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Coral reef and benthic specialist report for an EIA for the Seychelles Mariculture Master Plan

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Executive summary

A coral reef and benthic specialist study is being undertaken as part of an Environmental and Social Impact Assessment (ESIA) for the development of aquaculture development zones (ADZs) and associated infrastructure for the Seychelles Mariculture Masterplan on behalf of the Seychelles Fishing Authority. The Seychelles has adopted an ecosystems approach to aquaculture and the Seychelles Fishing Authority mariculture policy aims to enable the Seychelles to develop a sustainable mariculture sector that is integrated into the country's economic vision and respects the unique and sensitive nature of the marine environment.

Twelve proposed ADZs for the culture of finfish (Brown-marbled grouper *Epinephelus fuscoguttatus*, Mangrove river snapper *Lutjanus argentimaculatus*, Emperor snapper *Lutjanus sebae* and Snubnose pompano *Trachinotus blochii*), have been identified for the inner island group. The proposed ADZs range from 0.5 to 18.7 km^2 in seafloor extent. Floating cages are likely to be employed and initial production levels set at 1000 tons per annum per square kilometre with a view to increasing production levels depending on the environmental carrying capacity. Other marine-based developments include a pilot-project cage site for finfish and water supply pipelines for a land-based Brood-stock Quarantine and Acclimation Facility and a Research and Development Facility. The Seychelles has several diverse and sensitive marine habitats which include coral reefs and seagrass beds that accrue significant economic benefits via eco-tourism and fisheries related industries.

Impacts associated with the installation of cages within proposed ADZs are limited to disturbance and or mortality to soft-bottom benthic communities as a result of the placement of anchors and moorings on the seafloor. This impact is local, long-term although reversible, and of low intensity and assessed as having low negative overall significance.

Operational phase impacts of caged finfish farming on coral reefs and benthic habitats have been extensively covered in the literature and are detailed in this report. They include:

- Eutrophication and pollution of water and benthic habitats due to increased amounts of organic waste associated with faeces and uneaten food;
- Chemical pollution of marine food webs and mortality of sensitive organisms as a result of using certain chemical therapeutics on stock, antifouling treatments on cages and heavy metals in feed;
- Transmission of fish diseases and parasites from cultured fish to wild populations;
- Escape of genetically different cultured fish which may interbreed and compete with wild stocks that are depleted;
- Physical hazards to marine life which may become entangled in moorings and nets; and
- Piscivores such as sharks and other apex predators are attracted to cages and may damage nets leading to escapees. Conflicts are likely to arise between these animals and farmers who are likely to kill problem animals.

Several of these impacts were considered to have a medium to very high negative overall significance. These include transmission of diseases and parasites to wild stocks, decrease in the genetic fitness of wild stocks, particulate organic build-up beneath cages and an increase in water column nutrients (nitrate and phosphate) and toxic chemicals (copper and veterinary therapeutics) leading to a host of negative impacts on sensitive habitats. With the exception of disease and parasitic transmissions to wild stocks (rated to have high overall significance even after mitigation), these impacts could be reduced to have insignificant to medium overall significance (majority of impacts rated as having low overall significance after mitigation) if mitigation measures are carried out effectively. The pilot-project cage development had similar impacts but of lower significance.

Of particular concern, which could only be assessed with a low level of confidence, is the potential impact of dissolved nutrients, copper and any toxic veterinary therapeutics on sensitive habitats such as coral reefs and seagrass beds. There is no site-specific information on the degree (concentration) and extent (spatial) to which dissolved chemical plumes emanating from proposed ADZs may come into contact with sensitive habitats. Corals and other lower organisms are extremely sensitive to even very low levels of dissolved copper, and increased nutrients could have a profoundly negative impact on coral reefs which are still recovering from the 1998/99 mass coral bleaching event. It is therefore imperative that a detailed and thorough hydrodynamic modelling exercise is undertaken that takes these factors into account. Furthermore, the hydrodynamic modelling exercise must consider the cumulative effects of dissolved nutrients and chemicals emanating from all ADZs together, as plumes from adjacent ADZs may interact and act synergistically. Data for this exercise and baseline monitoring should be conducted for a period of at least a year prior to any ADZ development. Based on the results of these models, ADZs may need to be shifted further offshore to allow for appropriate dilution of nutrients and chemicals to ensure that thresholds are not exceeded. Furthermore, the siting of proposed ADZs should consider the locations of fish spawning aggregation sites as well as dolphin and whale movements (beyond the scope of this report).

The impacts of the proposed Brood-stock Quarantine and Acclimation Facility water-supply pipeline were assessed as having only low negative overall significance without mitigation. However, the proposed water supply pipeline for the Research and Development Facility was assessed as having up to medium level overall negative impacts as it has been zoned over more than 700 m of coral reef. By repositioning the pipeline ~200 m south, this impact can be reduced by 85% to have a very low negative overall significance.

Recommended baseline and continuous environmental monitoring is described as part of the Environmental Management Plan for the proposed developments. An adaptive management strategy is required with a phased development approach for the ADZs that carefully considers and appreciates the sensitivities of the receiving environment in line with the goals of the Seychelles Fishing Authority, to ensure a sustainable industry that respects the unique and sensitive nature of the marine environment.

1. Introduction

1.1. Scope of work

The Seychelles Mariculture Master Plan (MMP) has an overall goal of "enabling the Seychelles to develop a sustainable mariculture sector that is integrated into the country's economic vision and respects the unique and sensitive nature of the marine environment". The marine environment provides the Seychelles with significant ecosystem services and economic benefits via tourism and fisheries related industries. Due to the Seychelles' history of conservation and responsible environmental management, the mariculture industry is being developed according to an Ecosystems Approach to Aquaculture (EAA) in line with the FAO guidelines.

Although the MMP covers both the outer and inner islands of the Seychelles, this ToR is restricted to an ESIA for the inner island group. The focus of this document is to develop an understanding of the various benthic habitats that may be affected by the proposed MMP project. Within this context, the specific role of this report is to:

- Review the relevant existing specialist studies and reports;
- Determine potential impacts based on the project description and undertake an impact assessment for the local coral reef and benthic ecosystems; and
- Provide input into the Environmental Management Plans for the Aquaculture Development Zones and associated marine based developments.

1.2. Development proposal

With the goal of enabling the Seychelles to develop sustainable mariculture to enhance the country's economy, the Seychelles Fishing Authority has proposed the implementation of the Seychelles Mariculture Master Plan. Key components of this plan include developing (i) the necessary general infrastructure (e.g. accommodation, warehouses, municipal services etc.), (ii) specific infrastructure (e.g. hatcheries, grow-out facilities, feed production) and, (iii) improved logistics and freight to support the mariculture industry (sea freight/harbours, airfreight/airport).

As such, twelve proposed sea-based Aquaculture Development Zones (ADZs) have been identified within the inner island group (SFA 2016b). These proposed ADZs will be used to culture finfish. Four potential species have been identified for this purpose and include Brown-marbled grouper (*Epinephelus fuscoguttatus*), Mangrove river snapper (*Lutjanus argentimaculatus*), Emperor snapper (*Lutjanus sebae*) and Snubnose pompano (*Trachinotus blochii*) (SFA 2016a).

The development of these ADZs is expected to follow a phased approach with the operation of Tier 1 ADZs initially, followed by Tier 2 ADZs (SFA 2016a). The proposed ADZs collectively comprise a sea-floor area of 53.2 km^2 and are located in three loose clusters (Figure 1) (SFA 2016a). The sizes of the individual ADZs range from 0.51 to 18.73 km^2 (Table 1) (SFA 2016a).

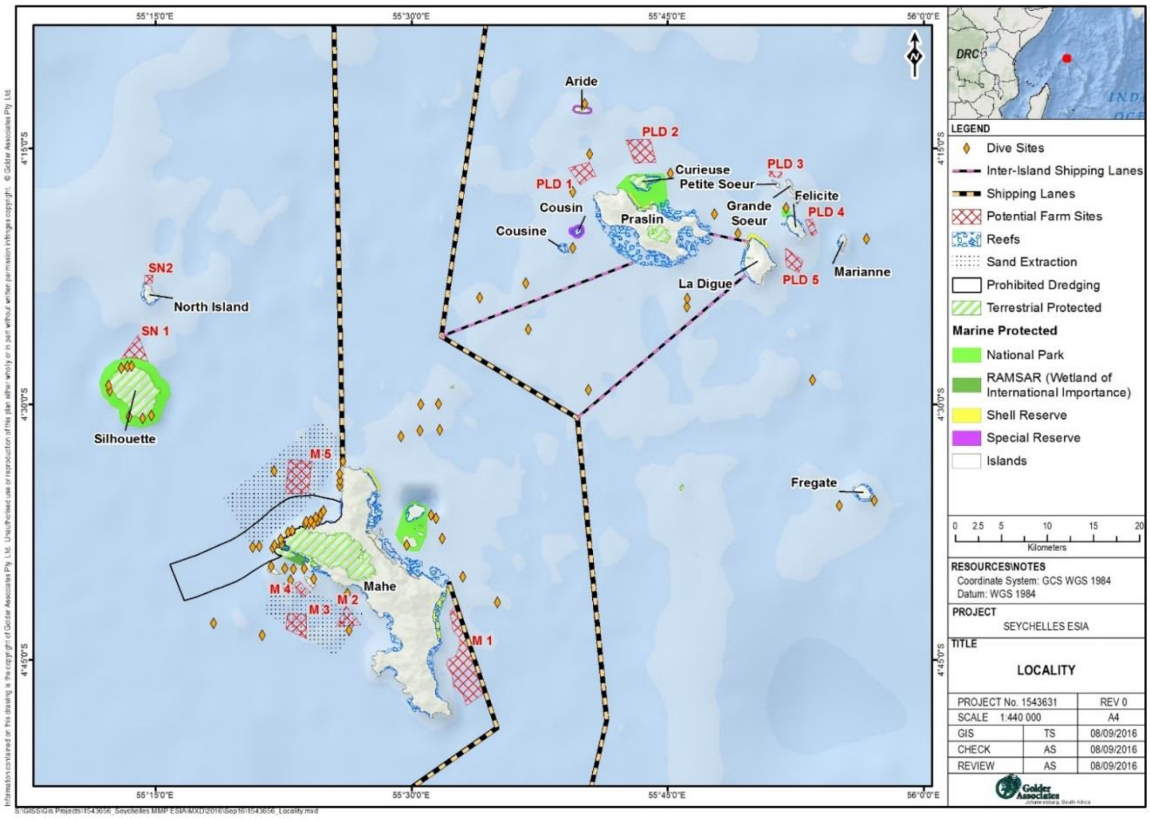

Figure 1. Locations of the proposed Aquaculture Development Zones (ADZs) around the inner island group, Seychelles (SFA 2016a).

Table 1. Proposed Aquaculture Development Zones (ADZs) around the inner island group and their sizes

Tier	Name	Size (sea-floor, km^2)
1	M2	2.85
	M3	3.46
	M5	8.59
	PLD2	6.14
2	M1	18.73
	M4	1.06
	PLD1	3.90
	PLD3	0.75
	PLD4	1.16
	PLD5	2.93
	SN1	3.05
	SN2	0.51

Within each proposed ADZ, floating cages will be anchored to the sea floor to house cultured finfish. Several cage designs exist, but the most likely type of cage to be used is a circular high-density polyethylene cage due to its suitability to rough sea conditions and adaptability (Figure 2). Table 1 provides detailed specifications of the probable cage design. Twelve such cages would be required for a 1000 ton per annum production unit (see SFA 2016b; SFA 2016a). Production and stocking densities will follow the precautionary principle (See SFA 2016b). Accordingly, a modest production level of 1000 tons per annum per square kilometre will be the limit within an ADZ. This equates to a maximum standing biomass of 650 tonnes per square kilometre at any one time (SFA 2016b).

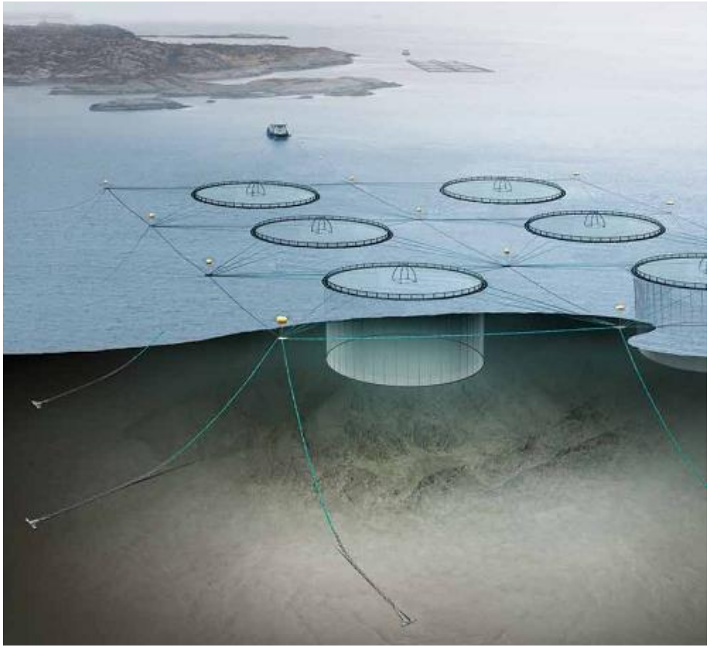

Figure 2. Circular high-density polyethylene cages likely to be used within Aquaculture Development Zones (ADZs).

Table 2. Typical cage specifications likely to be used within proposed Aquaculture Development Zones (ADZs)

Component	**Detail**	
Cage type	Polarcirkel -	High-density polyethylene
Cage size	Circumference -	100 m
Cage size	Diameter -	32 m
Floating pipes	Diameter -	315 mm
Net depth	Depth of net in water -	5 m (+1.3 m)
Cage volume	Volume in water -	4019 m^3

Associated with the ADZs are specific developments to support the culture of finfish. These include a i) pilot-project cage site, ii) Brood-stock Quarantine and Acclimation Facility (BQAF), and iii) a research and development (R&D) facility. With the exception of the pilot-project cage site, the other two developments are largely land-based but with associated water pipelines feeding them fresh seawater from the coastal zone.

All three of these developments will be situated on Mahé (Figure 3). The BQAF (Figure 4) and pilot-project cage site (Figure 5) will be located at Providence whereas the R&D facility will be located further south at Anse Royale (Figure 6). Details on the pipeline specifications and dimensions are not available yet.

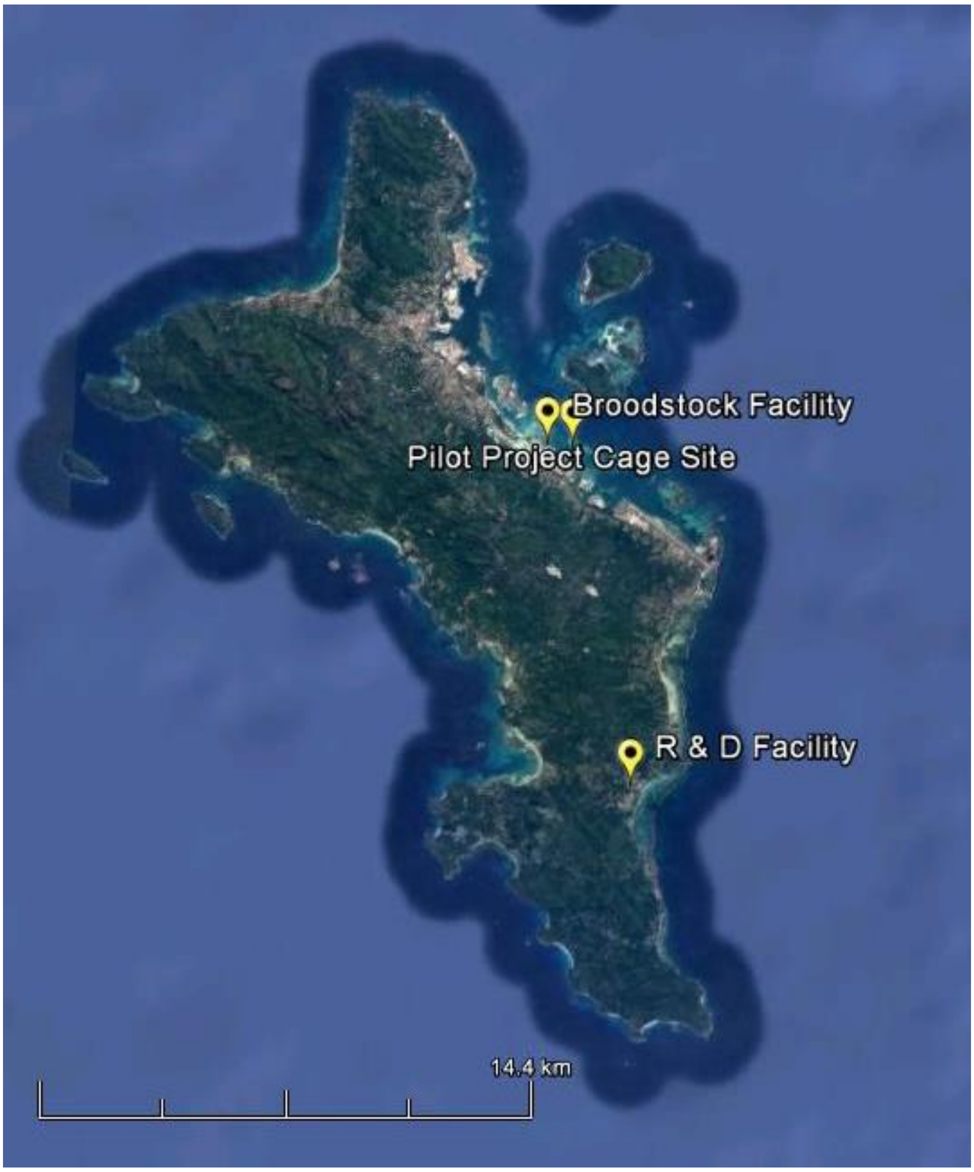

Figure 3. Mahé Island, Seychelles indicating the locations of the proposed i) brood-stock and quarantine facility ii) pilot project cage site, and iii) research and development facility (R & D facility).

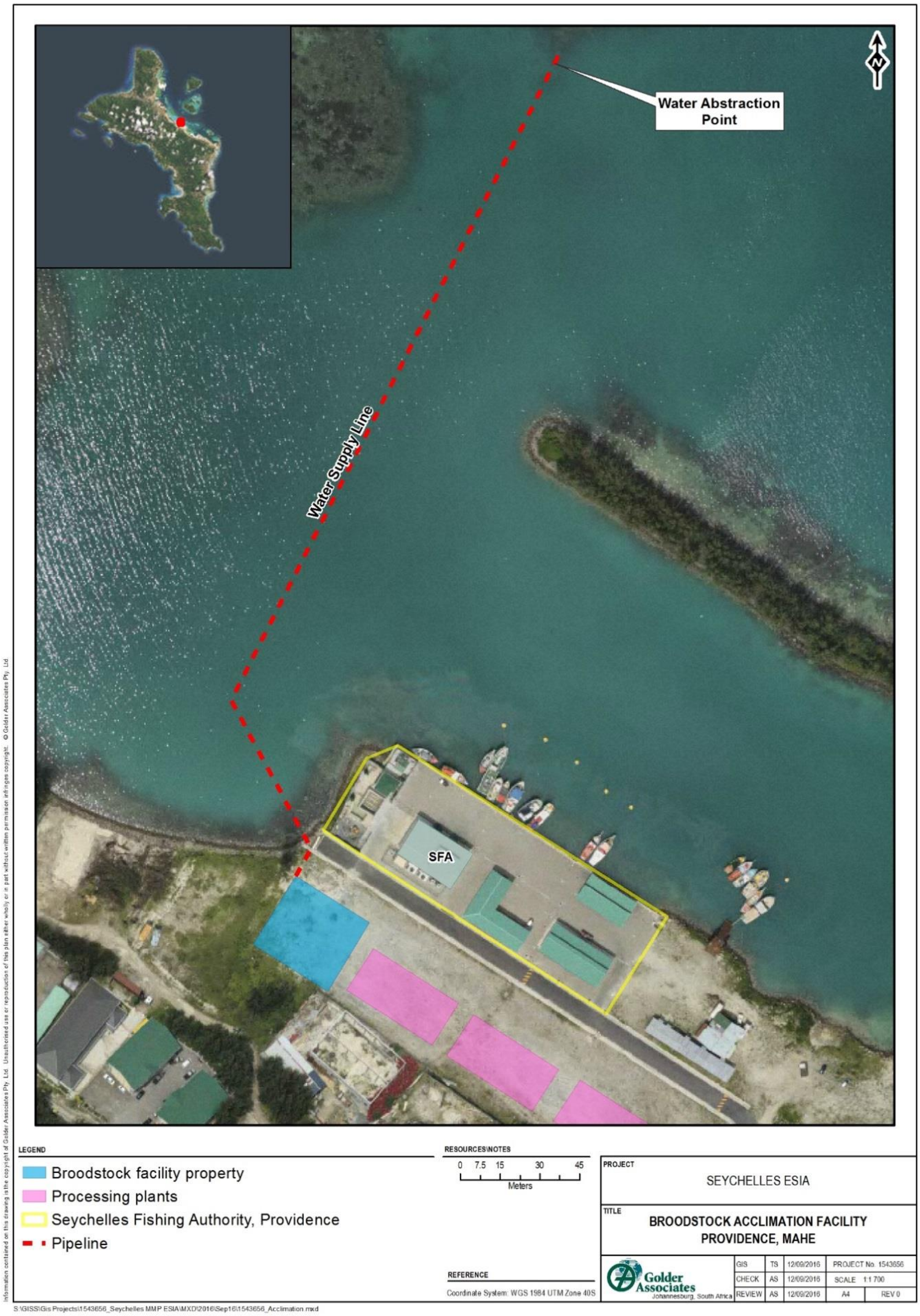

Figure 4. The proposed locations of the brood-stock and quarantine facility at Providence, Mahé indicating the location of the water supply pipeline (SFA 2016a).

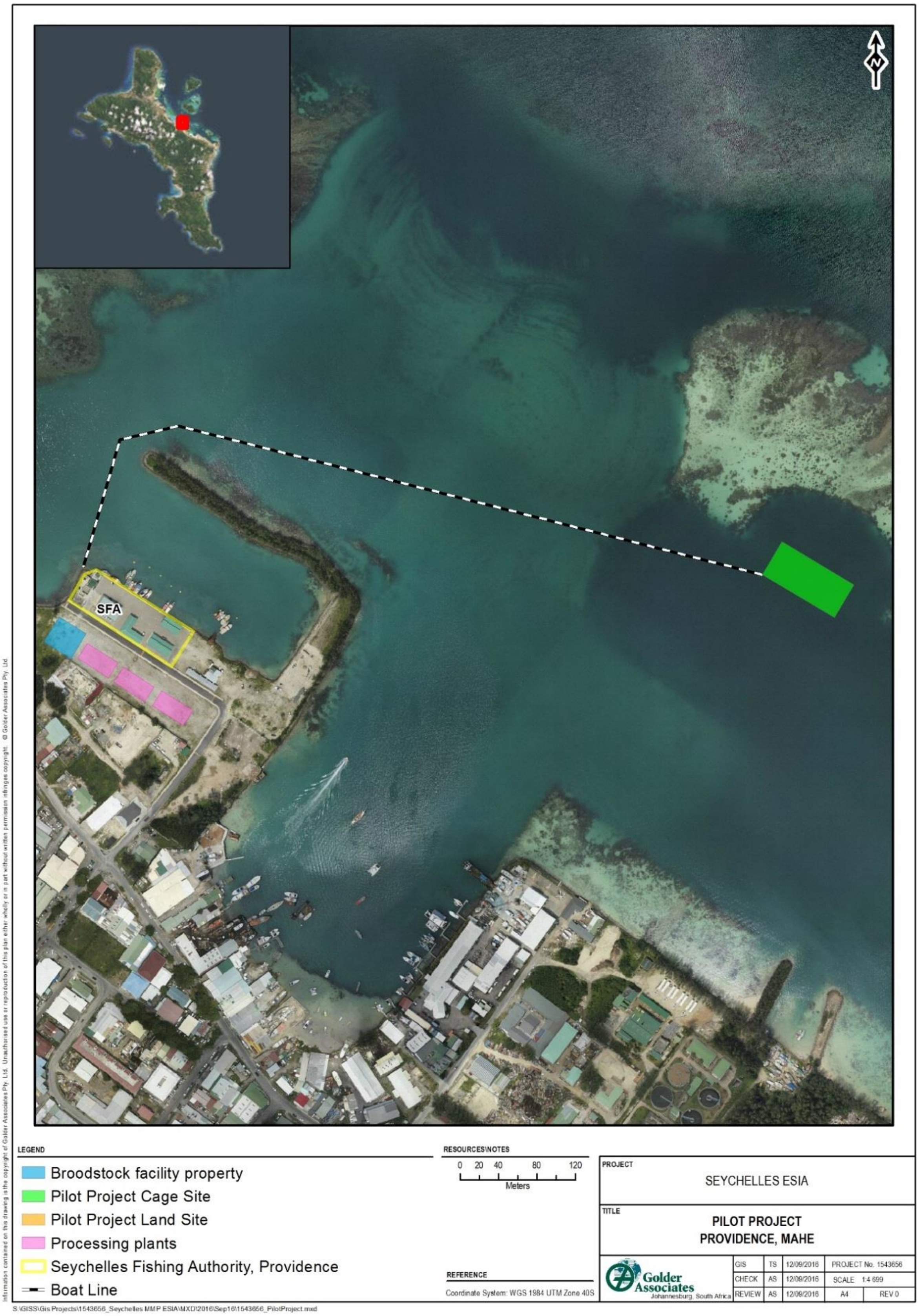

Figure 5. The proposed location of the pilot-project cage site at Providence, Mahé (SFA 2016a).

Figure 6. Proposed location of the research and development facility at Ansa Royale, Mahé with associated water supply pipeline (SFA 2016a).

2. Due Diligence Review

Key reports emanating from the ESIA process that were considered relevant to assessing the impacts of the proposed developments on coral reef and benthic habitats were as follows:

- SFA. 2016a. ESIA Scoping report and Terms of Reference (ToR) for the proposed implementation of the Seychelles Mariculture Masterplan (MMP). Seychelles Fishing Authority. Report Number: 1543656-307639-2.
- SFA. 2016b. Selection of aquaculture development zones (ADZs) around the inner islands of the Seychelles and their ecological carrying capacity. Advance Africa Management Services. Pp. 111.
- VASCO Consulting. 2009. Offshore sand-burrowing in Seychelles: Environmental impact assessment.

A relatively modest amount of biological information was provided on the benthic habitats specifically within the proposed development footprints in the reports. The biological information provided was at a general habitat level, of course scale and qualitative. For example, proposed ADZ M1 is 18 km^2 in extent but only two grab samples and no ROV surveys have been conducted within it to date. Similar issues are found with proposed ADZs PLD 5, PLD 4 and M 5. At the broad habitat level, all relevant habitats were considered when delineating sites for proposed ADZs, and sensitive habitats/areas such as coral reefs and marine protected areas were avoided. It is understood that at this stage the development proposal is not a specific project development with finite locations and parameters, but it is still an industry approach with dynamic components that need to be evaluated and fine-tuned before final sites for the proposed developments are selected.

However, key gaps at this stage that need be considered in the site selection process of ADZsinclude:

- The locations of fish spawning aggregations
- Movement patterns and behaviours of pelagic marine mammals such as whales and dolphins (not covered in the coral reef and benthic specialist report but probably still important to appoint a specialist to assess)
- Dispersion of dissolved organics (nitrates and phosphates), and other chemical pollutants, particularly copper and chemicals used as anti-foulants and veterinary therapeutics.

Aside from the gaps highlighted above, an extensive review of available literature was conducted on the coral reef and benthic habitats of the Seychelles Plateau and inner island group with the aim of gathering as much detailed information as possible on the affected area in general and within the footprints of the proposed developments to augment information compiled in the above studies. Little quantitative or fine-scale information could be found on benthic habitats within the proposed development footprints and the acquisition of the necessary data is discussed further in Section 3.

3. Description of the Seychelles Marine Environment and Benthic Habitats

3.1. Physical environment and oceanography

The Seychelles Archipelago comprises 115 islands located in the central Indian Ocean approximately 1 500 km from the east coast of Africa. They are true oceanic islands formed by continental drift and rifting which were emplaced 750 million years ago during the late Precambrian. Of these, 45 are granitic islands whilst the remainder are coral islands. The coral islands are generally flat whilst the granitic islands form mountains which can rise as high as ca. 900 m above sea level. The inner island group located on the Seychelles Bank, which includes Mahé and neighbouring smaller islands within a 56 km radius, is granitic and forms the northern arc of the Mascarene Ridge (Davies and Francis 1964; Israelson and Wohlfarth 1999). Around much of the inner granitic islands are fringing coral reefs which began forming during the Holocene Period approximately 8000 years ago (Braithwaite et al. 2000; Kennedy and Woodroffe 2002).

The inner island group is located only a few degrees south of the equator (-4.5°S; 55.5°E). It is therefore exposed to tropical oceanographic conditions largely influenced by the Indian Ocean Equatorial Counter Current, the North Equatorial Current and the South Equatorial Current (Hastenrath and Greischar 1991) (Figure 7). The monsoon and trade winds play significant roles in the dynamics of these circulation patterns and wave action in general (Woodberry et al. 1989).

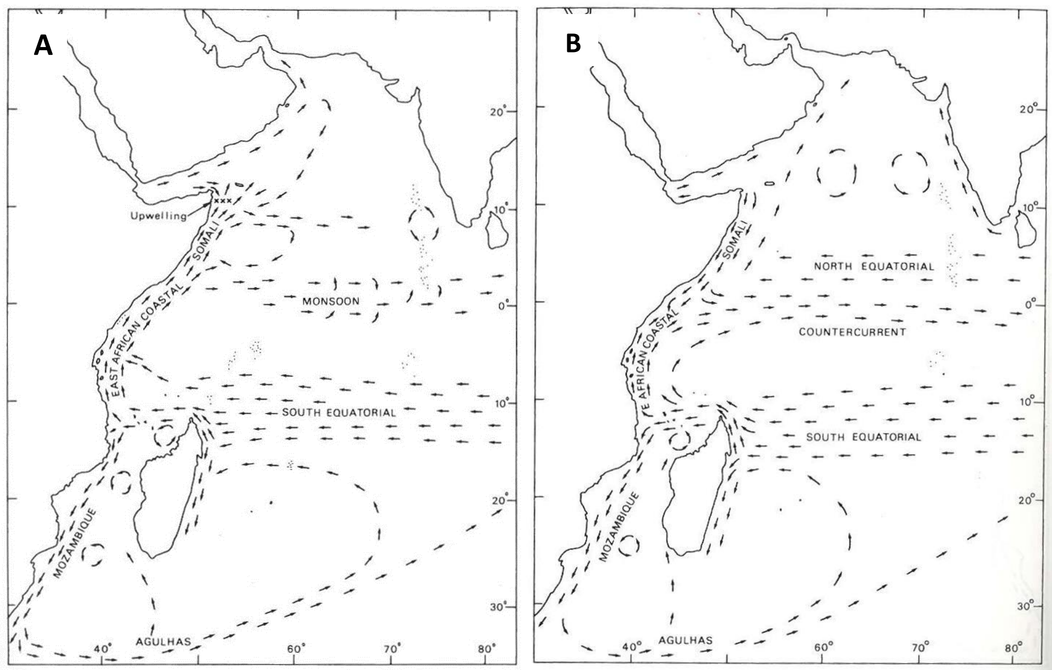

Figure 7. Current systems during A) the Southeast Trade Wind season (May-September), and B) Northwest Monsoon (October-April) (Source: Frazier 1984).

During summer, the eastward flowing Equatorial Counter Current dominates flow in the region of the inner granitic islands (Cazes-Duvat & Robert, 1997). Contrastingly, in winter, the South Equatorial

Current shifts to higher latitudes resulting in predominantly westward flow around the inner granitic islands (New et al. 2004). These circulation patterns and their alteration between periods have a profound influence on water temperatures that create two maxima and minima per year (ASCLME 2012) (Figure 8). Mean ± standard deviation sea-surface temperatures are 27.96 ± 1.5°C in the Seychelles (ASCLME 2012). The Seychelles region is characterised by a semi-diurnal tidal cycle with a relatively small spring tidal range of 1.2 m (Mahé) (Ngusaru 2002). Current velocities range from an average of approximately 0.1 m S^{-1} from May to October, before steadily increasing and peaking in January at 0.28 m S^{-1} (ACLME 2012) (Figure 9).

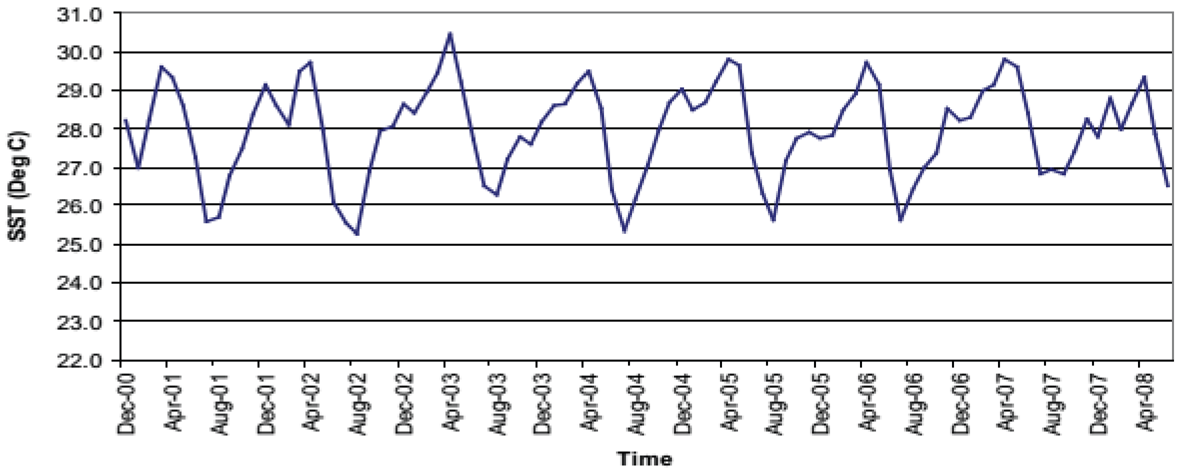

Figure 8. Sea-surface temperatures in the Seychelles (ACLEM 2012).

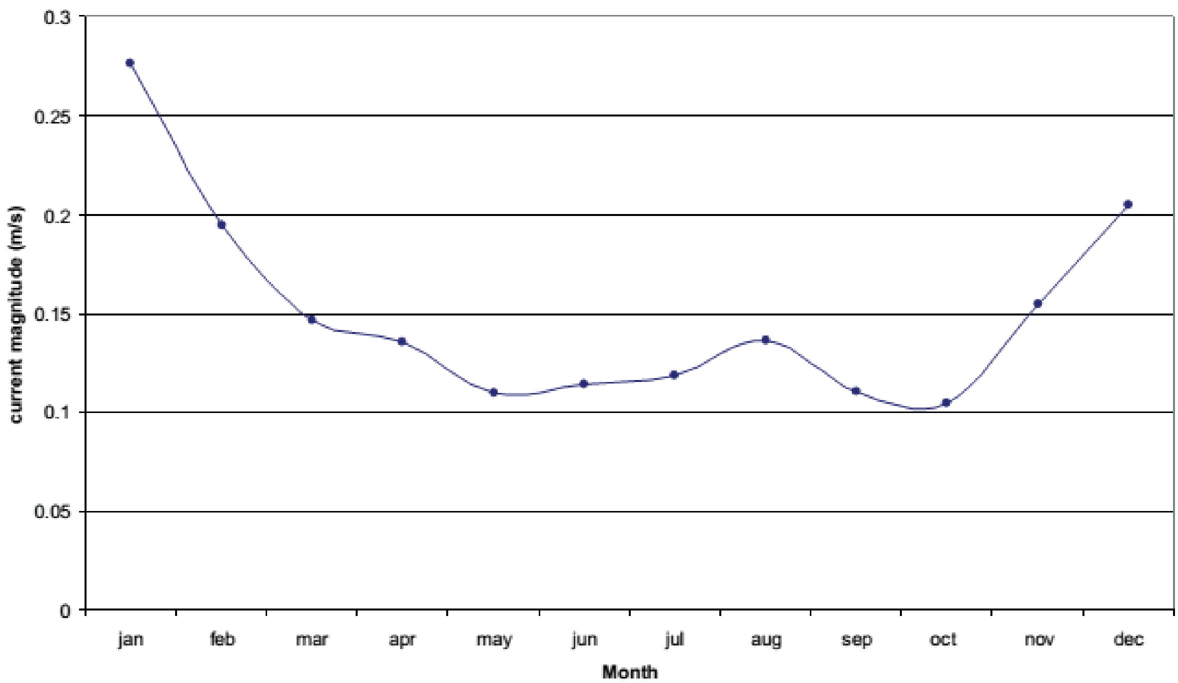

Figure 9. Mean monthly current velocities at Mahé derived from satellite altimetry (ACLME 2012).

The oceanic waters of the Seychelles are typically oligotrophic (ACLME 2014). However, the h effects of anomalously high nutrients and primary production have been felt. An extensive phytoplankton bloom occurred in August 2003 that resulted in large-scale death of benthic communities and fish (Bijoux et al. 2003). Nutrient levels of coastal waters are also generally low and oligotrophic (ACLME 2014). However, exceptions occur at point sources such as Port Victoria where there are food factories and around certain river mouths. This has led to eutrophication and the formation of algal blooms when hydrodynamic and climatic conditions are conducive (ACLME 2012).

3.2. Key benthic habitats and biodiversity

3.2.1. Regional biogeography

Spalding et al. (2007) have categorised the coastal and shelf areas of the worlds' oceans into a hierarchical classification system based on biodiversity. The largest geographic unit of this classification scheme are *realms,* with *provinces* nested within these and *ecoregions,* the smallest of these units, nested within provinces. The Seychelles group lies within its own ecoregion, the Seychelles Ecoregion, that encompasses all its islands but which is separate from mainland Africa, Madagascar and the Cargados Carajos/Tromelin Island region. This bioregion is one of nine that together comprise the Western Indian Ocean Province which extends from the Red Sea south to South Africa and eastwards to western Sumatra. The Western Indian Ocean Province is in turn one of seven provinces that make up the Western Indo-Pacific Marine Realm.

Like many tropical ecoregions, the Seychelles Ecoregion is well recognised for its high levels of biodiversity (Stoddart 1984a; Emmerton 1997; Bijoux et al. 2008). Characteristic coastal benthic habitats include coral reefs, rocky reefs, seagrass beds and soft bottom benthic habitats. These habitats exist along a continuum from hard consolidated habitats to soft unconsolidated substrata (Jordan et al. 2004; Halley and Bruce 2007).

3.2.2. Habitat zonation

At a broad habitat level and spatial scale, the Seychelles Bank is composed of more or less equal amounts of consolidated and unconsolidated habitat types (Table 3 and Figure 10). The Seychelles bank is shallow, averaging 44 to 65 m, and reaches a maximum depth of 100 m (Taylor 1968; Zuschin & Oliver 2003; Bijoux et al. 2008). This has been confirmed by SFA (2016b) for the proposed ADZs which have average depths of 34.4 to 46.0 m.

Table 3. Areal extent of various broad-level habitat types on the Seychelles Bank (Source: Bijoux et al. 2008).

Habitat category	**Area (km²)**	**Percentage Cover**
Algae	1014.72	2.67
Shallow area	1937.41	5.10
Hard substrata	17082.14	45.01
Mud	6133.57	16.16
Muddy sand	7369.45	19.42
Pinna shells	317.52	0.84
Sand and shells	4098.26	10.80
TOTAL	37953.07	100.00

Table 4. Depth ranges of proposed ADZs (SFA 2016b).

Proposed ADZ	**Depth Min (m)**	**Depth Max (m)**
PLD1	25	40
PLD2	30	45
PLD3	46	48
PLD4	36	42
PLD5	41	43
M1	32	52
M2	29	41
M3	42	48
M4	25	40
M5	40	43
SN1	32	62
SN2	35	48
Average ± SD	34.4 ± 6.8	46.0 ± 6.3

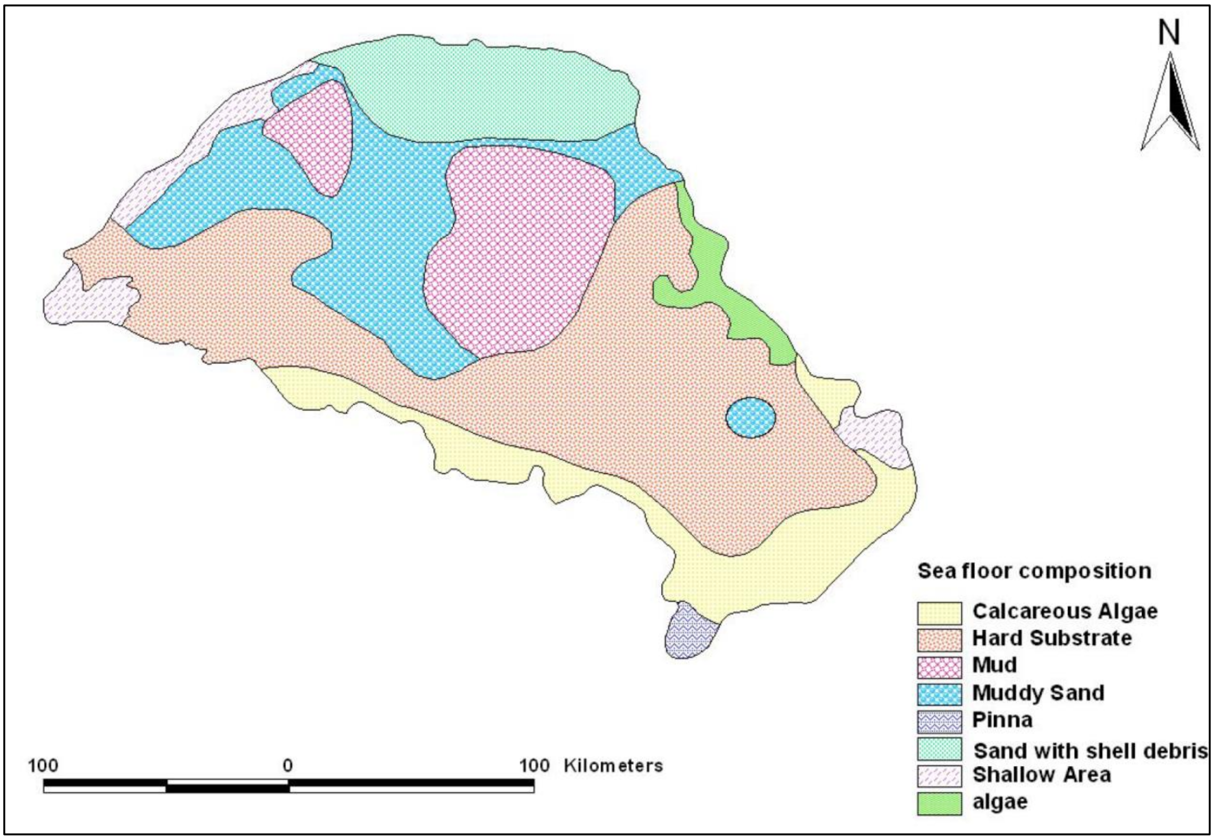

Figure 10. Benthic seabed composition of the Seychelles Bank (Source: Bijoux et al. 2008).

The inner island fringing reefs typically comprise several zones before they become fragmented progressively with depth giving way to isolated coral colonies and eventually deep (30-100 m) sandy unconsolidated habitats or rocky reef encrusted with a variety of sessile invertebrates (including corals) and algae (Figure 11). These zones are as follows:

1. Outer reef slopes. Support active coral growth up to a depth of 10 m before the abundance of hard corals decreases rapidly at greater depths.
2. Reef edge. This zone of approximately 20 -40 m wide characterised by a gentle seaward slope. It is a shallow exposed zone and consequently experiences rough wave action. Encrusting forms and species of hard corals are characteristic.
3. Algal ridge. This area lies inshore of the reef edge and at spring low tides may be exposed above the low water mark. It is comprised of a mixture of hard coral and algae species.
4. Radial zone. This zone is characterised by alternating cobble ridges and sand filled troughs. This zone is colonised by both algae and hard corals
5. Seagrass beds. These areas are characterised by sheltered sandy eulittoral flats or rubbly reefs dominated by marine angiosperms (seagrasses).
6. Rippled sand zone. This is a narrow belt of rippled and mobile sand between the seagrass beds and the beach.
7. Beach. Largely a mixture of carbonate and quartz sands usually 15-25 m wide.

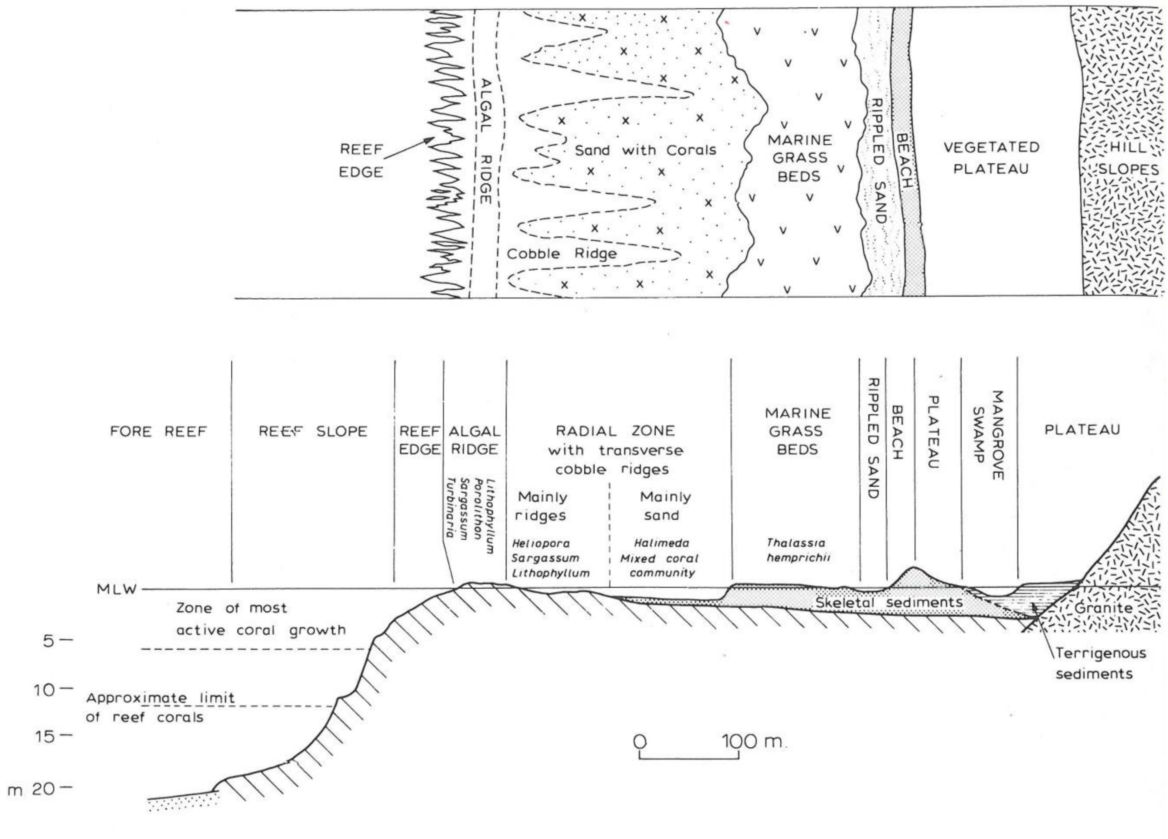

Figure 11. Typical reef zonation of fringing reefs and associated habitats in the inner island group such as those located at Mahé (Source: Stoddart 1984b).

3.2.3. Coral reefs

Coral reefs in general are restricted to shallow photic (< 20 m) regions of the ocean. Coral reefs of the Seychelles contribute high levels of biodiversity and provide significant economic benefits to the fisheries and ecotourism industries (Emmerton 1997; Bijoux et al. 2008). Relative to many other countries in the western Indian Ocean, the Seychelles is characterised by a large expanse of coral reef (Table 5). Three types of reef are present; fringing reefs, platform reefs, and atolls. Fringing reefs characterise the inner island group which can range in width by as much as 2800 metres.

Coral reefs are most extensive around Mahé and Praslin islands. The reefs of Mahé were first described by Lewis (1968, 1969) and Taylor (1968). The reefs along the south east coast of Mahé are continuous and vary in width from 500 to 700 m. Those reefs along the northwest coast, although more protected, are irregular and interspersed with deep channels, and vary in width by up to 1500 m. Reefs on the west coast are limited, disjointed and located mainly in bays. Contrastingly, on Praslin, reefs are widest on the west coast extending almost 3 km out to sea. On La Digue, reefs extend along most of the west coast, where they reach their widest (380-610 m), and are narrowest (75-150 m) along the southwest of the island.

Table 5. Areas of coral reefs for countries in the western Indian Ocean (Source: Spalding et al. 2001)

Country	Coral reef area (km^2)
Seychelles	1690
Comoros	430
Kenya	630
Madagascar	2230
Mauritius	870
Mayotte	570
Mozambique	1860
Réunion	<50
Seychelles	1690
Somalia	710
Tanzania	3580

Table 6. Fringing reefs of the Seychelles (Source: Stoddart 1984b)

Island	Area of island (km^2)	Area of fringing reefs (km^2)	Reef width (m)
Mahé	152.0	20.4	510-1300
Praslin	37.8	26.8	380-2870
La Digue	10.1	4.5	75-610
Curieuse	3.0	2.1	750
St Anne	2.2	0.6	100-330
Cousin	0.3	0.5	130-460
Cousine	0.3	0.4	

Coral reefs in the Seychelles Ecoregion are dominated by scleractinian (hard) corals. One hundred and forty-three species from 55 genera have been recorded for the Seychelles archipelago (Sheppard 1998). In the granitic islands specifically, the earliest work by Rosen (1971), Pillai et al. (1973) and Wijsman-Best et al. (1980) recorded 51 genera, 45 of which were hermatypic (photosynthetic). More recent surveys of the granitic islands have recorded 109 species from 37 genera (mainly around Mahé) (van der Land, 1994), and 109 species from 42 genera (Turner et al. 2000).

Stoddart (1984b) provides an historical account of the species composition on the granitic islands according to various reef zones around Mahé with a focus on corals. Similarly, Kalugina-Gutnik et al. (1992) do so for the algal flora at Mahé and adjacent islands where they recorded a total of 173 algal species. The upper areas of the outer reef slopes were found to be dominated by branching *Acropora* species, especially on exposed coasts around Mahé, in particular *A. pharaonic*, *A. divaricate*, *A. irregularis*, *A. palifera* and *A. humulis*. *Seriatopora caliendrum* and *Fungia fungites* were also characteristic (Figure 12).

Figure 12. A typical coral reef community on the west coast of Mahé dominated by branching *Acropora* species (Photograph: Tom Mannering ©)

Species of *Porites*, *Favia* and *Leptoria* were more common on the lower parts of the outer reef slope and exhibit massive growth forms. The reef edge was characterised by encrusting forms of coral, especially *Millepora dichotoma*, *Pocillopora danae*, *P. meandrina*, *A. digitifera*, *Goniastrea pectinate* and crustose coralline algae. Small colonies of *Stylocoeniella armata*, *Hydnophora microconos*, *G. pectinate*, *Montipora, Cyphastrea*, *Porites* and *Acanthastrea* frequent the algal ridge zone which they share with several species of brown algae mainly *Sargassum* spp. and *Turbinaria decurrens*, and crustose coralline algae *Lithophyllum* spp. and *Porolithon* spp. The radial zone of the reef was largely dominated by various algae in the shallower parts, especially *Sargassum* spp. and *Turbinaria* spp., but also *Halimeda opuntia.* The deeper troughs and waters of the radial zone were characterised by *A. pharaonic*, *Porites divaricate*, *P. nigrescens*, *Pocillopora damicornis*, *Heliopora coerulea*, *Goniastrea*, *Favia* and *Platygyra*.

Off Praslin Island, at a distance of 2-3 km from the shore and at a depth of 20-30 m, the reef platform is populated by branched *Acropora* and *Turbinaria* as well as solitary *Heteropsammia cochlea* (Selin et al. 1992). Similarly, in 1994, Graham et al. (2006) found that these reefs were characterised by high coral cover of branching and massive coral, soft coral and high structural complexity.

Soft corals also contribute significantly, particularly *Sinularia* spp. and *Sarcophyton* spp. (Pittman 1996) and generally compete for space with scleractinians. They can be particularly prevalent and sometimes dominant on the deeper (10-12 m) outer regions of the reef slope (Pittman 1996). Other commonly encountered cnidarians include several coralomorpharians and sea anemones (Pittman 1996). Up to 20% of the reef has been recorded to be covered by Coralomorpharians in certain areas (Pittman 1996).

Mobile invertebrates associated with these reefs include molluscs such as *Cypraea histrio*, *Conus distans*, *Lambis chiragra*, *L. truncata*, *L. crocata*, *Chicoreus ramosus*, *Tridacna maxima*, *Pinctada margaritifera* and echinoderms, in particular *Diadema savignyi* and *D. setosum* and various holothurians (Selin et al. 1992; Pittman 1996).

Recent accounts, subsequent to the mass 1998 coral bleaching event, indicate a far more sobering status of the coral reefs off the granitic islands. The granitic islands suffered severe degradation following the 1997/1998 mass coral bleaching event (Turner et al. 2000). The shallow continental shelf basin of the Seychelles Bank, with most fringing reefs extending to only 10 m depth, led to a 'bathtub effect' likely leading to extensive mortality and precluded any depth refuge below which corals could survive (Graham et al. 2008). Two years after this event, live coral cover had been reduced to less than 10% on most reefs around the inner islands and partial mortality of colonies was high (Turner et al. 2000). Species diversity was also low (Turner et al. 2000). Massive and sub-massive corals generally survived, such as *Porites*, *Goniopora*, *Acanthastrea* and *Diploastrea*. However, branching and or tabular species such as *Acropora* and *Pocillopora* were badly affected.

As a consequence of this mass climate-driven bleaching event, many reefs in the Seychelles have undergone a widespread phase shift from a coral-dominated state to a rubble and algal-dominated state (Figure 13) (Graham et al. 2006). For example, macroalgal cover has increased 7-fold (1994 versus 2005). This has led to local extinctions, substantial reductions in species richness, reduced taxonomic distinctness, and a loss of species within key functional groups of reef fish (Graham et al. 2006).

Consequently, reef structure began to break down, and exposed island shores to erosion during storms (Turner et al. 2000). Coral mortality in the Seychelles has been shown to increase wave energy reaching shores previously protected by reef flats (Sheppard et al. 2005). Recovery has been slow, and has been exacerbated by poor fishing practices, boat anchors and especially sedimentation and siltation from coastal developments (Turner et al. 2000; Payet et al. 2005). The coral communities of the Seychelles are particularly at risk, as a result of their isolated geographical location far from other sources of larvae and the shallow coastal plateau, which tends to accumulate warm water during warm months with a long residence time and a dearth of large rivers to cool coastal waters (Payet et al. 2005).

Figure 13. An algal dominated reef. (Photograph: Tom Mannering ©)

Table 7. Recovery potential of the granitic reefs (Source Payet et al. 2005).

Mean rate of recovery	Inner island granitic reefs (n = 13)
Negative (% yr^{-1})	7.60
Low (0-2% yr^{-1})	7.69
Medium (2-5% yr^{-1})	46.15
High (>5% yr^{-1})	38.46

3.2.4. Rocky reefs

At greater depths (30–100 m), accretive coral reefs do not exist and any exposed granitic rock may be colonized by isolated scleractinian corals, soft corals, sponges, ascidians and algae (Turner and Klaus 2005). Jennings et al. (1995) for example, have remarked that several of their study sites around Mahé and Praslin were small patch reefs consisting of coral communities growing on granitic substrate surrounded by sand. Rocky reefs are likely to occur on the Seychelles bank to depths of 100 m, as a large portion of the bank is comprised of hard consolidated substrate down to 100 m (Bijou et al. 2008) (Figure 10). However, very little is known about the benthic community composition on deep reefs in general. Deep reef locations are often easily detected due to changes in bottom topography or aggregations of fishermen, but they are difficult to sample quantitatively. In general, deep reefs are characterised by invertebrate filters feeders that don't rely on light for energy such as ahermatypic corals, sponges and ascidians.

Several botanical surveys by Kalugina-Gutnik et al. (1992) around Mahé, Praslin and La Digue islands extended down to depths of 50 m. At depths of 40 m, *Chlorodesmis comosa*, *Cladophora laetevirens*, *Halimeda* sp., *Cladophoropsis sundanensis*, *Dictyota divaricata*, *Champia salicomioides*, *Dasya* sp., *Antithamnion herminien*, *Chondria* sp., *Lobophora variegate* and *Laurencia* sp. were relatively common algae taxa (Kalugina-Gutnik et al. (1992).

Sponges are also likely to be an important contributor of reef community composition on deeper reefs. Early work by Thomas (1973) around Mahé recorded 73 species belonging to 56 genera divided among 25 families. Unfortunately, the study is largely taxonomic and does not provide information on the depths species were collected at.

Information on the diversity and community composition of the deep granitic reefs is a major knowledge gap.

3.2.5. Seagrass beds

Relative to mangrove and coral reef habitats, seagrass beds in the western Indian Ocean region have received limited scientific attention (Gullström et al. 2002), including those in the Seychelles (Hugues Dit Ciles 2002). Substantial seagrass beds grow on the shoreward zones of almost all reef flats around the coasts of the granitic islands (Sheppard et al. 2005). They are also common in deeper subtidal areas down to 35 m (Green and Short, 2003), but some species have even been recorded at depths of 50 m (Milchakova et al. 2005). Around the island of Mahé, seagrass beds cover 4.44 km^2 and are particularly prolific at St Anne and Anse aux Pins (Holland 2000).

Eight species (*Cymodocea rotundata, Cymodocea serrulata, Enhalus acocroides, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium, Thalassia hemprichii* and *Thalassodendron ciliatum*) have been recorded in the Seychelles, six of which have been found at Mahé (Aleem 1984; Kalugina-Gutnik et al. 1992; Spalding et al. 2001). *Thalassodendron ciliatum* and *Thalassia hemprichii* are common in subtidal areas at water depths of up to 33 m throughout the Seychelles (Green and Short, 2003). These two species are typically found at densities of 540-627 and 1123-1761 shoots per m^2 respectively (Ingram and Dawson, 2001). The density with which seagrass typically grows is well known to offer resistance to waves which mitigates coastal erosion (Fonseca and Calahan, 1992).

A variety of invertebrates use these habitats as nursery and foraging areas as well as predation refuges (Figure 14) (Gullström et al. 2002). These include sandy infaunal species of crustaceans (harpacticoid copepods, amphipods, and ostracods), bivalves, polychaetes, nematodes, cumaceans, holothuroids and phoronoids (Howard et al. 1989); epiphytic species such as various algae and bryozoans, hydroides (Kikuchi and Pérès 1977); and sediment-surface living taxa such as echinoderms (starfish, sea urchins, brittle stars and sea cucumbers), crustaceans (crabs) and molluscs (bivalves and snails) (Kirkman et al 1991; Kalk 1995). Seagrasses are a particularly important food source for green turtles (Zieman et al. 1984).

Figure 14. Seagrass meadows provide habitats for numerous species of invertebrate and fish. Photograph Klaus Stiefel ©

Beside their contribution to primary production, seagrasses therefore perform many other ecosystem functions including: provision of food for coastal food webs, provision of oxygen to waters and sediments, carbon sequestration from the atmosphere, organic carbon export to adjacent ecosystems, sediment stabilization, prevention of sediment resuspension, improvement of water clarity, wave attenuation, shoreline protection, habitat for many life forms (microbes, invertebrates, vertebrates) which are often endangered or commercially important, and trapping and cycling of nutrients (Duarte 2002).

3.2.6. Soft bottom benthos

Large expanses of soft bottom unconsolidated habitat is particularly common in the deeper areas of the Seychelles Bank, but due to its relative inaccessibility, its benthos has been poorly studied (Bijoux 2008). However, the soft sediment benthos has been investigated at 13 sites around Mahé by Mackie et al. (2005) who focused on the mollusc and polychaete worm assemblages (Figure 15). Arthropods and echinoderms were not analysed but sediment classification and grain-size analyses were also undertaken (Table 8). Species diversity levels were on par or at least as high as any others described from tropical regions. A tentative estimate of the species diversity of the molluscan fauna suggests a total of 400-500 species for the Seychelles. A total of 317 species were recorded by Mackie et al. (2005) comprising 145 polychaetes, 82 bivalves and 90 gastropod species.

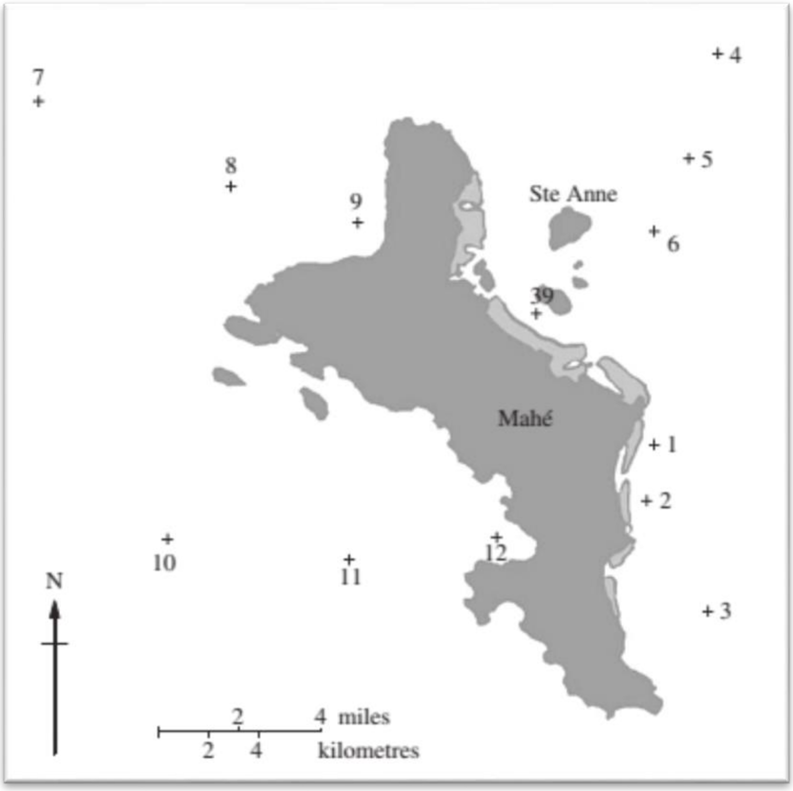

Figure 15. Locations around Mahé where soft sediment benthos was sampled between 12 – 63 m (Mackie et al. 2005)

Table 8. Sediment grain size analyses and classification for 13 sites around Mahé (Mackie et al. 2005)

Location	Gravel (%)	Sand (%)	Silt-clay (%)	Carbonate (%)	Depth (m)
1	6.25	93.56	0.17	99.9	21.0
2	24.08	75.88	0.04	66.1	30.0
3	5.74	89.19	5.08	41.0	45.0
4	0.88	96.35	2.78	91.8	35.0
5	2.23	97.78	0	93.4	35.0
6	3.46	96.39	0.15	98.8	25.5
7	2.00	86.21	11.80	32.2	62.5
8	10.44	88.84	0.71	22.8	41.5
9	0.27	91.86	7.87	16.4	28.0
10	5.46	69.79	24.75	91.0	56.0
11	5.67	92.97	1.36	10.0	48.0
12	0.0	56.74	43.26	65.8	27.5
39	1.74	91.37	6.89	99.0	12.5

Overall, communities at the deeper locations from the southeast to the northwest tended to form a group distinct from the shallower ones in the east/northeast and northwest. Generally, community composition correlated most with depth and the proportion of mud (silt-clay) comprising the sediments. Other studies on sandy macrofauna are largely taxonomic and descriptive (ten Hove et al. 1994; Westheide 2000; Westheide & Hass-Cordes 2001; Darbyshire & Mackie 2003; Mortimer & Mackie 2003), although Böggemann et al. (2003) investigated the composition and diversity of shallow sandy meiofaunal communities in lagoon areas around Mahé and recorded 33 different syllid polychaete species.

Underwater camera surveys have revealed the erratic presence of larger invertebrates including sea cucumbers, starfish and crabs in areas which have now been dredged off Mahé (sand borrow areas north west and south west of the island) (VASCO Consulting, 2009). More recent remotely operated vehicle and qualitative sediment and macrobenthic surveys, undertaken as part of this proposed development, have revealed mainly sandy unconsolidated habitats and the presence of sponges, anemones, polychaetes, bivalves, shrimps, crabs and brittlestars in the proposed ADZs (SFA 2016b).

Two extensive sand dredging/borrow areas are located north-west and west of Mahé (Figure 16). The two locations were heavily dredged and the sediments used for land reclamation. The benthic habitats within these two zones have therefore been significantly transformed and negatively impacted.

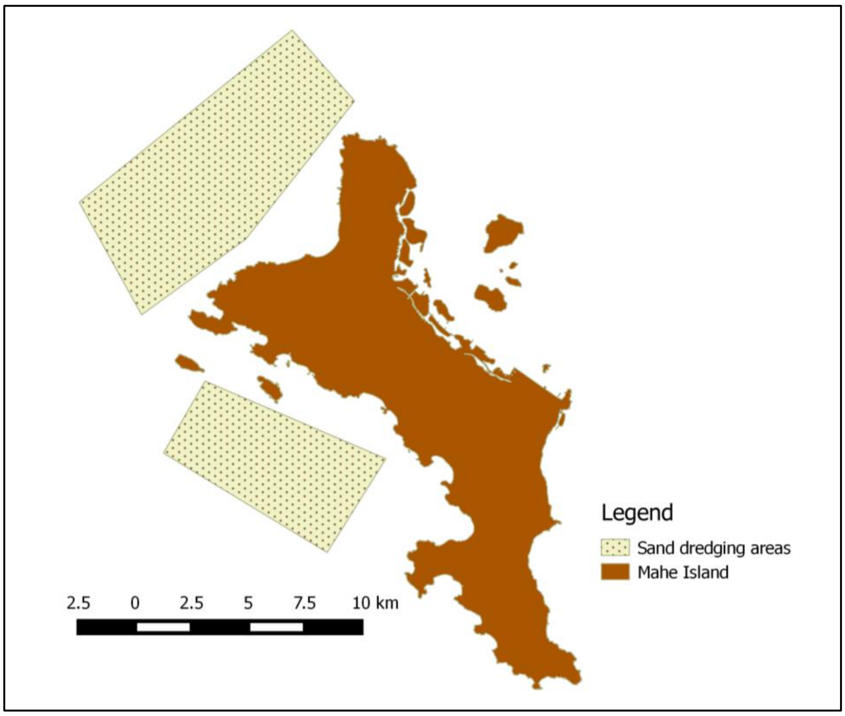

Figure 16. Sand dredging areas around Mahé.

3.2.7. Habitats within the footprints of proposed aquaculture development zones

Rapid surveys of the bottom habitat within each aquaculture development zone (ADZ) have been conducted as part of this development proposal using remotely operated vehicles, echo sounders and small Eckman grab sampling (SFA 2016b). The results of these surveys have been summarised by SFA (2016b) (Table 9). The majority of ADZs are dominated by unconsolidated sandy habitats. However, consolidated hard substratum and soft unconsolidated sediments were both detected in PLD 5.

Patches of macro-algae were detected down to 50 m at some locations. No coral reef, continuous algae fields or seagrass beds have been detected within the proposed ADZs as these were deliberately excluded in the site selection process (SFA 2016b).

Table 9. Summary of the benthic environments within each proposed aquaculture development zone (Modified from SFA 2016b)

ADZ	Seabed Echo	Seabed (ROV survey)	Seabed (grab samples)	Depth (m)	Benthos
PLD1	Soft	Sand	Medium sand	25-40	No macrobenthos
PLD2	Soft	Sand	Medium sand	30-45	Bivalves, small polychaetes
PLD3	Soft	Sand	Medium sand	46-48	No macrobenthos
PLD4	Mainly soft	tbd	Fine sand	36-42	Polychaetes
PLD5	Soft and hard	tbd	Fine / medium sand	41-43	Shrimp, polychaete.
M1	Mainly soft	tbd	Medium sand / shell grit	32-52	Sponge, Brittle star, gastropod, bivalve, sand anemone
M2	Soft	Sand	Coarse sand Shell grit	29-41	Crab, bivalve, polychaete
M3	Mainly soft	Sand/ Macro algae	Fine sand / shell grit	42-48	Sea urchin remains, crab, bivalves, brittle star
M4	Mainly soft	Sand/ Macro algae	Medium / coarse sand	25-40	No macrobenthos
M5	Soft	Sand	Medium & fine sand and silt	40-43	Anemone, bivalves, crabs, polychaete
SN2	Mainly soft	Sand	Coarse sand / shell grit	32-62	No macrobenthos
SN3	Mainly soft	Sand	Shell grit	35-48	Bivalves

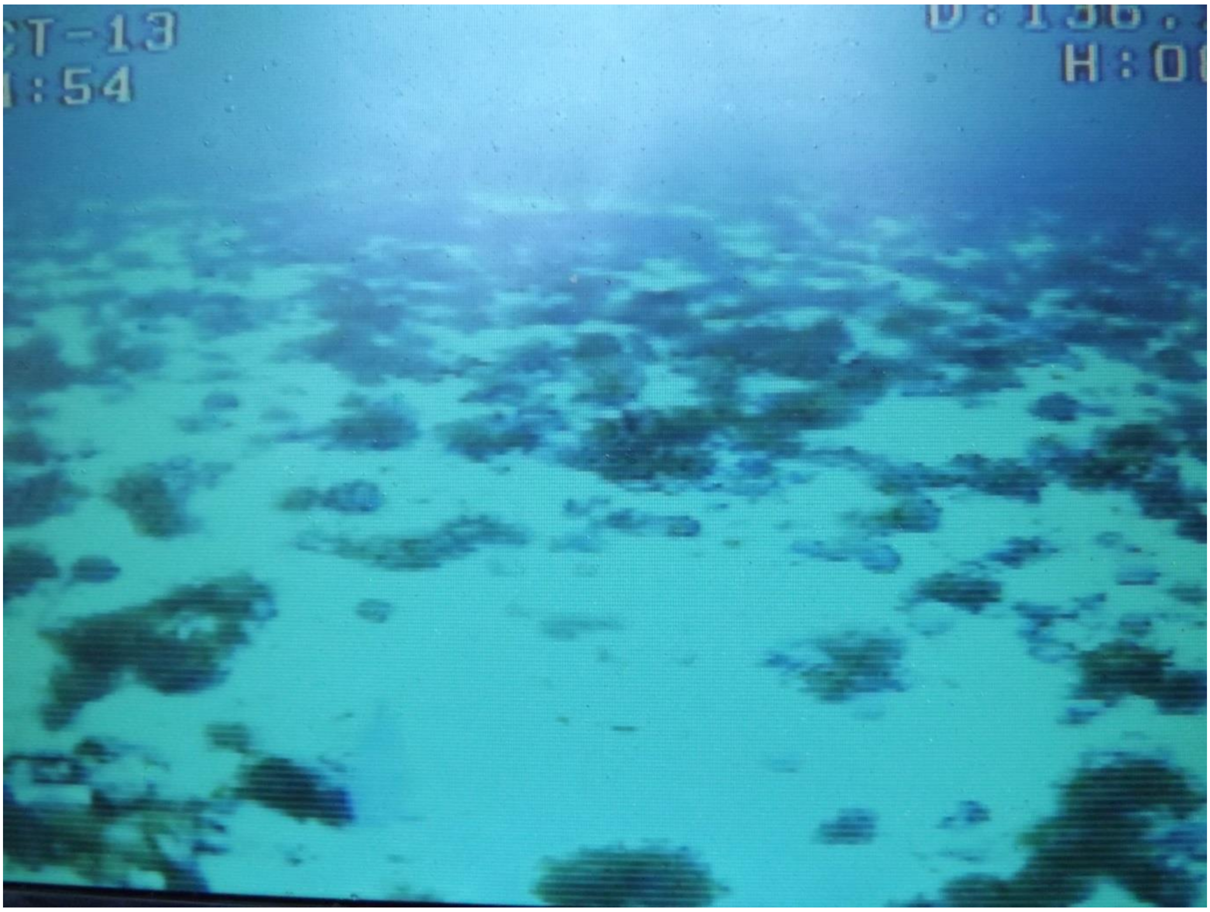

Figure 17. Macro-algal patches.

Finer scale and quantitative baseline information however is needed on the sediments and associated macrofaunal communities within proposed ADZs identified by SFA (2016b). It is envisaged that this will form an important component of the EMP commitments.

3.2.8. Benthic fish communities

Associated with each habitat type described above are distinct fish communities (Jennings et al. 1995, 1996) (Figure 18). The fishes of the Seychelles have been documented by Smith and Smith (1969) and are considered to be highly diverse (Spalding and Jarvis 2002). Up until 1969, approximately 775 species had been recorded (Smith 1969). Randall and van Egmond (1994) recorded a further 108 species by 1993. The most abundant reef fish found at several sites within marine protected areas around Mahé were from the Labridae (Wrasse), Scaridae (Parrotfish) and Pomacentridae (Damselfish) families (Jennings et al. 1996). A clear distinction was evident between communities inhabiting coral reef and granitic rocky reef habitats (Table 10).

Table 10. Most characteristic reef fish for coral and rocky reef habitats at several marine protected areas around Mahé based on Jennings et al. (1996).

Coral reef		Rocky reef	
Species	**%**	**Species**	**%**
Cousin		**Cousin**	
Cephalopholis argus	13.6	*Aprion virescens*	13.6
Aprion virescens	10.8	*Plectroglyphidodon lacrymatus*	6.5
Lethrinus obsoletus	6.0	*Scarus sordidus*	6.3
Scarus sordidus	4.7	*Lethrinus harak*	5.9
Plectroglyphidodon lacrymatus	3.7	*Lethrinus obsoletus*	4.7
Sainte Anne		**Sainte Anne**	
Hipposcarus harid	16.5	*Plectroglyphidodon lacrymatus*	19.3
Plectroglyphidodon lacrymatus	10.6	*Siganus puelloides*	7.4
Parupeneus barberinus	5.3	*Scarus sordidus*	6.3
Chromis atripectroralis	5.0	*Aprion virescens*	5.4
Siganus puelloides	4.1	*Scarus niger*	5.3
Baie Ternay		**Curieuse**	
Scarus sordidus	12.7	*Scolopsis frenatus*	11.7
Ctenochaetus striatus	11.3	*Ctenochaetus striatus*	7.7
Scarus niger	11.2	*Acanthurus leucosternon*	5.3
Cephalopholis argus	6.1	*Siganus puelloides*	5.1
Pomacentrus caeruleus	5.3	*Scarus rubroviolaceus*	4.3

A study by Spalding and Jarvis (2002) concluded that the effect of the 1998 mass coral bleaching event had little influence on the fish community composition despite massive changes in benthic cover. However, significant changes in abundance were noted for several species dependent on live coral for shelter and sustenance such as many of the corallivores. Nevertheless, underwater visual censuses several years after the mass bleaching event have recorded a general decrease in the numbers of reef fish, with a relatively low proportion of smaller size classes indicating that the loss in benthic cover and structure may have resulted in a decrease in recruitment (Engelhardt 2004; Graham et al. 2007). The families most affected were the monaenthids, chaetodontids and pomacentrids and species thought to have become locally extinct as a result include *Labrichthys unilineatus*, *Chaetodon lineolatus*, *Plectroglyphidodon johnstonianus*, and *Thalassoma hardwicke* (Graham et al. 2007). Spawning aggregations, particularly of snappers (Lutjanidae) and rabbitfishes (Siganidae), are a characteristic of several areas on the Seychelles Bank (Robinson et al. 2004; Robinson et al. 2007). Reef-associated fishes that are caught by the demersal fishery include mainly species of grouper, snapper, emperor and shark (Na 1996; STB 2016).

Figure 18. A shoal of Racoon butterflyfish (*Chaetodon lunula*) from the east coast of Mahé. (Photograph: Tom Mannering ©).

Seagrass beds provide very important habitat for juvenile fishes but also adults of many smaller sized species. A variety of fishes use these habitats as important nursery grounds, foraging areas, and predation refuges (Gullström et al. 2002). Most common families include Apogonidae, Blenniidae, Centriscidae, Gerreidae, Gobiidae, Labridae, Lethrinidae Lutjanidae, Monacanthidae, Scaridae, Scorpaenidae, Siganidae, Syngnathidae and Teraponidae. Little is known however of the species composition of fishes in Seychelles seagrass beds.

Species associated with sandy habitats include various sharks and rays, gobies, bonefish and goatfish (Smith and Smith 1969).

3.3. Natural resource harvesting by artisanal fishers

The benthic habitats support a wide variety of natural resources which are harvested by artisanal fishers that contribute 1-2% to GDP annually (ACLME 2012). The artisanal fishery is a vital source of income, employment and food security for many local people. Invertebrates harvested include sea cucumbers, lobsters, corals and shells (Bijoux 2008). Sea cucumbers are heavily harvested and more than 12 species are exploited in the Seychelles which are mainly exported to the Far East (ACLME) (Table 11).

Table 11. Sea cucumbers harvested in the Seychelles.

Year	Black teat	Sandfish	White teat	Prickly red	Pentard	Others	Total
2002	6926	903	41212	6561	9912	46027	111541
2003	8543	33	26374	15779	48504	69482	168717
2004	9417	622	41221	12254	59488	52181	175183
2005	11602	100	45928	17194	83822	98055	256701
2006	10050	1852	38148	16189	160190	103844	330273

Corals and shells are mainly harvested for the curio trade from reef platforms and seagrass beds. It has been suggested that 63 species are likely to be harvested for the trade. Certain species are used for jewellery (e.g. *Pinctada margeritifera*, *Cyprea* spp.). Many of the species collected were found to be listed on Appendix II of CITES (Bijoux 2008).

The artisanal fishery for demersal finfish is significant, with catches in excess of 4700 tons per annum (Table 12). The most common species comprising these catches are *Carangoides gymnostethus*, *Carangoides fulvoguttatus*, *Lutjanus sebae* and *Aprion virescens*.

Table 12. Percentage catch composition (by weight) for different groups/species (ACLME 2012)

Species Group	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Trevally (Carangiodes spp.)	37.1	30.1	41.7	33.6	28.2	24.8	19.7	18.7	25.7
Red snapper (*Lutjanus* spp.)	8.7	13.9	10.0	11.6	17.0	22.3	26.7	29.6	22.0
Jobfish (*Aprion virescens*)	11.6	16.4	12.5	15.8	12.5	11.2	15.5	15.7	15.8
Emperors (*Lethrinus* spp.)	8.9	11.2	6.9	6.1	6.2	5.1	4.4	4.6	7.1
Groupers (*Epinephelus* spp.)	3.2	2.5	1.5	2.4	2.3	2.1	3.2	3.8	3.2
Rabbitfish (*Siganus* spp.)	3.7	2.1	4.2	6.6	7.6	5.4	7.3	5.1	4.0
Mackerel (*Rastrelliger* sp.)	9.9	6.2	7.1	5.8	11.0	15.4	6.6	9.2	7.9
Other pelagics	8.1	8.9	8.8	10.8	7.4	7.5	8.6	7.7	8.0
Other trap fish	4.5	3.6	3.7	3.5	3.7	2.6	3.3	2.4	3.4
Others	4.3	5.1	3.6	3.8	4.2	3.5	4.9	3.1	2.8
Total annual catch (MT)	4748	4285	4889	3836	4174	4433	3845	4181	4777

3.4. Marine protected areas and critical biodiversity assets

The Seychelles has 14 areas that can be considered as marine protected areas (MPAs), 13 of which lie within the inner island group (Dominugue et al. 2000) (Table 13). There are five different types of MPA in the Seychelles:

- Marine National Park (National Parks and Nature Conservancy Act (Cap 141))
- Shell (Mollusc) Reserve (Fisheries Act (Cap 82))
- Special Reserve (National Parks and Nature Conservancy Act (Cap 141))
- Protected Areas (Protected Areas Act (Cap 185)
- Strict Natural Reserve (National Parks and Nature Conservancy Act (Cap 141))

Table 13. Marine protected areas located within the inner island group

Name	Legislation	Designated (year)	Area (ha)	Critical biodiversity assets
Port Launay Marine National Park	National Parks and Nature Conservancy Act	1979	163.29	Extensive mangrove systems declared as RAMSAR Site of Global importance, water catchment
Baie Ternay Marine National Park	National Parks and Nature Conservancy Act	1979	87.09	Healthy coral reef system, high marine biodiversity
Silhouette Island Marine National Park	National Parks and Nature Conservancy Act	1987	2131.84	Almost undisturbed coral reef, high marine biodiversity
Aride Special Reserve	National Parks and Nature Conservancy Act	1975	95.36	Protection of seabird colony. Largest breeding colonies of sea birds, endemic land birds, confined endemic Gardeni, high biodiversity
Ile Cocos, Ile La Fouche, Ilot Platte	National Parks and Nature Conservancy Act	1997	85.55	Protects coral reef
Saint Anne Marine National Park	National Parks and Nature Conservancy Act	1973	965.41	Protects and provides nursery for over 150 species of fish; nesting sites for Hawksbill turtle
Curieuse Marine National Park	National Parks and Nature Conservancy Act	1979	1340.74	Wild population of Giant land Tortoise, extensive mangrove system, coco-de-mer, population(s) of Black Parrot
La Digue (Anse Severe-Anse Gros Ros) Shell Res.	Seychelles Fisheries Act	1987	157.70	Protects a high diversity of reef organisms including many that are listed on CITES Appendix II
Praslin (Point Zanguire–Pt Chevalier) Shell Res.	Seychelles Fisheries Act	1987	174.78	Protects a high diversity of reef organisms including many that are listed on CITES Appendix II
Mahé (North East Pt.-Carana) Shell Res.	Seychelles Fisheries Act	1987	108.34	Protects a high diversity of reef organisms including many that are listed on CITES Appendix II

Name	Legislation	Designated (year)	Area (ha)	Critical biodiversity assets
Cousin Nature Reserve	National Parks and Nature Conservancy Act	1980	158.18	Breeding colonies of seabirds, endemic land birds, high biodiversity
Mahé (Anse Faure-Fairy Land) Shell Res.	Seychelles Fisheries Act	1987	334.47	Protects a high diversity of reef organisms including many that are listed on CITES Appendix II
Port Launay Marine National Park	RAMSAR Convention	2007	163.29	Extensive mangrove systems declared as RAMSAR Site of Global importance, water catchment

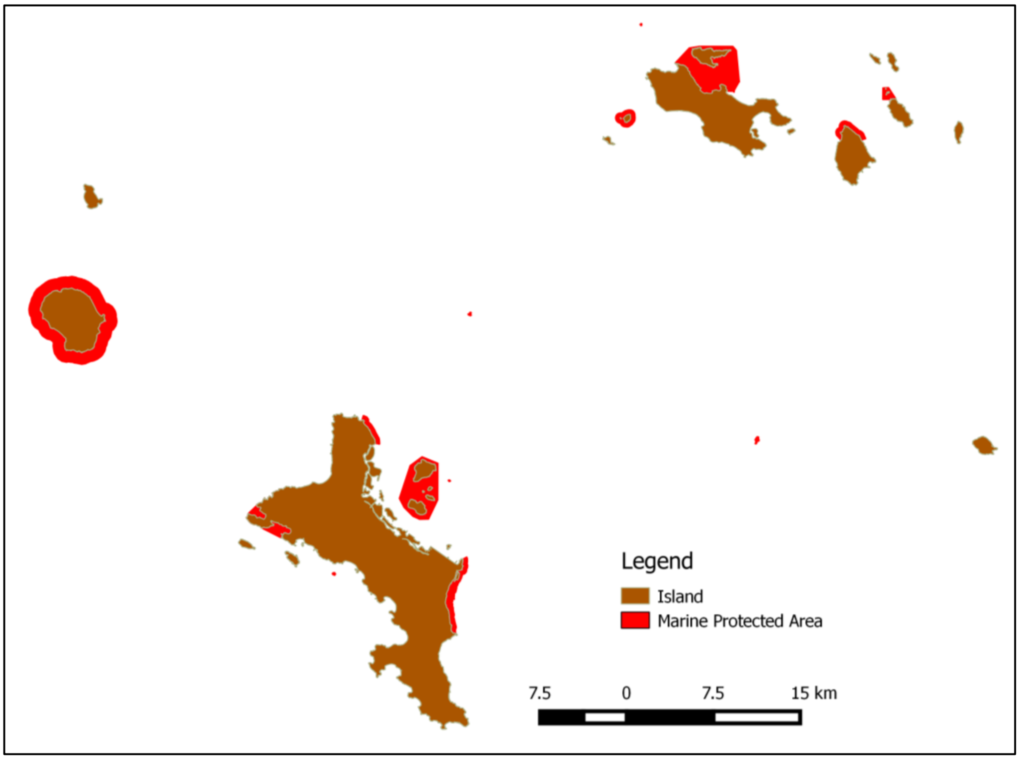

Figure 19. Marine protected areas located in the inner island group.

In addition to critical biodiversity areas such as those within marine protected areas, numerous species associated with coral reef and benthic habitats are also important biodiversity assets. These include several species of turtle and dolphin which are listed on the IUCN Red List of Threatened Species. Furthermore, at least 12 areas on the Seychelles Plateau within the inner island group have been identified as sites supporting important fish spawning aggregations (Robinson et al. 2007).

4. Impact Assessment

The impact methodology for the following assessment is given in Appendix 1: Impact rating methodology. Impacts are expected during construction, operational and maintenance phases of the different proposed developments.

4.1. Aquaculture development zones

4.1.1. Construction phase impacts on the benthic environment

Construction phase impacts on the benthic environment are limited to those resulting from the placement of anchoring and mooring infrastructure. These are likely to cause mortality and disturbance to benthic communities directly within the footprint of each anchor or mooring block and any movements of mooring cables or chains will result in disturbance. Surveys of the seafloor indicate that the benthic habitats within proposed ADZs largely comprise sandy substratum. M3 and M5 are already zoned in a previously disturbed and transformed part of the seafloor due to dredging operations. Areas of consolidated substratum with reef have been excluded, although some consolidated habitat has been detected within M1 (SFA 2016b). It is also obvious that parts of SN2 overlay reef. It is an essential mitigation measure that consolidated reef habitat is excised from M1 & SN2. The impact is likely to be localised, of low intensity and assessed has having low overall significance for each of the proposed ADZs.

Table 14. Impact 1: Assessment of the significance of possible impacts arising during the construction phase due to mooring blocks and installation of cages.

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local **1**	Low **1**	Long-term (ongoing but reversible) **3**	**Low 5**	Definite	**LOW**	**– ve**	High
Essential mitigation measures: • Consolidated hard/reef areas of seafloor should be excluded from M1 and SN2 Optional mitigation measures • Ensure mooring system is designed to limit movement of anchors and cables over the seafloor • Position mooring anchors/blocks strategically so that when undertaking maintenance or fallowing of sites moorings do not have to be moved.								
With mitigation	Local **1**	Low **1**	Long-term **3**	**Low 5**	Definite	**LOW**	**– ve**	High

4.1.2. Operational phase impacts on the benthic environment

Impacts associated with the operation of finfish cage culture include:

- Eutrophication and pollution of water and benthic habitats due to increased amounts of organic waste associated with faeces and uneaten food;
- Chemical pollution of marine food webs and mortality of sensitive organisms as a result of using certain chemical therapeutics on stock, antifouling treatments on cages and heavy metals in feed;
- Transmission of fish diseases and parasites from cultured fish to wild populations;
- Escape of genetically different cultured fish which may interbreed and compete with wild stocks that are depleted;
- Physical hazards to marine life which may become entangled in moorings and nets; and
- Piscivores such as sharks and other apex predators are attracted to cages and may damage nets leading to escapees. Conflicts are likely to arise between these animals and farmers who are likely to kill problem animals.

Each of these potential impacts is assessed in the following sections and mitigation measures provided where possible.

4.1.2.1. Eutrophication and organic pollution of water and benthic habitats

Due to faecal deposition and the sinking of uneaten food pellets, fouling and pollution resulting in particulate and dissolved organic build-up may occur in the water column and sediments directly below cages, but also at distances outside of the cage footprint (Pitta et al. 2005). These sources of nutrients can be significant (Brooks et al. 2002; Staniford 2002). Particulate material can shade and foul bottom communities resulting in mortality, while dissolved organic pollutants may significantly negatively affect sensitive coral reef organisms and seagrass habitats both directly and indirectly (Delgado et al. 1992; Lapointe 1997; Loya and Kramarsky-Winter 2003; Pusceddu et al. 2007).

Increases in toxic chemicals such as ammonia and hydrogen sulphide have been frequently observed in benthic habitats and surrounding waters (Carroll et al. 2003; Heggoey et al. 2005). Other effects include decreased dissolved oxygen content, increased redox potential, increased sedimentary organic matter, and increased heavy metal concentrations beneath fish cages (Brown et al. 1987; Mendiguchía et al. 2006). Under severe conditions, the benthic habitat becomes anaerobic and supports bacterial mats and sulphide-resistant invertebrates (Figure 20) (Loya and Kramarsky 2003). Most studies indicate that the effect is localised and occurs within a few hundred meters of each cage (Porello et al 2005; Merceron 2002; Kempf et al. 2002; Borja et al. 2009).

Effects are noticeable on sandy benthic communities but generally these habitats have better assimilatory capacity than consolidated habitats, especially in tropical waters (Price and Morris 2013; Angel *et al*. 1992). For example, in Tasmania, low macrofaunal richness, a dominance of capetillid and dorvelleid polychaetes and an absence of heart urchin (*Brissus* sp.) was found adjacent (<10 m) to cages (Edgar et al. 2005). Minor effects were also detectable 35 m outside of farm boundaries, most noticeably elevated numbers of the polychaete *Terrebellides* sp. and bivalve *Mysella donaciformis*. In the western Mediterranean, acute levels of disturbance in assemblages under cages was found, but no effects were detected in the area 25 m from cages (Tomassetti et al. 2009).

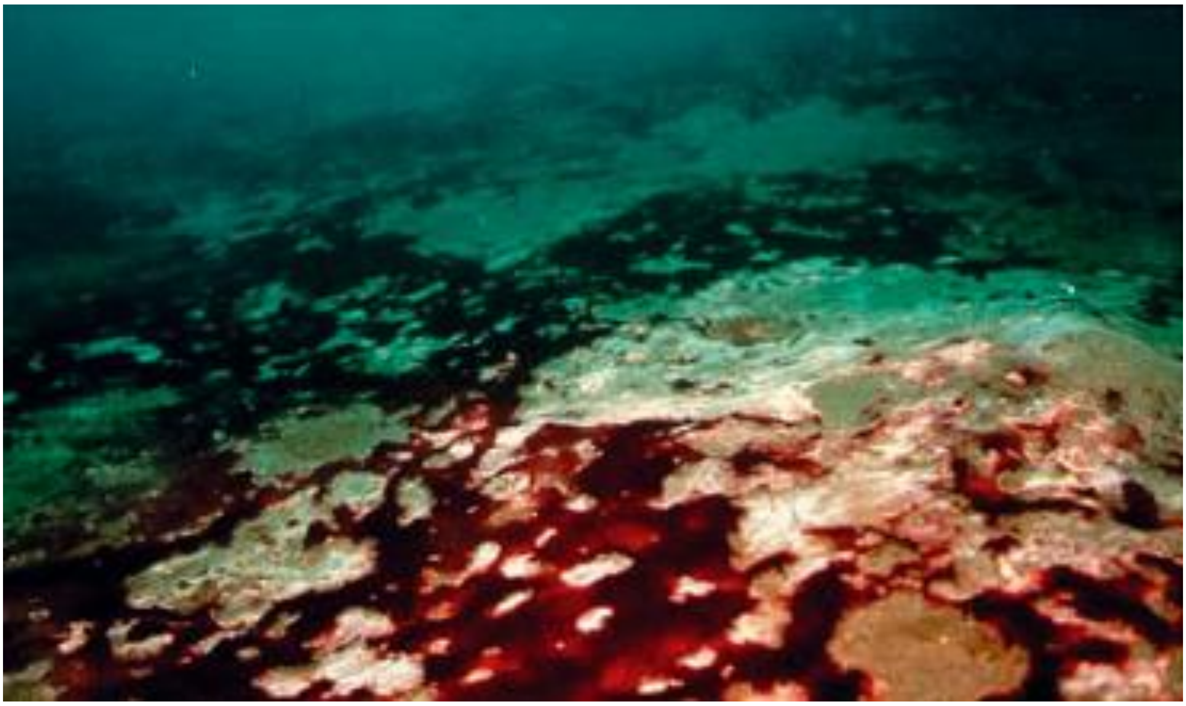

Figure 20. The seafloor near fish cages in the Mediterranean devoid of most life and dominated by bacterial mats (Loya and Kramarsky-Winter 2003).

Seagrasses are known to be negatively affected by aquaculture due to deterioration of light, sediment conditions and increased nutrients which effects there growth and productivity and results in higher rates of mortality (Cancemi et al. 2000; McGlathery 2001; Duarte 2004) (Figure 21). In addition, higher nutrient levels have been linked to greater epiphyte loads on seagrasses which negatively affects them by shading and limiting gaseous exchange (Short et al. 1995; Delgado et al. 1992). Even after the cessation of fish farming and the recovery of water conditions, seagrasses may continue to decline due to excess organic matter remaining in sediments (Delgado et al. 1992).

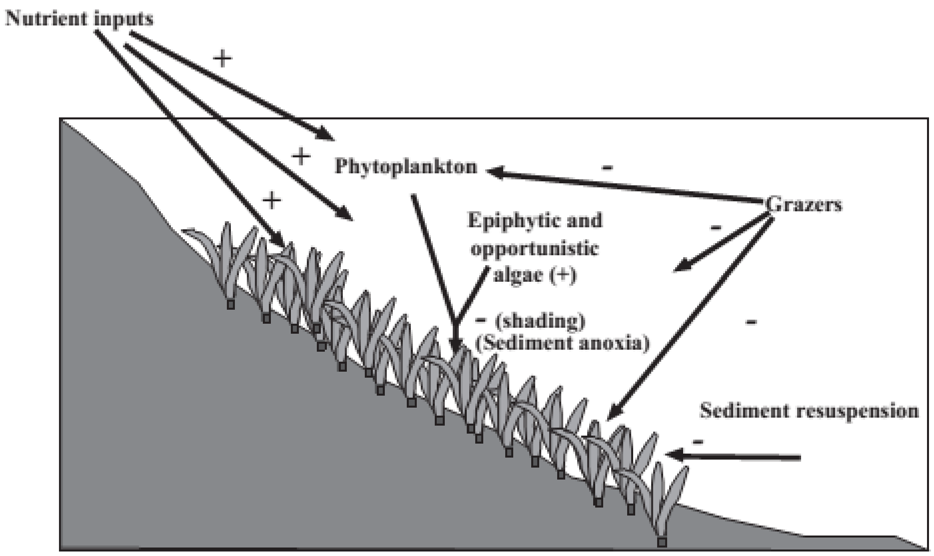

Figure 21. Effects of increased nutrient loading on seagrass beds.

Coral communities can be negatively affected by aquaculture too. Sinking particulate matter from cages can be resuspended by water motion and ground swell which then settles on nearby corals causing polyp suffocation and disease (Fabricius and Wolanski 2000). Furthermore, increased concentrations of dissolved nutrients associated with aquaculture are particularly harmful to corals affecting them both directly and indirectly. Higher nutrient concentrations result in quicker linear growth of corals (Hoegh-Guldburg et al. 1997). This is seemingly advantageous; however, the skeleton is of lower density which means it is less strong and resilient to breakage. Furthermore, corals with decreased skeletal densities near fish farms have higher infestations of boring organisms (Wielgus 2003). While higher nutrient concentrations may accelerate linear extension rates in corals, they also stimulate the growth of macroalgae (Lapointe 1997; McCook 1999). Macroalgae grows significantly faster than corals, smothering them and ultimately leading to disease and mortality of coral communities (Loya and Kramarsky-Winter 2003). This is of particular concern in the Seychelles as many of the reefs were badly affected by coral bleaching which allowed macroalgae to gain a foothold resulting in a shift from coral-dominated reefs to algal-dominated reefs. An increase in nutrient levels surrounding coral reefs are therefore likely to hinder their recovery even more so, and possibly maintain algal-dominated reefs into the future.

Figure 22. Macroalgal overgrowth of a coral community near a fish farm in the Gulf of Eilat (Loya and Kramarsky-Winter 2003).

Lastly, there is compelling evidence that increased nutrient levels negatively affect coral reproduction. Evidence of this has been seen in the Gulf of Eilat, Red Sea adjacent to fish farms (Loya and Kramarsky-Winter 2003). Reproductive effort was ca. three times lower in coral colonies near the fish farm than at a control site.

The extent of contamination of the sediments under fish cages is highly site and project specific. Inshore marine environments with low flushing rates or with substrata susceptible to organic loading should be avoided when selecting sites for finfish culture. Fallowing is the standard mitigation practice used to allow recovery of sediments beneath cages, but recovery may take up to fifteen months, as was observed in a Scottish fish farm (Black et al. 2004). Fallowing is not a viable option for consolidated (hard/reef) habitats comprising long-lived organisms such as coral and sponges, as this merely increases the impact footprint (Hall-Spencer and Bamber 2007). Feeding by wild fish on waste and uneaten food beneath cages has been shown to mitigate the impacts on the benthic environment. As much as 40-80% of the uneaten food and waste falling from cages may be eaten by wild fish (Vita et al. 2004; Felsing et al. 2005). This however, may increase the risk of parasite and disease transmission to wild fish and may also attract piscivores to cages resulting in several problems dealt with below.

In a meta-analysis of 41 studies from locations around the world focused on the effects of fish farms on sediments, the horizontal distance affected by fish farm wastes was found to decrease with greater depth, low latitude and fine sediment (Kalantzi and Karakassis 2006). These findings therefore contribute favourably to the locations of the proposed ADZs which are in relatively deep water, are located at low latitude and positioned over sandy unconsolidated sediments for the most part. It was, however, noted by SFA (2016b) that benthic macro-algal patches were prevalent in some of the proposed ADZs. The ecological roles that these algae may play in the Seychelles are unclear but it is likely that they could be very important in assimilating and recycling organic waste produced by farms. **It is therefore recommended that these areas are avoided as an important mitigation measure.**

The impacts of particulate wastes are assessed for all proposed ADZs together as the scale of the impacts are considered to be confined to within several hundred metres around each cage and therefore limited to/within an ADZ (i.e. limits of the concession area) regardless of its size (Table 15). They are expected to have high overall significance; or medium significance with effective mitigation.

Table 15. Assessment of potential impacts associated with particulate organic build-up on the benthic environment for all ADZs.

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1</td><td>High
3</td><td>Long-term (ongoing but reversible)
3</td><td>High
7</td><td>Definite</td><td>High</td><td>– ve</td><td>Medium (monitoring required to determine intensity of impact)</td></tr>
<tr><td colspan="9">Essential mitigation measures:
Sensible site selection. This has been partly achieved but consolidated hard/reef areas of seafloor must be excluded from M1 and SN2 (and any other proposed ADZs)
ADZs should be moved to avoid overlying benthic macro-algae patches (See SFA 2016b)
ADZs must be sited at least 500 m from fish spawning aggregation sites
ADZs must be located at least 500 m away from any coral reef and seagrass habitats
ADZs must be located at least 500 m away from rocky reef dive sites. M2 and M4 appear to be too close.
ADZs must be located at least 500 m away from marine protected areas
Rotate cages (fallowing) within each ADZ to allow for recovery of soft sediment benthos
Use species and system-specific feed to maximise food conversion ratios and minimise waste
No cleaning of fouling organisms from nets at sea
Monitor feeding behaviour and particulate deposition beneath cages and adapt feeding strategy to maximise feeding efficiency and minimise particulate matter fallout
Undertake benthic monitoring, including baseline surveys at control and ADZs sites to determine scale of impacts and decrease ADZ production levels should the impact exceed the accepted sacrificial footprint.
Optional mitigation measures:
Near-field modelling exercise of particulate organic matter for each proposed ADZ would add more confidence in assessing the scale of the fallout of particulates and thus its impact</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Medium
2</td><td>Long-term
3</td><td>Medium
6</td><td>Definite</td><td>Medium</td><td>– ve</td><td>Medium</td></tr>
</table>

However, the effects of increased dissolved water column nutrients may be far wider and more difficult to mitigate. Marine aquaculture developments are expanding rapidly without reliable quantification of effluents (Venayagamoorthy et al. 2011). Modelling of waste (nutrient and chemical) dispersal from a single proposed commercial scale fish farm in Mossel Bay, South Africa (an area with similar current speeds to Algoa Bay) was conducted by Mead et al. (2009). Particulate waste was expected to sink to the sea floor within 200 m of the cages (Mead et al. 2009). However, this study indicated that elevated levels of dissolved nutrients would likely occur up to 2 km from the fish cages, with nitrate levels expected to be above background concentrations 8-12 km from the site under certain oceanographic conditions and assumed a very efficient Food Conversion Ratio (FCR) of 1.2 in modelling calculations (Mead et al. 2009). Another hydrodynamic model by Venayagamoorthy et al. (2011) found that the presence of fish farm cages partially blocked current flow, leading to the deceleration of the approaching flow and formation of downstream wakes. After considering current dynamics, bathymetry, tides and the rotation of the earth, plumes of dissolved waste with relatively high concentration were detectable at considerable distances (5 km) from the source. Contrastingly, simulations by Doglioli et al. (2004) in the Ligurian Sea, Mediterranean indicated that dissolved particles tend to spread rapidly and undergo rapid dilution depending on the dominant wind and surface current direction, with particles therefore never exceeding the threshold for environmental concern.

Complicated interactions between variables and the lack of data, such as current speed, induce difficulties in setting common or uniform environmental quality standards for effects of fish farming in cages (Kalantzi and Karakassis 2006). The cumulative impact of organic waste discharge from several commercial scale fish farms and ADZs has the potential to impact significantly on sensitive habitats but it cannot be assessed with confidence based on available data from the Seychelles. Best management practices for cage culture in the Caribbean and USA state that impacts to nearshore coral reefs, seagrasses, and mangroves can be eliminated by siting farming operations in offshore areas to allow for dilution and assimilation of dissolved nutrients (Price et al. 2014). The question therefore becomes how far offshore and away from coral reefs and seagrass beds should ADZs be located to mitigate impacts from increased dissolved nutrients? The magnitude of such relative effects can be generally summarised according to size of ADZs and distance from sensitive habitat.

		Relative distance to sensitive habitats	
		Close	**Far**
ADZ Size	**Large**	High	Low
	Small	Medium	Low

Figure 23. The relative magnitude of negative effect of ADZs of different size located at different distances from sensitive habitats

The sizes of each proposed ADZs differ and they are each located in different oceanographic settings. The potential impact of waste disposal on water quality and sensitive habitats, is nonetheless assessed as similar for the proposed ADZs based on available data but both general and specific mitigation measures are indicated per ADZ (Table 16). The impact of dissolved nutrients is assessed as having a high overall significance, or low with effective mitigation measures applied). It is essential that an extensive hydrodynamic modelling study using detailed, site-specific current modelling data for each ADZ and all ADZs collectively be conducted prior to any development. The results of this study with respect to the potential impacts on sensitive habitats (coral reefs, seagrass beds) should be used to *assess the cumulative impacts of dissolved nutrients and toxic chemicals* and to guide the scale of developments on the ADZs (i.e. if the waste plume is modelled to reach sensitive habitats that carrying capacity of the ADZ should be reduced) or to shift them further offshore.

It is very likely that several proposed ADZs would need to be shifted further offshore to limit the impact of their dissolved nutrients on sensitive habitats, which should be considered before time and effort is invested in collecting site-specific data within the current locations of proposed ADZs. Proposed ADZs that would qualify for this include SN1, SN2, M1, M4, PLD3, PLD4. ADZs M2, PLD1, PLD2 and PLD5 are boarder line and should also be considered. In general, the further offshore the ADZs are proposed, the lower the risk will be for coral reefs and seagrass beds. This could be done in a phased approach starting with proposed Tier 1 ADZs first.

Table 16. Assessment of potential impacts of increased dissolved nutrients on sensitive habitats.

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1
(but likely to extend beyond the boundaries of ADZs)</td><td>High
3</td><td>Long-term (ongoing but reversible)
3</td><td>High
7</td><td>Definite</td><td>High</td><td>– ve</td><td>Low (Hydrodynamic model and monitoring required to determine intensity of impact)</td></tr>
<tr><td colspan="9">Essential mitigation measures:

• Prior to developing any ADZ, conduct a far-field hydrodynamic modelling exercise of dissolved nutrient dispersal for each ADZ and for all ADZs at one time (cumulative impact) using detailed current profiling data (and other relevant data i.e. bathymetry, wind, cage drag, Coriolis Force) collected over a period of at least a year.
    ○ Model different intensities of ADZ development and predict dissolved nutrient diffusion (nitrate and phosphate) from each ADZ and ensure that waste plumes have dissipated sufficiently before coming into contact with sensitive habitats such as coral reefs and seagrass beds.
• Use species specific dietary formulations designed to enhance nitrogen and phosphorus retention efficiency, and reduce metabolic waste output.
• Monitor feeding behaviour and adapt feeding strategy to ensure minimal wastage (excess) of feed
• Undertake monitoring of water quality and adjacent coral reef and seagrass habitats, including baseline surveys at control and ADZs sites to determine scale of impacts and decrease ADZ carrying capacity should the impact start effecting sensitive habitats.

Optional mitigation measures:

• Shift several of the ADZs (SN1, SN2, M1, M4, PLD3, PLD4. ADZs M2, PLD1, PLD 2 and PLD5) further offshore prior to gathering site specific data for the hydrodynamic modelling exercise</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Medium
2</td><td>Long-term
3</td><td>Medium
6</td><td>Possible</td><td>Low</td><td>– ve</td><td>Medium</td></tr>
</table>

4.1.2.2. Chemical pollution arising from cages

Therapeutic chemicals (medicines), disinfectants and antifoulants are usually used in caged finfish culture (Weston 2000; Boyd and McNevin 2015). Many of these chemicals are highly toxic to non-target organisms even at low concentrations and may persist in the environment for significant periods of time (Kerry et al. 1995; Costello et al. 2001). Some of the chemicals used historically on fish farms to combat sea lice infestations were carcinogenic, whilst others are known to adversely affect reproduction in salmonids (Staniford 2002, More & Waring 2001). Corals in particular, but also other primitive life forms, are especially sensitive to copper which is often the active ingredient in antifoulants (Reichelt-Brushett and Harrison 1999, 2000; Negri and Heyward 2001; Webster et al. 2001; Yanong 2010). Corals pre-exposed to high temperatures (such as is often the case in the Seychelles) followed by exposure to copper may be particularly sensitive and negatively affected (Nyström et al. 2001). Elevated levels of copper are also toxic to seagrass (Zhao et al. 2016). Global bodies, (e.g. the World Health Organisation and GESAMP), have highlighted the environmental and public health threats of chemical use on fish farms (GESAMP: 1997, WHO: 1999 cited in Staniford 2002).

Due to these concerns, the salmon farming industry is moving away from the use of antibiotics and organophosphates, but numerous other potentially hazardous chemicals such as: synthetic pyrethroids, artificial colorants, antifoulants, and antiparasitics, are still a serious concern (Staniford 2002). According to the Seychelles Fishing Authority: Responsible Finfish Cage Culture Section 7.7 "the use of antifouling coatings on nets or the use of biocidal chemicals for cleaning nets on site is prohibited" (SFA 2015). However, The Marine Aquaculture License Special Conditions: Finfish Grow-Out in Cages states that ""*The License Holder shall ensure that the Regulator approves any anti-fouling product used on the net pen material*". Despite this inconsistency, the use of a copper-based alloy material for the cage nets nevertheless seems likely.

Sediments below sea farms can accumulate copper at elevated levels (Loucks et al. 2012, Nikolaou et al. 2014), but the toxicity of the deposited copper is difficult to assess, as it depends on the interaction with the environment where organic carbons and sulfides are able to reduce the reactivity (Burridge et al. 2010). Of 279 farms whose sediment below the cages were monitored between 2011 and 2015, ~20% had copper concentrations considered toxic to marine life even during short term exposure (>84 mg Cu kg^{-1} dry weight sediment) (Svåsand et al. 2016). Similar to the effects of dissolved nutrients assessed above (see Section 4.1.2.1), it is difficult to confidently assess the impact of dissolved chemical pollutants without hydrodynamic modelling being conducted first.

Several of the proposed ADZs lie close to coral reef and it is probable that any impacts would have a high and negative significance (Table 17). With hydrodynamic modelling (particularly of copper) and probable rezoning based on the results of these models as well as responsible use of therapeutics and medicines, impacts could be reduced significantly.

Table 17. Assessment of the possible impacts resulting from the use of chemical therapeutics and antifoulants in cage culture operations for ADZs.

<table>
<tr><th></th><th>Extent</th><th>Intensity</th><th>Duration</th><th>Consequence</th><th>Probability</th><th>Significance</th><th>Status</th><th>Confidence</th></tr>
<tr><td>Without mitigation</td><td>Local
1
(but likely to extend beyond the boundaries of ADZs)</td><td>High
3</td><td>Long-term (ongoing but reversible)
3</td><td>High
7</td><td>Probable</td><td>High</td><td>– ve</td><td>Low (Hydrodynamic model and monitoring required to determine intensity of impact)</td></tr>
<tr><td colspan="9">Essential mitigation measures:
Prior to developing any ADZ, conduct a hydrodynamic modelling exercise of copper and therapeutic chemical dispersal for each ADZ and for all ADZs at one time (cumulative impact) using detailed current profiling data (and other relevant data i.e. bathymetry, wind, cage drag, Coriolis Force) collected over a period of at least a year.
Model different intensities of ADZ development and predict chemical diffusion from each ADZ and ensure that chemical concentrations have dissipated to below threshold/background levels before coming into contact with sensitive habitats such as coral reefs and seagrass beds.
Use only approved veterinary chemicals and antifoulants
Where possible use environmentally friendly alternatives
Use the lowest effective dose of therapeutics
Do not clean cages on site/in the sea. Clean cages on land but ensure that any effluent resulting from this process reaching the sea contains acceptable levels of copper and antifoulants.
Monitoring
Optional mitigation measures:
Shift several of the ADZs (SN1, SN2, M1, M4, PLD3, PLD4. ADZs M2, PLD1, PLD 2 and PLD5) further offshore prior to gathering site specific data for the hydrodynamic modelling exercise (see Section 4.1.2.1)</td></tr>
<tr><td>With mitigation</td><td>Local
1</td><td>Medium
2</td><td>Long-term
3</td><td>Medium
6</td><td>Possible</td><td>Low</td><td>– ve</td><td>Medium</td></tr>
</table>

4.1.2.3. Disease and parasites

A high stocking density of fish in cages promotes disease and parasitic infections (Lafferty et al 2015). Furthermore, cultured stock is often prevented from exercising natural parasite shedding behaviours and the high number of concentrated hosts facilitates parasite and disease reproduction and transmission. Parasites and infectious diseases are regarded as the most significant threat to aquaculture, with the estimated losses from sea lice (genus *Caligus)* infections of salmon stock alone amounting to hundreds of millions of dollars annually (Staniford 2002; Heuch et al. 2005). This threat is not only limited to cultured fish, but also poses a significant threat to wild stocks due to increased transmission of parasites and diseases from cultured stock to wild populations of fish (Olivier 2002; Ford and Myers 2008; Johansen et al. 2011). Transmission to wild stock may simply occur via direct contact with cultured fish as wild fish are attracted to cages, or simply as a result of the higher concentration of pelagic parasite life history stages arising from fish farms that would enhance transmission indirectly without physical contact.

Wild salmon for example have suffered from significant increases in parasitic infection rates due to contact with caged stock (Heuch et al. 2005). The increased load of parasites on wild salmon has increased mortality rates, reduced fecundity and delayed maturity which has synergistically reduced the productivity of wild stocks (Bjorn et al. 2002; Ford and Myers 2008). Similarly in the Mediterranean, intensive culture of seabass and seabream has resulted in severe disease problems to fishes caused by *Nodavirosis* and *Pasteurellosis* and parasitic infections from *Ichtyobodo* sp., *Ceratomyxa* sp., *Amyloodinium ocellatum*, *Trichodina* sp., *Myxidium leei*, and *Diplectanum aequans* (Agius and Tanti 1997). In Australia, yellowtail were infected by Monogenean parasites up to 18 km downstream from cages (Chambers and Ernst 2005).

Parasites are also known to affect some of the proposed culture species. In Indonesia, wild and cultured brown-marbled grouper *Epinephelus fuscoguttatus* had a species-rich parasite fauna, and most abundant parasites were monogeans on both cultured and wild stocks (Rüeckert et al. 2010) Twenty-five (25) and 30 parasite species/taxa were identified on cultured and wild grouper, respectively. It was concluded that the high levels of infestation of potentially pathogenic monogeneans throughout the year could result in significant parasite outbreaks at the locality studied (Rüeckert et al. 2010). Several disease problems including vibriosis caused by *Vibrio alginolyticus* and *Vibrio carchariae*, viral diseases caused by nervous necrosis virus and iridovirus, and protozoan parasite like *Crytocaryon irritans* have threatened commercial grouper farming in southeast Asia, including brown-marbled grouper (Yii et al., 1997; Fukuda et al., 1999; Yambot and Song, 2006). Diseases of cultured grouper are described by Seng (1998), Nagasawa and Cruz-Lacierda (2004) and Harikrishnan et al. (2011). Snappers are also susceptible to parasites (Kritsky and Diggles 2014), and disease outbreaks caused by *Caligus* sp. in cultured snubnose pompano have been recorded (Johnson et al. 2004).

Diseases and parasites of the cultured species could therefore easily spread to wild stocks. This is of particular concern as snappers and groupers comprise a large proportion of demersal and commercial catches (ACLME 2012). Furthermore, diseases at lower tropical latitudes, such as the Seychelles, progress more rapidly and result in higher cumulative mortality, in particular at early stages of development. Tropical countries suffer proportionally greater losses in aquaculture during disease outbreaks and have less time to mitigate losses (Leung and Bates 2013). Although treatment of cultured stock to control disease and parasite outbreaks is possible (unlike wild stocks), chemical treatment is not without further environmental impacts (See Section 4.1.2.2), whilst build-up of antibiotic and chemical resistance is becoming increasingly problematic (Staniford 2002).

Potential disease and parasite transmission to wild stocks could have negative impacts throughout the Seychelles inner island group and the natural distributional range of the species, the magnitude of the potential impact will be high as it could alter wider natural (ecosystem impacts) and social functions (fisheries), and the impacts will be enduring. Mitigation measures are not completely effective, and the overall significance of the impact is estimated as high to very high (Table 18).

Table 18. Assessment of the possible impacts resulting from disease and parasitic transmission to wild fish stocks with the development of proposed ADZs

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Regional **2** (Distributional ranges of indigenous species)	High **3**	Long-term (ongoing, may be reversible) **3**	**Very High** **8**	Definite	**VERY HIGH**	**– ve**	Medium
Essential mitigation measures: • Maintain strict bio-security measures within hatchery, holding tanks and sea cages • Ensure all fry undergo a health examination before stocking in cages • Regularly inspect stock for disease and parasites as part of a formalised stock health monitoring programme and take necessary actions to eliminate pathogens through the use of therapeutic chemicals or improved farm management. This will require focused research effort into the identification, pathology and treatment of diseases and parasites infecting farmed species, both in culture and in wild stocks. • Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied. These records should be made publically available to facilitate rapid responses by other operators to future outbreaks. • Locate cages stocked with different cohorts of the same species as far apart as possible, if possible stock different species in cages successively. • Treat adjacent cages simultaneously even if infections have not yet been detected. • Keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediate hosts and or pathogens								
With mitigation	Regional **2**	Medium **2**	Long-term **3**	**High** **7**	Probable	**High**	**– ve**	Medium

4.1.2.4. Genetic impacts on wild stocks

Escapees from sea cages are a reality and will be inevitable in the Seychelles given that this is a global occurrence. Even in countries with advanced sea cage farming industries and calm sheltered waters such as Norway, is it a regular occurrence. For example, an estimated 1.5 million escaped salmon are present in Norwegian fjords at any given time (Heuch et al. 2005) and from 2001 to 2009, 3.93 million Atlantic salmon, 0.98 million rainbow trout and 1.05 million Atlantic cod escaped (Jensen et al. 2010).

It is unlikely to be any different in the Seychelles, especially due to the exposed nature of the region and the abundance of large piscivores such as sharks; regular escapes probably of large numbers of cultured stock as a result of cage failure is likely. Furthermore, it is a possibility that cultured fish may be able to spawn in cages during the ongrowing period and therefore may release genetic material into the environment this way, as has been shown for cod (Jørstad et al. 2008).

As the proposed culture species are indigenous to the region, there is risk that escapees will breed with wild stocks. Cultured stocks are invariably genetically distinct from wild stocks, as they are typically spawned from a reduced number of brood stock, have reduced genetic diversity compared to wild stocks and have undergone different selective pressures, often to artificially select for traits such as rapid growth for example. Thus genetically distinct escaped stock may interbreed or possibly out compete wild stocks, resulting in an overall reduction of genetic diversity leading to reduced fitness of wild populations (Hershberger 2002; Naylor et al. 2005; Ford and Myers 2008).

The significance of genetic impacts on wild stocks is largely determined by the extent of genetic differentiation between farmed and wild stocks, the quantity of escapees compared to the size of the wild stock, and the survival and reproductive success of eggs and escaped fish (Falconer and Mackay 1996).

Where genetic effects on performance traits have been documented, they always appear to be negative in comparison with the unaffected native populations (Hindar et al. 1991). Improved containment is recommended as the key mitigation measure to minimizing the numbers and therefore the effects of escaped fish (Youngson et al. 2001). Reproductive sterility is recommended as a future key to eliminating the genetic potential of escaped fish (Cotter et al. 2000; Youngson et al. 2001). The maintenance of robust populations of wild fish is recommended as a key to minimizing the effects of escaped fish on wild populations. Without such measures the significance of genetic impacts on wild stock is likely to be negatively high (Table 19). The confidence of this aspect of the assessment is low, as negative impacts on genetic diversity of wild stocks will only be reflected should the populations of wild stocks face a threat and present signs of reduced environmental fitness. Furthermore, monitoring would be required to determine any changes in genetic diversity in wild stocks due to cultured escapees.

Table 19. Assessment of possible genetic impacts on wild stocks due to escapees from finfish cages used by proposed ADZs

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Regional **2** (Distributional ranges of wild stocks)	High **3**	Long-term (ongoing, irreversible) **3**	**Very High 8**	Possible	**HIGH**	**– ve**	Low

Essential mitigation measures:

- Maintain genetic compatibility between cultured and wild stocks by developing a genetic best-practice management guideline for finfish mariculture and ensure adequate genetic monitoring is undertaken routinely.
- Minimise the number of escapes by maintaining cage integrity through regular maintenance inspections and replacement of compromised or old infrastructure.
- Cages should have jump nets installed
- Develop and implement stock recovery procedures should escapes happen.
- During fish transfers or harvest, operations must be conducted in appropriate weather conditions and under constant visual supervision. Equipment appropriate to the weather and cage design must be used. Where necessary or appropriate, additional netting must be used to prevent escapes during transfer.

- Maintain robust and healthy populations of wild stocks

Optional mitigation measures:

- The use of anti-predator netting should be investigated to reduce the number of escapees that may produce offspring
- Develop the technology to mass produce sterile fry for cage culture

With mitigation	Regional **2**	Low **1**	Long-term **3**	**Medium** **6**	Improbable	**Low**	**– ve**	**Low**

4.1.2.5. Interactions with piscivorous fishes

The activity of numerous fish within sea cages, the routine feeding of cultured fish, any dead cultured fish that may sink to the bottom of cages and the physical structure of the cages themselves all attract piscivorous predators, in particular sharks and barracuda (Bevan et al. 2002; Vita et al. 2004; Papastimatiou et al. 2010; Sclodnick et al. 2011; Roberson 2012). These predators may become entangled in nets and cause damage to nets allowing stock to escape. This invariably creates conflict between animals and farmers, with farmers often shooting problem animals. Sharks are common in the waters of the Seychelles, and silvertip shark *Carcharhinus albimarginatus* are abundant around oceanic islands and are particularly inquisitive (van der Elst 1993). Bull sharks are another large shark also known from the Seychelles and are listed as Near Threatened by the IUCN red list of threatened species (IUCN 2016).

There are however several measures that can be put in place to reduce the impact of interactions with piscivorous fish from having a medium level of significance to a low level of significance (Table 20). The effectiveness of these measures remains uncertain in the local context and therefore requires monitoring.

Table 20. Assessment of the possible impacts resulting from piscivorous fish interacting with cage culture operations in the proposed ADZs.

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Medium **2**	Long-term (ongoing, but reversible) **3**	**Medium** **6**	Probable	**MEDIUM**	**– ve**	**Medium** (Monitoring required to confirm frequency of interactions)

Essential mitigation measures:

- Develop a protocol to deal with problematic piscivores with experts and officials (Independent scientists and SFA)
- Maintain a record of all interactions with piscivores as per EMP
- Remove any injured or dead fish from cages promptly
- Install and maintain suitable anti-predator nets
- During harvesting ensure that minimal blood enters the water

With mitigation	Local **1**	Medium **2**	Long-term **3**	**Medium 6**	Possible	**Low**	**– ve**	**Low** (Monitoring required to assess the effectiveness of mitigation measures)

4.1.2.6. Entanglement of marine animals (benthic associated)

Entanglement of marine animals, especially cetaceans but also turtles and birds, in cage infrastructure has been noted internationally (Wuersig & Gailey 2002; James et al. 2005; Watson-Capp and Mann 2005). Due to the mooring of cages with cables and chains and even the cages themselves the risk of entanglements is a possibility. Five species of turtle have been recorded in the Seychelles; the Hawksbill, Green, Loggerhead, Leatherback and Olive Ridley turtles. The Loggerhead, Leatherback and especially the Olive Ridley are however rarely reported. Both the Hawksbill and Green turtle are widespread and common in the Seychelles. Hawksbill turtle also nest on Saint Anne Island and are closely associated with benthic habitats, particularly coral reefs.

The Hawksbill and Green turtle are of particular concern as they are listed by the IUCN as being Critically Endangered and Endangered respectively (IUCN 2016). However, it is likely that in most cases turtles will avoid any lethal effects associated with entanglement in cage infrastructure. Sharks are also at risk of entanglement. As such the overall significance of these impacts is assessed as Medium; however certain mitigation measures must be in place to reduce the risk of entanglements as far as possible (Table 21).

Table 21. Assessment of possible impacts on turtles and sharks associated with the risk of entanglement in mooring lines and cages for proposed ADZs.

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Medium **2**	Long-term (ongoing, but reversible) **3**	**Medium 6**	Probable	**MEDIUM**	**– ve**	Medium (probability of entanglement deduced from studies elsewhere)

Essential mitigation measures:

- Ensure all mooring lines and nets are highly visible. Use thick visible lines.
- Keep all lines and nets as tight as possible and conduct regular inspections to ensure tautness
- Do not have any hanging lines or unnecessary lines from cages
- Maintain adequate separation between primary and secondary nets even during strong currents and rough seas
- Use square mesh and ensure that net mesh-size does not exceed 16 cm whilst stretched

Optional mitigation measures:

With mitigation	Local **1**	Medium **2**	Long-term **3**	**Medium 6**	Possible	**Low**	**– ve**	Medium (effectiveness of mitigation in local context unknown)

4.1.3. Decommissioning phase impacts on the benthic environment

4.1.3.1. Particulate pollution and entanglement hazards of cage infrastructure

Impacts associated with the decommissioning of ADZs are largely particulate forms of pollution such as cage infrastructure and mooring equipment if left in the sea which would also persist as entanglement hazards for marine life. These impacts will be limited to the proposed development footprints, of medium intensity, long-term and ongoing. However, they can be easily mitigated by ensuring that all infrastructure associated with the development of cages and the ADZs is removed.

Table 22. Assessment of impacts associated with the decommissioning of ADZs

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local **1**	Medium **2**	Long-term (ongoing, but reversible) **3**	**Medium 6**	Definite	**MEDIUM**	**– ve**	High
Essential mitigation measures: • Ensure that all infrastructure associated with the development of ADZs are removed from the sea and seafloor within 3 months of decommissioning a farm or ADZ								
With mitigation	Local **1**	Medium **2**	Short-term **1**	**Very low 4**	Improbable	**Insignificant**	**– ve**	**High**

4.2. Ancillary and supporting developments

4.2.1. Pilot-project cage site

A pilot cage for fin fish is proposed at Providence, Mahé (Section 1.2) (Figure 5). The development is likely to have similar impacts to those described above in Section 4.1, albeit at a much smaller intensity.

4.2.1.1. Construction phase impacts

During construction, mooring blocks and anchors will be placed on the seafloor. This is likely to be of very low overall significance as the area has been previously disturbed and mooring blocks are only likely to affect the benthic habitat within their footprints. The cage will be located near reef (~50 m) to the north-east and it is essential that this area is designated a "no-go" area for construction vessels and workmen. Furthermore, no mooring blocks/anchors should be positioned on any reef.

Table 23. Impact 1: Assessment of impacts during the construction phase of the pilot cage facility

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Low **1**	Medium-term (reversible) **2**	**Very Low 4**	Definite	**VERY LOW**	**– ve**	High
Essential mitigation measures: • Nearby reef to the north-east must be a designated "no-go" area to construction vessels, workmen and mooring blocks/anchors.								
With mitigation	Local **1**	Low **1**	Medium-term (reversible) **2**	**Very Low 4**	Definite	**VERY LOW**	**– ve**	High

4.2.1.2. Operational phase impacts

Impacts associated with the operational phase of the development are the same as those described above in detail (see Section 4.1.2) but which may have different levels of significance due to the scale and location of the proposed development, and include eutrophication and pollution of water and benthic habitats, chemical pollution, transmission of diseases and parasites to wild stocks, genetic impacts to wild stocks, physical entanglement to marine life and piscivore behavioural changes and associated human-animal conflicts.

Assessment of the impact of particulate organic build-up beneath cages is assessed as having medium negative status without mitigation and low negative significance with mitigation (Table 24).

Table 24. Assessment of impacts associated with particulate organic build-up on the benthic environment beneath cages

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Medium **2**	Long-term (ongoing	**Medium 6**	Definite	**Medium**	**– ve**	

			but reversible) **3**					Medium (monitoring required to determine intensity of impact)
Essential mitigation measures: • Sensible site selection. This has been achieved by zoning the cages over previously disturbed unconsolidated habitat however the depth is shallow • Rotate cages (fallowing) to allow for recovery of soft sediment benthos • Use species and system-specific feed to maximise food conversion ratios and minimise waste • No cleaning of fouling organisms from nets at sea • Monitor feeding behaviour and particulate deposition beneath cages and adapt feeding strategy to maximise feeding efficiency and minimise particulate matter fallout • Undertake benthic monitoring, including baseline surveys to determine scale of impacts and decrease stocking densities should the impact exceed the accepted sacrificial footprint. Optional mitigation measures: • Move pilot cages offshore and in deeper water								
With mitigation	Local **1**	Low **1**	Long-term **3**	**Low 5**	Probable	**Low**	**– ve**	Medium

The impacts of dissolved nutrients emanating from the pilot cages on sensitive habitats such as coral reefs and seagrass beds is considered to have medium negative significance without mitigation and low negative significance with mitigation (Table 25).

Table 25. Impact assessment of dissolved nutrients plumes on benthic habitats

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local **1** (but likely to extend beyond the boundaries of the cages)	Medium **2**	Long-term (ongoing but reversible) **3**	**Medium 6**	Definite	**Medium**	**– ve**	Low (Monitoring required to determine intensity of impact)
Essential mitigation measures: • Use species specific formulations designed to enhance nitrogen and phosphorus retention efficiency, and reduce metabolic waste output. • Monitor feeding behaviour and adapt feeding strategy to ensure minimal wastage (excess) of feed • Undertake monitoring of water quality and adjacent coral reef and seagrass habitats, including baseline surveys at control and cage sites to determine scale of impacts and decrease stocking density should the impact start effecting sensitive habitats.								

With mitigation	Local **1**	Low **1**	Long-term **3**	**Low 5**	Probable	**Low**	**– ve**	Medium

The impact of chemicals such as copper based antifoulants and therapeutics is assessed as having medium negative significance with mitigation and low negative significance with mitigation (Table 26).

Table 26. Assessment of the impact of chemical pollutants such as copper and veterinary therapeutics.

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1** (but likely to extend beyond the boundaries of ADZs)	Medium **2**	Long-term (ongoing but reversible) **3**	**Medium 6**	Probable	**Medium**	**– ve**	Low (monitoring required to determine intensity of impact)
Essential mitigation measures: • Use only approved veterinary chemicals and antifoulants • Where possible use environmentally friendly alternatives • Use the lowest effective dose of therapeutics • Do not clean cages on site/in the sea. Clean cages on land but ensure that any effluent resulting from this process reaching the sea contains acceptable levels of copper and antifoulants. • Monitoring: Total dissolved water column copper over reefs and seagrass beds not to exceed 1.3 ppm / 1.3 µg L^{-1} Optional mitigation measures: • Shift pilot cages further offshore								
With mitigation	Local **1**	Medium **2**	Long-term **3**	**Medium 6**	Possible	**Low**	**– ve**	Medium

The impact from the transfer of diseases and parasites from cultured stock to wild stocks is assessed as having very high negative significance without mitigation and high negative significance with mitigation (Table 27).

Table 27. Assessment of the impact of disease and parasitic transmission from cultured stock to wild stock

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional **2** (Distributional ranges of indigenous species)	High **3**	Long-term (ongoing, may be reversible) **3**	**Very High 8**	Definite	**VERY HIGH**	**– ve**	High
Essential mitigation measures: • Maintain strict bio-security measures within hatchery, holding tanks and sea cages								

• Ensure all fry undergo a health examination before stocking in cages • Regularly inspect stock for disease and parasites as part of a formalised stock health monitoring programme and take necessary actions to eliminate pathogens through the use of therapeutic chemicals or improved management. This will require focused research effort into the identification, pathology and treatment of diseases and parasites infecting farmed species, both in culture and in wild stocks. • Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the effectiveness of treatments applied. ○ These records should be made publically available to facilitate rapid responses by other operators to future outbreaks. • If possible stock different species in cages successively. • Treat adjacent cages simultaneously even if infections have not yet been detected. • Keep nets clean and allow sufficient fallowing time on site to ensure low environmental levels of intermediate hosts and or pathogens								
With mitigation	Regional **2**	Medium **2**	Long-term **3**	**High 7**	Probable	**High**	**– ve**	Medium

The significance of genetic impacts on wild stocks as a result of escapees is assessed as having high negative significance without mitigation and low negative significance with mitigation (Table 28).

Table 28. Assessment of the significance of genetic impacts on wild stocks

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Regional **2** (Distributional ranges of wild stocks)	High **3**	Long-term (ongoing, irreversible) **3**	**Very High 8**	Possible	**HIGH**	**– ve**	Low
Essential mitigation measures: • Maintain genetic compatibility between cultured and wild stocks by developing a genetic best-practice management guideline for finfish mariculture and ensure adequate genetic monitoring is undertaken routinely. • Minimise the number of escapes by maintaining cage integrity through regular maintenance inspections and replacement of compromised or old infrastructure. • Cages should have jump nets installed • Develop and implement stock recovery procedures should escapes happen. • During fish transfers, operations must be conducted in appropriate weather conditions and under constant visual supervision. Equipment appropriate to the weather and cage design must be used. Where necessary or appropriate, additional netting must be used to prevent escapes during transfer. • Maintain robust and healthy populations of wild stocks Optional mitigation measures: • The use of anti-predator netting should be investigated • Develop the technology to mass produce sterile fry for cage culture								
With mitigation	Regional **2**	Low **1**	Long-term **3**	**Medium 6**	Improbable	**Low**	**– ve**	**Low**

The impact of the pilot cages on piscivorous predators is assessed as having very low negative significance, however, several essential mitigation measures are required (Table 29).

Table 29. Impact assessment of the pilot cages on piscivorous predators

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Low **1**	Long-term (ongoing, but reversible) **3**	**Low 5**	Possible	**VERY LOW**	**– ve**	**Medium** (Monitoring required to confirm frequency of interactions)
Essential mitigation measures: • Develop a protocol to deal with problematic piscivores with experts and officials (Independent scientists, NGOs and SFA) • Maintain a record of all interactions with piscivores as per EMP • Remove any injured or dead fish from cages promptly • Install and maintain suitable anti-predator nets Optional mitigation measures:								
With mitigation	Local **1**	Low **1**	Long-term **3**	**Low 5**	Improbable	**Very low**	**– ve**	**High** (Monitoring required to confirm the effectiveness of mitigation measures)

The impact of entanglement of benthic associated marine life with pilot project cages and mooring ropes is assessed as having very low negative significance without mitigation, however, several mitigation measures are required to reduce the probability of entanglements (Table 30).

Table 30. Assessment of the impact of entanglements benthic associated marine life

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Low **1**	Long-term (ongoing, but reversible) **3**	**Low 5**	Possible	**VERY LOW**	**– ve**	Medium (probability of entanglement deduced from studies elsewhere)
Essential mitigation measures: • Ensure all mooring lines and nets are highly visible. Use thick visible lines. • Keep all lines and nets as tight as possible and conduct regular inspections to ensure this • Do not have any hanging lines or unnecessary lines from cages • Use square mesh and ensure that net mesh-size does not exceed 16 cm whilst stretched								

Optional mitigation measures:								
With mitigation	Local **1**	Low **1**	Long-term **3**	**Low** **5**	Improbable	**Very Low**	**– ve**	Medium (effectiveness of mitigation in local context unknown)

4.2.1.3. Decommissioning phase impacts

Impacts associated with the decommissioning of the pilot-project cages are largely associated with particulate forms of pollution such as cage infrastructure and mooring equipment if left in the sea. These impacts will be limited to the proposed development footprint, of relatively low intensity but nevertheless long-term and ongoing. However, this can be mitigated by ensuring that all infrastructure associated with the pilot project cages is removed (Table 31).

Table 31. Assessment of impact associated with the decommissioning phase of pilot project cages

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local **1**	Low **1**	Long-term (ongoing, but reversible) **3**	**Low** **5**	Definite	**LOW**	**– ve**	High
Essential mitigation measures: • Ensure that all infrastructure associated with the development of the pilot-project cages are removed from the sea and seafloor								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very low** **3**	Improbable	**Insignificant**	**– ve**	**High**

4.2.2. Brood-stock Quarantine & Acclimation Facility

A brood-stock facility is proposed at Providence, Mahé which will have a submarine pipeline into the coastal zone providing it with fresh seawater (Section 1.2). The proposed pipeline will be positioned over soft unconsolidated sediments which have previously undergone disturbance due to historical construction of the harbour (Figure 4). The pipeline will thus cover an already disturbed area of low biodiversity value. Minimal impacts are expected during construction, operational and maintenance phases which are likely to be due to smothering and disturbance of the benthos in the footprint and close proximity of the pipeline (Table 32).

Table 32. Mortality and disturbance associated with the construction, operation and maintenance phases of the pipeline development.

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Possible	**INSIGNIFICANT**	**– ve**	High
Essential mitigation measures: • Sensitive coral reef habitat exists in close proximity (<50 m) to the north-west of the proposed pipeline. This area must be a designated "no-go" area during construction and maintenance phases.								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Improbable	**INSIGNIFICANT**	**– ve**	High

When the brood-stock facility is decommissioned, all associated pipeline infrastructure must be removed from the seafloor as this constitutes a source of pollution and could eventually breakup and physically damage adjacent reef and infrastructure (Table 33). This must be carefully done so that adjacent coral reefs are not impacted.

Table 33. Pollution and physical damage from the water supply pipeline associated with the decommissioning phase of the development

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Low **1**	Long-term **3**	**Low 5**	Definite	**Low**	**– ve**	High
Essential mitigation measures: • Remove all pipeline infrastructure • Sensitive coral reef habitat exists in close proximity (<50 m) to the north-west of the proposed pipeline. This area must be a designated "no-go" area during the removal of all infrastructure								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Improbable	**INSIGNIFICANT**	**– ve**	High

4.2.3. Research and Development Facility

A research and development facility (R & D) is proposed at Ansa Royal, Mahé which will have a pipeline running below the high water mark into the coastal zone providing it with fresh seawater (Section 1.2). The proposed pipeline will be positioned across the fringing reef (Figure 6). Impacts are expected during the construction and maintenance phases. During construction, mortality of coral reef organisms, caused by trampling by construction workers, is likely to occur during the construction and lying down of the pipeline. The impacts of this are evaluated in Table 34. Essential mitigation measures are provided in this table as well.

Table 34. Mortality associated with the construction of the pipeline due to trampling.

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Medium **2**	Short-term **1**	**Low 4**	Definite	**LOW**	**– ve**	High
Essential mitigation measures: • Limit trampling to within the development footprint. The development footprint should be set at 1 m either side of the location of the proposed pipeline so that only a swath of approximately 2 m wide is affected. • Construct the pipeline from within the development footprint and not from outside of the development footprint.								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Definite	**VERY LOW**	**– ve**	High

The pipeline is to be constructed over existing reef with high biodiversity value directly adjacent to the R & D facility. The pipeline will cover more than 700 m^2 of reef. This will lead to mortality of all coral reef organisms beneath the pipeline with limited or no mobility and the impacts of this are assessed in Table 35. Essential mitigation measures are also included in this table and illustrated in Figure 24. **This entails rerouting the pipeline which will reduce the amount of coral reef affected by approximately 85%.**

Table 35. Mortality associated with the construction of the pipeline due to the footprint of the pipeline

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Medium **2**	Long-term **3**	**Medium 6**	Definite	**MEDIUM**	**– ve**	High
Essential mitigation measures: • It is advised that the pipeline be re-routed so that it overlies less coral reef, and in particular, does not traverse the reef edge and slope where fragile corals typically grow. The new proposed route for the pipeline is indicated in Figure 24 by the solid red line.								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Possible	**VERY LOW**	**-ve**	High

Figure 24. The proposed re-routing of the pipeline indicated by the solid red line

The pipeline may need to undergo inspections and maintenance from time to time and the impacts of this are likely to be further trampling and disturbance albeit to a lesser intensity. The impacts of this are assessed in Table 36 and mitigation measures provided.

Table 36. Mortality associated with the periodic and routine maintenance of the pipeline

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Definite	**VERY LOW**	**– ve**	High
Essential mitigation measures: • Limit trampling to within the development footprint. The development footprint should be set at 1 m either side of the location of the pipeline so that a swath of approximately 2 m wide is affected. • Any maintenance to the pipeline must be undertaken from within the development footprint and not from outside of the development footprint.								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Definite	**VERY LOW**	**– ve**	High

When the research and development facility is decommissioned the pipeline should be removed. Ageing infrastructure that is no longer maintained such as the pipeline after it has been decommissioned is likely to eventually break up and cause pollution and physical damage to the adjacent reef at it moves about with wave action. This impact is assessed as having medium significance but can be mitigated to have very low significance (Table 37).

Table 37. Assessment of impacts associated with the decommissioning of the pipeline due to ageing infrastructure and physical damage

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Local **1** (but not confined to the development footprint)	Medium **2**	Long-term **3** (reversible)	**Medium 6**	Probable	**MEDIUM**	**– ve**	Medium
Essential mitigation measures: • Remove all pipeline infrastructure within a year of it being decommissioned • Work only within a 2-m swath to reduce damage to adjacent reef								
With mitigation	Local **1**	Low **1**	Short-term **1**	**Very Low 3**	Possible	**INSIGNIFICANT**	**– ve**	Medium

4.3. Impact summary

A summary of impacts and the significance of each are provided prior to and after mitigation measures have been implemented for the aquaculture development zones (Section 4.3.1), and ancillary and supporting developments (Section 4.3.2).

4.3.1. Proposed aquaculture development zones

Significant negative impacts on coral reefs, seagrass habitats and benthic environments are expected from the proposed ADZs (Table 38). Of particular concern are impacts from the transmission of diseases and parasites to wild fish stocks, genetic impacts to wild fish stocks, particulate organic build-up beneath ADZs, dissolved organic nutrient plumes and dissolved copper and other chemical therapeutics. Some of these impacts are difficult to mitigate in practice. The impact of dissolved nutrients and copper (as well as other chemical) emanating from proposed ADZs on sensitive coral reef and seagrass habitats is difficult to assess confidently and therefore an in depth hydrodynamic modelling study for each ADZ and all ADZs collectively is critically important.

Table 38. Impact assessment summary for impacts expected from the development of the proposed ADZs.

Phase	Potential Environmental Impact	Before mitigation					After mitigation				
		Consequence	Probability	Status	Significance	Confidence	Consequence	Probability	Status	Significance	Confidence
CONSTRUCTION	Mortality and disturbance to benthic communities within the footprints of mooring infrastructure	Low	Definite	-ve	Low	High	Low	Definite	-ve	Low	High
OPERATIONAL	Disease and parasite transmission to wild stocks	Very high	Definite	-ve	Very high	Medium	High	Probable	-ve	High	Medium
	Genetic impacts on wild stocks	Very high	Possible	-ve	High	Low	Medium	Improbable	-ve	Low	Low
	Particulate organic build-up beneath cages	High	Definite	-ve	High	Medium	Medium	Definite	-ve	Medium	Medium
	Dissolved nutrients on sensitive habitats	High	Definite	-ve	High	Low	Medium	Possible	-ve	Low	Medium

	Antifoulants (e.g. copper) and therapeutics	High	Probable	-ve	High	Low	Medium	Possible	-ve	Low	Medium
	Interactions with piscivorous fishes	Medium	Probable	-ve	Medium	Medium	Medium	Possible	-ve	Low	Low
	Turtle and shark entanglement with cage infrastructure	Medium	Probable	-ve	Medium	Medium	Medium	Possible	-ve	Low	Low
DECOMMISSIONING	Pollution and entanglement from decom-missioned cage infrastructure	Medium	Definite	-ve	Medium	High	Very low	Im-probable	-ve	Insig-nificant	High

4.3.2. Ancillary and supporting developments

4.3.2.1. Pilot-project cage site

There are several potentially significant impacts associated with the pilot-project cage site development (Table 39). In particular, the impact of disease and parasite transmission to wild fish stocks. Other impacts can generally be mitigated to have low significance.

Table 39. Summary of impacts associated with the proposed pilot-project cage site

Phase	Potential Environmental Impact	Before mitigation					After mitigation				
		Consequence	Probability	Status	Significance	Confidence	Consequence	Probability	Status	Significance	Confidence
CONSTRUCTION	Mortality and disturbance to benthic communities within the footprints of mooring infrastructure	Very low	Definite	-ve	Very low	High	Very low	Definite	-ve	Very low	High
OPERATIONAL	Disease and parasite transmission to wild stocks	Very high	Definite	-ve	Very high	High	High	Probable	-ve	High	Medium
	Genetic impacts on wild stocks	Very high	Possible	-ve	High	Low	Medium	Im-probable	-ve	Low	Low
	Particulate organic build-up beneath cages	Medium	Definite	-ve	Medium	Medium	Low	Probable	-ve	Low	Medium
	Dissolved nutrients on sensitive habitats	Medium	Definite	-ve	Medium	Low	Low	Probable	-ve	Low	Medium

	Antifoulants (e.g. copper) and therapeutics	Medium	Probable	-ve	Medium	Low	Medium	Possible	-ve	Low	Medium
	Interactions with piscivorous fishes	Low	Possible	-ve	Very low	Medium	Low	Im-probable	-ve	Very low	High
	Turtle and shark entanglement with cage infrastructure	Low	Possible	-ve	Very low	Medium	Low	Im-probable	-ve	Very low	Medium
DECOMMISIONING	Pollution and entanglement from decom-missioned cage infrastructure	Low	Definite	-ve	Low	High	Very low	Im-probable	-ve	Insig-nificant	High

4.3.2.2. Brood-stock facility

The water supply pipeline associated with the brood-stock facility is expected to have impacts of low negative significance (Table 40).

Table 40. Summary of impacts associated with the water supply pipeline to the brood-stock facility

Phase	Potential Environmental Impact	Before mitigation					After mitigation				
		Consequence	Probability	Status	Significance	Confidence	Consequence	Probability	Status	Significance	Confidence
CONSTRUCTION & OPERATION	Mortality and disturbance of benthic communities	Very low	Possible	-ve	Insig-nificant	High	Very low	Im-probable	-ve	Insig-nificant	High
DECOMMISIONIN	Pollution and mortality	Low	Definite	-ve	Low	High	Very low	Im-probable	-ve	Insig-nificant	High

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4.3.2.3. Research and development facility

The water supply pipeline associated with the research and development facility is assessed as having negative impacts of up to medium significance without mitigation (Table 41). **With the rezoning of the pipeline so that it overlies less reef the impacts can be reduced to very low levels.**

Table 41. Summary of impacts associated with the research and development facility water supply pipeline.

Phase	Potential Environmental Impact	Before mitigation					After mitigation				
		Consequence	Probability	Status	Significance	Confidence	Consequence	Probability	Status	Significance	Confidence
CONSTRUCTION	Mortality of coral and reef organisms associated with trampling by workmen and machinery	Low	Definite	-ve	Low	High	Very low	Definite	-ve	Very low	High
	Mortality of coral and reef organisms associated with the footprint of the pipeline	Medium	Definite	-ve	Medium	High	Low	Possible	-ve	Very low	High
OPERATIONAL	Trampling and disturbance of coral reef during routine maintenance	Very low	Definite	-ve	Very low	High	Very low	Definite	-ve	Very low	High
DE	Pollution and physical	Medium	Probable	-ve	Medium	Medium	Very low	Possible	-ve	Insig-nificant	Medium

C O M M I S I O N I N G	damage to coral reef										

5. Environmental Management Plan

5.1. Framework

Due to the potentially numerous negative impacts discussed in Section 4 that are associated with the proposed developments, it is imperative that a holistic environmental management plan (EMP) be designed and correctly implemented. As part of the Environmental Authorisation process (Section 15(1) of EPA), governed by the Seychelles Environmental Protection Act (EPA), Act No. 9 of 1994, an essential component is the submission of an EIA, and the EMP forms part of a comprehensive EIA required by the Marine Aquaculture and Sea-ranching Regulations (Fisheries Act 2014).

The aim of an EMP is to document and plan the management approach that will best achieve the avoidance and minimisation of potential environmental impacts in the construction, operation and decommissioning phases of the proposed developments. The Marine Aquaculture and Sea-ranching Regulations: Regulations for the Sustainable Development and Management of Aquaculture and Sea-ranching in the Republic of the Seychelles, provides a framework for such an EMP and highlights relevant components required for monitoring of aquaculture facilities (Fisheries Act 2014).

It is recommended that EMPs are developed for each ADZ in their entirety, for each individual fish farm within a particular ADZ and for each ancillary development (i.e. pilot-project cage site, brood-stock facility, and research and development facility). The EMP for ADZ's will allow for the management of the cumulative effects of all farms within it holistically. This EMP should include all recommendations listed in the Environmental Impact Assessment Report and conditions outlined in the Environmental Authorisation. EMP's for farms within ADZs however, will allow for more efficient and precise management at the scale of individual concessions. This will in turn provide farmers with the opportunity to custom-manage their facilities and allow designated authorities to more efficiently manage compliance. EMP's for farms should be formulated so that they are compatible, supportive and facilitative of the EMP for the ADZ within the limits of the Environmental Authorisation.

A critical component of the proposed project and its associated EMP is the management and monitoring of potential impacts on the environment. As discussed in the ESIA Scoping Report (SFA 2016a), it is recommended that the **proposed development be phased in**; this will allow for an adaptive management strategy that can be formulated and adjusted based on real-time environmental monitoring data as the project evolves and production increases in accordance with acceptable environmental thresholds and Republic of Seychelles Marine Aquaculture and Sea-ranching Regulations contained in the Fisheries Act 2014.

An efficient and detailed monitoring programme that will guide and inform an adaptive management strategy is therefore an essential requirement. In order to manage the programme, a Monitoring Forum that comprises stakeholders from SFA, the mariculture industry, Seychelles National Parks Authority, independent scientists and community members should be established. An independent company(s) should then be managed and tasked by the Monitoring Forum to conduct environmental monitoring at each individual fish farm within ADZs and for the ADZs and Inner Island area at large. This will ensure objectivity and transparency, and facilitate the requirements and goals of the EMP.

The Republic of Seychelles Marine Aquaculture and Sea-ranching Regulations is particularly relevant in highlighting specific aspects that need to be incorporated into a monitoring programme. These emphasise sustainability and the maintenance of ecosystem integrity informed by the FAO Code of Conduct for Responsible Fisheries and the associated Technical Guidelines for Aquaculture, in particular Supplement 4, “Ecosystem approach to aquaculture”. They specifically mention fallowing, the maintenance of genetic diversity and biodiversity, pollution, disease, water quality and sediment monitoring and management. Furthermore, the Fisheries Act (2014) requires that an ecological baseline survey be conducted prior to any sea ranching activities to provide a benchmark for monitoring. This has not been undertaken in the detail required to allow for appropriate monitoring of potential impacts of the ADZs on benthic habitats and needs to form part of the monitoring programme of the EMP.

As such, operations must be conducted within sustainable production capacities to prevent environmental degradation. Monitoring data may therefore be collected:

- as part of an EIA generated environmental management plan (EMP);
- in compliance with some form of code of practice;
- for the information of the farmer in support of husbandry;
- by regulatory authorities as part of compliance; and
- by regulatory authorities as part of monitoring in the wider environment

It is recognised that components of a monitoring programme for each EMP (ADZ, farm, pilot-cage project etc.) may vary and overlap to differing degrees, depending on whether the EMP is for an individual farm or for an entire ADZ, or depending on the individual characteristics and requirements of each individual farm/development. Essentially, each fish farm within an ADZ should have its own monitoring programme for their respective EMP that is project specific and is compiled as and when it is developed. This should include for example farm specific monitoring and record keeping of animal husbandry, stock health, feeding programmes, water quality within and adjacent to cages, sediment sampling in the immediate vicinity of the farm cages and plans to deal with escapees and predators.

Components of a monitoring programme for an ADZ EMP, however, would include monitoring for wider spatial and cumulative impacts of farms including monitoring further afield outside of zoned ADZs and at control sites so that the overall footprint of each ADZ can be determined. Furthermore, monitoring for the ADZ EMP would include studies of disease and parasites and genetic variability within wild stocks, and status of ecosystem indicators further afield (e.g. coral reefs, habitat use by fish, cetaceans and sharks via telemetry studies). All farmers should contribute to an ADZ monitoring trust that provides funding for the monitoring component of the ADZ EMP, with assistance from the state (SFA etc.).

In view of the guidelines provided by the Seychelles Aquaculture Standard: Responsible Finfish Cage Culture, studies undertaken in South Africa (CCA Environmental 2008; DAFF 2013), and the impacts highlighted in Section 4, components for monitoring and management with particular reference to coral reef and benthic habitats are provided for the following sections for each proposed development.

5.2. Aquaculture development zones

Mitigation and monitoring components required for the proposed ADZs are detailed in Table 42 along with specific objectives, performance criteria, responsibilities and time lines/frequencies of monitoring. These management and monitoring components are intended to supplement the general standards contained in the Seychelles Aquaculture Standard: Responsible Finfish Cage Culture and those in the Seychelles Marine Aquaculture and Sea-ranching Regulations, Regulations for the Sustainable Development and Management of Aquaculture and Sea-ranching in the Republic of the Seychelles.

It is critical that baseline data on several aspects are collected prior to any development to allow for the impacts of the proposed developments to be assessed and adaptive management strategies formulated if and when necessary. Management and monitoring requirements outlined in Table 42 are explained in more detail according to each phase of the development and the relevant Section Numbers contained in Table 42.

5.2.1. Construction phase

5.2.1.1. Section 4.1.1

Quarterly monitoring of the positions of mooring blocks must be done for the first year into the operational phase for each newly established farm to ensure they are well settled. Thereafter checks can be done annually or after major sea-storm events when infrastructure may have shifted for the duration of the operational phase. Quarterly reporting during the first year and ad hoc reporting after that should be used to inform management regarding the status of the mooring infrastructure. If mooring infrastructure is moving then management needs to rectify this within 6 months.

5.2.2. Operational phase

5.2.3. Section 4.1.2.1 and 4.1.2.2

Qualitative and quantitative baseline data of the benthic environment must be acquired before any development proceeds. A qualitative survey using dated colour videography or colour still photography must be conducted prior to the development and thereafter twice a year (January and July) of the sea floor under and adjacent to each cage on a 100 meter transect up the prevailing current from the edge of the net and 100 meters down the prevailing current from the edge of the cage to determine solids loadings and whether eutrophication of the local environment is occurring as a result of food loss and fish excretion. Monitoring will include recording the date(s) on which monitoring was conducted, a site schematic of the video track(s) or still photos in relation to the cage, and Global Positioning System (GPS) locations of the beginning and end points for the transects. The video survey shall be continuous. Still photographs should be taken at least every 5 meters using a 0.25 m^2 (50 x 50 cm) quadrat made of white PVC conduit tube. The video or photographic survey will document sediment type and colour as well as features such as erosional and depositional areas, flora and fauna and their relative abundance, feed pellets, and any other manmade debris. The presence of faeces as well as the presence of bacterial mats and black anoxic sediments should also be detailed. Images shall be of sufficient detail and clarity to allow for the accurate assessment of benthic conditions. A brief written narrative with the tape or photographs describing current speed and direction and reference points shall be included. The recording or photographs with narrative will be submitted to the Regulator within 30 days of completion of the survey.

In addition, quantitative baseline and monitoring surveys of the benthic environment must be undertaken. Indicators of sediment characteristics and quality (e.g. particle size analysis, organic content, redox, pH, hydrogen sulphide concentration and the concentration of any potentially harmful chemicals that have been used in operations, including antifoulant constituents and heavy/trace metals including copper, zinc, lead etc.) should be monitored annually for three years. Monitoring may be reduced after three years of annual monitoring, provided production rates are stable and benthic environmental health is acceptable. Thereafter monitoring should be done every 5 years. Samples should be examined for the presence of macrobenthos too, using the same schedule (see below).

Sediment samples will need to be collected for the above parameters immediately adjacent to at least four cages per farm on the North, East, South and West edges of expected impacts (e.g. 50 m from a cage cluster) and at four control sites at least 1km North, East South and West from the limits of each ADZ in areas with similar physical characteristics (depth, sediment type etc.). Sampling should be conducted using a reasonably sized (mouth > 0.01m^2) grab sampler (Van Veen type or other).

Biological samples should be identified, counted and weighed, to allow for quantitative assessments of the benthic biota over time (i.e. k-dominance curves). Importantly, much of the macrofauna is likely to be undescribed and therefore a reference collection should be built up and morpho-species used in analyses where species level identification is not possible.

Compulsory fallowing must be conducted at all farms within ADZs as stipulated by the Sea-ranching Regulations. This is to be done once every second year for a period not less than six (6) months and / or until such time as the seabed has recovered to baseline levels. Detailed records of all fallowing activities must be submitted to the relevant authorities.

All results should be reported annually for the first three years and thereafter every five years, except for fallowing reports which must be submitted annually for the life of each farm.

Quantitative baseline and monitoring data from the water column also needs to be collected for dissolved chemical substances such as nitrate, phosphate and copper, as well as any other antifoulants and veterinary therapeutics and disinfectants that will be used routinely. Water samples for baseline data of dissolved nitrate, phosphate and copper should be collected from at least four to 12 sites evenly distributed within each ADZ at depths of 5 m. Similarly, water samples need to be collected between ADZs and sensitive habitats, from waters overlying sensitive coastal habitats (coral reefs and seagrass beds) and at control sites at least 10 km away from ADZs (or outside of the sphere of influence deduced from hydrodynamic models) (Figure 25). Ideally, control sites should be close enough to the farm to reflect local conditions, but distant enough so as not to be influenced by the farm itself (Jansen et al. 2016). By adopting this study design, gradients of dissolved chemicals can easily be detected in the directions of sensitive habitats. For the collection of baseline data, sampling should be conducted at each site every month for a period of a year to account for seasonal fluctuations. Thereafter, once stocking has taken place, water sampling can be conducted quarterly for the next three years. If stocking levels are not increased, monitoring can be restricted to quarterly sampling from coastal sites overlying sensitive habitats and from control sites.

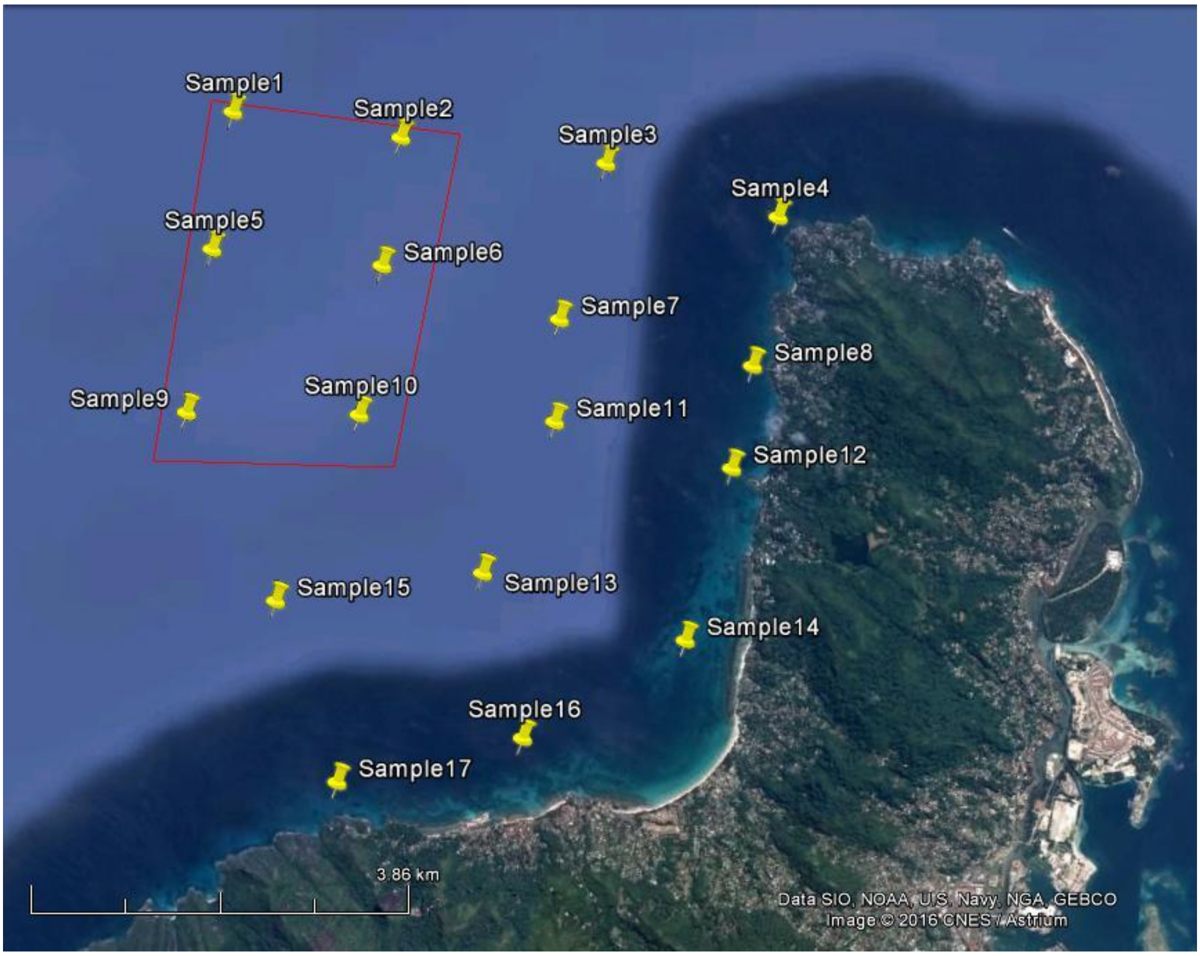

Figure 25. An example of a strategic sampling design for water quality sampling for proposed aquaculture development zone M6 (indicated by red polygon). Note the figure does not illustrate Control Sites which lie offshore of the ADZ.

In addition, it is advised that coral reefs and seagrass beds are monitored for shifts in coral algal dominance. A series of permanent twenty-metre long transects on coral dominated reef and seagrass beds adjacent to proposed ADZs should be surveyed initially for baseline data and then annually for a period of at least five years from the commencement of farming operations. Coral and algal cover should be assessed with photo-quadrats at 1-m intervals along each transect and analysed using Coral Point Count Software. Urchins should be counted. Similarly, seagrass beds should be surveyed with quadrats and the percentage cover of species determined, as well as the percentage cover of epiphytes and macro-algae (see McKenzie 2003; McKenzie et al. 2003).

The data should be analysed using a repeated measures before-after-control-impact (BACI) design (Jansen et al. 2016). If threshold levels are reached or exceeded, adaptive management strategies must be quickly formulated and initiated. Either stocking densities should be decreased and or feed changed. Each farm manager must maintain a comprehensive and detailed register of the quantities of feed, chemicals, antibiotics, antifoulants and hormones, etc. that are utilised.

The information must include:

a. the name of the license holder;

b. the Aquaculture License number of the license holder;

c. the location of the aquaculture operation;

d. the date;

e. the species being cultured;

f. the name and contact details of the fish veterinarian as well as a copy of the

prescription;

g. the names of all antibiotics and therapeutic agents prescribed;

h. the procedure for administering the antibiotics and therapeutic agents; and

i. any other relevant information

All raw data and reports must be archived on multiple servers by farm managers and the SFA to ensure that it cannot be lost or corrupted.

5.2.4. Section 4.1.2.3

All fry must undergo a health inspection by a veterinarian and be certified disease and parasite free before being stocked into sea cages. Cages should be inspected daily for mortalities and any dead fish removed promptly to limit the spread of possible diseases. Parasite and disease checks should be undertaken daily/weekly. Veterinary therapeutics should be added without delay if parasites and disease are detected and adjacent cages should also be treated as infected. Parasite and disease outbreaks should be reported to the relevant authorities within 24 hours of detection. Annual inspections of facilities should be conducted by a veterinarian.

Detailed records must be kept by farm managers of all incidences, the quantity and type of treatments applied and adaptive management strategies implemented to reduce outbreaks (e.g. lower stocking densities, different dosages of therapeutics, different therapeutics, less susceptible culture species). This should form part of an approved Biosecurity and Fish Health Management Plan. A parasite and fish-health monitoring programme should be established by the SFA in collaboration with the industry to monitor both cultured and wild stocks which must include pathogen identification and quantification. Representative samples of wild stocks should be sampled on an annual basis adjacent to ADZs for this purpose for the duration of the operational phase. The findings should be reported on annually. All findings and reports must be made publicly available.

5.2.5. Section 4.1.2.4

A brood-stock management guideline or species specific permit conditions that use precautionary principles to reduce genetic impacts, must be developed by the SFA. This should be updated with genetic information gained from a monitoring programme that assesses the genetic status of both farmed and wild populations of each species in terms of genetic variability and compatibility every three to five years. The interval of the monitoring programme can be adjusted based on the actual results and changes within the breeding population (mortalities, replacements, etc.). The monitoring programme would require that appropriate molecular markers and procedures (sampling, etc.) be identified and developed for assessment of Brown-marbled grouper, Mangrove river snapper, Emperor snapper and Snubnose Pompano. A genetic monitoring programme is beyond the scope of this EMP, however, it must be developed before brood-stock is acquired for culture. For example, brood-stock should be sourced from local wild populations at random, bearing in mind that an effective population size needs to be achieved and a mating programme implemented to ensure that no inbreeding occurs in the brood-stock. The responsibility for carrying out the genetic monitoring and analysis of brood-stock and wild populations should be the SFA and associated research authorities, as they should be responsible for the profiling of their commercial brood-stock/cultured stock.

To furthermore reduce the risk of genetic impacts, escapes must be limited by ensuring that predator and jump nets are used, fish transfers are done in calm weather and above extra nets, regular maintenance is done on cages and robust and diverse wild stocks are maintained and not depleted. All escapes must be recorded and include:

a. the name of the license holder;

b. the Aquaculture License number of the license holder;

c. the location of the aquaculture operation;

d. the species escaped;

e. date and estimated time of escaper;

f. size of escapees;

g. estimated number of fish having escaped;

h. cause of escape; and

i. remedial actions undertaken to prevent escape in future

5.2.6. Section 4.1.2.5

Behavioural changes in piscivores such as sharks are often noticed in the vicinity of aquaculture developments, as the cultured fish attract these predators. It is imperative that detailed records are kept by staff of all interactions. Records must include:

a. the name of the license holder;

b. the Aquaculture License number of the license holder;

c. the location of the aquaculture operation;

d. the species being cultured;

e. date and time;

f. a basic identification of the predator;

f. estimated size of the predator;

i. description of its behaviour and the duration of interaction. Is more than predator this should be noted too;

j. what workers were doing at the time when predators were noticed. i.e. feeding, rotating cages/maintenance, harvesting fish etc.; and

j. any other information that is deemed relevant

This information can then be used to inform an adaptive management strategy. Based on these results management guidelines could be formulated by the SFA in collaboration with specialists and farm managers how best to deal with problem piscivores if this materialises (e.g. installation of shark-repellent metal alloy nets). Before any methods are used by farm managers/license holders to minimise interactions with predators, prior written permission must be obtained from the Regulator and monitoring must be continued.

5.2.7. Section 4.1.2.6

Daily monitoring of infrastructure as well as entanglements and records must be done and reported on monthly. This should be ongoing for the duration of the development. Information to be collected when an entanglement occurs must include:

a. the name of the license holder;

b. the Aquaculture License number of the license holder;

c. the location of the aquaculture operation;

d. the species being cultured;

e. date and time entanglement detected;

f. identification of animal entangled;

g. what the animal is entangled in (e.g. mesh, mooring ropes, etc.);

h. method/description of what was done to free the animal;

i. time the animal was freed;

j. apparent state of the animal when released (e.g. sunk to the bottom, swam off slowly, swam of fast); and

k. did the animal require veterinary attention/rehabilitation

The information collected would be used to inform adaptive management strategies that farm managers can use on the ground. Regular entanglements of sharks and even rare entanglements of turtles would constitute a serious concern and mooring structures and/or nets may have to be adapted to minimise risk (beyond proposed mitigation measures). If an entanglement is detected, the incident must be reported immediately to the farm manager, SFA and Seychelles Nature Conservation Authority, so that immediate action can be undertaken to free an animal. Farm workers should be trained how to best disentangle sharks and turtles safely. Injured animals such as endangered turtles should be rehabilitated. A local marine mammal specialist should also be consulted for entanglement issues pertaining to whales and dolphins.

5.3. Decommissioning phase

All infrastructure associated with sea cages must be removed within 3 months of decommissioning as the infrastructure poses a pollution and entanglement hazard. The site should be rehabilitated in terms of the Seychelles Marine Aquaculture and Sea-Ranching Regulations 2014.

Table 42. Mitigation and monitoring measures for proposed aquaculture development zones

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
CONSTRUCTION / IMPLEMENTATION PHASE									
4.1.1	Benthic environment	Mortality and disturbance to benthic macrofauna	To minimise footprint of mooring infrastructure and disturbance caused by movement of mooring infrastructure	NA	Essential mitigation measures: ▪ **Consolidated (hard/reef) areas of seafloor should be excluded from M1 and SN2 (and from any other proposed ADZs)**	Specialist appointed by SFA	During ADZ zonation/ delineation	NA	NA
				Ensuring that any shifting mooring equipment is prevented from doing so again within 6 months	Optional mitigation measures: ▪ Ensure mooring system is designed to limit movement of anchors and cables over the seafloor; ▪ Position mooring anchors/blocks strategically so that when undertaking maintenance or	Engineering contractors, Fish farm manager and independent ECO/auditor	Duration of Construction Activities	Quarterly for the first year after mooring cages within an ADZ, thereafter at periodic intervals after severe storm events. Quarterly and ad hoc reporting	Farm EMP

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					fallowing of sites moorings do not have to be moved.				
OPERATIONAL PHASE									
4.1.2.1	Particulate organic loading/pollution of benthic environment beneath cages	Particulate organic build-up beneath cages and mortality of macrofauna	Minimisation of particulate organic build-up and its impact on sensitive habitats	FAO Code of Conduct for Responsible Fisheries/ Specialist advice	Essential mitigation measures: ▪ Sensible site selection. This has been partly achieved but consolidated (hard/reef) areas of seafloor must be excluded from M1 and SN2 (and any other proposed ADZs) ▪ ADZs should be moved to avoid overlying benthic macro-algae patches (See SFA 2016b) ▪ ADZs must be sited at least 500 m from fish spawning aggregation sites ▪ ADZs must be located at least 500 m away from	Specialist appointed by SFA	During ADZ zonation/ delineation	NA	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/part y	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					any coral reef and seagrass habitats ▪ ADZs must be located at least 500 m away from rocky reef dive sites. M2 and M4 appear to be too close. ▪ ADZs must be located at least 500 m away from marine protected areas				
				Sediment type and colour, erosional and depositional areas, relative abundance of flora and fauna, presence of feed pellets and manmade debris (See Seychelles Aquaculture Standard: Finfish cage culture)	▪ Undertake benthic monitoring, including baseline surveys at control and ADZs sites to determine scale of impacts and decrease ADZ production levels should the impact exceed the accepted sacrificial footprint. ▪ Rotate cages (fallowing) within each ADZ to allow for recovery of soft sediment benthos	Farm manager, SFA, independent ECO auditor	Duration of operationa l phase	▪ Qualitative surveys biannually in January and in July as per Seychelles Aquaculture Standard: Finfish cage culture. Biannual reporting ▪ Quantitative surveys should be conducted	Farm and ADZ

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					▪ Use species and system-specific feed to maximise food conversion ratios and minimise waste ▪ No cleaning of fouling organisms from nets at sea			prior to development to obtain baseline data and repeated thereafter every year. Monitoring may be reduced after three years of annual monitoring, provided production rates are stable and benthic environmental health is acceptable. Annual reporting	
				Maximum of 10% of feed quantity uneaten and settling below cages	▪ Monitor feeding behaviour and particulate deposition beneath cages and adapt feeding strategy to maximise feeding	Farm manager	Duration of operational phase	▪ Feeding rates recorded daily and pellet deposition bi-annually in qualitative	Farm

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					efficiency and minimise particulate matter fallout			survey. Monthly reporting	
					Optional mitigation measures: ▪ Near-field modelling exercise of particulate organic matter for each proposed ADZ would add more confidence in assessing the scale of the fallout of particulates and thus its impact	Independent specialist	During ADZ zonation/ delineation	Once off	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
4.1.2.1	Nutrient enrichment in the form of dissolved organic nutrients. Effects on adjacent sensitive habitats (e.g. coral reefs and seagrass beds)	Increased epiphyte load on seagrasses leading to competition and mortality. Decrease in skeletal density, higher infestation of boring organism and decreased reproductive effort in corals. Increased shading of corals due to increase in macro-algal abundanc	Minimise concentrations of dissolved nutrients (nitrate and phosphate) sufficiently before they come into contact with sensitive habitats	European Union recommendations (Huntingdon 2006). Mean ambient water column nitrogen and phosphorus concentrations must not exceed 5% of background levels at coral reef and seagrass beds	Essential mitigation measures: ▪ Prior to developing any ADZ, conduct a far-field hydrodynamic modelling exercise of dissolved nutrient dispersal for each ADZ using detailed current profiling data (and other relevant data i.e. bathymetry, wind, cage drag, Coriolis Force) collected over a period of at least a year. Model different intensities of ADZ development and predict dissolved nutrient diffusion (nitrate and phosphate) from each ADZ and ensure that waste plumes have dissipated sufficiently before coming into contact with sensitive habitats	Independent specialist	During ADZ zonation/ delineation. Acoustic Doppler Current Profiler (ADCP) data to be collected for each proposed ADZ for at least a year for input into hydro-dynamic models	NA	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/part y	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
		e. Mortality			such as coral reefs and seagrass beds.				
					▪ Use species specific formulations designed to enhance nitrogen and phosphorus retention efficiency, and reduce metabolic waste output. ▪ Monitor feeding behaviour and adapt feeding strategy to ensure minimal wastage (excess) of feed.	Farmer managers, SFA	Duration of operation phase	▪ Feeding rates recorded daily. Monthly reporting	Farm
					▪ Undertake monitoring of water quality (Nitrate & phosphate in particular) and adjacent coral reef and seagrass habitats, including baseline surveys at control and ADZs sites to determine baseline concentrations and scale of impacts. Decrease ADZ carrying	Independent specialist	Prior to any developme nt for at least a year (baseline). Then for the duration of the operationa l phase	▪ Monthly water sampling for baseline year and first three years thereafter. If no increase in stocking, sampling can be done quarterly at coastal sites overlying	Farm and ADZ

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/part y	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					capacity should the levels of dissolved organics exceed performance criteria.			sensitive habitats and at Control Sites. Quarterly and annual reporting	
					Optional mitigation measures: ▪ Shift several of the ADZs (SN1, SN2, M1, M4, PLD3, PLD4. ADZs M2, PLD1, PLD 2 and PLD5) further offshore prior to gathering site specific data for the hydrodynamic modelling exercise	SFA and stakeholders	Prior to ADCP deploy-ments	NA	NA
4.1.2.2	Water quality: Chemical pollution especially copper, veterinary therapeutics etc. in water	Mortality to corals and other lower life forms	Minimise concentrations to levels that are on par with background copper levels. Levels of	FAO Code of Conduct for Responsible Fisheries/ Specialist advice	Essential mitigation measures: ▪ Prior to developing any ADZ, conduct a hydrodynamic modelling exercise of copper and therapeutic	Independent specialist, independent ECO auditor	Prior to any developme nt	NA	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
	column and trace metals in sediments		therapeutics and disinfectants etc. below toxic levels for lower life forms. Trace metals in sediments below toxic levels		chemical dispersal for each ADZ using detailed current profiling data (and other relevant data i.e. bathymetry, wind, cage drag, Coriolis Force) collected over a period of at least a year. Model different intensities of ADZ development and predict chemical diffusion from each ADZ and ensure that chemical concentrations have dissipated to acceptable levels before coming into contact with sensitive habitats such as coral reefs and seagrass beds.				
					▪ Use only approved veterinary chemicals and antifoulants ▪ Where possible use environmentally friendly alternatives	Farm managers, independent ECO auditor	Duration of the operational phase	Detailed records must be taken every time chemicals are used.	Farm

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					▪ Use the lowest effective dose of therapeutics ▪ Do not clean cages on site/in the sea. Clean cages on land but ensure that any effluent resulting from this process reaching the sea contains acceptable levels of copper and antifoulants.			Quarterly reporting	

				US: EPA (2016) Total dissolved water column copper not to exceed 1.3 ppb / 1.3 µg.L^{-1} at sensitive habitats (see also Young 2003; Beilmyer et al. 2010). For veterinary products chronic toxicity thresholds must not be exceeded as per instructions and MSDS. For sediment trace metals within ADZs: BCLME (2006) Guidelines (mg/kg dry weight) Copper < 18.7; Lead < 30.2; Zinc < 124; Chromium <	▪ Monitoring	Independent specialist, independent ECO auditor	Prior to any developme nt for at least a year (baseline). Then for the duration of the operationa l phase	Monthly water sampling and yearly sediment sampling. Yearly reporting	Farm and ADZ

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
				52.3; Arsenic < 7.24; Mercury < 0.13; Cadmium < 0.68; Nickel < 15.9; Silver < 0.78; Tin as Tributylin-Sn < 0.0005.					
					Optional mitigation measures: ▪ Shift several of the ADZs (SN1, SN2, M1, M4, PLD3, PLD4. ADZs M2, PLD1, PLD 2 and PLD5) further offshore prior to gathering site specific data for each hydrodynamic modelling exercise (see Section 4.1.2.1)	Specialist appointed by SFA	Prior to the collection of ADCP data	NA	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
4.1.2.3	Disease and parasites	Transfer to wild stocks leading to increased mortality rates, reduced fecundity, delayed maturity and reduced productivity of wild stocks	Minimise disease and parasitic infections on wild stocks	Target = Zero infections and pathogens of farmed species. No increase in disease and pathogens above baseline levels in wild stocks should be acceptable.	Essential mitigation measures: ▪ Maintain strict bio-security measures within hatchery, holding tanks and sea cages ▪ Ensure all fry undergo a health examination before stocking in cages ▪ Regularly inspect stock for disease and parasites as part of a formalised stock health monitoring programme and take necessary actions to eliminate pathogens through the use of therapeutic chemicals or improved farm management. This will require focused research effort into the identification, pathology and treatment of diseases and parasites	Farm managers, SFA, independent veterinarians, independent ECO auditors, Specialists	Duration of operational phase	**Daily/weekly checks of cultured stock** (or at frequencies determined by a formal stock health monitoring programme). Reporting routinely at monthly intervals and within 24 hrs of outbreaks. Wild-stock health to monitored and reported on annually	Farm and ADZ

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					infecting farmed species, both in culture and in wild stocks. ▪ Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied. These records should be made publically available to facilitate rapid responses by other operators to future outbreaks. ▪ Locate cages stocked with different cohorts of the same species as far apart as possible, if possible stock different species in cages successively.				

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/part y	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					▪ Treat adjacent cages simultaneously even if infections have not yet been detected. ▪ Keep nets clean and allow sufficient fallowing time on sites to ensure low environmental levels of intermediate hosts and or pathogens				
4.1.2.4	Genetic integrity of wild stocks	Reduced genetic diversity and fitness in wild stocks	Avoid reductions in fitness of wild stocks due to genetic contamination	Genetic homogeneity of cultured and wild stocks	Essential mitigation measures: ▪ Maintain genetic compatibility between cultured and wild stocks by developing a genetic best-practice management guideline for finfish mariculture and ensure adequate	SFA	Duration of operational phase	At initiation when each species are first stocked and thereafter every five years. Reporting every five years	ADZ

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					genetic monitoring is undertaken routinely.				
				Target = zero escapees	▪ Minimise the number of escapes by maintaining cage integrity through regular maintenance inspections and replacement of compromised or old infrastructure. ▪ Cages should have jump nets installed ▪ Develop and implement stock recovery procedures should escapes happen. ▪ During fish transfers or harvest, operations must be conducted in appropriate weather conditions and under constant visual supervision. Equipment appropriate to the	Farm managers, independent ECO auditors	Duration of operational phase	Continuous monitoring and Monthly reporting. Escapes must be reported to the regulator within 24 hours	Farm

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					weather and cage design must be used. Where necessary or appropriate, additional netting must be used to prevent escapes during transfer. ▪ Record all escapees and cage failures				
					▪ Maintain robust and healthy populations of wild stocks.	SFA and Seychelles National Parks Authority	Duration of operational phase	Whenever routine stock assessments are done	ADZ/ Seychelles inner islands at large
					Optional mitigation measures: ▪ The use of anti-predator netting should be investigated.	Farmer mangers	Duration of operational phase	NA	Farm
					▪ Develop the technology to mass produce sterile fry for cage culture.	SFA	Duration of operational phase	NA	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
4.1.2.5	Interactions with Piscivores	Behaviour changes in piscivores	Reduce interactions with piscivores and human animal conflicts	Target = Zero mortality of piscivores	Essential mitigation measures: ▪ Develop a protocol to deal with problematic piscivores with experts and officials ▪ Maintain a record of all interactions with piscivores as per EMP ▪ During harvesting ensure that minimal blood enters the water	SFA, independent scientists, farm managers, independent ECO auditors	Duration of operational phase	Daily monitoring. Monthly reporting	Farm and ADZ
		Escape of cultured stocks	Minimise escapees	Target = Zero cage failures	▪ Remove any injured or dead fish from cages promptly ▪ Install and maintain suitable anti-predator nets	Farm managers, independent ECO auditors	Duration of operational phase	Daily monitoring. Monthly reporting	Farm
4.1.2.6	Entanglements in cage infrastructure	Mortality of turtles and sharks	Minimise risk of entanglements	Target = Zero entanglements	Essential mitigation measures:	Farm managers, independent ECO auditors, Seychelles	Duration of the operational phase	Daily monitoring.	Farm

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/part y	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
					▪ Ensure all mooring lines and nets are highly visible. Use thick visible lines. ▪ Keep all lines and nets as tight as possible and conduct regular inspections to ensure this ▪ Do not have any hanging lines or unnecessary lines from cages ▪ Maintain adequate separation between primary and secondary nets even during strong currents and rough seas ▪ Use square mesh and ensure that net mesh-size does not exceed 16 cm whilst stretched	National Parks Authority		Monthly reporting	

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/party	Time-frame	Monitoring and Reporting Frequency	Required for farm EMP or ADZ EMP
DECOMMISSIONING PHASE									
4.1.3.1	Pollution and entanglement hazard	Disturbance and mortality to benthic organisms, sharks and turtles	Remove risk	Removal of all infrastructure	Essential mitigation measures: ▪ Ensure that all infrastructure associated with the development of ADZs are removed from the sea and seafloor within 3 months of decommissioning a farm or ADZ ▪ Rehabilitate site in terms of the Seychelles Marine Aquaculture and Sea-Ranching Regulations 2014.	Farm managers, SFA, independent ECO auditors	Within 3 months of decommissioning	Reporting at the end of the project	Farm and ADZ

5.4. Pilot-cage site

The management of the pilot-cage site requires the same type of attention and monitoring as the aquaculture development zones. These are detailed in Table 43 below, along with specific objectives, performance criteria, responsibilities and time lines/frequencies of monitoring. Specific components including the management of the benthic environment, water quality, diseases and parasites, genetic integrity of cultured and wild stocks, piscivorous predators and entanglements for the pilot-cage development are described above in detail in Section 5.2.

It is important that annual monitoring of the adjacent coral reef is done due to its close proximity to the cages. Permanent transects of 20-m length should be surveyed annually using photo-quadrats at 1-m intervals. Coral Point Count with Excel extensions should then be used to analyse the data. Trends in percentage cover of coral cover and macro-algae as well as counts of urchins should be quantified. These data should then be analysed using a repeated measures ANOVA design.

Figure 26. An example of a survey design for monitoring coral reef habitat (or seagrass). Transects are indicated by red lines.

Table 43. Mitigation and monitoring measures for the proposed pilot-cage site

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
CONSTRUCTION / IMPLEMENTATION PHASE								
4.2.1.1	Benthic environment and adjacent coral reef	Disturbance and mortality	Minimise disturbance and impact at adjacent coral reef	NA	Essential mitigation measures: ▪ Nearby reef to the north-east must be a designated "no-go" area to construction vessels, workmen and mooring blocks/anchors.	Contractor, independent ECO auditor	Duration of construction activities	Continuous supervision. Weekly reporting
OPERATIONAL PHASE								

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
4.2.1.2	Benthic environment beneath cages	Smothering, disturbance and mortality	Minimise severity of impact	Maximum of 10% of feed quantity uneaten and settling below cages. Sediment type and colour, erosional and depositional areas, relative abundance of flora and fauna, presence of feed pellets and manmade debris (See Seychelles Aquaculture Standard: Finfish cage culture)	Essential mitigation measures: ▪ Sensible site selection. This has been achieved buy zoning the cages over previously disturbed unconsolidated habitat however the depth is shallow ▪ Rotate cages (fallowing) to allow for recovery of soft sediment benthos ▪ Use species and system-specific feed to maximise food conversion ratios and minimise waste ▪ No cleaning of fouling organisms from nets at sea ▪ Monitor feeding behaviour and	Farm manager, specialists, SFA, independent ECO auditor	Duration of operational activities	Daily monitoring of feeding behaviour, biannual visual surveys of benthos. Annual quantitative monitoring. Monthly, biannual and annual reporting

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					particulate deposition beneath cages and adapt feeding strategy to maximise feeding efficiency and minimise particulate matter fallout ▪ Undertake benthic monitoring, including baseline surveys to determine scale of impacts and decrease stocking densities should the impact exceed the accepted sacrificial footprint. Optional mitigation measures: ▪ Move pilot cages offshore and in deeper water			

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
4.2.1.2	Water quality: dissolved nutrients	Eutrophication of adjacent coral reef and seagrass beds leading to stress and mortality	Minimise nitrates and phosphates	European Union recommendations (Huntingdon 2006). Mean ambient water column nitrogen and phosphorus concentrations must not exceed 5% of background levels at coral reef and seagrass beds	Essential mitigation measures: ▪ Use species specific formulations designed to enhance nitrogen and phosphorus retention efficiency, and reduce metabolic waste output. ▪ Monitor feeding behaviour and adapt feeding strategy to ensure minimal wastage (excess) of feed ▪ Undertake monitoring of water quality and adjacent coral reef and seagrass habitats, including baseline surveys at control and cage sites to determine scale of impacts and decrease stocking density should the	Pilot-cage site manager, independent specialist, independent ECO auditor	Prior to any development measure baseline levels for at least a year (baseline). Then for the duration of the operational phase.	▪ Monthly water sampling and quarterly reporting ▪ Daily monitoring of feeding behaviour, monthly reporting

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					impact start effecting sensitive habitats.			

4.2.1.2	Water quality: Chemical pollution especially copper, veterinary therapeutics etc. in water column and trace metals in sediments	Toxicity from copper and veterinary therapeutics	Minimise concentrations to levels that are on par with background copper levels. Levels of therapeutics and disinfectant s etc. below toxic levels for lower life forms	US: EPA (2016) Total dissolved water column copper not to exceed 1.3 ppb / 1.3 µg.L^{-1} at sensitive habitats (see also Young 2003; Beilmyer et al. 2010). For veterinary products chronic toxicity thresholds must not be exceeded as per instructions and MSDS. For sediment trace metals below cages: BCLME (2006) Guidelines (mg/kg dry weight) Copper < 18.7; Lead < 30.2; Zinc < 124; Chromium < 52.3; Arsenic < 7.24; Mercury < 0.13; Cadmium < 0.68; Nickel < 15.9; Silver < 0.78; Tin as Tributylin-Sn < 0.0005.	Essential mitigation measures: ▪ Use only approved veterinary chemicals and antifoulants ▪ Where possible use environmentally friendly alternatives ▪ Use the lowest effective dose of therapeutics ▪ Do not clean cages on site/in the sea. Clean cages on land but ensure that any effluent resulting from this process reaching the sea contains acceptable levels of copper and antifoulants. ▪ Monitoring: Total dissolved water column copper over reefs and seagrass beds not to exceed 1.3 ppm / 1.3 µg	Farm manager, SFA, independent specialist, independent ECO auditor	Duration of the operational phase	Monthly monitoring and record keeping of dissolved copper and therapeutics etc. Annual sediment monitoring. Monthly reporting

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					L^{-1}. Sediment monitoring Optional mitigation measures: ▪ Shift pilot cages further offshore.			
4.2.1.2	Disease and parasites	Transfer of disease and parasites to wild stocks	Reduce the risk of disease and parasitic transmissions	Target = Zero infections and pathogens of farmed species. No increase in disease and pathogens above baseline levels in wild stocks should be acceptable.	Essential mitigation measures: ▪ Maintain strict bio-security measures within hatchery, holding tanks and sea cages ▪ Ensure all fry undergo a health examination before stocking in cages ▪ Regularly inspect stock for disease and parasites as part of a formalised stock health monitoring programme and take necessary actions to eliminate pathogens	Farm manager, veterinarian, independent ECO auditor, SFA	Duration of the operational phase	Daily/weekly checks of stock (or at frequencies determined by a formal stock health monitoring programme). Reporting routinely at monthly intervals and within a week of outbreaks.

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					through the use of therapeutic chemicals or improved management. This will require focused research effort into the identification, pathology and treatment of diseases and parasites infecting farmed species, both in culture and in wild stocks. ▪ Maintain comprehensive records of all pathogens and parasites detected as well as logs detailing the efficacy of treatments applied. These records should be made publically available to facilitate rapid responses by other operators to future outbreaks.			

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					▪ If possible stock different species in cages successively. ▪ Treat adjacent cages simultaneously even if infections have not yet been detected. ▪ Keep nets clean and allow sufficient fallowing time on site to ensure low environmental levels of intermediate hosts and or pathogens			
4.2.1.2	Genetic integrity of wild stocks	Heterogeneity between cultured and wild stocks and reduced fitness of wild stocks	Maintain genetic homogeneity between cultured and wild stocks. Minimise risk of genetic contamination to wild stocks Maintain		Essential mitigation measures: ▪ Maintain genetic compatibility between cultured and wild stocks by developing a genetic best-practice management guideline for finfish mariculture and ensure adequate	Farm manager, SFA, Seychelles Nature Conservation Authority, Independent ECO auditor, specialists	Duration of the operational phase	At the initiation of when each species are first stocked and thereafter every five years. Reporting every five years

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
			diverse and healthy populations of wild stocks		genetic monitoring is undertaken routinely. ▪ Minimise the number of escapes by maintaining cage integrity through regular maintenance inspections and replacement of compromised or old infrastructure. ▪ Cages should have jump nets installed ▪ Develop and implement stock recovery procedures should escapes happen. ▪ During fish transfers, operations must be conducted in appropriate weather conditions and under constant visual supervision. Equipment			

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					appropriate to the weather and cage design must be used. Where necessary or appropriate, additional netting must be used to prevent escapes during transfer. ▪ Maintain robust and healthy populations of wild stocks Optional mitigation measures: ▪ The use of anti-predator netting should be investigated ▪ Develop the technology to mass produce sterile fry for cage culture			
4.2.1.2	Interactions with piscivores	Behavioural changes in piscivores	Reduce interactions with piscivores and human animal	Target = Zero mortality of piscivores	Essential mitigation measures:	SFA, independent scientists, farm managers,	Duration of operational phase	Daily monitoring.

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
			conflicts		▪ Develop a protocol to deal with problematic piscivores with experts and officials (Independent scientists and SFA) ▪ Maintain a record of all interactions with piscivores as per EMP ▪ Remove any injured or dead fish from cages promptly ▪ Install and maintain suitable anti-predator nets	independent ECO auditors		Monthly reporting
4.2.1.2	Entanglements in cage infrastructure	Mortality of turtles and sharks	Minimise risk of entanglements	Target = Zero entanglements	Essential mitigation measures: ▪ Ensure all mooring lines and nets are highly visible. Use thick visible lines.	Farm managers, independent ECO auditors, Seychelles National Parks Authority	Duration of the operational phase	Daily monitoring. Monthly reporting

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					▪ Keep all lines and nets as tight as possible and conduct regular inspections to ensure this ▪ Do not have any hanging lines or unnecessary lines from cages ▪ Use square mesh and ensure that net mesh-size does not exceed 16 cm whilst stretched ▪ Report entanglements to authorities immediately. Attempt to remove animals as quickly and safely as possible. ▪ Rehabilitate any injured turtles and other endangered species			

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
DECOMMISSIONING PHASE								
4.2.1.3	Pollution and entanglement hazard	Disturbance and mortality to benthic organisms, sharks and turtles	Remove risk	Removal of all infrastructure	Essential mitigation measures: ▪ Ensure that all infrastructure associated with the development of ADZs are removed from the sea and seafloor within 3 months of decommissioning a farm or ADZ ▪ Rehabilitate site in terms of the Seychelles Marine Aquaculture and Sea-Ranching Regulations 2014.	Farm managers, SFA, independent ECO auditors	Within 3 months of decommissioning	Reporting at the end of the project

5.5. Brood-stock facility

Mitigation and monitoring components required for the water supply pipeline associated with the proposed land-based brood-stock facility are detailed in Table 44, along with specific objectives, performance criteria, responsibilities and time lines/frequencies of monitoring. During the construction phase of the pipeline, workmen need to be monitored and adjacent coral reef areas delineated “no-go” areas.

During the operational phase, the same must be done, and adjacent coral reef areas delineated no-go areas, which must not be anchored on for example. The structural integrity of the pipeline should be assessed annually (or as per engineers requirements) and after severe storm events. If components of the pipeline are damaged they should be immediately repaired and any free-moving broken infrastructure salvaged within a week to prevent physical damage to adjacent coral reef. During the decommissioning phase, all infrastructure must be removed and adjacent coral reefs designated “no-go” areas for workman and anchors/vessels.

Table 44. Mitigation and monitoring measures associated with the water supply pipeline for the proposed brood-stock facility

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
CONSTRUCTION / IMPLEMENTATION PHASE								
4.2.2	Benthic organisms including adjacent coral reef	Mortality and disturbance to benthic organisms	Limit disturbance of the benthic environment to within the pipeline footprint	NA	Essential mitigation measures: ▪ Sensitive coral reef habitat exists in close proximity (<50 m) to the north-west of the proposed pipeline. This area must be a designated "no-go" area during construction and maintenance phases.	Contractor. Independent ECO auditor	Duration of Construction Activities	Weekly
OPERATIONAL PHASE								
4.2.2	Benthic organisms including adjacent coral reef	Mortality and disturbance to benthic organisms	Limit disturbance of the benthic environment to within the pipeline footprint	NA	Essential mitigation measures: ▪ Sensitive coral reef habitat exists in close proximity (<50 m) to the north-west of the proposed pipeline. This area must be a designated "no-go" area during maintenance and inspection activities.	Contractor. Independent ECO auditor	Duration of Operational Activities	During maintenance
				No breakages	▪ Visually inspect pipeline to ensure its integrity	SFA and contractor	Duration of Operational Activities	Annually and after high seas. Annual

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
								reporting
DECOMMISSIONING PHASE								
4.2.2	Benthic organisms including adjacent coral reef	Disturbance and mortality	Limit disturbance and mortality of benthic environment and adjacent reef	NA	Essential mitigation measures: ▪ Remove all pipeline infrastructure ▪ Sensitive coral reef habitat exists in close proximity (<50 m) to the north-west of the proposed pipeline. This area must be a designated “no-go” area during the removal of all infrastructure	SFA, Contractor, Independent ECO auditor	Within 3 months of decommissioning brood-stock facility	After 3 months have expired from the date of decommission. Report 4 months after the date of decommission

5.6. Research and development facility

Mitigation and monitoring components required for the water supply pipeline associated with the proposed research and development facility are detailed in Table 45, along with specific objectives, performance criteria, responsibilities and time lines/frequencies of monitoring.

Importantly, the pipeline must be constructed further south to minimise damage to coral reef organisms. Management of the pipeline during the construction phase involves restricting construction workers and their machinery to within 1 m either side of the footprint of the planned pipeline to minimise trampling. Similarly, during the operational phase, when inspections on the pipeline are being conducted they must be done to limit tramping to a small area either side of the pipeline. Inspections of the pipelines integrity should be done annually (or as per engineering guidelines) and after heavy seas. If any breakages to the pipeline occur, material must be retrieved as soon as possible within a week from the affected area to limit structural damage to the adjacent reef. During the decommissioning phase, all infrastructure associated with the pipeline must be removed. This must be done from within the development footprint and adjacent areas must be designated “no-go” areas to workmen and machinery.

Table 45. Mitigation and monitoring measures associated with the water supply pipeline for the proposed research and development facility

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
CONSTRUCTION / IMPLEMENTATION PHASE								
4.2.3	Coral reef organisms	Mortality to coral reef organisms due to trampling	Minimise disturbance and mortality from trampling	No deviation outside of 1 m either side of the pipeline footprint by construction workers or machinery.	Essential mitigation measures: ▪ Limit trampling to within the development footprint. The development footprint should be set at 1 m either side of the location of the proposed pipeline so that a swath of approximately 2 m wide is affected. ▪ Construct the pipeline from within the development footprint and not from outside of the development footprint.	Contractor, Independent ECO auditor	Duration of construction phase	Continuous supervision/ monitoring monthly reporting
			Minimise pipeline footprint on reef	NA	Essential mitigation measures: ▪ The pipeline must be re-routed so that it overlies less coral reef, and in particular, does not traverse the reef edge and slope where fragile corals typically grow. The new proposed route for the pipeline is indicated in Figure 24 by the solid red	SFA, Engineer and contractor, independent ECO auditor	Design stage and construction phase	NA

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
					line and reduces the impact by ~85%.			
OPERATIONAL PHASE								
4.2.3	Coral reef organisms	Mortality to coral reef organisms as a result of trampling during routine pipeline inspections	Minimise disturbance and mortality from trampling	No deviation outside of 1 m either side of the pipeline footprint by inspectors	Essential mitigation measures: ▪ Limit trampling to within the development footprint. The development footprint should be set at 1 m either side of the location of the pipeline so that a swath of approximately 2 m wide is affected. ▪ Any maintenance to the pipeline must be undertaken from within the development footprint and not from outside of the development footprint.	SFA, engineer, contractor	Duration of the operational phase	Monitor annually and after significantly large seas. Yearly reporting

Section No	Aspect (of Activity Service or Product)	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person / party	Time-frame	Monitoring and Reporting Frequency
DECOMMISSIONING PHASE								
4.2.3	Coral reef organisms	Mortality to coral reef organisms as a result of trampling and physical damage	Minimise disturbance and mortality from trampling and ageing infrastructure	No deviation outside of 1 m either side of the pipeline footprint by inspectors. All infrastructure removed within one year of decommissioning	Essential mitigation measures: ▪ Remove all pipeline infrastructure within a year of it being decommissioned ▪ Work only within a 2-m swath to reduce damage to adjacent reef	SFA, engineer, contractor	Within one year of the R & D facility being decommissioned	At the end of the project

6. Conclusion

Several significantly negative impacts emanating from the proposed development have been highlighted. These are largely associated with the aquaculture development zones (ADZs) and include impacts associated with dissolved organic nutrients and toxic chemicals such as copper and veterinary therapeutics, transmission of diseases and parasites to wild stocks as well as genetic impacts on wild stocks.

Several mitigation measures are suggested in each case and are detailed in the environmental management plan. Of particular concern is the cumulative impact of dissolved nutrients and toxic chemicals that would emanate from proposed ADZs which cannot be assessed with confidence based on available data. It is advised that an **extensive far-field hydrodynamic modelling exercise is undertaken to determine the extent of such plumes before any ADZ development takes place.** Data for such an exercise should be collected for at least a year and from within each ADZ. The proposed development could be done in an ecologically sustainable manner. This would require careful consideration and effective implementation of all mitigation measures, a focus on compliance, and a phased development approach accompanied by an adaptive management strategy.

The impacts that have been determined were re-assessed using the standard methodology employed by all specialist studies which form part of the Seychelles MMP ESIA study. By using a consistent methodology, impacts that have been determined have been summarised in Appendix 3: Impacts rated for inclusion in ESIA Report according to consistent methodologyThese impacts have been used to inform the compilation of the ESIA Report.

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8. Appendices

8.1. Appendix 1: Impact rating methodology

The significance of all potential impacts that would result from the proposed project is determined in order to assist decision-makers. The significance rating of impacts is considered by decision-makers, as shown below.

- **INSIGNIFICANT**: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity.
- **VERY LOW**: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity.
- **LOW**: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity.
- **MEDIUM**: the potential impact **should** influence the decision regarding the proposed activity.
- **HIGH**: the potential impact **will** affect a decision regarding the proposed activity.
- **VERY HIGH**: The proposed activity should only be approved under special circumstances.

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact[1] was thus rated according to the methodology set out below:

Step 1 – Determine the **consequence** rating for the impact by determining the score for each of the three criteria (A-C) listed below and then **adding** them. The rationale for assigning a specific rating, and comments on the degree to which the impact may cause irreplaceable loss of resources and be irreversible, must be included in the narrative accompanying the impact rating:

Rating	Definition of Rating	Score
A. ***Extent*** *– the area over which the impact will be experienced*		
Local	Confined to project or study area or part thereof (e.g. limits of the concession area)	1
Regional	The region (e.g. the whole of Seychelles Bank)	2
(Inter) national	Significantly beyond the Seychelles Bank and adjacent sea areas	3
B. ***Intensity*** *– the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources*		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. ***Duration*** *– the time frame for which the impact will be experienced and its reversibility*		
Short-term	Up to 2 years	1
Medium-term	2 to 15 years	2

[1] This does not apply to minor impacts which can be logically grouped into a single assessment.

Long-term	More than 15 years (state whether impact is irreversible)	3

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score **(A+B+C)**	3 – 4	5	6	7	8 – 9
Consequence Rating	Very low	Low	Medium	High	Very high

Example 1:

Extent	***Intensity***	***Duration***	***Consequence***
Regional **2**	Medium **2**	Long-term **3**	**High** **7**

Step 2 – Assess the **probability** of the impact occurring according to the following definitions:

Probability*– the likelihood of the impact occurring*	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Example 2:

Extent	***Intensity***	***Duration***	***Consequence***	***Probability***
Regional **2**	Medium **2**	Long-term **3**	**High** **7**	Probable

Step 3 – Determine the overall **significance** of the impact as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Example 3:

Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***
Regional **2**	Medium **2**	Long-term **3**	**High** **7**	Probable	**HIGH**

Step 4 – Note the **status** of the impact (i.e. will the effect of the impact be negative or positive?)

Example 4:

Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*
Regional **2**	Medium **2**	Long-term **3**	**High 7**	Probable	**HIGH**	**– ve**

Step 5 – State the level of **confidence** in the assessment of the impact (high, medium or low).

Depending on the data available, a higher level of confidence may be attached to the assessment of some impacts than others. For example, if the assessment is based on extrapolated data, this may reduce the confidence level to low, noting that further groundtruthing is required to improve this.

Example 5:

Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Regional **2**	Medium **2**	Long-term **3**	**High 7**	Probable	**HIGH**	**– ve**	High

Step 6 – Identify and describe practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact. Mitigation and optimisation measures must be described as either:

- **Essential**: must be implemented and are non negotiable; and
- **Optional**: must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Essential mitigation and optimisation measures must be inserted into the completed impact assessment table. The impact should be re-assessed with mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures.

Example 6: A completed impact assessment table

	Extent	*Intensity*	*Duration*	*Consequence*	*Probability*	*Significance*	*Status*	*Confidence*
Without mitigation	Regional **2**	Medium **2**	Long-term **3**	**High 7**	Probable	**HIGH**	**– ve**	High
Essential mitigation measures: • xxxxx • xxxxx								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Improbable	**VERY LOW**	**– ve**	High

Step 7 – Prepare a summary table of all impact significance ratings as follows:

Impact	***Consequence***	***Probability***	**Significance**	***Status***	***Confidence***
Impact 1: XXXX	Medium	Improbable	**LOW**	–ve	High
With Mitigation	Low	Improbable	**VERY LOW**		High
Impact 2: XXXX	Very Low	Definite	**VERY LOW**	–ve	Medium
With Mitigation:	*Not applicable*				

Indicate whether the proposed development alternatives are environmentally suitable or unsuitable in terms of the respective impacts assessed by the relevant specialist and the environmentally preferred alternative.

8.2. Appendix 2: Impact rating methodology for ESIA

Note: This impact assessment methodology has been used during this specialist study. Impacts have been determined using this methodology, which is consistent with all other studies as part of the ESIA. These impacts which have been summarised under section 8.3 Appendix 3, will be included in the ESIA Report.

The significance of the identified impacts have been determined using the approach outlined below (terminology from the Department of Environmental Affairs and Tourism Guideline document on EIA Regulations, April 1998). This approach incorporates two aspects for assessing the potential significance of impacts, namely occurrence and severity, which are further sub-divided as follows:

Occurrence		**Severity**	
Probability of occurrence	Duration of occurrence	Scale / extent of impact	Magnitude (severity) of impact

To assess each of these factors for each impact, the following four ranking scales are used:

Probability	**Duration**
5 - Definite/don't know	5 - Permanent
4 - Highly probable	4 - Long-term
3 - Medium probability	3 - Medium-term (8-15 years)
2 - Low probability	2 - Short-term (0-7 years) (impact ceases after the operational life of the activity)
1 - Improbable	1 – Immediate
0 - None	
Scale	**Magnitude**
5 - International	10 - Very high/don't know
4 - National	8 - High
3 - Regional	6 - Moderate
2 - Local	4 - Low
1 - Site only	2 - Minor
0 - None	

Once these factors are ranked for each impact, the significance of the two aspects, occurrence and severity, is assessed using the following formula:

SP (significance points) = (magnitude + duration + scale) x probability

The maximum value is 100 significance points (SP). The impact significance will then be rated as follows:

SP >75	Indicates **high** environmental significance	An impact which could influence the decision about whether or not to proceed with the project regardless of any possible mitigation.
SP 30 – 75	Indicates **moderate** environmental significance	An impact or benefit which is sufficiently important to require management and which could have an influence on the decision unless it is mitigated.
SP <30	Indicates **low** environmental significance	Impacts with little real effect and which should not have an influence on or require modification of the project design.
+	Positive impact	An impact that constitutes an improvement over pre-project conditions

For the methodology outlined above, the following definitions were used:

- **Magnitude** is a measure of the degree of change in a measurement or analysis (e.g., the area of pasture, or the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none/negligible, low, moderate or high. The categorization of the impact magnitude may be based on a set of criteria (e.g. health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely-recognised standards are to be used as a measure of the level of impact.
- **Scale/Geographic extent** refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international.
- **Duration** refers to the length of time over which an environmental impact may occur: i.e. immediate/transient, short-term (0 to 7 years), medium term (8 to 15 years), long-term (greater than 15 years with impact ceasing after closure of the project), or permanent.
- **Probability of occurrence** is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40% to 60% chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).

8.3. Appendix 3: Impacts rated for inclusion in ESIA Report according to consistent methodology

The below impacts have been determined by using the impact assessment methodology described in section 8.2 Appendix 2 and which is consistent with the methodology used by other specialist studies used to inform the compilation of the ESIA Report.

Table 46: Impact assessment summary for impacts expected during construction phase

POTENTIAL ENVIRONMENTAL IMPACT: CONSTRUCTION PHASE	ENVIRONMENTAL SIGNIFICANCE											
	Before mitigation						After mitigation					
	M	D	S	P	SP	Rating	M	D	S	P	SP	Rating
Importation of genetically distinct fingerlings - Disease Impact	10	2	4	5	80	High	10	2	4	4	64	Moderate
Importation of genetically distinct fingerlings -Genetic Impact	8	5	4	5	85	High	8	5	4	4	68	Moderate
Importation broodstock fish that are not sourced from the Seychelles Inner Islands - Disease impact	8	4	4	4	64	Moderate	6	4	4	3	42	Moderate
Importation broodstock fish that are not sourced from the Seychelles Inner Islands -genetic impact	6	5	3	4	56	Moderate	6	5	3	2	28	Low
Cage installation - ADZs	2	2	1	5	25	Low	2	2	1	5	25	Low
Pilot-project cage construction	2	1	1	5	20	Low	2	1	1	5	20	Low
Brood-stock facility water intake pipeline construction	2	1	1	3	12	Low	2	1	1	1	4	Low
R & D facility water intake pipeline construction	6	4	1	5	55	Moderate	4	4	1	2	18	Low

Table 47: Impact assessment summary for impacts expected during operational phase

POTENTIAL ENVIRONMENTAL IMPACT: OPERATIONAL PHASE	ENVIRONMENTAL SIGNIFICANCE											
	Before mitigation						After mitigation					
	M	D	S	P	SP	Rating	M	D	S	P	SP	Rating
Genetic Contamination	8	5	3	4	64	Moderate	6	5	3	2	28	Low
Disease and parasite transmission to wild fish stocks	8	4	3	5	75	Moderate	8	4	2	3	42	Moderate
Degraded water quality as a result of organic wastes	8	4	2	4	56	Moderate	4	4	2	2	20	Low
Particulate organic build-up beneath cages	6	4	1	5	55	Moderate	4	4	1	4	36	Moderate

Chemical pollution arising from finfish cages	8	4	2	4	56	**Moderate**	4	4	2	2	20	**Low**
Entanglement of cetaceans	2	4	1	2	14	**Low**	2	4	1	1	7	**Low**
Entanglement of turtles and sharks	2	4	1	2	14	**Low**	2	4	1	1	7	**Low**
Interactions with piscivorous marine animals	2	4	1	5	35	**Moderate**	2	4	1	2	14	**Low**
Impacts on fishing, yachting and recreational vessels	2	1	1	4	16	**Low**	2	1	1	2	8	**Low**
Interactions with piscivores-pilot cages	4	4	1	2	18	**Low**	4	4	1	1	9	**Low**
Entanglement of turtles and sharks - pilot cages	2	4	1	1	7	**Low**	2	4	1	1	7	**Low**
R & D facility water intake pipeline maintenance	2	2	1	5	25	**Low**	2	2	1	5	25	**Low**

Table 48: Impact assessment summary for impacts expected during decommissioning phase

POTENTIAL ENVIRONMENTAL IMPACT:DECOMMISSION PHASE	ENVIRONMENTAL SIGNIFICANCE											
	Before mitigation						After mitigation					
	M	D	S	P	SP	Rating	M	D	S	P	SP	Rating
Farm operations cease	6	3	2	4	44	**Moderate**	2	2	1	1	5	**Low**
General decommissioning - ADZ cages	6	4	1	5	55	**Moderate**	6	2	1	1	9	**Low**
General decommissioning - pilot-project cages	6	4	1	5	55	**Moderate**	6	2	1	1	9	**Low**
Brood stock pipeline	4	4	1	5	45	**Moderate**	4	1	1	1	6	**Low**
R & D facility water intake pipeline	6	4	2	4	48	**Moderate**	2	1	1	1	4	**Low**