Mid West Aquaculture Development Zone Environmental Monitoring and Management Plan

1164_001/1_Rev6

April 2016

Mid West Aquaculture Development Zone

Environmental Monitoring and Management Plan

Prepared for

Department of Fisheries

Prepared by

BMT Oceanica Pty Ltd

April 2016

Report No. 1164_001/1_Rev6

Client: Department of Fisheries

Document history

Distribution

Revision	Author	Recipients	Organisation	No. copies & format	Date
A	D. Rivers	G. Shiell	BMT Oceanica	1x .docm	07 Aug 2015
B	D. Rivers	G. Shiell	BMT Oceanica	1x .docm	14 Aug 2015
C	D. Rivers	K Hoefhamer	BMT Oceanica	1x .docm	19 Aug 2015
D	D. Rivers and G. Shiell	J. Eyres	DoF	1 x .docm	20 Aug 2015
E	D. Rivers and G. Shiell	J. Eyres	DoF	1 x docm	01 Oct 2015
0	G. Shiell	J. Eyres	DoF	1 x pdf	4 Nov 2015
1	G. Shiell	J. Eyres	DoF	1 x pdf	6 Nov 2015
2	G. Shiell	J. Eyres	DoF	1 x pdf	15 Dec 2015
3	G. Shiell	J. Eyres	DoF	1 x pdf	16 Dec 2015
4	G. Shiell	J. Eyres	DoF	1 x pdf	4 March 2016
5	G. Shiell	J. Eyres	DoF	1 x pdf	15 April 2016
6	G. Shiell	J. Eyres	DoF	1 x pdf	28 April 2016

Review

Revision	Reviewer	Intent	Date
B	G. Shiell	Technical review	16 Aug 2015
C	K Hoefhamer	Editorial review	19 Aug 2015
D	J. Eyres	Client	24 Aug 2015
E	J. Eyres	Client	28 Oct 2015
0	J. Eyres	Client	4 Nov 2015
1	J. Eyres	Client	7 Dec 2015
2	J. Eyres	Client	16 Dec 2015
3	OEPA	OEPA	19 Feb 2016
4	J. Eyres	Client	14 April 2016
5	J. Eyres	Client	26 April 2016

Quality Assurance

Compliance Australia Certification Services OHSAS 18001 SAFETY

Compliance Australia Certification Services AS/NZS 4801 SAFETY

Compliance Australia Certification Services ISO 14001 ENVIRONMENT

Compliance Australia Certification Services ISO 9001 QUALITY

BMT Oceanica Pty Ltd has prepared this report in accordance with our Health Safety Environment Quality Management System, certified to OHSAS 18001, AS/NZS 4801, ISO 14004 and ISO 9001: 2008.

Status

This report is 'Draft' until approved for final release, as indicated below by inclusion of signatures from: (i) the author and (ii) a Director of BMT Oceanica Pty Ltd or their authorised delegate. A Draft report may be issued for review with intent to generate a 'Final' version, but must not be used for any other purpose.

Approved for final release:

Author
Date: 28 April 2016

Director (or delegate)
Date: 28 April 2016

Disclaimer

This report has been prepared on behalf of and for the exclusive use of Department of Fisheries, and is subject to and issued in accordance with the agreed terms and scope between Department of Fisheries and BMT Oceanica Pty Ltd. BMT Oceanica Pty Ltd accepts no liability or responsibility for it in respect of any use of or reliance upon this report by any third party.

Contents

List of Figures

List of Tables

List of Appendices

1. Background

1.1 Environmental approvals

In late 2011, the Minister for Fisheries announced a funding package to establish two aquaculture development zones in Western Australia's (WA) coastal waters. The WA Department of Fisheries (DoF) is managing the project, and is responsible for undertaking the environmental impact assessments (EIA) for zones in the Kimberley and Mid-west regions of the State.

This document relates to the Mid West Aquaculture Development Zone (MWADZ) which is proposed to be established within the Fish Habitat Protection Area of the Houtman Abrolhos Islands (hereafter the 'Abrolhos'). The MWADZ consists of two areas: a northern area (2200 ha), located roughly halfway between the Easter and Pelsaert groups and a southern area (800 ha), immediately north of the Pelsaert group (Figure 1.1).

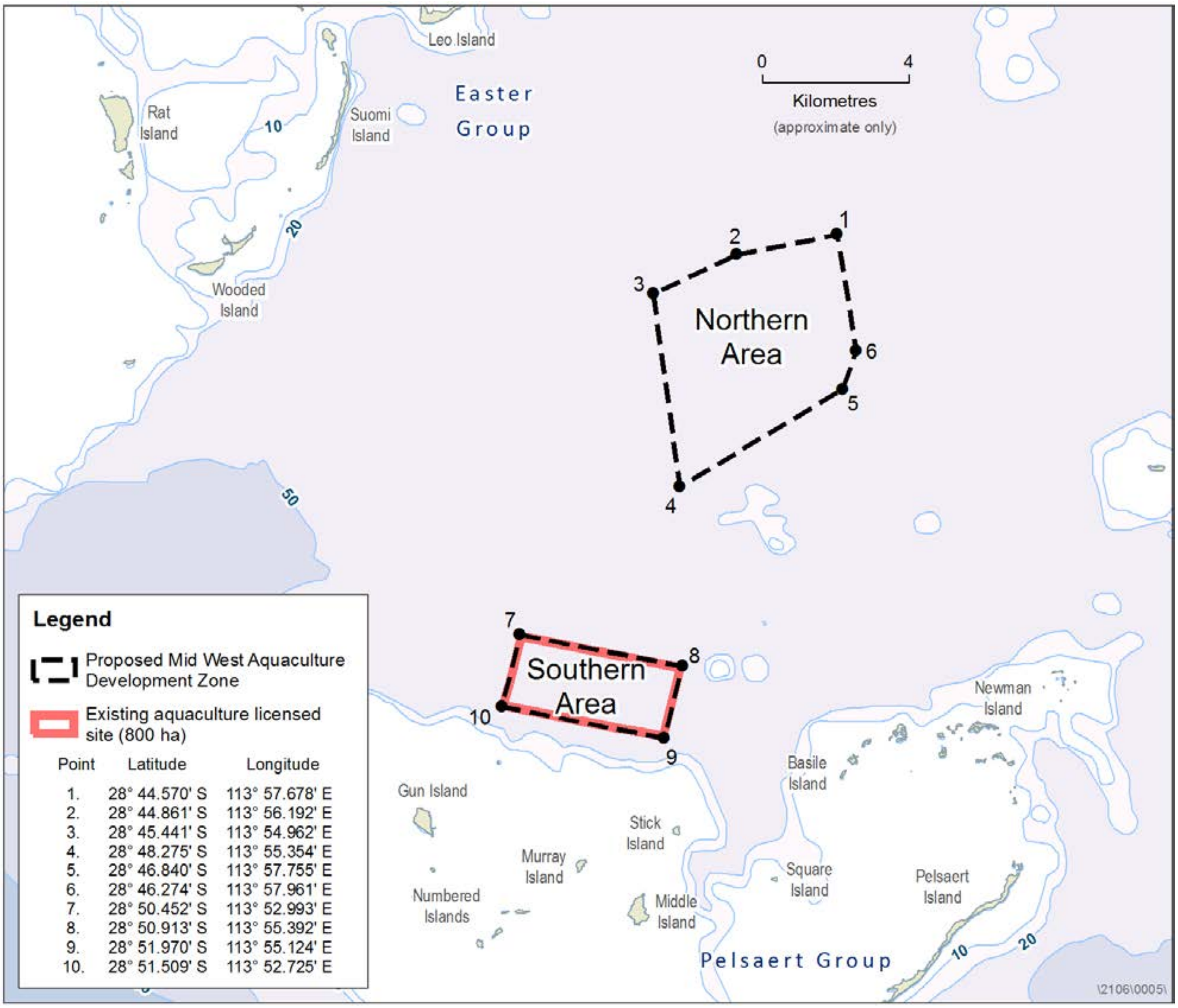


Figure 1.1 Location of the proposed Mid West Aquaculture Development Zone

The strategic proposal to develop the MWADZ was referred to the Environmental Protection Authority (EPA) in May 2013 and the level of assessment was set at Public Environmental Review (PER), under Section 38 of the Environmental Protection Act 1986. The Minister for Fisheries is the proponent for the strategic proposal under Part IV of the *Environmental Protection Act 1986* (EP Act). The Department of Fisheries (DoF) is acting as the proponent for the strategic proposal on behalf of the Minister for Fisheries. Existing and future aquaculture operators who refer project proposals to the Environmental Protection Authority (EPA) as derived proposals under the approval of the strategic proposal are herein referred to as ‘Proponents’.

The requirements of the EIA are defined in the EPA prepared environmental scoping document (ESD; EPA 2013) and included a number of technical studies including environmental modelling and multiple desktop assessments. The outcomes of these studies are detailed in BMT Oceanica (2015a, 2015b), Halfmoon Biosciences (2015) and DoF (2015a, 2015b and 2015c).

In addition to the technical studies required of the EIA, a further requirement of the ESD was to develop an environmental quality management framework (EQMF) for future aquaculture operations. The framework defines the environmental values (EVs) to be protected, the environmental quality objectives (EQO) and levels of ecological protection to be achieved and where they apply spatially.

1.2 Purpose of this Plan

This document, the Environmental Monitoring and Management Plan (EMMP) (hereafter 'the Plan'), provides the EQMF to protect sediment and water quality within the broader aquaculture zone, to a level commensurate with the agreed levels of ecological protection. While the EQMF is designed to manage water and sediment quality within the MWADZ (Sections 4.1 and 4.2), this Plan also includes proactive management strategies to protect the important biological and ecological values of the Abrolhos region, including its significant marine mammal, turtle, seabird, wild fin-fish and invertebrate populations (Sections 4.4, 4.5, 4.6 and 4.7).

2. Existing Marine Environment

The Abrolhos Islands are a group of islands located approximately 60 km west of Geraldton, Western Australia (WA). The islands are clustered into three main groups – Wallabi, Easter and Pelsaert, and are approximately 100 km in length from the northern to the southern tip. Both the MWADZ and the broader Abrolhos region have high conservation status owing to their near-pristine marine environmental qualities and the high socio/economic importance of the area.

This Plan details the monitoring and management strategies that will be used to protect the MWADZ and the broader Abrolhos marine environment for the life of the project. The key environmental elements are described in Sections 2.1 to 2.6, with an emphasis on the key environmental factors identified in the ESD (Table 2.1). The potential impacts of the proposal on key environmental factors are considered in Section 3.2.1.

Table 2.1 Key environmental factors and impacts identified in the Environmental Scoping Document

Key environmental factors	Key environmental impacts
• Hydrodynamics	• Alterations to hydrodynamics
• Marine water and sediment quality (including accumulation of trace contaminants)	• Degradation of marine water and sediment quality
• Marine flora and benthic primary producer habitat • Significant marine fauna • Marine benthic infauna and invertebrates	• Direct and indirect disturbance or loss of benthic communities and habitat • Direct and indirect impacts to key sensitive receptors • Impacts to marine environment and biota quality through release of pharmaceuticals, metals/metalloids and, or petroleum hydrocarbon • Direct and indirect impacts on significant marine fauna

2.1 Hydrodynamics

The MWADZ is located on the edge of the WA continental shelf between 28°S and 29°S, in the pathway of the warm poleward-flowing Leeuwin Current (Pearce 1997). It is also situated in the Zeewijk Channel, one of three breaks in the Houtman Abrolhos archipelago (Maslin 2005). The region surrounding the Abrolhos is a dynamic system influenced by large-scale regional currents (e.g. Leeuwin Current, Capes Current), wind stresses, upwelling and wave dynamics (Pearce & Pattiaratchi 1999, Feng et al. 2007, Waite et al. 2007, Woo & Pattiaratchi 2008, Rossi et al. 2013). The Leeuwin Current is a well-studied oceanic flow of warm, low salinity tropical water (originating in the Timor Sea) that travels southwards along the Western Australian coast. It is driven by a southwards pressure gradient, and under the influence of Coriolis deflections, hugs the coastline as it travels from near North West Cape to Cape Leeuwin (south of Perth) and then onwards to the Great Australian Bight (Cresswell 1991).

The Leeuwin Current flow is strongest in autumn, winter and early spring. The flow is greatest and most consistently south along the shelf break, a relatively short distance to the west of the Abrolhos Islands (Webster et al. 2002). The currents through and inshore of the islands vary spatially and temporally. During the late spring and summer months, the current through and inshore of the islands tends to set to the north, driven by the prevailing southerly winds with occasional current reversal to the west along the shelf break (Pearce et al. 1999). During the winter months strong westerlies and north-westerlies can generate southward setting currents through and inshore of the Abrolhos Islands (Pearce et al. 1999).

The waters of the MWADZ are well flushed and experience high levels of water circulation and dispersion. Their position within the Zeewijk Channel means that the area is exposed to significant westerly currents, which expel large volumes of water out of the zone toward the continental shelf slope (Maslin 2005). Differences in the hydrodynamics between the surface and bottom of the Zeewijk channel have been shown to affect particle transport times (Maslin 2005). Particles in the surface waters are expected to be flushed out of the system rapidly (within 24 hrs), while particles at the bottom of the water column are expected to be retained in the system for longer periods, due to the recirculation of bottom currents (Maslin 2005).

2.2 Water and sediment

Waters inside the MWADZ are clean and well mixed (BMT Oceanica 2015). Maximum and minimum water temperatures are achieved in autumn (23.5°C) and winter (20.8°C), respectively. Salinity and dissolved oxygen levels are consistent through the water column with little evidence of stratification. The water is highly oxygenated, achieving surface oxygen saturation levels between 96% and 99% and bottom oxygen saturation levels between 95% and 98% (BMT Oceanica 2015).

MWADZ water currents are variable, ranging between 5.8 and 14.4 cm/s. Concentrations of ammonium (2.7 µg/L) and chlorophyll-a (0.43 µg/L) are comparable to those recorded in Perth's coastal waters, pointing to an overall oligotrophic (nutrient poor) environment. Nitrite + Nitrate levels (12.9 µg/L) were higher than those recorded in Perth's coastal waters (6.5 µg/L) and in the Kimberley Aquaculture Development Zone (8.7 µg/L). Concentrations of inorganic nutrients and chlorophyll-a are seasonally variable, but are higher in the cooler months (BMT Oceanica 2015).

The benthic environment consists generally of a shallow (~15 cm thick) layer of sand overlying rocky substrate. Higher current speeds in the northern area (northern 13-14.5 cm/s compared to the south 8.7-11 cm/s) are reflected in the tendency toward larger sediment grain sizes in the northern reaches of the MWADZ. Sediment conditions are also variable, with seasonal fluctuations in nitrogen, phosphorus and total organic carbon, with generally higher values for these analytes in the warmer months. Infaunal assemblages are diverse (10 phyla; 129 families) and dominated by polychaetes. Higher levels of infauna diversity and abundance are observed in the summer months (BMT Oceanica 2015).

2.3 Marine flora and benthic primary producing habitats

Surveys undertaken in 2014 indicate that the seafloor is a mosaic of habitats consisting of open sandy meadows and mixed biological assemblages (BMT Oceanica 2015), comprising filter feeders (sponges, and bryozoans), macroalgae, rhodoliths and some hard corals (though the latter was observed infrequently). Despite the observed diversity of the biological assemblages, their presence is considered itinerant given their propensity to change significantly between surveys, and over time (BMT Oceanica 2015).

Habitats in the northern MWADZ are more diverse and comprise 83% bare sand and 17% mixed assemblages. Small patches of reef were observed outside the north-east boundary of the MWADZ but make up only 8.5% of the total habitat within the study area. By contrast, the habitats in the southern area comprise 99% bare sand and 1% mixed assemblages. Although ephemeral seagrass communities have historically been observed in the MWADZ, no seagrasses were observed in the 2014/2015 assessment (BMT Oceanica 2015).

2.4 Seabirds

The Houtman Abrolhos is the most significant seabird breeding location in the eastern Indian Ocean. Eighty percent (80%) of the brown (Common) noddies, 40% of sooty terns and all lesser noddies found in Australia nest at the Houtman Abrolhos (Ross et al. 1995). It also contains the largest breeding colonies in Western Australia of wedge-tailed shearwaters, little shearwaters, white-faced storm petrels, white-bellied sea eagles, osprey, caspian terns, crested terns, roseate terns and fairy terns (Storr et al. 1986, Surman and Nicholson 2009). The Houtman Abrolhos also represents the northernmost breeding islands for both the Little Shearwater and White-faced Storm Petrel.

Within the Pelsaert and Easter Groups, 17 species have been confirmed as breeding regularly. These are the white-bellied sea eagle, osprey, wedge-tailed shearwater, little shearwater and white-faced storm Petrel, Pacific gull, silver gull, caspian tern, crested tern, bridled tern, roseate tern, fairy tern, brown noddy, lesser noddy, eastern reef egret, pied oystercatcher and pied cormorant (Surman and Nicholson 2009).

Seabirds are of great ecological significance in the Abrolhos region and have been considered carefully in this Plan. Management strategies for protecting seabirds and limiting their interaction with the proposed sea-cage operations are outlined in Section 4.4 of this Plan.

2.5 Marine mammals and turtles

The Abrolhos Islands and surrounding waters provide important habitat for an array of marine mammals, comprising mainly whales, dolphins and sea lions. Thirty one cetacean and two pinniped species are known to occur within a 50 km radius of the MWADZ (DoE 2014). Some species occasionally transit through the area at low densities, but there is insufficient information to confirm a definitive presence. Species that are likely to occur within a 50 km radius include: humpback whale, Australian sea lion, Indo-Pacific bottlenose dolphin and the common bottlenose dolphin. Species with a low likelihood of occurrence include: the blue whale, southern right whale, Bryde’s whale, killer whale and the dugong. Four marine turtles may occur within a 50 km radius, including the loggerhead turtle, flatback turtle, leatherback turtle and green turtle, with the last two species more likely.

Adverse interactions between marine mammals and sea-cage aquaculture are well documented in the literature (BMT Oceanica 2015). The potential for adverse effects, particularly between sea lions and the sea-cage infrastructure has been considered in this plan and will require careful management. Management strategies aimed at reducing the potential for adverse interactions are outlined in Section 4.5 of this Plan.

2.6 Finfish (including sharks and rays)

The significant finfish of the Abrolhos are considered in detail in DoF (2015a, 2015b). The benthic habitats of the Abrolhos support rich fish communities, with up to 389 fish species recorded (Hutchins 1997). The majority of these species (~60–65%) are tropical species, ~15% are subtropical, and ~20–25% are temperate species (Hutchins 1997, Watson et al. 2007). The structure of the fish assemblages differs between fished and non-fished areas (Watson et al. 2007) and there is a greater relative abundance of many of the targeted fish species in areas protected from fishing (Watson et al. 2009, Nardi et al. 2004).

Within these rich communities exists a number of Endangered, Threatened and Protected (ETP) species of finfish. These comprise a variety of sharks, rays, Queensland grouper and syngnathid (pipefish, seahorses and sea-dragons). Most syngnathid species inhabit shallow, sheltered coastal waters, away from the proposed MWADZ. While Queensland grouper possibly exist at the Abrolhos Islands the likelihood of an interaction with the proposed sea-cage operations was considered remote (DoF 2015b). However, interactions between the sharks/rays and the proposed sea-cages are considered more plausible (DoF 2015b).

Management strategies for limiting the potential for adverse interactions between the sea-cage infrastructure and finfish, including sharks and rays, are provided in Sections 4.6 and 4.7 of this Plan.

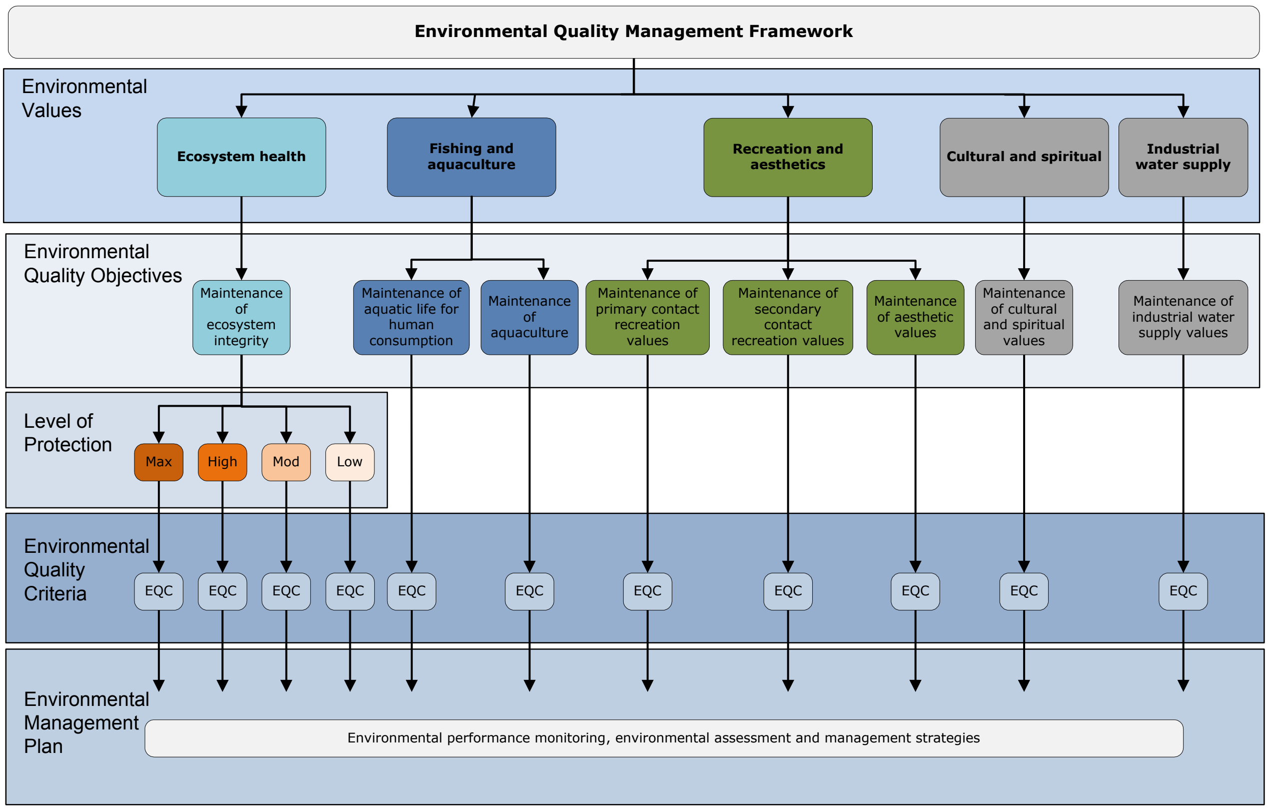
3. Environmental Management Framework

3.1 Approach to marine environmental management

Marine environmental management in WA is undertaken according to the environmental quality management framework (EQMF) described in EAG 15 (EPA 2015). The purpose of this section is to describe the elements of the EQMF, which together provide the foundation for this Plan.

3.1.1 Environmental values and environmental quality objectives

The intent of the EQMF is that, for each significant water body in WA, a series of EVs with associated EQOs will be selected and applied in consultation with the community and stakeholders. EVs refer a particular value or use of the marine environment that are important for a healthy ecosystem or, for public benefit, welfare, safety or health, and which requires protection from the effects of pollution, environmental harm, waste discharges and deposits. The EQOs are high-level management objectives required to protect the EVs (EPA 2015) (Figure 3.1). The objective is to ensure the marine environment (in this case the MWADZ and surrounding region) is managed to achieve the relevant Environmental Values (EVs) and Environmental Quality Objectives (EQOs), as outlined in Environmental Assessment Guideline (EAG) No. 15 (EPA 2015) and the State Water Quality Management Strategy (Government of Western Australia 2004) (Table 3.1).



Notes:

1. Modified from Figure 1 (page 7) of EPA (2015a)
2. EQC are environmental quality criteria (see Section 3.1.4)

Figure 3.1 Conceptual overview of the environmental quality management framework applied to Western Australia's marine environment

Table 3.1 Environmental values and environmental quality objectives that apply in the MWADZ and surrounds

Environmental Values	Environmental Quality Objectives
Ecosystem health	1. Maintain ecosystem integrity at a high level of ecological protection 2. Maintain ecosystem integrity at a moderate level of ecological protection This means maintaining the structure (e.g. the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems to an appropriate level
Recreation and aesthetics	Water quality is safe for primary contact recreation (e.g. swimming and diving). Water quality is safe for secondary contact recreation (e.g. fishing and boating). Aesthetic values of the marine environment are protected.
Cultural and spiritual	Cultural and spiritual values of the marine environment are protected.
Fishing and aquaculture	Seafood (caught or grown) is of a quality safe for eating. Water quality is suitable for aquaculture purposes.
Industrial water supply	Water quality is suitable for industrial use.

Notes:

1. Modified from Table 1 of EPA (2015a).
2. Refer to Figure 3.7 of this EMMP.

3.1.2 Environmental values and objectives at risk from operations

While aquaculture Proponents have an obligation to meet each of the EQOs, only a small number EQO are at risk due to aquaculture operations. The cause effect pathways related to fin-fish aquaculture are outlined in Section 3.2.2 of this Plan. The EVs for Recreation, Fishing and aquaculture and Industrial water supply are concerned with the protection of the human population from the potential adverse effects of toxicants and microbiological contaminants (typically present in sewage and storm water) and the protection of nearby aquaculture and industry from the effects of toxicants and other contaminants (EPA 2015a). The key pressures associated with aquaculture are inputs of nutrients and organic material derived from fin-fish metabolic processes and feeding. As such, none of the pressures identified in Section 3.2.2 of this Plan are expected to compromise the EQOs for these EVs.

The cultural and spiritual values of the Abrolhos region will be protected by maintaining key ecosystem functions, and the general aesthetic qualities of the nearby water. These are protected in this Plan by a commitment to meet the EQOs for maintenance of ecosystem integrity and aesthetic values, which in turn will to be assessed against a series of Environmental Quality Criteria (EQC), also been developed as part of this Plan.

3.1.3 Levels of ecological protection

The EQO, to ‘maintain ecosystem integrity’, is unique in that it encompasses differing levels of ecological protection (LEP): maximum, high, moderate and low (Table 3.2). Differing levels are applied in recognition of the competing environmental, societal and industrial uses of the marine environment. Because of competing interests, it is recognised that not all areas can achieve (or retain) high to maximum levels of ecosystem protection, and that some areas must instead be given either moderate or low ecological protection status (EPA 2015), with corresponding limits of acceptable change. The framework allows for small localised effects, while aiming to maintain overall environmental integrity (EPA 2015). This is important in the context of this Plan, which includes strategies to manage the expected reduction in environmental quality beneath and immediately adjacent to the MWADZ sea-cages, while maintaining broader regional environmental quality (see Section 3.2.4).

Table 3.2 Levels of ecological protection linked to the environmental quality objective for maintenance of ecosystem integrity

Level of ecological protection	Environmental quality conditions (limit of acceptable change)	
	Contaminant concentration indicators	Biological indicators
Maximum	No contamination – pristine	No detectable change from natural variation
High	Very low levels of contaminants	No detectable change from natural variation
Moderate	Elevated levels of contaminants	Moderate changes from natural variation
Low	High levels of contaminants	Large changes from natural variation

3.1.4 Environmental quality criteria

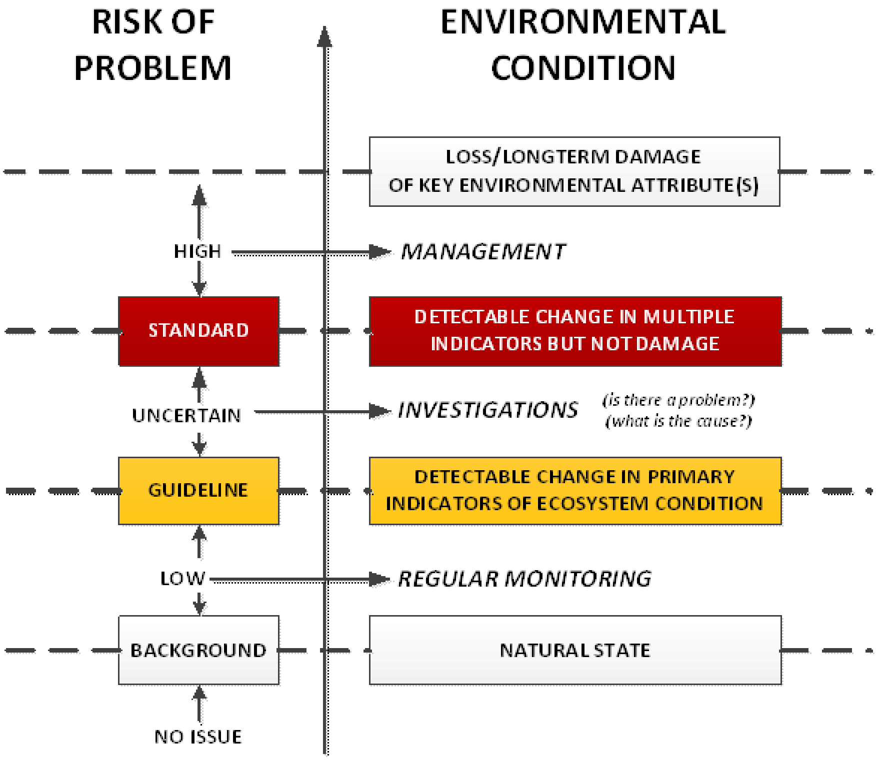
Following commencement of aquaculture operations, Proponents will be required to demonstrate they are achieving the EQOs. The extent to which the EQOs have been achieved will be assessed against a suite of environmental quality criteria (EQC). The EQC, comprising guidelines and standards, provide the benchmarks against which environmental quality is measured. Unlike the EQOs, which are qualitative and described as a narrative, the EQC are quantitative and described numerically (EPA 2015).

The EQC are based on cause-effect-response relationships relating to the potential impacts (pressures) of the proposed activity, and to the specific environmental systems (response) where the activity will occur (EPA 2015).

An important aspect of the EQMF is that the EQC define the limits of acceptable change to environmental quality. Under the EQMF, Proponents are required to maintain environmental quality within the bounds described by the EQC. If the EQC are met, then it is assumed that the EQOs have been achieved. There are two levels of EQC:

- Environmental Quality Guidelines (EQGs) are quantitative, investigative triggers which, if met, indicate there is a high degree of certainty that the associated EQO has been achieved. Indicators used as EQGs should be closer to the pressure end of a pressure-response relationship (i.e. provide early warning of a potential problem). If the guideline is not met, there is uncertainty as to whether the associated EQO has been achieved; and
- Environmental Quality Standards (EQSs) are threshold numerical values or narrative statements that indicate a level beyond which there is a significant risk that the associated EQO has not been achieved. EQSs should be closer to the response end of a pressure-response relationship (i.e. measure the affected organisms/habitats). Continued exceedance of an EQS will trigger a management response. The response would normally focus on identifying the cause of the exceedance and reducing the contaminant loads. In situ remedial work may also be required. EQSs are generally equivalent to the water quality objectives described in ANZECC & ARMCANZ (2000a).

The conceptual framework for applying the EQC is illustrated in Figure 3.2.



Notes:

1. Adapted from Figure 3 (page 14) of EPA (2015a)

Figure 3.2 Conceptual framework for applying the environmental quality guidelines and standards

3.2 Applying the management framework

3.2.1 Environmental pressures of aquaculture

This section of the plan considers the potential for adverse interactions between the MWADZ and the marine environment. The potential for adverse effects is considered in the context of the key environmental factors and impacts outlined in the ESD (Table 2.1). Strategies for managing the potential impacts of the MWADZ proposal are outlined in Section 4.

Aquaculture service vessels

Noise generated by vessel movement and other aquaculture activities has the potential to disturb marine fauna, causing temporary or long-term avoidance of an area. Depending on their magnitude and frequency, underwater sounds may interfere with communication systems, mask important biological cues or cause behavioural disturbances (Richardson et al. 1995, National Research Council 2005, Southall et al. 2007). Underwater noises associated with aquaculture are expected to be limited to engine noises generated by service vessels (i.e. feeding barges) and intermittent low intensity sounds such as those generated by infrastructure maintenance. Engine noises are expected to be of similar frequency and intensity to those of commercial fishing boats (Olesiuk et al. 2012). For marine mammals, the effects of these vessels are transitory and the animals can generally habituate to these sounds with regular exposure. Risks associated with underwater noise are therefore considered low. Mitigation strategies for managing the effects of underwater noise are included in Section 4.5.

Sea-cage infrastructure and feeding

The MWADZ will employ floating sea cages, arranged within clusters anchored to the seafloor (Figure 3.3) and will employ state of the art sea-cage infrastructure encompassing durable high-tensile materials and anchoring systems appropriate to the local environment. A conceptual overview showing indicative sea-cage configuration is shown in Figure 3.4.

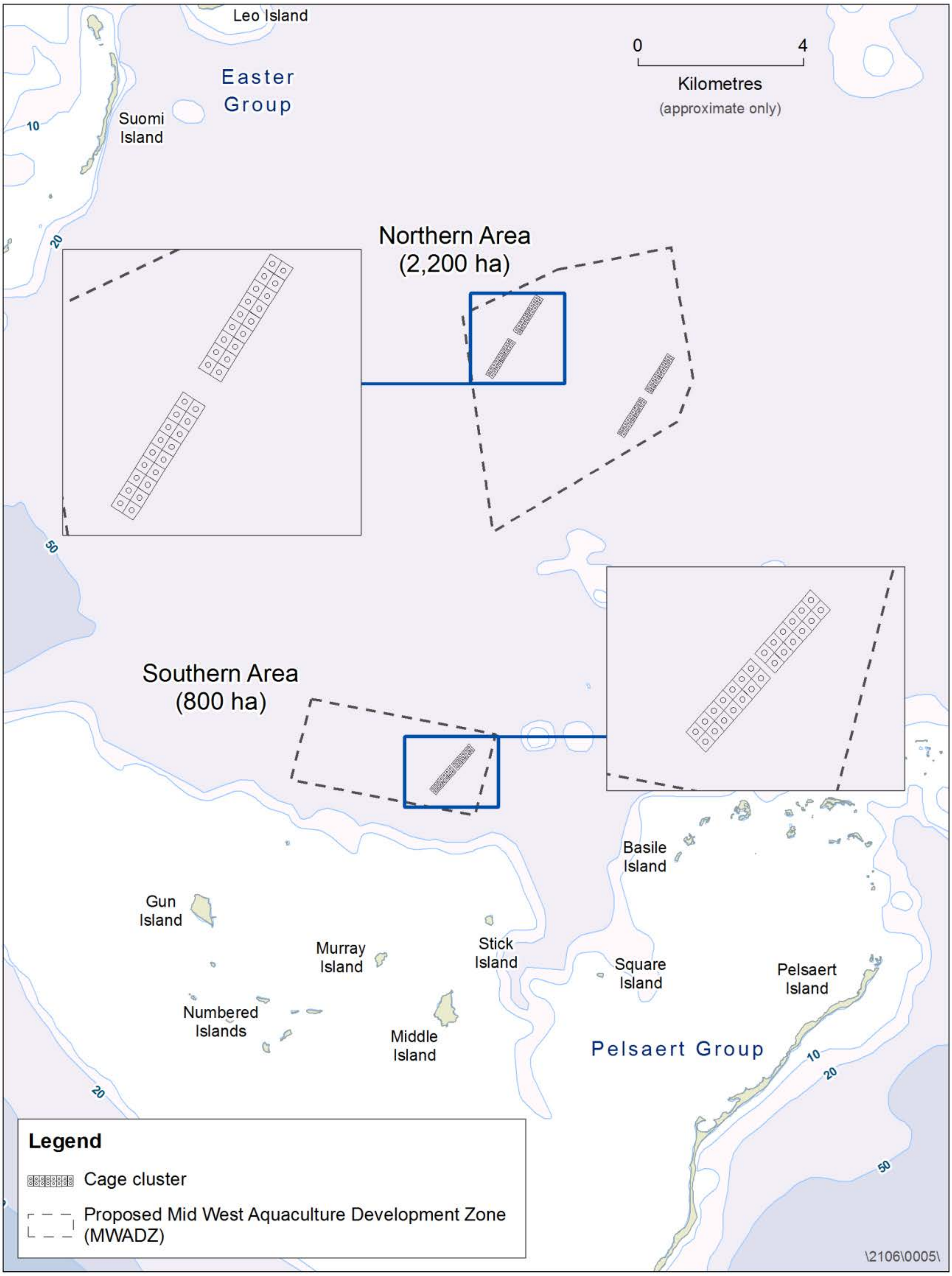


Figure 3.3 Conceptual overview of possible sea-cage cluster configurations

Of the potential pressures imparted by the infrastructure, most (i.e. physical presence, changes to hydrodynamics, risk of entanglement/entrapment and an attractant/distraction) are considered manageable (BMT Oceanica 2015), and few present residual risks with ongoing needs for environmental monitoring. These findings notwithstanding, the pressures resulting from feeding (and to a lesser extent, care of stock) are potentially significant, and form a key consideration in this Plan. There are two significant cause-effect pathways beginning with inputs of artificial feeds: (1) those resulting in changes to seabird, turtle, marine mammal and finfish behaviour, and (2) those resulting in environmental nutrient enrichment and the secondary effects which follow (Section 3.2.2).

The Proponent will include in the Annual Compliance Report, aquaculture associated data recorded quarterly for each operational cage[1]:

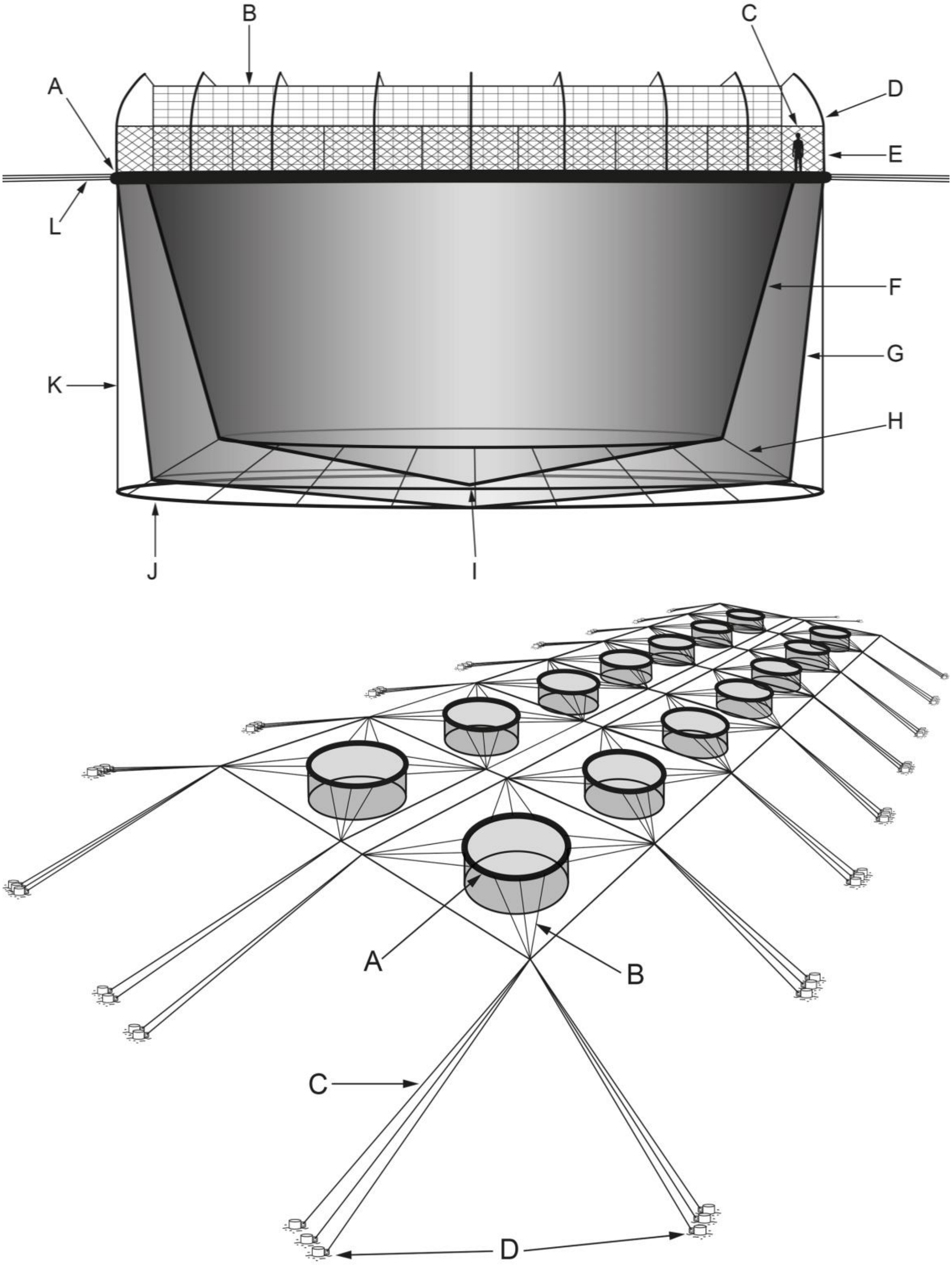
1. Standing stock densities;
2. Stock biomass;
3. Stock growth rates;
4. Feed/waste ratio;
5. Location, i.e. GPS coordinates;
6. Depth of water;
7. Quantity of feed administered to stock;
8. Feed type, make and specifications; and
9. Type and quantity of treatment pharmaceuticals administered to stock in situ.

Seabirds, marine mammals and finfish

The EIA for this proposal (BMT Oceanica 2015) identified certain seabirds (Pacific and silver gulls) and the Australian sea-lion as being particularly at risk due to the introduction of sea-cages. Through their attraction to artificial food sources (and to a lesser extent artificial habitats), both may exhibit changes in behaviour and feeding habitats, with potential for secondary effects to populations structure (through either increases or decreases in population size). However, experience gained in Australia and internationally has resulted in advances in knowledge of aquaculture environmental management, including methods for minimising the risks to seabirds and marine mammals.

The EIA for this proposal found that the use of best practice approaches to the design of sea cages, management of netting, exclusion devices and protocols for reducing feed wastage are expected to reduce the potential for exploitation by these animals (Sections 4.4, 4.5 and 4.6). Mitigation strategies for managing the potential adverse effect of artificial feed sources (both pelletised feeds and the aquaculture stock) on sea-birds, marine mammals and finfish are outlined in Sections 4.4, 4.5 and 4.6, respectively.

[1] *Parameters 1 - 9 can be estimated using all available information (i.e. are not required to be precise, direct measurements).*



Notes:

1. Upper Panel: All nets and mesh are durable and high tensile: A - Floating collar to suspends nets; B - Taut overhead net to prevent seabird access to stock and feed; C - High sea lion-exclusion barrier to prevent wildlife from accessing the walkway; D - Long flexible net-poles to support, suspend and maintain tension of the overhead seabird-exclusion nets several metres above the water; E - Stanchions (posts) to support the sea lion-exclusion barrier; F - Stock containment net (fully enclosed); a component of the double net system; G - Marine-predator exclusion net (fully enclosed); a component of the double net system; H - Net-baseline rope to link nets to the sinker tube; I - False net-bottom, created by the double net system, to keep stock separated from marine predators; J - Sinker tube, suspended from the nets, to maintain tension and support the structure of the nets; K - Weight line to facilitate lifting the sinker tube and bottom of the nets; L -Mooring lines, connected to the anchoring system, to hold the sea cage in position.
2. Lower Panel: All lines and cables are durable, high tensile and appropriate for an anchoring system designed to withstand extreme loads: A - Sea Cage; B - Mooring lines; C - Anchor cables; D - Low profile mooring-anchors.

Figure 3.4 Indicative sea-cage engineering (upper), configuration and anchoring (lower)

Sediments
Finfish aquaculture has the potential to impact the sediment when organic wastes settle beneath or in close proximity to the sea-cages (Mazzola et al. 2000, Carroll et al. 2003), resulting in increased nutrient loads. Significant nutrient loadings are generally associated with increased episodes of anoxia, particularly in stratified waters, with subsequent detrimental effects to infauna (Baden et al. 1990, Hargraves et al. 2008, Schaffner et al. 1992). Heavy metals form a small constituent of aquaculture feeds which are consumed and excreted in the faeces. A review of the metal content of trout faeces by Moccia et al. (2007) found that copper, iron and zinc were present in the highest proportions, although overall concentrations were low. Despite the low concentrations in commercial feeds, monitoring in Tasmanian waters has recorded copper and zinc values at concentrations higher than the ANZECC & ARMCANZ (2000) ISQG-low and ISQG-high guideline values at some sea-cage sites (DPIPWE 2011). The EIA for this proposal found that metal in feeds posed a very low risk to the marine environment. The approach to monitoring and managing the potential impacts of organic wastes is outlined in Section 4.2.

In addition to contributing organic wastes to the seafloor, aquaculture may contribute pharmaceuticals to the marine environment. Antibiotics are used as needed to treat bacterial disease occurring in farmed fish and are generally administered in feed. Calculations have shown that 70% to 80% of drugs administered in fish farms end up in the environment, and drug concentrations with antibacterial properties have been detected in sediments beneath sea-cages (Samuelsen et al. 1992). Antibiotics may impart pressure on the environment by reducing or changing numbers of sediment bacteria, which in turn may affect biochemical and/or broader ecological processes. The persistent use of antibiotics has also been shown to lead to bacterial resistance (Anderson and Levin 1999). In the treatment of farmed salmon in Tasmania, oxytetracycline is the most common antibiotic used, accounting for more than 70% of total antibiotic use during 2006–2008 (Parsons 2012). A strong seasonal component to the use of antibiotics has been noted in Tasmania, with the greatest requirement in the summer months when water temperatures are elevated and pathogens most virulent. Oxytetracycline has been found to persist in marine sediments beneath sea cages for up to twelve weeks, with a half-life of ten weeks (Jacobsen and Berglind 1988). However, traces of the drug may be present for up to two years after treatment (Lalumera et al. 2004). It is also relatively persistent to anoxic conditions which are common under sea-cages (Jacobsen and Berglind 1988). Because antibiotics are administered in feeds, the spatial extent of potential impacts is likely reflected in the settlement patterns of organic wastes. Modelling predicted that the majority of wastes[2] in the MWADZ would be deposited to the seafloor within 60 m of the sea-cages[3]. If antibiotics are required, it would be administered for short periods of time. The strongest effects of antibiotics could last for up to 10 weeks but are likely to be constrained to relatively small areas.

Water Column
Sea-cage aquaculture contributes inorganic nutrients to the water column either directly through secretion of ammonia by fish, or indirectly through organic matter deposition and remineralisation and the sea-floor level. Inorganic nutrients (ammonia, nitrite + nitrate and orthophosphate) may lead to adverse environmental effects via a number of cause-effect-response pathways (Figure 3.5). Nutrients may be assimilated directly by phytoplankton and/or macroalgae, leading to shading effects, phytoplankton blooms or the proliferation of ‘nuisance’ epiphytes.

---

2 *As represented by the Zone of High Impact*
3 *After 3 years production*

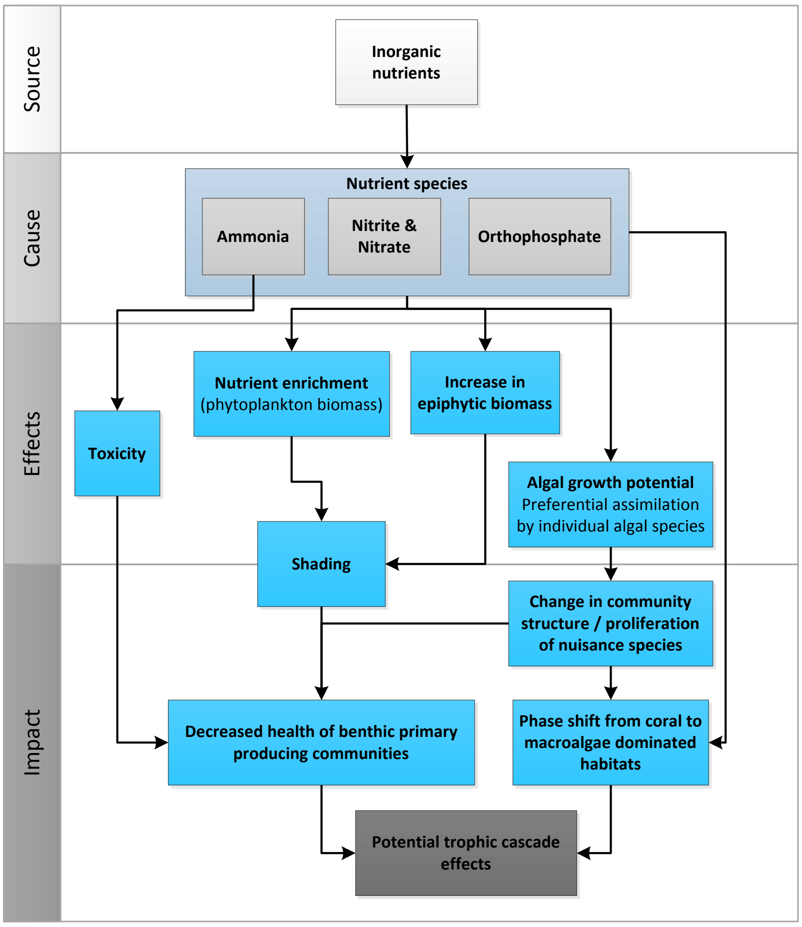


Figure 3.5 Cause-effect-response pathways relevant to inorganic nutrients

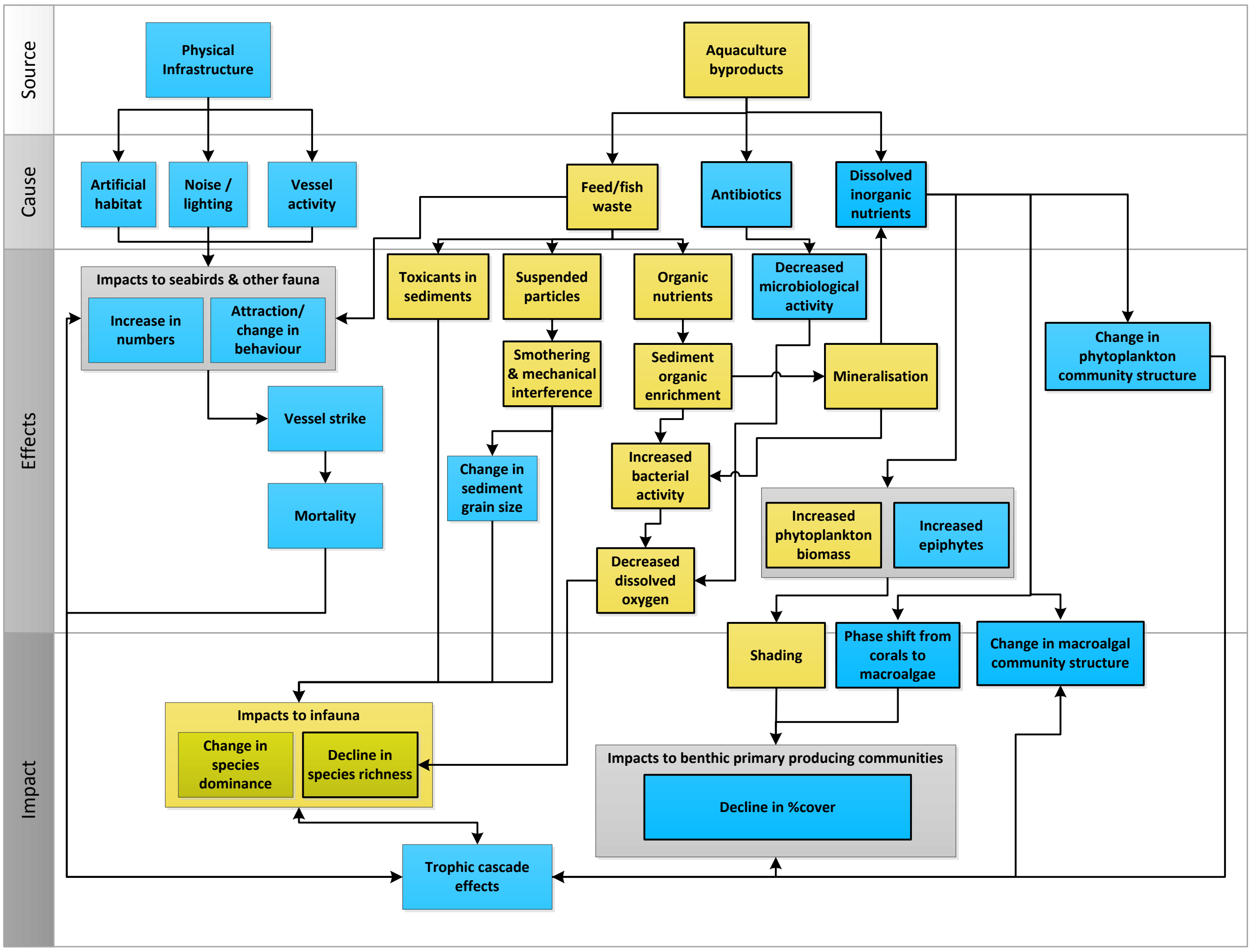
Sea-cage aquaculture may also lead to an increase in the concentration of suspended particles (total suspended solids) in the water column (Figure 3.6). Smothering may be an issue when the organic wastes expelled from the sea-cages settle to the sea-floor. Smothering occurs when the volume of material reaching the seafloor exceeds the shedding capacity of marine organisms, or their limit of inundation tolerance (PIANC 2010). Smothering is a concern under conditions of low shear stress, when dispersion potential is reduced (BMT Oceanica et al. 2015). A proportion of these wastes may be resuspended, creating additional scope for mechanical interference to filter feeding processes, or reduction of photosynthetic pathways particularly at depth (Erftemeijer et al. 2012). The deposition of organic material may also lead to dissolved oxygen drawdown in the water column as biological respiration increases in response to increased sediment nutrient loads (Gray 1992). Episodes of hypoxia or anoxia can subsequently cause loss of benthic populations, changes in benthic communities, or reduced growth rates (Forbes & Lopez 1990, De Zwann et al. 1992, Josefson & Jensen 1992, Stachowitsch 1992, Gaston & Edds 1994, Forbes et al. 1994).

The potential for the MWADZ to adversely affect the local and regional marine environment was evaluated using an integrated environmental model (BMT Oceanica et al. 2015). Deposition of organic material was predicted to lead to changes in sediment oxygen and sulphide concentrations beneath the sea-cages. Results indicated that the size of the impact was related to stocking density and the duration of operations (BMT Oceanica 2015).

Concentrations of dissolved inorganic nitrogen (DIN) down-current of the sea-cages increased with increasing finfish biomass. However, the plumes dissipated rapidly, and concentrations generally returned to levels commensurate with a high level of ecological protection inside the MWADZ boundary (BMT Oceanica 2015). Any corresponding increase in chlorophyll-a resulting from aquaculture activities would therefore be expected to occur away from the sea cages. Although the proposal presents conditions under which phytoplankton may flourish, thus also increasing light attenuation, none of the modelled scenarios predicted increases in chlorophyll-a concentrations and sub-surface light conditions were not affected.

3.2.2 Cause-effect-response relationships

The cause-effect-response pathways are summarised below (Figure 3.6). The objective was to identify the key stressors and their effects, based on the risks identified in Section 3.2.1. The understanding gained by this process was used to identify the indicators and receptors that form the EQC in this Plan.



Notes:

1. Key cause-effect-response pathways. Pathways shown in yellow represent those for which EQC were developed.

Figure 3.6 Hierarchical stressor model showing the cause-effect pathways of most concern and the receptors potentially impacted by aquaculture

3.2.3 Environmental quality criteria for aquaculture

EQC were derived based on the key environmental pressures identified in Section 3.2.1 and the cause-effect pathways shown in Figure 3.6. EQG and EQS were developed for measurable indicators, or for indicators for which there were precedents as guided by EPA (2014) (Table 3.3). EQC were thus developed for water quality, sediment quality and aesthetics. The EQC for these elements are included in Sections 4.1, 4.2 and 4.8.

The potential for adverse effects to other receptors, marine mammals, turtles, sea-birds and finfish were considered manageable via engineering and/or proactive management solutions, and no EQC were developed in these cases. Management strategies relevant to these elements are included in Sections 4.4, 4.5, 4.6, and 4.7.

Table 3.3 Measurable indicators used to derive the environmental quality criteria

<table>
<tr><th>Source / Cause</th><th>Monitoring</th><th>EQG</th><th>EQS</th></tr>
<tr><td rowspan="9">• Aquaculture feeds
• Finfish wastes
• Inorganic nutrients</td><td rowspan="4">Water quality</td><td>Light attenuation coefficient</td><td rowspan="2">Total suspended solids
Infauna community diversity</td></tr>
<tr><td>Total suspended solids</td></tr>
<tr><td>Chlorophyll-a</td><td>Light attenuation coefficient</td></tr>
<tr><td>Dissolved oxygen</td><td>Surface-bottom dissolved oxygen</td></tr>
<tr><td rowspan="5">Sediment</td><td>Total nitrogen</td><td rowspan="3">Sediment infauna
Bottom water dissolved oxygen</td></tr>
<tr><td>Total phosphorus</td></tr>
<tr><td>Total organic carbon</td></tr>
<tr><td>Copper</td><td rowspan="2">Infauna community diversity</td></tr>
<tr><td>Zinc</td></tr>
<tr><td rowspan="5">• Physical infrastructure
• General operations
• Finfish and other wastes
• Litter and spills</td><td rowspan="5">Aesthetics</td><td colspan="2">Nuisance organisms</td></tr>
<tr><td colspan="2">Water clarity (qualitative)</td></tr>
<tr><td colspan="2">Petrochemical surface films</td></tr>
<tr><td colspan="2">Surface debris</td></tr>
<tr><td colspan="2">Odours</td></tr>
</table>

3.2.4 Levels of ecological protection for aquaculture

The EQO for maintenance of ecosystem integrity requires the spatial definition of four or less LEPs – maximum, high, moderate and low (Section 3.1.3). The rationale for designation of LEPs is based on the expectation that aquaculture operations will reduce environmental quality on a local scale, such that a maximum or high LEP may not be achievable immediately beneath and adjacent to operational infrastructure. The EPA expects the cumulative size of the areas designated as moderate or low ecological protection areas to be proportionally small compared to the areas designated high and maximum.

Guidance provided by the EPA suggests that finfish aquaculture (defined as sea-cages) in Western Australia should be managed to achieve a 'moderate' LEP (LEP) (Table 3, EAG 15). In areas assigned a moderate LEP, operational pressures are expected to result in small changes to the abundance and biomass of marine life, and in the rates but not the types of ecosystem processes. Under the same LEP, there should be no detectable and persistent changes in biodiversity due to waste discharges or contamination.

Environmental modelling undertaken for this project (BMT Oceanica 2015) predicted that any organic enrichment resulting from aquaculture would be locally constrained, with no resulting regional scale adverse effects (BMT Oceanica 2015). For example, modelling predicted that the most severe impacts would be restricted to a distance of 110 m after 5 years production, and 55 m and 50 m after 3 and 2 years production, respectively. While changes to the sediment chemistry and resident biological assemblages are expected to occur under these scenarios, the changes are predicted to be locally constrained, with no resulting detectable impacts beyond 100 m from the sea-cages (under full production). Furthermore, any changes to the sediment chemistry and the resident invertebrate fauna are expected to be fully reversible under a program of routine fallowing (see Section 6).

Based on the above, it is proposed to establish three moderate ecological protection areas (MEPAs), each of 300 m radii, within a broader high ecological protection area (HEPA): two in the northern area and one in the southern area. The framework has been designed to be moderately protective of habitats within the MEPA (with a decreasing gradient of effect between the sea-cages and the HEPA boundary) and highly protective of habitats outside of the MEPA, including sensitive coral reef habitats. Proponents will be expected to demonstrate they are meeting the designated LEPs for the life of the project, by complying with the EQC for moderate and high ecological protection as outlined in Sections 4.1 and 4.2 of this Plan.

The proposed MEPAs will be complemented by an additional six recovery zones, which when operational, will also be assigned a moderate LEP. At the commencement of fallowing, the recovery zones will be monitored until it can be demonstrated that they have recovered to levels consistent with a high LEP. The cumulative area occupied by the MEPAs and the recovery zones is less than 5% of the area within a 10 km radius of the MWADZ, which is within the acceptable limit for MEPAs specified in EAG 15 (EPA 2015). The spatial arrangement and extent of the moderate and high LEPs to be applied to the MWADZ is illustrated in Figure 3.7.

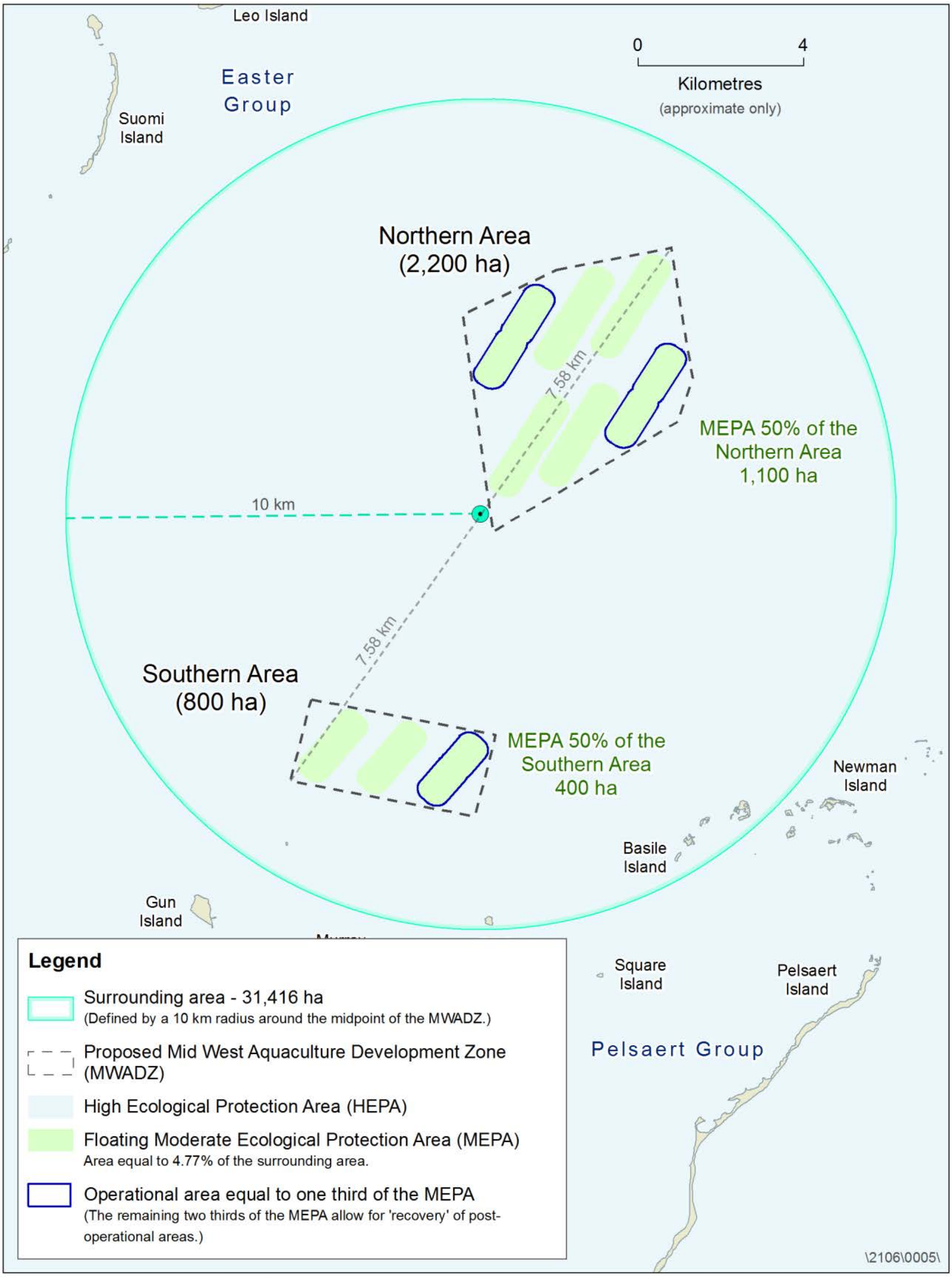


Figure 3.7 Environmental Quality Plan (EQP) for the MWADZ and surrounds. The locations of the MEPAs are conceptual, but will be contained within the Northern and Southern areas of the MWADZ and not exceed 50% of the area in each.

Note: The MEPAs and HEPA shown in the EQP relate to the EV of 'Ecosystem Health'. All social use EVs ('Fishing and Aquaculture', 'Recreation and Aesthetics', 'Cultural and Spiritual' and 'Industrial Water Supply') apply throughout the MWADZ and surrounds.

4. Monitoring and Management

Each of the key environmental factors identified in the ESD is encompassed within the EV for ecosystem health and the EQO for maintenance of ecosystem integrity. In this context, the Plan includes strategies and contingency management responses to protect the major elements of the ecosystem: water and sediment quality, as required under the EQMF, with additional emphasis on seabirds, marine mammals, turtles, and finfish (Sections 4.1, 4.2, 4.4, 4.5 and 4.6). The importance of biosecurity is also considered (Section 4.7). The EQOs for aesthetic, cultural and spiritual values are also considered relevant, but only the EQO for aesthetic values is considered further in this Plan (Section 4.8).

4.1 Water quality

4.1.1 Objectives

The water quality monitoring program aims to determine whether the EQC have been met in the MEPA generally, and at the HEPA boundary located 300 m down-current of the sea-cages. It complements the sediment monitoring program by providing complementary information about the volume of suspended materials (TSS) and dissolved oxygen (DO) near to and at increasing distances from the sea-cages. It also provides data necessary to determine the extent of nutrient enrichment (if any) at the Zone boundary (Chl-a) and the potential for secondary shading effects (LAC). The water quality monitoring program includes measurements for total suspended solids (TSS), chlorophyll-a, light attenuation coefficient (LAC) and dissolved oxygen (DO). All records associated with the water quality monitoring program, including the results of statistical analyses, shall be included in the Annual Compliance Report (see Section 7.1).

4.1.2 Timing

Water quality sampling will be conducted at monthly intervals between December and February (three times in total), capturing the summer season, and at monthly intervals between June and August (three times in total), capturing the winter season.

4.1.3 Program design

Dissolved oxygen and TSS

DO and TSS measurements will be taken along a transect bridging the high and moderate ecological protection areas, with three sites in the HEPA and seven in the MEPA. Each transect will be positioned along the vector corresponding to the prevailing current direction (Figure 4.1). To enable comparisons with background levels, sampling for DO and TSS will also be undertaken at the nearest four reference sites (Figure 4.1). Reference site coordinates are provided in Appendix A.

Chlorophyll-a and light attenuation coefficient sampling design

The program for chlorophyll-a and LAC was developed based on the assumption that any signature attributable to aquaculture will not be immediately detectable (given levels of flushing and the time-lag between nutrient assimilation and phytoplankton growth). Sampling will be undertaken at six compliance sites around the northern zone boundary and four compliance sites around the southern zone boundary[4] (Figure 4.1), all of which will be required to achieve a high LEP. To enable comparison with background levels, sampling for chlorophyll-a and LAC will also be undertaken at the four reference sites nearest to the area occupied (Figure 4.1). Zone and Reference site coordinates are provided in Appendix A.

---

[4] *If only one zone is occupied, then sampling will be restricted to the boundary of that zone. Once both zones (northern and southern areas) are operational, then monitoring will be undertaken at the boundaries of both zones. Proponents will be responsible for monitoring the boundaries of the zones in which they hold leases.*

Chlorophyll-a samples should be collected in duplicate. While both chlorophyll-a samples will be frozen prior to analysis, only one of the samples will be analysed immediately. The other should be stored as a back-up sample.

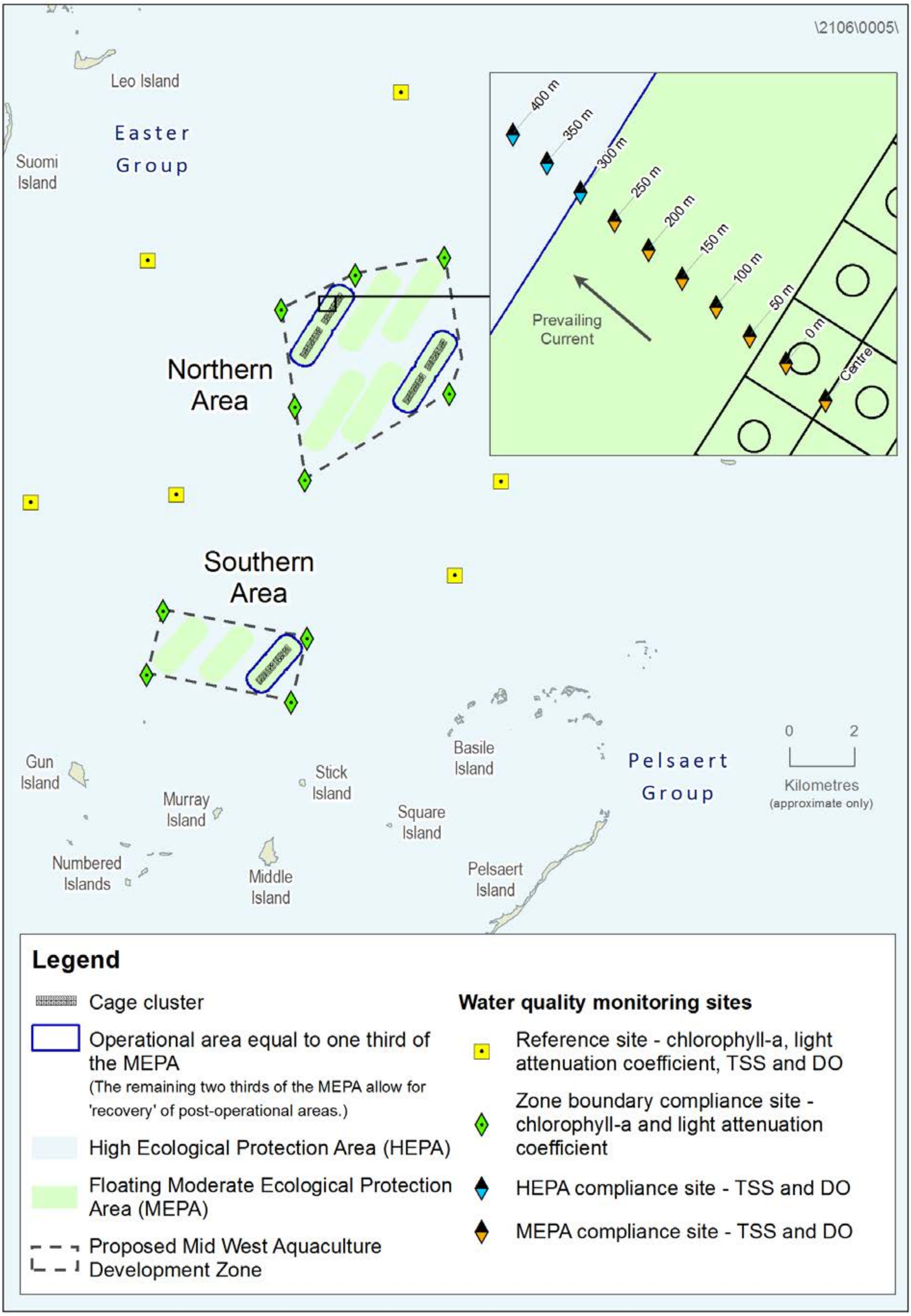


Figure 4.1 Water quality monitoring sites

4.1.4 Approach to sampling

The suite of parameters to be sampled on each occasion is detailed in Table 4.1.

Table 4.1 Water quality parameters to be sampled on each occasion

Protection zone	Parameters			
	TSS	DO	LAC	Chlorophyll-a
MEPA	✓	✓	-	-
HEPA	✓	✓	-	-
Area (HEPA) boundary	-	-	✓	✓
Reference	✓	✓	✓	✓

Notes:

1. TSS = total suspended solids; LAC = light attenuation coefficient; DO = dissolved oxygen

Dissolved oxygen and light attenuation coefficient sampling methods

DO measurements will be taken approximately 50 cm from the bottom using a calibrated water quality sensor. LAC measurements will be conducted using one light sensor positioned ~1 m below the surface and the second approximately 7 m below the surface (this may vary depending on the depth of the water at each site). The light attenuation coefficient (LAC) should be calculated as the difference between the logarithim_{10} of irradiance values at each depth according to the equation:

$$\textit{Light Attenuation Coefficient}\ (\text{LAC}) = (\log_{10} I_1 - \log_{10} I_7) \div \text{water depth}$$

Total suspended solids and chlorophyll-a sampling methods

Measurements of TSS and chlorophyll-a will be undertaken using depth-integrated sampling. Additional measurements of TSS will be taken ~50 cm from the bottom of the water column using a Niskin bottle, being careful not to disturb the seabed during sampling. Standard laboratory analytical procedures will be employed throughout and all sampling and analyses undertaken according to NATA-accredited methods.

4.1.5 Environmental Quality Criteria

The EQG and EQS for water quality and their triggers are provided in Table 4.2 and Table 4.3, respectively. The EQG provide early warning of environmental change, and focus on primary (TSS and LAC) and secondary effects (DO and chlorophyll-a) along the cause-effect-response pathways. As the ammonia fraction of DIN is rapidly assimilated by phytoplankton[5], the potential for adverse effects resulting from inorganic nutrients will be assessed against the EQG for nutrient enrichment, following EPA (2015b). In some instances, the EQS have multiple criteria. The EQS will be exceeded if one of more of the criteria is exceeded. Details on how to apply the EQG and the EQS, including the application of the control charting approach, are provided in Section 5.

[5] *Microscopic algae in the water column*

Table 4.2 Environmental quality guidelines for water quality

Effect[2]	EQG[1]	High Protection	Moderate Protection
Shading & smothering	TSS	Median TSS over a three month period, at any HEPA compliance site, must be less than the 80%ile of reference site data	Median TSS over a three month period, at any MEPA compliance site must be less than the 95%ile of reference site data
	LAC	Median LAC over a three month period, at any Area (HEPA) compliance site, must be less than the 80th %ile of reference site data	N/A[3]
Nutrient enrichment	Chl-a	Median chlorophyll-a over a three month period at any Area (HEPA) compliance sites must be less than the 80th percentile of reference site data	N/A[3]
Physical & chemical stressors	DO	Median bottom water DO over a three month period at any HEPA compliance site must be greater than 90% saturation	Median bottom water DO over a three month period at any MEPA compliance site must be greater than 80% saturation

Notes:
1. EGQ = environmental quality guideline; TSS = total suspended solids; LAC = light attenuation coefficient; DO = dissolved oxygen
2. Effect refers to the cause-effect pathways described in Figure 3.6
3. Assessed in the HEPA only

Table 4.3 Environmental quality standards for water quality

Effect[1]	EQS[2]	High Protection	Moderate Protection
Shading & smothering	TSS	The upper 95% CI of TSS from pooled HEPA compliance sites, not to be lower than the lower 95% CI of the reference sites, as determined via control charting	(i) The number of infauna families recorded (across pooled MEPA sites) is not to be less than the number of families recorded during baseline surveys, or relative to the reference sites in two consecutive sampling events or (ii) Video surveys undertaken under or at any distance from the sea-cages shall not record the combined presence of bacterial mats (*Beggiatoa* spp.) or spontaneous outgassing of hydrogen sulphide, relative to earlier baseline assessments
	LAC	The upper 95% CI of LAC from pooled Zone compliance sites, not to be lower than the lower 95% CI of the reference sites, as determined via control charting	N/A[4]
Nutrient enrichment	Chl-a	The upper 95% CI of Chl-a from pooled Zone compliance sites, not to be lower than the lower 95% CI of the reference sites, as determined via control charting	N/A[4]
Physical & chemical stressors	DO	(i) Median bottom water DO over a three month period at any HEPA compliance site must be greater than 60% saturation, and not the result of a regional event as indicated by similar reductions in DO at the reference sites or (ii) The number of infauna families recorded (across pooled MEPA sites) is not to be less than the number of families recorded during baseline surveys, or	(i) Median bottom water DO over a three month period at any MEPA compliance site must be greater than 60% saturation and not the result of a regional event as indicated by similar reductions in DO at the reference sites or (ii) The number of infauna families recorded (across pooled MEPA sites) is not to be less than the number of families recorded during baseline surveys, or

Effect[1]	EQS[2]	High Protection	Moderate Protection
		relative to the reference sites in two consecutive sampling events or (iii) Video surveys undertaken under or at any distance from the sea-cages shall not record the combined presence of bacterial mats (*Beggiatoa* spp.) or spontaneous outgassing of hydrogen sulphide, relative to earlier baseline assessments	relative to the reference sites in two consecutive sampling events or (iii) Video surveys undertaken under or at any distance from the sea-cages shall not record the combined presence of bacterial mats (*Beggiatoa* spp.) or spontaneous outgassing of hydrogen sulphide, relative to earlier baseline assessments

Notes:

1. Effect refers to the cause-effect pathways described in Figure 3.6
2. CI = Confidence Interval
3. EQS = environmental quality standard; TSS = total suspended solids; LAC = light attenuation coefficient; DO = dissolved oxygen
4. Assessed in the HEPA only

4.2 Sediment quality

4.2.1 Objectives

The sediment quality monitoring program aims to determine whether the EQC have been met in the MEPA generally, and at the HEPA boundary located 300 m down-current of the sea-cages. It complements the water monitoring program by providing information about the extent of contamination (metals) and/or organic enrichment in the sediments, and the potential for secondary biological effects (infauna) near to and at increasing distances from the sea-cages. The sediment monitoring program includes the following analytes: total nitrogen (TN), total phosphorus (TP), total organic carbon (TOC), metals (copper and zinc) and infauna. All records associated with the sediment quality monitoring program, including the results of statistical analyses, shall be included in the Annual Compliance Report (see Section 7.1).

4.2.2 Timing

Consistent with the water quality sampling, sampling for nutrients and metals will be undertaken at monthly intervals (three times) in the summer season (December to February) and again at monthly intervals in the winter season (June to August). Sampling for infauna will be undertaken once at the beginning of the summer season and again at the end of the summer season.

4.2.3 Program design

Sediment sampling will be undertaken along a transect bridging the high and moderate ecological protection areas, with three sites in the HEPA and seven in the MEPA. Each transect will be positioned along the vector corresponding to the prevailing current direction (Figure 4.2). To enable comparisons with background levels, sampling will also be undertaken at the nearest four reference sites (Figure 4.2). Reference site coordinates are provided in Appendix A.

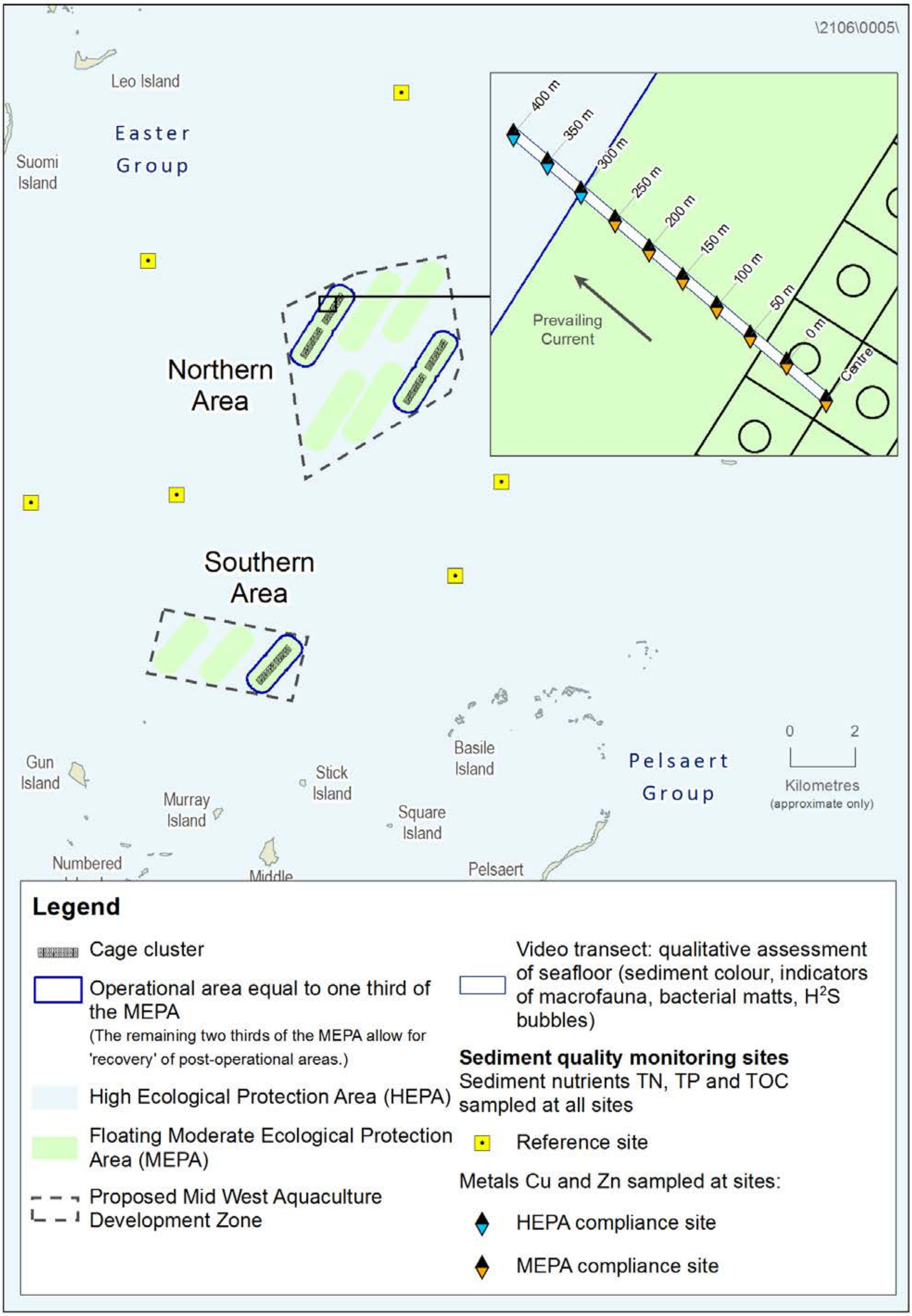


Figure 4.2 Sediment quality monitoring sites

4.2.4 Approach to sampling

The suite of parameters to be measured on each sampling occasion is detailed in Table 4.4.

Table 4.4 Sediment quality parameters to be measured on each sampling occasion

Protection zone	Parameters					
	TN	TP	TOC	Copper	Zinc	Infauna[2]
MEPA	✓	✓	✓	✓	✓	✓
HEPA	✓	✓	✓	-	-	✓
Reference	✓	✓	✓	-	-	✓

Notes:

1. TN = total nitrogen; TP = total phosphorus; TOC = total organic carbon; Copper and Zinc to be sampled four times in the winter and four times in the summer season
2. Infauna to be sampled once at beginning of summer and once at the end of summer

Sediment samples will be collected using protocols modified from EPA (2005). Sample analysis will be undertaken by NATA-accredited laboratories and will achieve limits of reporting (LOR) equal to or less than the ANZECC/ARMCANZ (2000) sediment quality guidelines. Where concentrations are less than the LOR, the LOR will be used in the calculations.

Nutrients and metals

Sediment samples for nutrients and metals will be collected using a Van Veen or equivalent grab sampler. Nutrients will be sampled at MEPA and HEPA compliance and at the reference sites. Metals will be sampled at MEPA compliance sites only (Table 4.4). A minimum[6] of three grabs incorporating the upper 2 cm of sediment will be taken at each site. Each of the grabs shall be homogenised to form one sample as shown in Figure 4.3. The sample will be divided into identical aliquots for nutrient analysis and metals analysis. All aliquots will be frozen for transport to the laboratory, but only half of the subsamples will be analysed immediately. The other half are to be retained as a back-up samples (see Section 5.1.2).

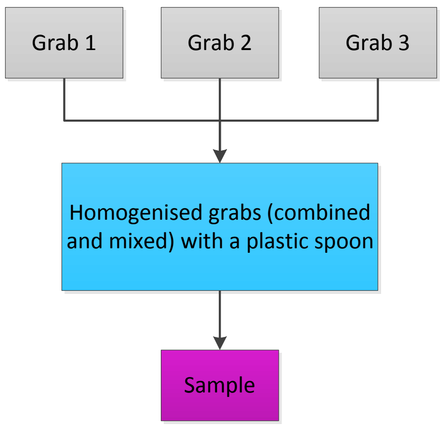


Figure 4.3 Sampling protocol for sediment

Infauna sampling methods

Sampling for infauna will be undertaken once at the beginning of the summer season and again at the end of the summer season. Infauna samples will be collected at the MEPA and HEPA compliance sites and the nearest four reference sites (Figure 4.4; Appendix A). Sediment samples for infauna will be collected using a Van Veen or equivalent grab sampler. Four grabs incorporating the upper 2-5 cm of sediment will be taken at each site. Following collection, the contents of two of the grabs will be consolidated to form one sample, and the content of the other two, to form another. The content of one of the samples will be gently washed through a series of

[6] *It may be necessary to use more than two grabs if two grabs fails to yield enough sample for analysis.*

graded sieves (1-4 mm). Any material retained on the sieves will be fixed in 10% formalin in seawater. This process should then be repeated for the other sample. One of the samples will be sent to the laboratory, and the other stored for later analysis as necessary (see Section 5.1.2). Infauna samples will be processed by laboratories specialising in invertebrate taxonomy. Individual organisms will be identified to family level and counts of each taxonomic group will be recorded.

Although best-practice is to enumerate the number of infauna families present using standard microscopy, it is also recognised that the process is costly and laborious. In the last five years there has been significant progress in 'eDNA bar coding' techniques. These methods offer potentially accurate, cost effective and rapid assessments of infauna taxonomy, particularly if only presence/absence resolution is required. It is recommended that future Proponents investigate the viability of the method and possibly look to use it as an alternative to the approach described above.

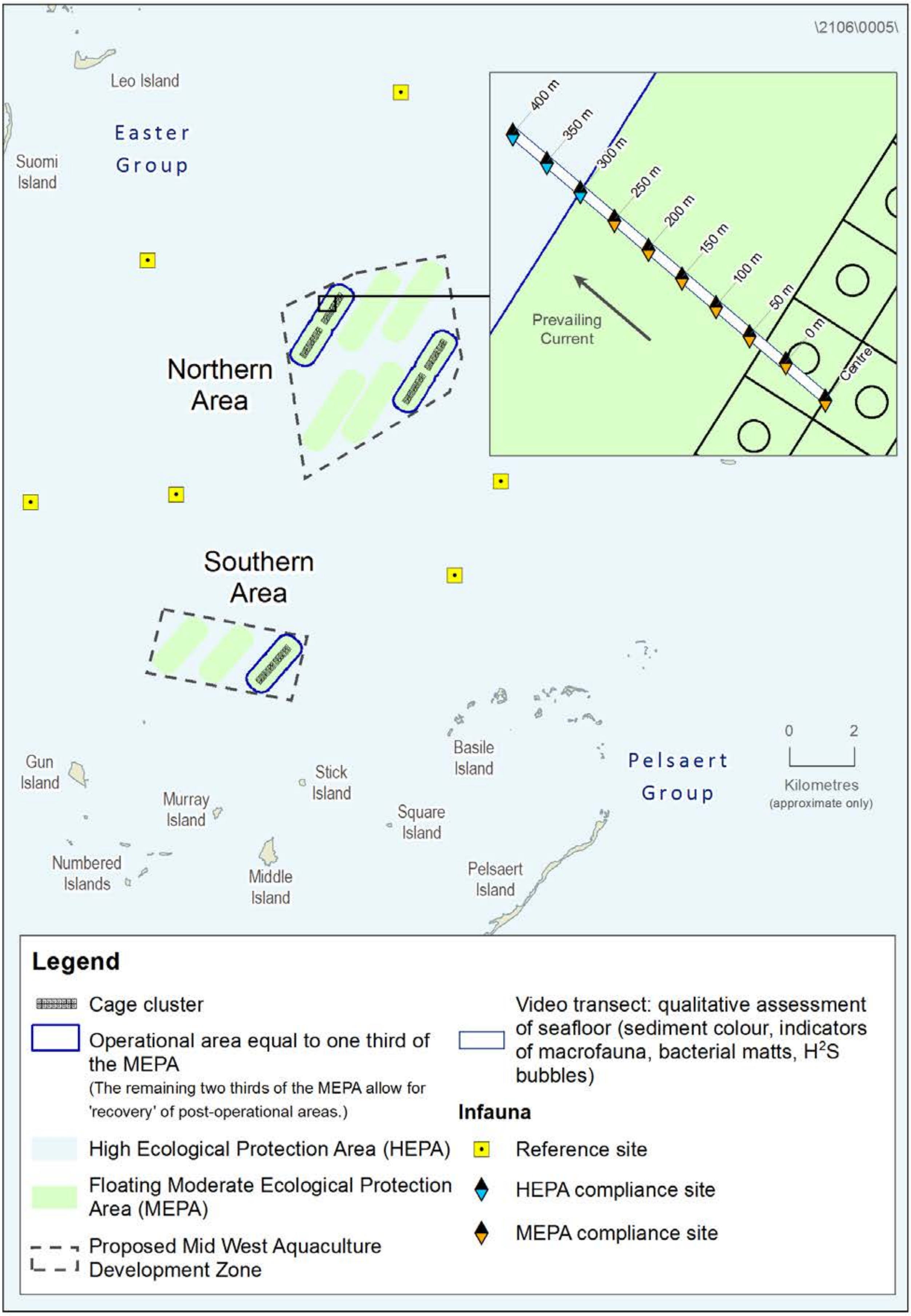


Figure 4.4 Infauna monitoring sites

4.2.5 Environmental Quality Criteria

The EQG and EQS for sediments are outlined in Table 4.5 and Table 4.6, respectively. In some instances, the EQS have multiple criteria. The EQS will be exceeded if one or more of the criteria are exceeded. For details on how to apply the EQG and the EQS, refer to Section 5.

Table 4.5 Environmental quality guidelines for sediments

Effect	EQG	High protection	Moderate protection
Nutrient enrichment	TN TP	Median nutrient concentration over a three month period at any HEPA compliance site must be less than the 80th %ile of reference site data	Median nutrient concentration over a three month period at any MEPA compliance site must be less than the 95th %ile of reference site data
	TOC	Median concentration of TOC over a three month period at any HEPA compliance site must be less than the 80th %ile of reference site data	Median concentration of TOC over a three month period at any MEPA compliance site must be less than the 95th %ile of reference site data
Toxicity	Copper Zinc	Median metal concentration over a three month period at any HEPA compliance site must be less than the Interim Sediment Quality Guidelines - Low (ANZECC/ARMCANZ 2000) (65 mg/kg for copper; 200 mg/kg for zinc)	Median metal concentration over a three month period at any MEPA compliance site must be less than the Interim Sediment Quality Guidelines - Low (ANZECC/ARMCANZ 2000) (65 mg/kg for copper; 200 mg/kg for zinc)

Notes:

1. TN = total nitrogen; TP = total phosphorus; TOC = total organic carbon

Table 4.6 Environmental quality standards for sediments

Effect	EQS	High protection	Moderate protection
Nutrient enrichment	TN TP TOC	(i) The number of infauna families recorded (across pooled HEPA sites) is not to be less than the number of families recorded during baseline surveys, or relative to the reference sites in two consecutive sampling events or (ii) Median bottom water DO at any HEPA compliance site over a three month period must be greater than 60% saturation or (iii) Video surveys undertaken under or at any distance from the sea-cages shall not record the combined presence of bacterial mats (*Beggiatoa* spp.) or spontaneous outgassing of hydrogen sulphide, relative to earlier baseline assessments	(i) The number of infauna families recorded (across pooled MEPA sites) is not to be less than the number of families recorded during baseline surveys, or relative to the reference sites in two consecutive sampling events, or (ii) Median bottom water DO calculated from pooled MEPA compliance sites over a three month period must be greater than 60% saturation and not the result of a regional event as indicated by similar reductions in DO at the reference sites, or (iii) Video surveys undertaken under or at any distance from the sea-cages shall not record the combined presence of bacterial mats (*Beggiatoa* spp.) or spontaneous outgassing of hydrogen sulphide, relative to earlier baseline assessments
Toxicity	Copper Zinc	The number of infauna families recorded (across pooled HEPA sites) is not to be less than the number of families recorded during baseline surveys, or relative to the reference sites in two consecutive sampling events	The number of infauna families recorded (across pooled MEPA sites) is not to be less than the number of families recorded during baseline surveys, or relative to the reference sites in two consecutive sampling events

Notes:

1. TN = total nitrogen; TP = total phosphorus; TOC = total organic carbon
2. CI = Confidence Interval
3. The environmental quality standard for copper and zinc is commensurate with EQS E in Table 3 of EPA (2014). EQS E requires that there be no significant changes in a biological or ecological indicator that can be demonstrably linked to the contaminant.

4.3 Benthic quality (video)

4.3.1 Objectives

In addition to the quantitative measurements described above, further qualitative assessments will be undertaken using underwater video. The objective of the video assessment is to provide complementary observational data based on known indicators of sediment organic enrichment, including presence/absence of 'blackened' sediment, indicators of bioturbation (burrows & tracks), bacterial mats (*Beggiatoa* spp.) and the presence of gaseous bubbles (typically hydrogen sulphide). The use of such criteria is well established in other parts of Australia, and its use here forms complementary but essential data for comparison with the EQS.

4.3.2 Timing

Video assessment will be undertaken prior to commencement of stocking and then at six monthly intervals during operations (timed to coincide with the summer and winter monitoring programs). Monitoring will be undertaken at the operational and recovery sites.

4.3.3 Monitoring program design

Video assessments will be undertaken along a single transect commencing at the sea-cages (centre) and finishing 400 m down-current (Figure 4.2). The transect will be positioned along the vector corresponding to the prevailing current direction and will encompass MEPA and HEPA compliance sites.

4.3.4 Approach to sampling

To capture video footage an appropriate sled or remotely operated vehicle (ROV) carrying an underwater video camera will be flown along the transect. Two passes will be made along each transect. Video footage will be analysed and a database of observations will be generated.

The presence and number of sighted benthic fauna and flora (including the presence of *Beggiatoa* spp.) will be recorded along with observations of other benthic characteristics, including evidence of spontaneous outgassing, sediment colour and bioturbation. An example template for semi-quantitative and qualitative observations is provided in Table 4.7, with red cells indicating observations of concern, some of which form part of the EQS outlined in Table 4.6.

Table 4.7 Example template showing potential qualitative criteria for video surveys

LEP	Distance	Colour					
		Baseline	June 2016	Jan 2017	June 2017	Jan 2018	June 2018
MEPA	Centre	White	Off white	Brown	Brown	Near black	Black
	0 m	White	Off white	Off white	Off white	Off white	Brown
	50 m	White	White	Off white	Off white	Off white	Off white
	100 m	White	White	White	Off white	Off white	Off white
	150 m	White	White	White	White	White	White
	200 m	White	White	White	White	White	White
	250 m	White	White	White	White	White	White
HEPA	300 m	White	White	White	White	White	White
	350 m	White	White	White	White	White	White
	400 m	White	White	White	White	White	White
LEP	**Distance**	**No. burrows (per m^2)**					
		Baseline	**June 2016**	**Jan 2017**	**June 2017**	**Jan 2018**	**June 2018**
MEPA	Centre	15	16	10	5	2	0
	0 m	21	24	24	12	6	1
	50 m	15	16	18	8	7	5
	100 m	21	17	21	19	15	10
	150 m	14	13	14	12	14	21
	200 m	12	10	12	24	12	14
	250 m	24	52	24	17	24	12
HEPA	300 m	17	19	17	21	15	24
	350 m	20	21	17	23	16	15
	400 m	18	17	22	15	14	17
LEP	**Distance**	**Presence of *Beggiatoa* spp.**					
		Baseline	**June 2016**	**Jan 2017**	**June 2017**	**Jan 2018**	**June 2018**
MEPA	Centre	Nil	Nil	Nil	Nil	Present	Present
	0 m	Nil	Nil	Nil	Nil	Nil	Present
	50 m	Nil	Nil	Nil	Nil	Nil	Nil
	100 m	Nil	Nil	Nil	Nil	Nil	Nil
	150 m	Nil	Nil	Nil	Nil	Nil	Nil
	200 m	Nil	Nil	Nil	Nil	Nil	Nil
	250 m	Nil	Nil	Nil	Nil	Nil	Nil
HEPA	300 m	Nil	Nil	Nil	Nil	Nil	Nil
	350 m	Nil	Nil	Nil	Nil	Nil	Nil
	400 m	Nil	Nil	Nil	Nil	Nil	Nil

Notes:

1. Table dates are hypothetical. Categories are indicative only. Qualitative categories (i.e. colour, No. burrows and presence of Beggiatoa spp) are not exhaustive. Proponents may add categories as they see fit.

4.4 Seabirds

4.4.1 Objectives

The potential for adverse interactions between seabirds and sea-cage aquaculture infrastructure was investigated as part of the EIA for the MWADZ (see BMT Oceanica et al. 2015; Halfmoon biosciences 2015). Several risk factors were identified including: entanglement, habitat exclusion, disturbance from aquaculture activities, increased prey availability, creation of roosting sites, and implications to foraging success and spread of pathogens (Sagar 2008, 2013, Lloyd 2003, Comeau et al. 2009). Of the risks identified, only lighting and waste feeds were listed as residual risks (Halfmoon Biosciences 2015).

The objective of the seabird monitoring and management program is to maintain the integrity of Abrolhos seabird populations, and particularly to limit the interaction of potential increaser species with sea-cage infrastructure and waste feeds.

4.4.2 Protocols

The integrity of seabird populations will be maintained using a combination of best-practice and proactive infrastructure management. The success of these programs will be monitored by the Proponent with assistance from suitably qualified experts. Reactive management strategies will be employed to manage incidents as they arise. The proposed approaches to seabird monitoring and management follow those recommended in Halfmoon Biosciences (2015) and Surman (2008).

Infrastructure management

Infrastructure will be managed as follows:

- Sea-cage infrastructure will be managed to minimise entanglement hazards, roosting opportunities and potential collisions due to the disorientating effects of lighting; key to this will be the selection and use of appropriate bird netting; wherever practicable, the above-water portion of the sea-cages should be completely enclosed in bird netting of an appropriate mesh size;
- All pelletised feeds used in open sea-cages must be Australian Quarantine and Inspection Service (AQIS) approved or produced by a manufacturer that complies with AS/NZS ISO 9001:2008 standards or equivalent. Contemporary feeding technologies and practices will be used in order to minimise the release of feed to the surrounding environment; sinking pelletised feeds are to be used in preference to floating pelletised feeds; wet feeds, such as pilchards, will not be permitted in the MWADZ (see also Section 4.7); pelletised food should be stored in secure bulk feed hoppers, and any 'loose' bags stored in the below deck compartment of the supply boat or on deck covered by a heavy tarpaulin.
- Cameras or sensors should be deployed to determine optimum feed input rates and feeding systems should incorporate stop-feeding signals to reduce feed wastage.
- Seabirds will be prevented from gaining access to waste feeds/ dead stock through best practice approaches to feeding and use of bird netting, and dissuaded from roosting opportunities via the implementation of industry best-practice sea-cage design; sea-cages will be completely enclosed by the bird netting. The recommended mesh for excluding seabirds is high-visibility 2 mm polyethylene with a maximum bar size of 60 mm; Proponents may consider other seabird deterrents (visual and audio) in accordance with the Zone Management Policy, providing the deterrent does not cause any harm to seabirds or other fauna;
- The need for lighting will be carefully managed. Although spotlights may be used from time to time they are not expected to form a part of everyday operations. The majority of work will

be conducted during daylight hours. If bright lights are required, care will be taken to minimise usage and to utilise low wattage and long wavelength lights wherever possible;

- The following strategies will be employed to minimise risk of injury to migrating seabirds through disorientation resulting from marine farm lights (following Surman 2008). Wherever practicable, Proponents will:
  - utilise low wattage lights;
  - utilise sensory and, or, timed lighting systems;
  - install wildlife-friendly Low Pressure Sodium Vapour lighting on vessels;
  - orientate lights by either directing, shielding, or focusing;
  - tint vessel windows or where vessel lighting is required at night, use drapes;
  - extinguish non-essential lighting.

Monitoring

Monitoring will be undertaken as follows:

- Interactions between seabirds and sea-cage infrastructure will be monitored daily using semi-quantitative approaches. Seabirds will be identified and enumerated, and the data compared with the baseline assessment published in Halfmoon Biosciences (2015);
- Proponents will arrange for an independent Consultant to attend the site in the early stages of operation to validate the Proponent's field observations against the Consultant's observations. The Consultant will develop and facilitate a training program for farm staff to enable 'in-house' monitoring capabilities. Training will focus particularly on species identified as high risk species. e.g. surface feeding silver gulls and Pacific gulls, as well as sub-surface feeders the pied cormorant and wedge-tailed shearwater;
- The responsibility for monitoring of seabird activity will be handed over to the farm crew at the completion of training, and the Consultant will provide identification guides and data sheets. The crew will be required to record daily the:
  - number and species of seabird in the vicinity (100 m) of the cages and the type of behaviour, i.e. roosting on floats, feeding on fish food etc., and
  - incidence, location/cause of any entanglement/entrapment and the bird species (Table 4.8); and
  - any incidence of seabirds colliding with sea-cages, service vessels, or other aquaculture infrastructure.
- Where multiple Proponents are operating, data will be consolidated and shared in a common database. Results of the individual and combined monitoring programs will be recorded.
- Based on the success of silver gull exclusion measures, the need to conduct broad scale survey of silver gull populations will be assessed after six and twelve months of each operation (derived proposal) introducing stock to sea cages. The Department of Fisheries will determine the need to continue or cease the monitoring of seabirds interactions in consultation with the OEPA (see reactive management protocols below).
- All records associated with the monitoring, shall be included in the Annual Compliance Report (Section 7.1).

Table 4.8 Details of interactions to be recorded for seabirds

Data recorded	Details required
Date	Location, i.e. GPS coordinates
Type of seabird	Species
Number of seabirds	Approximate number
Type of behaviour	Examples: • Roosting on floats, feeding on fish food • Sighted flying in the vicinity of the sea-cage infrastructure • Direct interaction with sea-cage infrastructure • Attempting to enter sea-cages via the side walls
Incidence (record which infrastructure component was involved and the cause of any entanglement / entrapment)	Examples: • Collision with infrastructure / entanglement in the bird netting • Trapped between the predator net and the containment net

Reactive management

Reactive management will be implemented as follows:

- Upon discovery of distressed and/or entangled seabirds in fish farming infrastructure, efforts will be made to untangle the individual bird. Entanglements of seabirds in fish farming equipment will be reported to DPaW Wildcare Hotline on (08) 9474 9055 and the local DPaW office within 24 hrs of the incident. In event of collision between a seabird and aquaculture infrastructure, the following procedure will be followed:
    - Pick up bird with a towel, keeping it lightly wrapped and the wings contained (folded in natural position against side of birds body). Be aware of the sharp beak. Wear gloves and eye protection.
    - Place the bird in a well-ventilated cardboard box, and place in a covered, quiet location.
    - Record and report the species, number, location found (infrastructure component involved), likely cause of collision and any injuries.
    - Do not forcefully administer food or water via the bird's mouth.
    - If the bird has no obvious signs of injury then the bird may be released. The recommended approach is to take the bird to a quiet part of the vessel at dawn, and release the bird in an area free from obstructions (masts, railings, wires etc.) so that it may take off directly into the wind.
- If monitoring finds that pied cormorant, pacific gull and/or silver gull numbers are increasing, and the increase is attributable to aquaculture, then further monitoring will be conducted by a suitable expert. If significant increases in gull populations are detected and the cause is confirmed attributable to the MWADZ then population control measures will be taken, with guidance of a qualified seabird expert.

4.4.3 Timing

Proactive approaches to infrastructure management will be undertaken for the life of the project. Routine inspections of predator exclusion nets, fences, and stock containment nets will be undertaken on a daily basis, if weather and sea conditions permit. An independent assessment of the efficacy of the exclusion approaches will be undertaken (Table 4.9). Monitoring of sea bird numbers near the sea-cages will be undertaken by the Proponent during feeding of stock. Broad-scale assessments of the efficacy of approaches to infrastructure management (including the efficacy of seabird exclusion practices) will be assessed by the Department of Fisheries in consultation with a relevant seabird expert after six and twelve months of each operation (derived proposal) introducing stock to sea cages. The Department of Fisheries will consult with the OEPA and DPaW in relation to any adaptive management measure that may be required.

The design, frequency and scope of the monitoring and management program will be reviewed after the first ten years of implementation in consultation with the OEPA.

Table 4.9 Frequency of seabird monitoring

Performance Indicator	Frequency	Responsibility
Baseline assessment of silver gull population	Prior to stocking	Complete (Halfmoon Biosciences 2015)
Entanglement or injury of seabirds due to fish farm infrastructure and activities	Within 24 hours of incident	Proponent
Interactions with sea birds	Daily	Proponent
Independent assessment of efficacy of seabird exclusion practices	Six months and twelve months post commencement of operations	Relevant independent expert (to be appointed)[1]

Notes:

1. Consultant with relevant expertise in seabird management who is not employed directly by the Proponent

4.5 Marine mammals and turtles

4.5.1 Objectives

The potential for adverse interactions between marine mammals and turtles and proposed aquaculture operations was reviewed as part of the EIA process (BMT Oceanica (2015). A number of risk factors were identified including: the physical presence of sea-cages, availability of supplementary feeds, service vessels and the use of artificial lighting.

The availability of supplementary feeds was identified as a significant risk factor, with potential to alter the natural feeding regimes of mammals and turtles. Other risk factors included physical presence of sea-cages, anchor lines and the use of service vessels, all of which create potential for injury (or mortality) via collision and/or entanglement. Furthermore, mitigation measures aimed at reducing interactions with the sea-cage infrastructure may inadvertently result in changes to marine fauna distribution and/or migration patterns.

The marine mammal and turtle management program aims to maintain the integrity of local populations, and particularly limit interactions between vulnerable species and the sea-cage infrastructure. In the context of preventing interactions with marine mammals, particular consideration has been given to managing the risks associated with the physical presence of sea-cage infrastructure, vessel movements and artificial light. Mitigation of risks will be undertaken using proactive and reactive management strategies.

4.5.2 Protocols

The integrity of marine mammal and turtle populations will be maintained using a combination of best-practice and proactive infrastructure management and ongoing monitoring by the Proponent. Reactive management strategies will also be employed to manage incidents as they arise. The proposed approaches to management follow those approved by the EPA for the KADZ EMMP (DoF 2014).

Infrastructure management

Infrastructure will be managed as follows:

- Staff and contractors will be trained and inducted in MWADZ policies to ensure they are fully aware of the correct manner in which to interact with marine mammals and turtles; staff representatives shall receive training in marine mammal and turtle identification, to allow for identification and enumeration of fauna (see Table 4.10).
- The operation will utilise external predator-exclusion nets (double barrier) or, as required, rigid predator-exclusion mesh (single barrier) to avoid predation on farmed stock by sea lions, sharks and dolphins; mesh sizes greater than 15 cm in diameter have been shown to reduce incidence of entanglements, and should be used wherever practicable; sea-cages should be inspected on a daily basis; nets will be checked for integrity and any faults that may increase the probability of marine mammal interaction.
- Sea lions must be prevented from hauling out onto sea-cage collars or breaching the any barriers above or below the water; wherever practicable, high walled sea-cages will be used to restrict access by sea lions; all practicable measures must be taken to prevent marine mammals and turtles from gaining access to or gaining reward from the sea-cage aquaculture operation. Feeding protocols must be observed to minimise the amount of uneaten feed entering the surrounding water; wet feeds, such as pilchards, are not permitted in the MWADZ. To discourage scavenging or predation by marine fauna, dead stock will be removed from sea-cages on a daily basis and disposed to landfill (or recycled) on the mainland in accordance with waste management authority (City of Greater Geraldton) regulations.
- Aquaculture staff and visitors will be prevented from feeding, touching, interacting or swimming with marine fauna. Interaction in this context includes recreational fishing; if sighted, under no circumstances will vessels be a permitted to approach whales. Vessels will attempt to maintain a distance of 100 m from whales at all times; though it is recognised that fauna may approach vessels from time to time.
- Wherever practical and especially following a sighting of a whale, vessels are to maintain speeds less than 15 knots as the incidence of serious injury or mortality to whales from vessel strikes has been shown to decrease at this speed; if any marine mammals are sighted, vessels should avoid sudden and/or repeated changes in direction; navigate with caution.
- The need for lighting will be carefully managed: although spotlights may be used from time to time they are not expected to form a part of everyday operations. The majority of work will be conducted during daylight hours. If bright lights are required, care will be taken to minimise usage and to utilise low wattage lights wherever possible.
- The following strategies will be employed to minimise risk of injury to migrating marine mammals through disorientation resulting from marine farm lights. The licensee will:
  - utilise low wattage and long wave-length lights wherever practicable
  - utilise sensory and, or, timed lighting systems
  - wherever practicable, install wildlife-friendly Low Pressure Sodium Vapour lighting
  - orientate lights by either directing, shielding, or focusing
  - where vessel lighting is required, use drapes on vessel windows
  - extinguish non-essential lighting whenever practicable

Monitoring

Interactions between marine mammals and turtles and sea-cage infrastructure will be monitored using semi-quantitative approaches. Numbers and types of marine mammals and turtles coming within a 50 m radius of the sea-cage infrastructure will be recorded, and a description of their activity noted (Table 4.10). All records associated with the monitoring, shall be included in the Annual Compliance Report.

Table 4.10 Details of interactions to be recorded for marine mammals and turtles

Data recorded	Details required
Date	Location, i.e. GPS coordinates
Type of fauna	Species
Number of fauna	Single or multiple (approximate number)
Population	Adults, juveniles or a combination
Level of interaction (i.e. physical contact / feeding)	Example: • Vessel strike • Collision / entanglement • Attempting to enter sea-cages • Feeding on pelletised feeds or biofouling
Activity	Example: • Sighted at distance swimming away from sea-cage infrastructure • Direct interaction with sea-cage infrastructure

Reactive management

Reactive management actions will include:

- Collision or entanglement incidents will be reported to the DPaW Wildcare Hotline on (08) 9474 9055 and the local DPaW office within 24 hrs of the incident occurring, and the details of the incident including the actions taken, will be documented
- Any incident involving a marine mammal or turtles in distress, including that resulting from entanglement, collision or stranding will be reported immediately to DPaW Wildcare Hotline on (08) 9474 9055 and the local DPaW office within 24 hrs of the incident occurring
- Ongoing incidents of entanglement and/or breaching of sea-cage netting / barriers will be reported to DPaW and an appropriate management response will be determined by DoF in consultation with OEPA.

4.5.3 Timing

Proactive approaches to infrastructure management will be undertaken for the life of the project. Monitoring of interactions will be undertaken by the Proponent. The efficacy of these programs will be monitored by the Proponent, and reviewed in consultation with the OEPA twelve and 24 months post commencement of operations.

4.6 Finfish

4.6.1 Objectives

The objective of wild finfish management is to minimise environmental and ecological risks to wild finfish populations, including sharks, rays and other finfish. Endangered threatened, and protected (ETP) finfish species have been given special consideration. The potential for adverse interaction between ETP, other finfish species and the proposed aquaculture operations was investigated as part of the EIA (BMT Oceanica et al. 2015). Identified risk factors included:

- wild finfish attracted to sea-cage infrastructure to feed on stock or pelletised feeds

- behavioural changes in ETP species of fish
- transfer of disease/parasites to wild finfish populations
- escape of aquaculture stock leading to competition with wild finfish and
- genetic contamination from escaped stock fish breeding with wild finfish

The primary residual risk, apart from transfer of disease and genetic contamination (covered separately in Section 4.7), was the presence of excess feed pellets or dead/moribund stock attracting wild finfish to sea cage infrastructure to feed. The intent is to manage these attractants to reduce or prevent:

- the strength of signals that may attract sharks and rays
- opportunity for interactions between ETP species of sharks/rays and aquaculture
- predators breaching the sea-cage netting
- the biological/ecological impacts of interactions

4.6.2 Protocols

The integrity of ETP and other wild finfish populations will be maintained using a combination of proactive and reactive management strategies.

Infrastructure management

Infrastructure will be managed as follows:

- All practicable measures must be taken to prevent ETP species of finfish and other finfish from gaining access to or gaining reward from the sea-cage aquaculture operation; feeding protocols must be observed to minimise the amount of uneaten feed entering the surrounding water; to discourage scavenging or predation by marine fauna, dead stock will be removed from sea-cages on a daily basis and disposed to landfill (or recycled) on the mainland in accordance with waste management authority (City of Greater Geraldton) regulations.
- Sea-cages should be designed taking into account best practice management strategies as guided by the Norwegian Standards and the Aquaculture Council of Western Australia Environmental Code of Practice for marine finfish aquaculture.
- Proponents shall wherever practicable: use durable, high tensile sea-cage (e.g. ultra-high molecular weight, polyethylene fibre) mesh of suitable bar width (size); use anti-predator nets (e.g. external ‘armour’ nets); maintain appropriate stocking densities (i.e. stocking densities kept at levels below or equal to industry-best-practice bench marks (e.g. 10-25 kg m^3)); use humane harvesting methods; contain all post-harvest blood water, and implement regular inspections of sea-cages.
- Proponents shall wherever practicable: aim to minimise feed wastage to less than 2%, use high quality and sinking pelletised feeds and immediately remove dead or moribund stock;
- Proponents shall develop an ETP species interaction plan and staff shall be aware of procedures for dealing with ETP species; in the event of entanglement, and/or breach of the sea-cage walls by an ETP animal, the Proponent shall implement the plan and wherever possible avoid harming the animal. Considerations should be given to sea-cages designs that allow for easy release of an ETP or any other large marine animal.
- All pelletised feeds used in open sea-cages must be Australian Quarantine and Inspection Service (AQIS) approved or produced by a manufacturer that complies with AS/NZS ISO 9001:2008 standards or equivalent; contemporary feeding technologies and practices will be used in order to minimise feed wastage to the surrounding environment. Wet feeds, such as pilchards, are not permitted in the MWADZ.
- Pellet food will primarily be stored on site in bulk feed hoppers. Loose bags of feed will be stored in the below deck compartment of the supply vessel or on deck covered by heavy duty PVC tarpaulin.

- Cameras or sensors should be deployed to determine optimum feed input rates and feeding systems should incorporate stop-feeding signals to reduce feed wastage.

Monitoring

Interactions between ETP species of fish and sea-cage infrastructure will be monitored using semi-quantitative approaches, as documented in the ETP species interaction plan. Numbers and species of ETP species coming into contact with the sea-cage infrastructure will be recorded, and a description of any interactions recorded (Table 4.11). All records associated with the monitoring, shall be included in the Annual Compliance Report (Section 7.1).

Table 4.11 Details of interactions to be recorded for Endangered, Threatened and Protected species of fish

Data recorded	Details required
Date	Location, i.e. GPS coordinates
Type of fish	Species
Number of individuals	Single or multiple (approximate number)
Type of behaviour	Example: Direct interaction with sea-cage infrastructure e.g. attempting to feed on stock via the side walls of the sea cage.
Incidence (location/cause of any entanglement/entrapment)	Example: Entanglement/entrapment in the sea-cage, such as shark trapped between the predator net and the containment net.

Reactive management

Management and reporting of escaped fish stock shall be undertaken in consultation with DoF, and in alignment with MWADZ biosecurity protocols described below (Section 4.7). Incidents of fish stock escapes must be reported in the Annual Compliance Report (Section 7.1).

4.6.3 Timing

Proactive and reactive management will be undertaken for the life of the project.

4.7 Biosecurity

4.7.1 Objectives

The objective of the biosecurity section of this Plan is to minimise risks associated with disease, parasites, marine pests and the potential for adverse genetic effects. Potential risk factors relevant to biosecurity were investigated as part of the EIA for the MWADZ project (DoF 2015c). The assessment identified and assessed individual hazard pathways associated with each of three primary biosecurity risks, including:

1. Spread of pathogen disease from an infected aquaculture facility
2. Impacts on the (genetic) sustainability of wild fish following escape of aquaculture stock and
3. The introduction and/or spread of marine pests associated

The biosecurity management protocols described below outlined the approach to reducing these risks through a number of mitigation protocols and management strategies.

4.7.2 Protocols

A high level of biosecurity will be maintained using a combination of best-practice and proactive infrastructure management. Reactive management strategies will be employed to manage incidents as they arise. The proposed approaches to risk mitigation and incident management follow a comprehensive analysis of risks and a review of best practice mitigation strategies undertaken by DoF (2015c), and the proposed management protocols outlined below are excerpted directly from this document (DoF 2015c).

Infrastructure management

Infrastructure will be managed as follows:

- Prior to commencement of operation, the Proponent will seek input on biosecurity measures from the Western Australian Department of Fisheries (Principal Research Scientist in the Fish Health Unit). Prior to stocking, the Proponents will develop and implement biosecurity management arrangements, as part of a Management and Environmental Monitoring Plan, in accordance with the Zone Management Policy and in consultation with DoF; These arrangements will cover all aspects of biosecurity management including a disease testing regime and relevant response protocols, translocation, biosecurity and quarantine including management of vessels, equipment and infrastructure. Responses to biosecurity hazards and incidents shall be informed by the development and implementation of the biosecurity management arrangements; all staff will receive appropriate training to enable them to implement the biosecurity management arrangements to effectively deal with biosecurity hazards and/or incidents as they arise.
- Sea-cage systems shall be designed and maintained so as to eliminate or reduce the likelihood of fish escapes, and/or the breach of sea-cage netting by external predators, including ETP species; in addition, Proponents will be required to conduct regular inspections of the sea-cage systems to ensure integrity, by looking for and resolving any issues that may increase the probability of escape.
- The Proponent will continually review and update their approach to biosecurity and associated protocols as agreed with DoF.
- In addition to the above, the Proponents will implement the following mitigation measures to reduce the risk of disease due to the proximity of another farm: monitor the health of brood-stock and immediately quarantine any individuals suspected of carrying disease; use only Australian sourced brood-stock; and maintain controls over stock and feed input to the MWADZ to prevent introduction of pathogens to the marine environment.
- All pelletised feeds used in open sea-cages must be Australian Quarantine and Inspection Service (AQIS) approved or produced by a manufacturer that complies with AS/NZS ISO 9001:2008 standards or equivalent. Wet feeds, such as pilchards, are not permitted in the MWADZ.
- Proponents will use best management practices to prevent escapes from sea-cages, including observing the Aquaculture Council of Western Australia (ACWA) marine based finfish Environmental Code of Practice, which has been designed to encourage environmentally responsible behaviour in the aquaculture industry. Proponents are required to operate in accordance with the Zone Management Policy and the conditions of an aquaculture licence, which require the prevention of stock escapes. The Zone Management Policy also documents the importance of the suitable site location (i.e. frequency of storm events, degree of exposure), minimizing risks during stock transfers, using strong and durable materials for culture unit construction and regularly inspecting and adjusting the infrastructure to ensure no tears or openings.
- Proponents must develop site-specific contingency plans (escape emergency plans) that describe actions to be taken in the event of any major stock escapes. Guidance on what to do in the event of an escape is provided in the Fish Resources Management Regulations 1995. The use of any recapture nets requires authorisation of the CEO of DoF.
- To prevent the introduction and spread of introduced marine pests, Proponents will undertake regular inspection and cleaning of sea-cage nets; prior to bringing aquaculture gear into the MWADZ, thoroughly inspect and clean any used equipment / infrastructure sourced (including vessels) from areas outside of the MWADZ. In addition to the biosecurity management arrangements mentioned above, Proponents will observe the National Biofouling Management Guidelines for the Aquaculture Industry.

Reactive management

Reactive management actions will include:

- Proponents must (with DoF) develop incident response plans detailing the procedures to be followed in the event of (i) disease outbreaks, (2) escapes of significant volumes of stock or (3) detection of introduced marine pests; the intent of these plans is to ensure adequate reporting of the events, managed the escaped fish and any predators including ETP species, prevent wherever practicable, the establishment and proliferation of that pest or disease, aiming to control and potentially eradicating that pest or disease, and to minimise the risk of that pest or disease being transferred to other locations within Western Australia.
- All unusually high levels of mortalities, or suspicions or signs of diseases or conditions, must be recorded and details (quantity of stock/circumstances) reported in writing to the Principal Research Scientist in DoF's Fish Health Unit[7], within 24 hours of becoming aware, or suspecting, any fish at the property are affected. The Proponent will work with DoF to resolve the issue using an agreed response plan or as otherwise determined with DoF.
- ALL species listed as pests or noxious fish and any other species that appear to have clear impacts or invasive characteristics must be reported to DoF via FISHWATCH (ph. 1800-815-507) or by email at biosecurity@fish.wa.gov.au,within 24 hours following (a) initial detection and (b) subsequent analysis and confirmation of identity. If the species is positively identified as a marine pest, the Proponent will work with DoF to resolve the issue using an agreed response plan or as otherwise determined with DoF.
- Any use of treatment chemicals and/or pharmaceuticals, under advisement of the Principal Research Scientist in the Fish Health Unit at DoF, will be recorded and reported to DoF and the OEPA in accordance with approved protocols.
- All instances of suspected significant (i.e. greater than 100 fish) stock-escapes must be recorded and details (quantity of stock/circumstances) reported to the CEO of DoF within 24 hrs of the event. Interactions with ETPs, which result in escapes, should be reported to the relevant authority. The Proponent must investigate and determine how an escape occurred and what is required to prevent future similar stock-escapes; the findings of the investigation shall be reported to DoF within 5 working days of the event. The Proponent will work with DoF to resolve the issue using an agreed response plan or as otherwise determined by DoF.
- All biosecurity incidents (including stock-escapes) and use of treatment chemicals, e.g. pharmaceuticals, must be recorded in the Annual Compliance Report. Best management practices to facilitate biosecurity will be maintained for the life of the MWADZ. The Proponent will review and adapt management practices to remain in step with best-practice approaches.

4.8 Aesthetics

4.8.1 Objective

The EQO to maintain aesthetic values aims to ensure that WA's coastal waters are aesthetically pleasing and that the aesthetic value is protected. The Abrolhos Islands are multi-use with an array of stakeholders, all of which have vested interest in preserving the unique features of the Islands and the surrounding marine environment.

The objective of the aesthetic management program is to assess whether the EQG and EQS have been met at the HEPA/MEPA boundary, and to provide contextual information about the extent of aesthetic changes in the vicinity of the sea-cages. The results of semi-quantitative

---

[7] *A reference to the Principal Research Scientist in the Fish Health Unit includes reference to an accredited pathologist or epidemiologist.*

measurements will be compared against the EQG and EQS in Table 4.12, following those recommended in EPA (2015b).

4.8.2 Timing

Monitoring will be undertaken twice each year, in summer and winter. Monitoring will coincide with the seasonal water quality and sediment monitoring (Sections 4.1 and 4.2).

4.8.3 Environmental quality criteria

Aesthetic quality will be assessed against the EQG and EQS in Table 4.12 using a combination of semi-quantitative and qualitative assessments. The required management response following an exceedance of the EQC is set out in Section 5.2.

Table 4.12 Environmental quality criteria for the environmental quality objective of maintenance of recreation and aesthetics

Environmental Quality Indicators	Environmental Quality Criteria	
	Environmental Quality Guideline (EQG)	Environmental Quality Standard (EQS)
Nuisance organisms	Macroalgae, phytoplankton and encrusting invertebrates, should not be present in excessive amounts on and around the sea-cages.	There should be no overall decrease in the aesthetic water quality values of the Zeewijk Channel, Abrolhos Islands that are attributable to aquaculture using direct measures of the community's perception of aesthetic value.
Water clarity	The natural visual clarity of the water should not be reduced by more than 20%.	
Surface films	Petrochemicals, such as engine oil, should not be noticeable as a visible film on the water or detectable by odour.	
Surface debris	Water surfaces should be free of aquaculture-derived floating debris, feed dust and other objectionable matter.	
Odours	There should be no objectionable odours.	

Note:

1. Derived from EPA (2015b)
2. Many of the environmental quality guidelines for aesthetic quality are subjective and relate to the general appreciation and enjoyment of the Abrolhos by the community as a whole. Consequently, when using these criteria, consideration should be given to whether the observed change is in a location, or of intensity, likely to trigger community concern and to whether the changes are transient, persistent or regular events.
3. Further investigation (environmental quality standards) involves direct measures of aesthetic value to determine whether there has been a perceived loss of value. For example, regular community surveys can be used to show trends in community perception of aesthetic value over time.

4.8.4 Visual indicators

In addition to monitoring against the EQG and EQS in Table 4.12, the visual appearance of the marine environment will be taken into account. Assessment against the EQG will be supplemented via a questionnaire supplied to field personnel (Table 4.13). The questionnaire will be completed during the annual water quality monitoring survey and will be based on observations made adjacent to sea-cage clusters.

Proponents will provide community users of the Abrolhos Islands FHPA and other relevant stakeholders with an open invitation to comment on any depreciation of the aesthetic values of the Zeewijk Channel that may be attributable to the aquaculture within the MWADZ. The DoF website at www.fish.wa.gov.au will provide a mechanism by which the community and stakeholders can submit comments. Any decreases in aesthetic water quality values of the Zeewijk Channel will be measured as an increase in the number of complaints or a distinct change in the perception of the community (Refer to EQS in Table 4.12). Instances of complaints will be recorded and documented in the Annual Report. All records associated with the monitoring, need to be included in the Annual Compliance Report.

Table 4.13 Field sheet for demonstrating compliance with environmental quality guidelines for aesthetics

Site: Date:	Recorder:	Comments
EQG Indicator		
Algal material / invertebrate encrustation visible on and around the sea-cages?	Yes/No	
Water clarity (light attenuation)	Metres	
Petrochemicals or other pollutants visible on the surface of the water?	Yes/No	
Floating debris visible on the surface of the water?	Yes/No	
Noticeable odour associated with the water?	Yes/No	

5. Statistical approach

5.1 Water quality and sediment monitoring

The objective of the water and sediment monitoring programs is to assess whether the EQG and EQS have been met within the MEPA generally and at the HEPA boundary (Figure 4.1). Comparison with the guidelines and standards requires calculation of test statistics (medians [50th percentiles] and 80th and 95th percentiles), and the application of control charting procedures is recommended. The approach for calculating test statistics and running the control charting procedures is outlined in Appendix B. Procedures are described in the context of a single sea-cage cluster positioned within a single MEPA. Transects will be replicated as production increases. For example, there should be one transect, incorporating sites at centre, 0 m, 50 m, 100 m, 150 m, 200 m, 250 m (MEPA), 300 m, 350 m and 400 m (HEPA) for every 12 cages in a cluster. Hence a cage-cluster with 13 or more cages will incorporate 2 transects, and a cage-cluster with 25 or more cages will incorporate 3 transects, as per the example in Figure 5.2. Transects should be regularly spaced with approximately the same number of cages each side of the transect, e.g. 4-6 cages on each side (as per the example in Figure 5.2).

5.1.1 Environmental quality guidelines

Sections 4.1 and 4.2 describe the EQG criteria for application within the MEPA and HEPA. The frequency of assessment is the same irrespective of the LEP. In the case of the MEPA, HEPA and Area (HEPA), comparison with the EQG will be undertaken at the completion of the three month winter sampling period and again at the end of the three month summer sampling period.

On completion of the seasonal sampling periods, the relevant EQG test statistics (median, 80th and 95th percentiles) will be calculated from the pooled:

1. individual HEPA compliance sites (n=3)
2. individual Zone compliance sites (n=3)
3. MEPA compliance sites (n=3) and
4. Reference site data (n=12)

For sediment metals and dissolved oxygen, the median values should be respectively compared against the ISQG trigger values and the percentage saturation criteria in Table 4.5. For all other analytes, median values should be compared against the 80th or 95th percentile values calculated from pooled reference site data obtained over the entire three month period (n=12).

In the event that an EQG is exceeded, assessment against the relevant EQS should be undertaken as soon as reasonably practicable. The decision scheme for assessing the EQG is summarised in Figure 5.1.

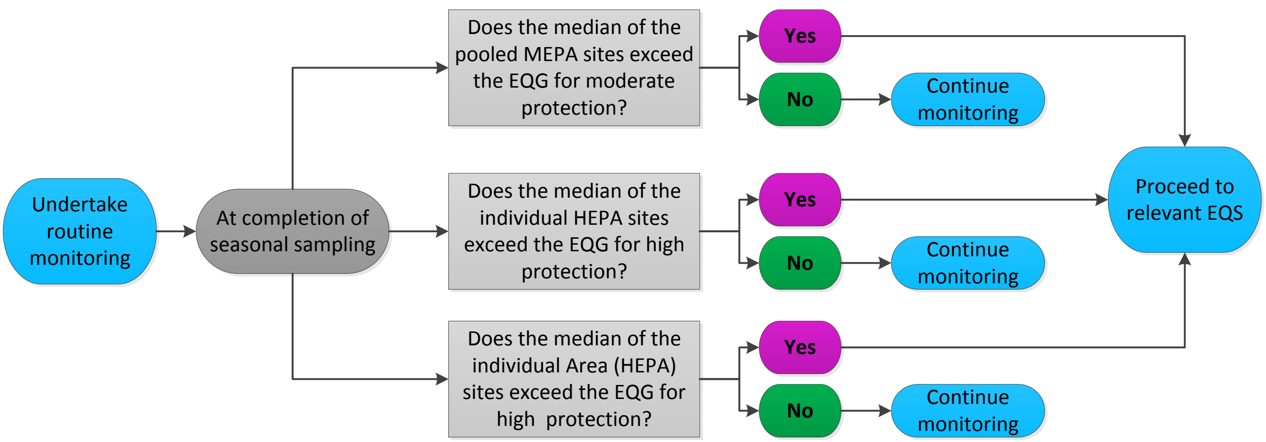


Figure 5.1 Decision scheme for assessing the environmental quality guidelines

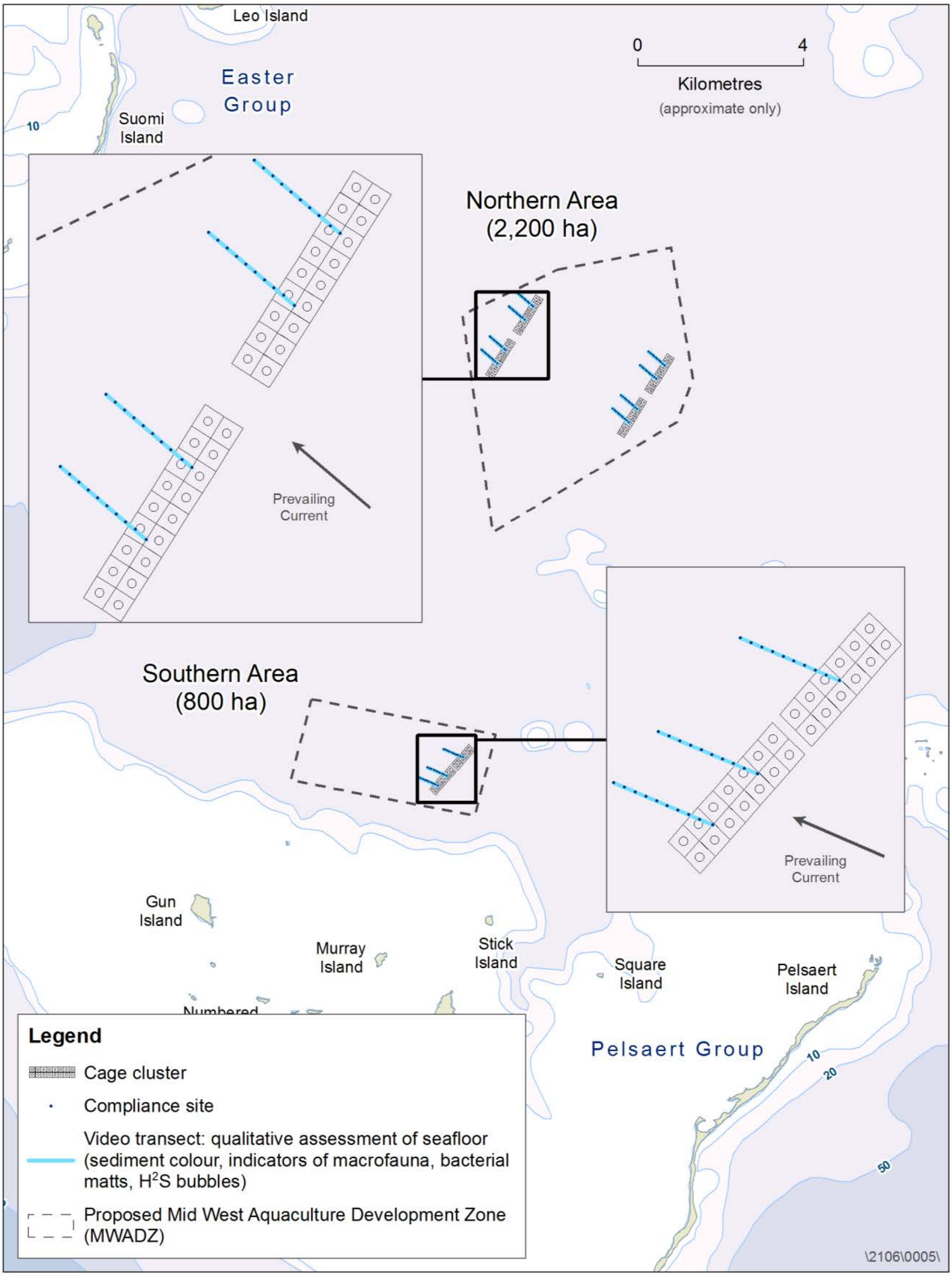


Figure 5.2 Conceptual number and arrangement of transects under different cage configurations

5.1.2 Environmental quality standards

Upon an exceedance of an EQG, the Proponent will undertake monitoring against the relevant EQS as soon as reasonably practicable. Calculations should be based on the data from the cage cluster(s) where the exceedance was detected and the relevant Reference site data. Test statistics shall be compared with the EQS triggers in Table 4.3 and Table 4.6.

DO

Assessment of the EQS for dissolved oxygen is straightforward and only requires calculation of the median DO percent saturation value. The median value should be compared against the EQS criteria listed in Table 4.3. The EQS will be exceeded where the median value is less than 60% saturation, provided it has occurred in the absence of a similar exceedance at the reference sites, which may indicate a natural regional effect.

TSS, LAC and chlorophyll-a

Assessment against the EQS for TSS, LAC and chlorophyll-a requires the application of control charting procedures. Control charting procedures are an effective way for visually comparing the trajectories of two or more times series data, and are thus a simple but useful tool for managers. When upper and lower confidence limits (around the means) are incorporated into time series data, control charts may also be used to run simple statistical tests, which in practice are equivalent to Analysis of Variance (ANOVA) and t-test procedures. A control charting example is provided in Appendix B.

Infauna

Assessment against the EQS for infauna requires the analysis and enumeration of infauna families present in the MEPA and HEPA compliance site samples. While infauna samples are required to be taken at all MEPA and HEPA sites, only the MEPA samples should be analysed immediately upon sampling and irrespective of the result of the moderate protection EQG assessment. HEPA samples shall be analysed only upon an exceedance of the high protection EQG for dissolved oxygen, TSS or sediment nutrients. This is in recognition of the point source nature of the operation, in which sites positioned closer to the sea-cages are more likely to undergo changes (and more rapidly) than sites positioned further from the sea-cages.

The EQS for infauna is consistent with the guidance set out in the relevant EPA policies and Guidelines (e.g. EAG 15) and has been developed following advice from the OEPA. The intent is to demonstrate that the number of infauna families across the MEPA (pooled sites) does not differ from the number observed during the baseline assessment, and does not differ from those observed at the reference sites in the ongoing assessments. OEPA recognises that the high family richness together with its highly variable abundance may lead to false positives where an EQS is exceeded because a family is excluded simply be chance (i.e. the family is actually present at the site, but was missed in the sampling due to its rareness). To counter this, the EQS is based upon only those families with a greater than 20% probability of occurring in a single sample over the summer period and within a specific area (either north or south). Therefore there is a reasonable chance of detecting each of these families provided five or more samples are collected and provided the family is present. Table 5.1 provides the list of families for each of the aquaculture areas, and their probability of detection based on their abundance during the baseline surveys.

Table 5.1 Families included in the EQS for infauna with their probability of detection

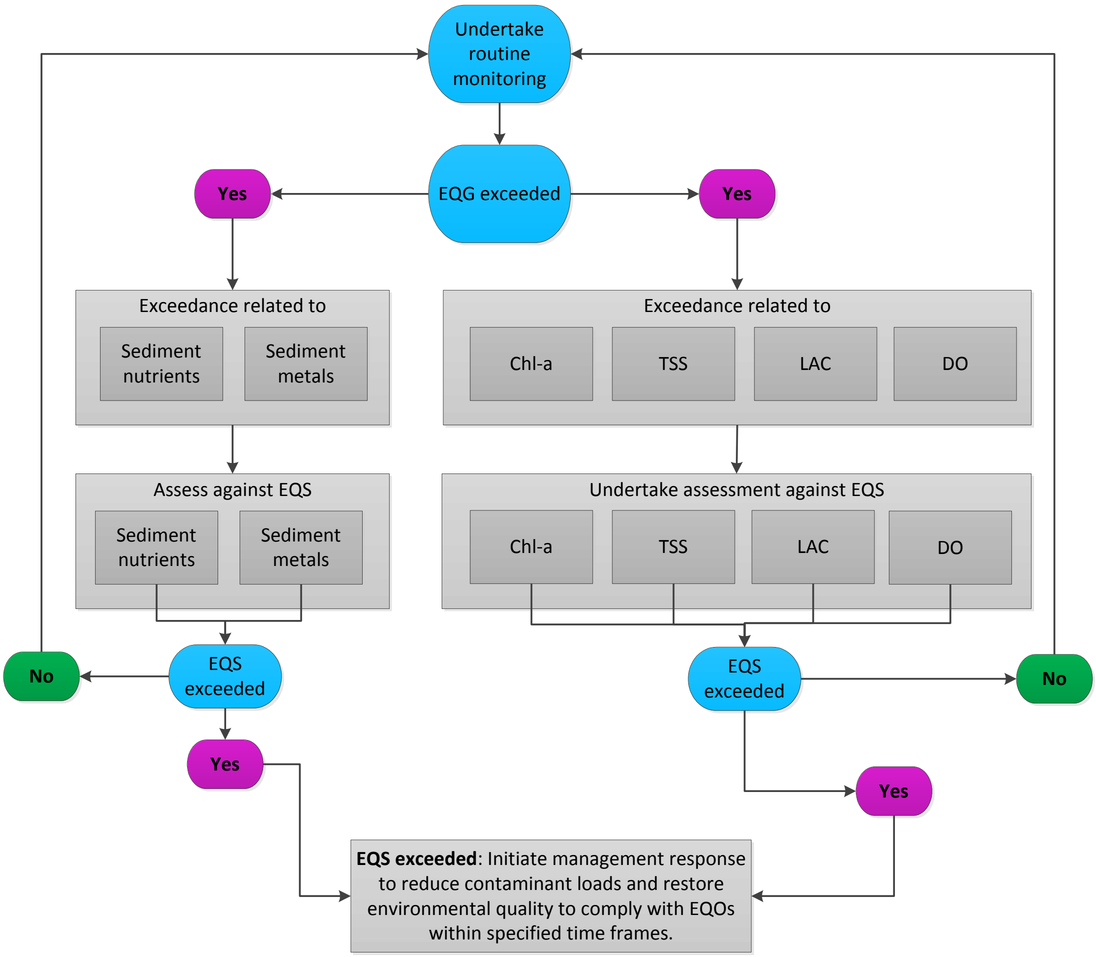
Southern Area			Northern Area		
Family	**Taxa**	**Probability of detection**	**Family**	**Taxa**	**Probability of detection**
Ampeliscidae	Worm	30%	Glycymerididae	Worm	21%
Phoxocephalidae	Worm	21%	Psammobiidae	Worm	45%
Caprellidae	Worm	21%	Veneridae	Bivalve	33%
Ostracoda (Class)	Crustacean	24%	Ampharetidae	Worm	24%
Glycymerididae	Bivalve	21%	Eunicidae	Worm	36%
Psammobiidae	Worm	52%	Lumbrineridae	Worm	24%
Retusidae	Worm	21%	Onuphidae	Worm	36%
Eunicidae	Worm	30%	Orbiniidae	Worm	27%
Onuphidae	Worm	45%	Phyllodocidae	Worm	21%
Orbiniidae	Worm	24%	-	-	-
Phyllodocidae	Worm	21%	-	-	-

The intent of this approach is to (a) maintain a moderate level of ecological protection across the zone by demonstrating no change in the infauna families across the MEPA generally and (b) to build a comprehensive understanding of the type and number of infauna present, and of the effect of aquaculture pressures on these assemblages, as the pressures grow over time. This understanding is likely to be used in the future to develop a new EQS based on some other environmental indicator. The utility of the approach will be reviewed in consultation with the OEPA once an appropriate data-set has been established.

Recommended additional sampling and / or analyses

The decision scheme for assessing EQS is depicted in Figure 5.3. Assessments against the EQS should be undertaken carefully and with consideration of the potential for making a Type I or II statistical inference error. For EQS assessments, Proponents are advised to increase the level of replication at the appropriate sites, or relevant boundaries, wherever practicable. Proponents are also advised to consider collecting more data, or undertaking further analyses that may serve as additional lines of evidence. Additional analyses such as multivariate statistical procedures for example may be used to provide either early warning and/or context to the observed changes in infauna communities, which may be driven by a combination of species richness and abundance measures. Suggested approaches include the use of visual tools such as control charting (Appendix B), non-metric Multidimensional Scaling (nMDS), and hypothesis-based statistical methods such as PERMANOVA (following Anderson et al. 2008) or generalised linear modelling.

In the event that an EQS is exceeded, Proponents are advised to undertake contingency management action as outlined in Section 6.



Notes:

1. EQS = environmental quality standard; Chl-a = chlorophyll-a; LAC = light attenuation coefficient; TSS = total suspended solids; DO = dissolved oxygen; TN = total nitrogen; TP = total phosphorus; TOC = total organic carbon; ANOVA = analysis of variance; EQO = environmental quality objectives

Figure 5.3 Decision scheme for assessing environmental quality standards

5.2 Aesthetics monitoring

Aesthetic appearance will be compared against the criteria in Table 4.12. Assessment against the EQG will be facilitated by a questionnaire supplied to field personnel (Table 4.13). The questionnaire will be completed during the annual water quality monitoring survey and will be based on observations made around the perimeter of the sea-cage clusters. Assessment against the EQS will be based upon credible community observations of the aesthetics within the MWADZ.

The decision scheme for assessing EQG and EQS related to aesthetics, including management responses summarised in Table 5.2.

Table 5.2 Management response following an exceedance of the environmental quality criteria for maintenance of aesthetic values

Environmental Quality Indicators	Management following trigger level exceedance	
	Environmental Quality Guideline (EQG)	**Environmental Quality Standard (EQS)**
All instances	Upon an exceedance of the EQG, the Proponent will investigate the cause and the source of the exceedance. An exceedance of the EQG will result in further assessment against the EQS. Any instances of an exceedance of the EQG will be reported by the Proponent in the Annual Compliance Report (Section 7.1).	If there is a decrease in the aesthetic values of the Abrolhos marine environment as determined using direct measures of the community's perception of aesthetic values, the Proponent will consult with DoF and OEPA to determine an appropriate management response.

6. Contingency Management

6.1 Cage cluster relocation as a management option

The periodic relocation of cage-clusters (fallowing) allows sediments to return to the equivalent of baseline physical/chemical conditions. Such practices have been shown to be a highly effective method for reducing the point source impacts of aquaculture. Relocation of entire cage clusters may be undertaken to allow impacted habitats to recover, and shift from conditions representing a moderate level of ecological protection, to conditions representing a high level of ecological protection (see Section 3.1.3).

Fallowing may be undertaken as part of routine operations, or in response to an exceedance of an EQS. In the case of an EQS exceedance, the intent is to reduce the source of the contaminants and to restore environmental quality to a level commensurate with high level of ecological protection.

6.2 Other management options

Apart from relocating sea-cages, Proponents have the following options for managing site specific contamination:

- Movement or partial harvest of the stock may be considered as a temporary measure to reduce pressures on water or sediment quality, and to allow time for sediment and water quality indicators to comply with the specified levels of ecological protection
- Reduction of stocking density through splitting cages and selective harvest may be implemented as a temporary measure to reduce pressures on water or sediment quality, and to allow time for sediment and water quality indicators to comply with the specified levels of ecological protection, and
- Reduction of feed input rates may be implemented as a temporary measure to reduce pressures on water or sediment quality, and to allow time for sediment and water quality indicators to comply with the specified levels of ecological protection.

6.3 Reporting of exceedances

In the event an EQS is exceeded, the Proponent will report the matter to DoF and the OEPA within 24 hours of detecting the exceedance and will commence management to (i) reduce the effect and/or mitigate the source of the contaminants, and (ii) to restore environmental quality within the specified level of ecological protection.

6.4 Recovery monitoring

6.4.1 Following relocation

As described in Section 6.1, relocation of sea-cages may be undertaken in response to an exceedance, or as part of a routine fallowing program. In any case, Proponents will be required to capture the transition from operational (or impacted) conditions to remediated conditions via a supplementary monitoring program, using a sub-set of sites and analytes.

Recovery monitoring will be undertaken at the former MEPA compliance sites (Section 4.2), which will be referred to as recovery sites (Figure 3.7, Figure 4.1 and Figure 4.2). Sampling will be undertaken at a sub-set of the former MEPA compliance sites at distances: centre, 0 m, 50 m and 100 m. Recovery monitoring will be undertaken once during the scheduled summer sampling period and will be supplemented by qualitative video assessment. Recovery will be monitored until the sediment chemistry at the fallowed site achieves conditions commensurate with a high LEP. To assess recovery, data from the recovery (previously monitoring) sites will be compared against data from baseline or reference sites using appropriate statistical methods. The Proponent shall report the results of recovery monitoring program to DoF and the OEPA annually (Section 7.1).

6.4.2 Following exceedance of an environmental quality standard

All of the EQSs in this Plan are designed to be assessed within the MEPA, or at either the HEPA boundary or the Area (HEPA) boundaries. For an exceedance within the MEPA or at the HEPA boundary, the most appropriate course of action may be to move the cage-cluster, or if this is not feasible, implement one of the approaches outlined in Section 6.2. If relocation is selected, then the timing and extent of monitoring shall proceed as in Section 6.4.1. If the Proponent chooses to implement other forms of management, the Proponent will be required to consult with DoF for endorsement of intended actions and needs to monitor the impacted site(s) on a monthly basis, until an appropriate level of environmental quality has been restored (to a 'moderate' level or higher in this case).

For an exceedance at the northern or southern MWADZ Area boundaries, management will be determined in consultation with DoF and OEPA. Management options such as those listed in Section 6.2 will be considered. During the consultation meetings, monitoring of the impacted site(s) will proceed on a monthly basis, until the approach to management has been decided.

During the contingency management phase, the Proponent will be required to report the results of the monitoring to DoF and the OEPA on a quarterly basis (four times per annum) until it can be demonstrated that a high level of environmental quality has been restored, and is being maintained.

7. Implementation

7.1 Reporting and auditing

Each Proponent will produce an Annual Compliance Report summarising the results of the monitoring and submitted it to the OEPA and DoF by 1 June annually in accordance with the conditions of their Derived Proposal approval. Refer to Section 4, Monitoring and Management, for details on requirements relating to records and reports.

7.2 Review and revision

The DoF will undertake regular audits to ensure each of the components of this Plan have been implemented and the results reported annually.

The design, frequency and scope of the monitoring and management program will be reviewed after the first three years of implementation in consultation with the OEPA. Subsequent reviews will be undertaken every three years after that.

8. References

ACWA/DoF (2013) Environmental Code of Practice for the Sustainable Management of Western Australia's Marine Finfish Aquaculture Industry, pp41

Anderson DI, Levin BR (1999) The biological cost of antibiotic resistance. Curr. Opin. Microbiol. 2: 489–493

Anderson MJ, Gorley RN, Clarke KR (2008) PERMANOVA+for PRIMER: Guide to Software and Statistical Methods. PRIMER-E Ltd, Plymouth, UK

ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, National Water Quality Management Strategy No. 4 & 7

BMT Oceanica (2015) Modelling and Technical Studies in Support of the Mid-West Aquaculture Development Zone. Prepared for Western Australian Department of Fisheries by BMT Oceanica Pty Ltd, BMT WBM, and AED UWA, Report No. 1051_009/1_Rev0, Perth, Western Australia, September 2015

Carroll ML, Cochrane S, Fieler R, Velvin R, White P (2003) Organic enrichment of sediments from salmon farming in Norway: Environmental factors, management practices, and monitoring techniques. Aquaculture 226: 165–180

Comeau LA, St-Onge P, Pernet F, Lanteigne L (2009) Deterring coastal birds from roosting on oyster culture gear in eastern New Brunswick, Canada. Aquaculture Engineering 40: 87-94.

De Zwaan, A Cortesi P, van den Thillart G, Brooks S, Storey KB, van Lieshout G, Cattani, O, Vitali G (1992) Energy metabolism of bivalves at reduced oxygen tensions. Marine Coastal Eutrophication 1029–1039

DPIPWE (2011) Section 40 report in relation to the draft amendment no.3 to the D'Entrecasteaux Channel Marine Farming Development Plan February 2002. Department of Primary Industries, Parks, Water and Environment, Tasmania

DoE (2014) Protected Matters Search Tool. Australian Government Department of the Environment, Canberra, Australian Capital Territory. Available at <http://www.environment.gov.au/topics/about-us/legislation/environment-protection-and-biodiversity-conservation-act-1999/protected> [Accessed 6 November 2014]

DoF (2014) Kimberley Aquaculture Development Zone Environmental Monitoring and Management Plan. Version 1, January 2014

DoF (2015a) Threat identification, hazard pathway analysis and assessment of a key risk presented by the establishment of the Mid West Aquaculture Development Zone, to the sustainability of threatened, endangered and protected fish populations at the Abrolhos Islands, Western Australia, Version 4, August 2015

DoF (2015b) Threat identification, hazard pathway analysis and assessment of the key risks presented by the establishment of the Mid West Aquaculture Development Zone to invertebrate and finfish species and fisheries at the Abrolhos Islands, Western Australia, Version 2, July 2015

DoF (2015c) Threat identification, hazard pathway analysis and assessment of the key biosecurity risks posed by the development of the Mid West Aquaculture Development Zone in Western Australia, Final, August 2015

EPA (2005) Manual of standard operating procedures for environmental monitoring against the Cockburn Sound environmental quality criteria (2004): a supporting document to the state environmental (Cockburn Sound) policy 2005. Report 21; Environmental Protection Authority, Western Australia.

EPA (2013) Environmental Scoping Document for the Mid-west Aquaculture Development Zone. Prepared by the Environmental Protection Authority, July 2013

EPA (2015a) Environmental Assessment Guideline for Protecting the Quality of Western Australia's Marine Environment. Environmental Protection Authority, Report No. EAG 15, Perth, Western Australia, March 2015

EPA (2015b) Environmental quality criteria reference document for Cockburn Sound (2015), Perth, Western Australia

Erftemeijer PLA, Hagedorn M, Laterveer M, Craggs J, Guest JR (2012) Effect of suspended sediment on fertilization success in the scleractinian coral Pectinia lactuca. Journal of the Marine Biological Association of the United Kingdom 92: 741–745

Forbes TL, Lopez G R (1990) The effect of food concentration, body size and environmental oxygen tension on the growth of the deposit-feeding polychaete, Capitella species 1. Limnology and Oceanography 35: 1535–1544

Forbes TL, Forbes VE, Depledge MH (1994) Individual physiological responses to environmental hypoxia and organic enrichment: Implications for early soft-bottom community succession. Journal of Marine Research 52: 1081–1100

Gaston GR, Edds KA (1994) Long-term study of benthic communities on the continental shelf off Cameron, Lousiana: a review of brine effects and hypoxia. Gulf Res Reports 9: 57–64

Government of Western Australia (2004) State Water Quality Management Strategy No 6 - Implementation Framework for Western Australia for the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and Water Quality Monitoring and Reporting (Guidelines Nos. 4 & 7: National Water Quality Management Strategy), Prepared by Government of Western Australia, Report no. SWQ 6, Perth, Western Australia

Gray JS (1992) Eutrophication in the sea. In: Marine Eutrophication and Population Dynamics. Colombo G, Ferrari I, Ceccherelli VU, Rossi R. Olsen and Olsen, Fredensbor (eds), Denmark, pp. 3–16

Halfmoon Biosciences (2015) Impact Assessment of Aquaculture on seabird Communities of the Abrolhos Islands, to Support the MidWest Aquaculture Development Zone Proposal. Prepared by Halfmoon Biosciences for Western Australian Department of Fisheries, Report No. DoF21/2013, Perth, Western Australia, August 2015

Hutchins JB (1997) Recruitment of tropical reef fishes in the Houtman Abrolhos Islands, Western Australia. In Wells FE (ed) Proceedings of the Seventh International Marine Biological Workshop: The marine flora and fauna of the Houtman Abrolhos Islands, Western Australia Western Australia, Perth, pp 83-87

Jacobsen P, Berglind L (1988) Persistence of Oxytetracycline in Sediments from Fish Farms. Aquaculture 70: 365-370

Josefson AB, Jensen JN (1992) Effects of hypoxia on soft-sediment macrobenthos in southern Kattegat, Denmark. In: Marine Eutrophication and Population Dynamics. Colombo G, Ferrari I, Ceccherelli VU, Rossi R (eds). Olsen and Olsen, Fredensborg, Denmark, pp. 21–28

Lalumera GM, Calamara D, Galli P, Castiglioni GC, Fanelli R (2004) Preliminary investigation on the environmental occurrence and effects of antibiotics used in aquaculture in Italy. Chemosphere 54: 661-668

Lloyd, B.D. (2003). Potential effects of mussel farming on New Zealand's marine mammals and seabirds: a discussion paper. Department of Conservation, Wellington

Mazzola A, Mirto S, La Rosa T, Fabiano M, Danovaro R (2000) Fish-farming effects on benthic community structure in coastal sediments: analysis of meiofaunal recovery. ICES Journal of Marine Science, 57: 1454–1461

Nardi K, Jones GP, Moran MJ, Cheng YW (2004) Contrasting effects of marine protected areas on the abundance of two exploited reef fishes at the sub-tropical Houtman Abrolhos Islands, Western Australia. Environmental Conservation, 31:160–168

National Research Council (2005) Marine Mammal Populations and Ocean Noise: determining when noise causes biologically significant effects. National Academies Press, Washington, USA

Olesiuk PF, JW Lawson, Trippel EA (2012) Pathways of effects of noise associated with aquaculture on natural marine ecosystems in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/025. Vi, 64 pp

Richardson WJ, Greene Jr, Malme CL, Thomson DH (1995) Marine mammals and noise, Academic, New York, USA

Ross, G J B, Burbidge, A A, Brothers, N, Canty, P, Dann, P., Fuller, P J, Kerry, K R, Norman, F I, Menkhorst, P W, Pemberton, D, Shaughnessy, G, Shaughnessy, P D, Smith, G C, Stokes, T. and Tranter, J (1995). The status of Australia's seabirds. In 'State of the marine environment report of Australia Technical Annex: 1'. (eds L Zann and P Kailola), Department of the Environment, Sport and Territories: Canberra, pp 167–182

Sagar, P (2008) Assessment of the potential impacts on waders and seabirds of finfish marine farming in the Firth of Thames. Environment Waikato, 30pp

Samuelsen OB, Lunestad BT, Husevag, B, Holleland T, Ervik A (1992) Residues of oxolinic acid in wild fauna following medication in fish farms. Dis. aquat. Org. Vol. 12 pp I 11/19

Storr, GM, Johnstone, RE and Griffin, P (1986) Birds of the Houtman Abrolhos, Western Australia. Rec. W.A. Mus. 24: 1–42. Southall et al. 2007

Stachowitsch M (1992) Benthic communities: eutrophication's "memory mode". In: Marine Coastal Eutrophication (eds) Vollenweider RA, Marchetti R, Viviani R. Elsevier, Amsterdam, London, New York, Tokyo. pp. 1017-1028

Surman, CA and LW Nicholson (2008) Seabird Monitoring and Management Program Fin Fish aquaculture Pelsaert Group Houtman Abrolhos. Unpublished report for Indian Ocean Fresh, 14pp

Surman CA and Nicholson LW (2009) A survey of the breeding seabirds and migratory shorebirds of the Houtman Abrolhos, Western Australia. Corella, 33(4):89-98

Watson DL, Harvey ES, Kendrick GA, Nardi K, Anderson MJ (2007) Protection from fishing alters the species composition of fish assemblages in a temperate-tropical transition zone. Marine Biology 152(5):1197-1206

Appendix A

Sample Site Coordinates

Appendix B

Control Charting Example

BMT Oceanica Pty Ltd
PO Box 462 Wembley
WA 6913 Australia
Tel: +61 8 6272 0000
Fax: +61 8 6272 0099
bmtoceanica@bmtoceanica.com.au
www.bmtoceanica.com.au