2.3 Overall Residual Risk

Residual Risk level is Negligible

5.3 Risk 3 - Impact on invertebrate fisheries (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery)

5.3.1 Inherent Risk Analysis

5.3.1.1 Likelihood

It has been identified through the assessment process that the MWADZ proposal is likely to have some impacts on the Abrolhos Islands and Mid West Trawl Managed Fishery (AIMWTMF). The physical presence of aquaculture infrastructure including sea cages, anchors and feeding systems will directly exclude scallop trawl fishing vessels from fishing in the immediate vicinity of the sea cage infrastructure within the aquaculture development zone.

The aquaculture activities are also likely to have localised impacts on the benthic habitat of the target species (i.e. saucer scallop). This may result in some small changes in settlement/recruitment patterns and potential changes in the abundance and distribution of this species within the MWADZ area.

The inherent likelihood that the MWADZ proposal will have an impact on the AIMWTMF was rated as **Likely (4)**.

5.3.1.2 Consequence

The overall consequence of any potential changes in the distribution and abundance patterns of scallops within the Abrolhos Islands FHPA (i.e. the ecological impacts) has been deemed as Minor (1).

While there may potentially be some localised changes in the distribution and abundance patterns of scallops directly underneath the sea cages and within close proximity to the infrastructure, the consequences to the overall scallop stocks in the Abrolhos region is likely to be minimal.

As mentioned previously, the physical presence of aquaculture infrastructure is likely to restrict the availability of historical fishing ground with the AIMWTMF. However, the MWADZ area represents a very small proportion (i.e. less than 0.2 % or 3,000 hectares) of the overall available AIMWTMF fishing ground (1,309,740 hectares) and 1.3% of the historically-fished scallop fishing ground in the fishery (pers comm DoF 2015).

Historical fishing effort information collected by the Department of the Fisheries for the AIMWTMF from 2003 to 2011 has indicated that the southern area in the MWADZ has represented an important area for scallop fishing (refer to PER document AIMWTMF effort map). However, due to the highly variable nature of the recruitment and settlement of scallops within the AIMWTMF from year to year, there has been no commercial scallop fishing in this area in recent years.

The northern site of the MWADZ proposal area does not represent a key fishing area for the fishery. Commercial fishing effort in this area has been very limited over the last 10 years [pers comm Kangas, M (DoF)].

Under the proposed management arrangements for the MWADZ, commercial fishers will still be permitted to operate within the aquaculture development zone provided they do not interfere with the aquaculture infrastructure.

Given this information, the Inherent consequence of the proposed aquaculture activities in the MWADZ having a significant impact on the AIMWTMF was rated as **Minor (1).**

5.3.1.3 Overall Inherent Risk

Inherent Risk level is Low

5.3.2 Residual Risk Analysis

5.3.2.1 Likelihood

The overall residual likelihood remained unchanged as **Likely (4)** due to the inability to mitigate any potential localised impacts on the potential changes to benthic habitat, settlement/recruitment patterns, and distribution and abundance of the saucer scallop species.

5.3.2.2 Consequence

The consequence could potentially be reduced if information is provided to industry of the actual locations of mooring/anchoring systems and sea cage infrastructure within the MWADZ at any one time. Armed with this information, the AIMWTMF could maximise the area available to be fished within the zone. Nevertheless, the Residual Consequence remains unchanged at **Minor (1).**

5.3.2.3 Overall Residual Risk

Residual Risk level is Low

5.4 Risk 4 - Impact on finfish fisheries

5.4.1 Inherent Risk Analysis

5.4.1.1 Likelihood

In this risk analysis a number hazard pathways were analysed as part of the assessment of the potential impacts of the MWADZ proposal on the finfish fisheries. These included changes to fish habitat, changes in recruitment patterns and spawning stock of finfish species, pest or pathogen transfer, physical exclusion of fishing vessels and changes in the abundance and distribution of finfish species.

Baseline benthic habitat surveys conducted in the MWADZ have indicated the MWADZ area does not represent a key habitat area for target finfish species such as coral trout, baldchin groper, redthroat emperor and other demersal fish species that are commonly targeted by finfish fisheries. These species tend to prefer limestone reef, macroalgae and coral habitats; which are generally located on the western and central parts of the Abrolhos Island groups.

While there may be some localised changes to the habitat within the aquaculture development zone, it is unlikely to result in any significant changes in the abundance, distribution, recruitment patterns and spawning stock of these finfish species within the Abrolhos FHPA.

Catch and effort information reported for the finfish fisheries permitted to fish within Abrolhos FHPA indicates that the MWADZ proposal area does not represent a key fishing area for these fisheries. The majority of the commercial fishing effort for these fisheries is conducted outside of the MWADZ proposal area. While commercial finfish fishers may be physically excluded from fishing certain parts of the MWADZ due to the presence of aquaculture infrastructure, the overall area of the proposed aquaculture development zone represents a very small proportion (i.e. less than 1%) of the overall fishing area for these finfish fisheries. Therefore, the inherent likelihood that the MWADZ proposal would have a significant impact on finfish fisheries within the Abrolhos Islands FHPA was rated as **Unlikely (2).**

5.4.1.2 Consequence

The consequence of the proposed aquaculture activities in the MWADZ having a significant impact on finfish fisheries in the Abrolhos Islands FHPA was rated as **Minor (1).**

5.4.1.3 Overall Inherent Risk

Inherent Risk level is Negligible

5.4.2 Residual Risk Analysis

5.4.2.1 Likelihood

The likelihood that the proposed aquaculture activities will have a significant impact on the sustainability of finfish fisheries may be further reduced through the implementation of management measures. Management controls that can mitigate potential effects from the proposal include those detailed in table below:

Control Category	Management Control	DoF Control Mechanism
1. Reducing the potential impacts of aquaculture activities on fish habitat	• Situating sea cages in well flushed areas over sand habitat and away from potential fish habitat. • Fallowing of sea cages – rotation and movement of cages to enable fish habitat to recover.	Compliance with individual operator's MEMPs to achieve best management practices, in accordance with the EMMP for the Zone, the Aquaculture Council of Western Australia's (ACWA) Code of Practice, and the Zone Management Policy.
2. Reducing the positive attraction of finfish species to the sea cages due to availability of additional food	• Limiting maximum biomass to be held on farm. • Maximising feeding efficiency and reducing fish waste. • Removal of dead and moribund stock on a daily basis. • Use of high-quality pellet feed.	Development of and compliance with a Management and Environmental Monitoring Plan (MEMP) and best-management practices in aquaculture.

Based on implementation of these measures, the residual likelihood of aquaculture operations in the MWADZ proposal area having a significant impact on the sustainability on finfish fisheries is considered to be **Remote (1).**

5.4.2.2 Consequence

Residual Consequence remains unchanged at **Minor (1).**

5.4.2.3 Overall Residual Risk

Residual Risk level is Negligible

6 Summary

The potential risks arising from aquaculture activities in the proposed MWADZ on invertebrate and finfish species and key fisheries were assessed using the risk assessment methods that conform to international standards (ISO 31000, 2009; IEC/ISO; 2009; SA-HB89; 2012). Information that was used as part of the assessment included relevant biological and ecological information on invertebrate and finfish species, previous marine finfish aquaculture risk assessments, commercial fisheries catch rate and catch information, and relevant scientific studies and publications on aquaculture.

During the risk assessment, four key risks were identified as having the potential to be realised as a result of the proposed finfish aquaculture activities within the MWADZ. These are summarised as follows:

1. *An impact on populations of invertebrate species (i.e. saucer scallop) within the Abrolhos Islands FHPA;*
2. *An impact on populations of finfish species within the Abrolhos Islands FHPA;*
3. *Potential impacts on the invertebrate fisheries (i.e. Abrolhos Islands and Mid West Trawl Managed Fishery); and*
4. *Potential impacts on the finfish fisheries.*

Results from the risk assessment concluded that the proposal poses a negligible and acceptable risk to three of the four key risks identified. The MWADZ proposal is anticipated to generate negligible impacts on saucer scallop and finfish populations within the Abrolhos Islands FHPA. While it was recognised during the assessment process that there may be some localised impacts on these species, the overall impacts on the abundance, distribution, recruitment patterns and spawning stock of these species within the Abrolhos Islands FHPA is likely to negligible. The area of the MWADZ (i.e. approximately 3,000 hectares) represents a very small proportion of the overall natural range of these species within the Abrolhos region and Western Australia. Any changes to the abundance of these species within the aquaculture development zone, is likely to have minimal impact on the overall populations of these species.

The risk assessment identified that MWADZ proposal poses a low risk to the AIMWTMF. Some areas of the aquaculture zone (i.e. southern site) have historically been a key area for scallop fishing in the AIMWTMF. The physical presence of aquaculture infrastructure in the zone is likely to directly exclude scallop trawl fishing vessels from fishing in the immediate vicinity of the sea cage infrastructure within the aquaculture development zone. This has the potential to limit the amount of available fishing ground in the fishery.

The MWADZ area, however, represents only a very small proportion (i.e. less than 0.2 %) of the overall available AIMWTMF fishing ground and 1.3% of the historically-fished scallop fishing ground in the fishery. There has been no commercial scallop fishing in the proposed MWADZ in recent years. Under the proposed management arrangements for the MWADZ proposal, commercial and recreational fishing vessels will still be permitted to operate within the aquaculture development zone provided they do not interfere with the sea cage infrastructure.

Additional hazard pathways identified as having potential impacts (such as changes to behavioural characteristics of species and biosecurity risks) on the invertebrate and finfish species and their associated fisheries are likely to pose a low or negligible risk.

The level of risk posed by these hazards and other risks assessed as part of this assessment can be managed to acceptable levels through the adoption of best-practice management arrangements and regular compliance monitoring and enforcement around the implementation of Management and Environmental

Monitoring Plans (MEMPs). Under the requirements of the MEMP's, individual aquaculture operators will be required to conduct mandatory environmental monitoring within the MWADZ.

In addition to their responsibilities under the MEMP's, industry is also encouraged to adhere to Marine Finfish Environmental Code of Practice developed by the Aquaculture Council of Western Australia.

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