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SEYCHELLES FISHING AUTHORITY

Technical Aquaculture Inputs for the Proposed Implementation of the Seychelles Mariculture Masterplan (MMP)

Submitted to:
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DRAFT FOR COMMENT

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REPORT

Golder Associates

Executive Summary

The Seychelles Mariculture Master Plan (MMP), which was initiated in 2011 aims to develop a marine aquaculture industry in the Seychelles. This report will form a part of the larger Environmental and Social Impact Assessment document and evaluates the suitability of the Seychelles for aquaculture, including the selection of sites, species and technologies, the determination of aquaculture site carrying capacities, expected impacts and mitigation measures.

The environmental evidence indicates that the Seychelles provides a suitable location for cage aquaculture due to the constant tropical environmental conditions, shallow water (20-50m depth) with generally soft/sandy sediments, low average wind and swell regimes, and no cyclones. There was a paucity of environment data for the 12 proposed Aquaculture Development Zones (ADZs). However, the surveys undertaken revealed that they share similar attributes characteristic of the open water Mahé Plateau, namely, 20-60m depth, current speeds of 2-10m/s, sandy/silty sediments and a well-mixed water column with homogenous temperature and salinity.

The ADZ areas off Beau Vallon beach which were previously sand mined, are regarded as preferred sites due to their disturbed nature. No ecological issues mitigating against ADZ establishment were identified, however, in view of the limited site specific data, it is recommended that site survey and monitoring is initiated six months before cage installation to verify that there are no sensitive benthic habitats or other issues which may result in negative ecological impacts. The Seychelles Fishing Authority (SFA) has indicated that ADZ sites may be adjusted by up to one nautical mile to accommodate any site specific ecological issues that may arise.

A precautionary approach has been adopted by the Seychelles authorities, with respect to the production carrying capacity of the ADZ sites. As the sites are in open water with consistent monsoon currents and water column mixing, organic waste from fish faeces and waste food will be efficiently dispersed. This is confirmed by the MOM model for determining the productive carrying capacity of a site. While the MOM predicted a productive carrying capacity of 4000t/ha, a precautionary level of 1000t/ha has been adopted until site specific performance and monitoring data is available. The MOM model indicates that sedimentation of organic particulate waste is expected to be negligible and that the limiting factor for production will be the **level of dissolved oxygen in the fish cages**.

The species that have been selected to launch the aquaculture sector are naturally distributed in the Seychelles waters, have established markets and are cultured commercially in aquaculture. The technologies and carrying capacities calculated for the MMP ensure that any adverse environmental impacts and diseases are minimised by adopting a precautionary approach. Standards for responsible aquaculture and fish-health further ensure that the industry will be operated according to international best practises to ensure sustainability.

The predicted impacts that were evaluated include:

- genetic contamination of wild stock;
- disease and parasite transmission to wild fish stocks;
- organic waste pollution,
- chemical pollution;
- entanglement of cetaceans;
- interactions with piscivorous[1] marine animals; and,

[1] a carnivorous animal which eats primarily fish.

- impacts on fishing, yachting and other recreational vessel activity.

Due to the comprehensive Seychelles Mariculture Masterplan process, these impacts were anticipated and planned for with appropriate mitigation and management strategies, including the identification of sustainable ADZ sites, the setting of aquaculture production carrying capacities, Aquaculture Standards and Regulations, and institutional and Government capacity to support sector development. Only two impacts, imported fish genetic contamination of wild stock and disease and parasite transmission to wild stock, were rated as 'high' impact without mitigation. All other issues were ranked as 'moderate' and 'low' impact without and with mitigation (Table 1).

Table 1: Summary Table of assessed potential impacts and mitigation measures for the development of finfish cage culture on the Seychelles ADZs

Potential Impact	**Essential/Recommended Mitigation**	**Significance**	
(applicable to ADZ)		***Without Mitigation***	***With mitigation***
Genetic contamination of wild stocks	■ Adequate steps must be taken to prevent the escape of production organisms, especially from the hatchery environment where individual organisms may be very small. ■ Escape barriers may include netting, grids, sand and other filters, predator ponds, chemical treatment areas, soak away systems, etc.Barriers should be adequate to prevent escape during flooding, overflows and during other unforeseen circumstances. ■ It should be noted that during Operation this impact was rated as 'Moderate' before mitigation and 'Low' thereafter, as the main risk is brining in new genetic material into the country.	**High**	**Moderate**
Disease and parasite transmission to wild fish stocks	■ Staff trained in fish health management and disease recognition. ■ Implement a Fish Health Management Programme. ■ Apply aquaculture best management practices. ■ Maintain strict bio-security measures within hatchery, holding tanks and sea cages. ■ Ensure all fry undergo a health examination prior to stocking in sea cages. ■ Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme. ■ Take necessary action to eliminate pathogens through the use of therapeutic chemicals or improved farm management. ■ Research into the identification, pathology and treatment of diseases and parasites infecting farmed species. ■ Treat adjacent cages simultaneously even if infections have not yet been detected in these cages. ■ It should be noted that during Operation this impact was rated as 'Moderate' before and after mitigation due to the magnitude of the impact.	**High**	**Moderate**

Potential Impact (applicable to ADZ)	Essential/Recommended Mitigation	Significance	
		Without Mitigation	*With mitigation*
Organic Pollution from fish faecal and feed waste	■ Bio filtration of shore based hatchery effluent. ■ Set production carrying capacity limits for cage sites. ■ Cage location in areas with current **>2m/s.** ■ Ongoing MOM modelling and feedback into management measures.	**Low**	**Low**
Chemical Pollution arising from fish cages	■ Utilise professional fish health services and/or veterinary expertise to diagnose disease prior to initiating any disease treatment. ■ No veterinary therapeutic-products and medicinal premixes for inclusion in fish feeds may be applied to fish unless they are approved for use by the Regulator. ■ Follow manufacturer's/veterinarian's instructions regarding dosage, frequency and duration. ■ Keep a current copy of the veterinarian's written recommendation. ■ Use environmentally-friendly detergents. ■ Ensure all chemicals and drugs are secured to prevent unauthorised useDispose of unutilised therapeutic agents and medicines according to conventional hazardous waste disposal practices.	**Moderate**	**Low**
Cetacean entanglement in cage infrastructure	■ Do not locate ADZs in important cetacean habitats and migration routes. ■ Ensure all mooring lines and nets are highly visual. ■ Keep all lines and nets tight through regular inspections and maintenance. ■ Ensure that mesh size on primary and secondary nets does not exceed 16 cm stretched mesh.	**Low**	**Low**

Potential Impact (applicable to ADZ)	Essential/Recommended Mitigation	Significance	
		Without Mitigation	*With mitigation*
Interactions with marine piscivorous animals	■ Install and maintain suitable predator nets (sufficient strength, visibility and mesh size, above and below water line). ■ Install visual deterrents (e.g. tori line type deterrents for birds). ■ Store feed so piscivores cannot access it, and implement efficient feeding strategy. ■ Remove any injured or dead fish from cages promptly. ■ During harvesting of stock, ensure that minimal blood or offal enters the water. ■ Implement mitigation measures as for entanglement impacts. ■ Develop a protocol for dealing with problem piscivores in conjunction with experts and officials (SFA).	**Low**	**Low**
Impacts on fishing, yachting and other recreational vessel activity	■ Install navigational markers and lights as required by the Seychelles Maritime Safety Association. ■ Include position of ADZs on navigational charts. ■ Ongoing consultation with user groups to keep them informed of the ADZ developments.	**Low**	**Low**

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Cover Photo: http://mauritiusaquaculture.blogspot.co.za/

LIST OF ACRONYMS

ADCP	Acoustic Doppler current profiler
ADZ	Aquaculture Development Zone
BOD	Biological Oxygen Demarnd
BQAF	Broodstock Quarantine and Acclimation Facility
CC	Carrying Capacity
cm	Centimetres (unit of measure)
COD	Chemical Oxygen Demarnd
EAP	Environmental Assessment Practitioners
EMP	Environmental Management Plan
ESIA	Environmental and Social Impact Assessment
FADs	Fish Aggregating Devices
FAO	Food and Agriculture Organization of the United Nations
GPS	Global Positioning System
HAB	Harmful Algal Blooms
HAT	Highest Astronomical tide
HDPE	High Density Poly-Ethylene
Hs	Significant wave height
km	Kilometres (unit of measure)
km^2	Square Kilometres (unit of area)
LAT	Lowest astronomical tide
m	Meters (unit of measure)
MHWN	Mean high water neap
MHWS	Mean high water spring
MHWS	Mean high water
MLWN	Mean Low water neap
MLWN	Mean Low water
MLWS	Mean Low water Spring
MMP	Mariculture Master Plan
MOM	Modelling-Ongrowing fish farm -Monitiring
MPA	Marine Protected Areas
NH_3	Ammonia
POC	Particulate organic carbon
PON	Particulate organic nitrogen
PSU	Practical Salinity Unit
R&D	Research and Development
ROV	Remote Operated vehicle
SFA	Seychelles Fishing Authority
UNISEY	University of Seychelles

1.0 INTRODUCTION

The Seychelles Mariculture Master Plan (MMP), which was initiated in 2011 aims to develop marine aquaculture in Seychelles. As a core component of the Blue Economy Strategy, the development of an aquaculture sector has been prioritised by the Seychelles government.

Golder Associates Africa (Pty) Ltd have been appointed by the Seychelles Fishing Authority (SFA) as independent environmental assessment practitioners (EAPs) for the purpose of conducting an Environmental and Social Impact Assessment (ESIA) for the proposed implementation of the Seychelles Mariculture Master Plan (MMP).

This report will form a component of the larger ESIA document and details the approach taken to determine the suitability of the Seychelles for aquaculture, the selection of sites, species and technologies as well as the carrying capacities and biosecurity of developing such a sector.

2.0 SUITABILITY OF THE AREA FOR AQUACULTURE

2.1 Environmental Conditions

The Seychelles MMP proposes the development of cage aquaculture off the populated 'Inner Islands', namely; - Mahé, Praslin, La Dique, Silhouette and North Island. The Inner Islands are situated on the granitic Mahé Plateau, which forms the northern crescent of the Mascarene ridge. The area is characterized by a remarkably constant tropical environmental conditions, shallow water (20-50m depth) with generally soft/sandy sediments, low average wind and swell regimes, and no cyclones. This makes the area particularly attractive for cage aquaculture.

2.1.1 Temperature

The ambient water temperature regime is the key environmental factor determining the suitability of a site for aquaculture. This is because fish are poikilotherms ('cold-blooded') with the ambient environmental temperature determining their metabolic rate and hence growth rate. It is for this reason that the bulk of the world's aquaculture production occurs in tropical areas where the year round consistently high temperatures promote provide for efficient aquaculture production.

The narrow all year round range of the Seychelles average water temperature regime (25-30°C) is particularly well suited to the culture of tropical species such as the grouper, as the maximum growth rate occurs within this range (Table 2). Available temperature data indicate that the water column over the Mahé plateau is well mixed with no thermocline (Table 2). This is good for cage aquaculture as a vertical temperature differential can affect fish behaviour, health and growth performance.

Table 2: Minimum, maximum and mean temperature at 5 and 15 m around Mahé and Praslin/La Digue (Source: SFA Oceanographic database from World Ocean Database (NOAA/USAODC); SFA, 2016)

Location	Min (°C)	Max (°C)	Mean (°C)
Mahé (5m)	24.73	30.52	27.65
Mahé (15m)	23.55	30.17	27.51
Praslin/La Digue (5m)	25.26	30.25	27.82
Praslin/La Digue (15m)	24.94	30.42	27.77

The consistent water temperature regime of the Seychelles provides a potential comparative production advantage over aquaculture producers in higher latitudes (e.g. Mauritius, South Africa) where lower winter temperatures are experienced with a concomitant reduction in fish growth performance.

Although long-term temperature data sets are lacking for the 12 proposed aquaculture development zones, the shallow water across the Mahé plateau is well mixed by the prevailing winds and currents and has a consistent temperature profile. It is thus a reasonable assumption that the available temperature data is indicative of the temperature regime at the 12 proposed sites.

2.1.2 Water depth, Bathymetry and Sediments

The water depth of the 12 proposed sites (20-66m, Table 11) is considered to be in the ideal range for cage aquaculture as the water column depth under cages (5-41m) provides for i) effective flushing of the relatively mobile surface waters through the cages and ii) dispersal of organic particulate wastes with minimal sedimentation under the cages. See Golder Report 1543656-308203-7 and 1543656-308204-8 “The Seychelles Islands Physical Oceanography and Aquaculture Development Zones Modelling” for further details on these findings.

The flat to gently sloping bathymetry of the selected sites, with no high profile reef or coral structure, is highly suitable for cage aquaculture because:

- The even bottom topography provides for a consistent current regime;
- Even current and wave forces on the cages and moorings; and
- Efficient installation and maintenance of cage moorings.

The sediment composition of the proposed sites is generally sandy, ranging from ‘fine sand and silt’ to ‘fine gravel/ coarse sand and coral’. The gradation is probably indicative of the current regime with the coarser sediments being a reflection of higher current speeds which scour and lift fine particulates into the water column. This is consistent with the location of the 12 sites which are subject to consistent wind driven current regimes. The sediment characteristics are suitable for the installation of aquaculture cage moorings and indicate likely current driven dispersal of organic wastes.

The macrobenthos of the proposed sites is of relatively low diversity and is characteristic of relatively sterile, sandy substrates according to SFA (2016) (Table 10). At some sites, no macrobenthic organisms were recorded (Praslin PLD1, PLD3; Mahé M4, Silhouette, SN1). This, seen together with the current data and MOM organic effluent dispersal (Section 2.1.10 and Section 5.0 below), indicates that there likely to be little biotic interaction between the caged fish biomass and the benthic fauna.

The benthic sediments at the proposed zone off Beau Vallon (M5) are considered highly impacted/disturbeddue to the sand mining on the site that was undertaken to provide fill for land reclamation (SFA, 2016, Figure 1). Therefore, cage aquaculture in this zone can be undertaken with a high level of confidence in respect of its potential impact on pristine benthic habitats.

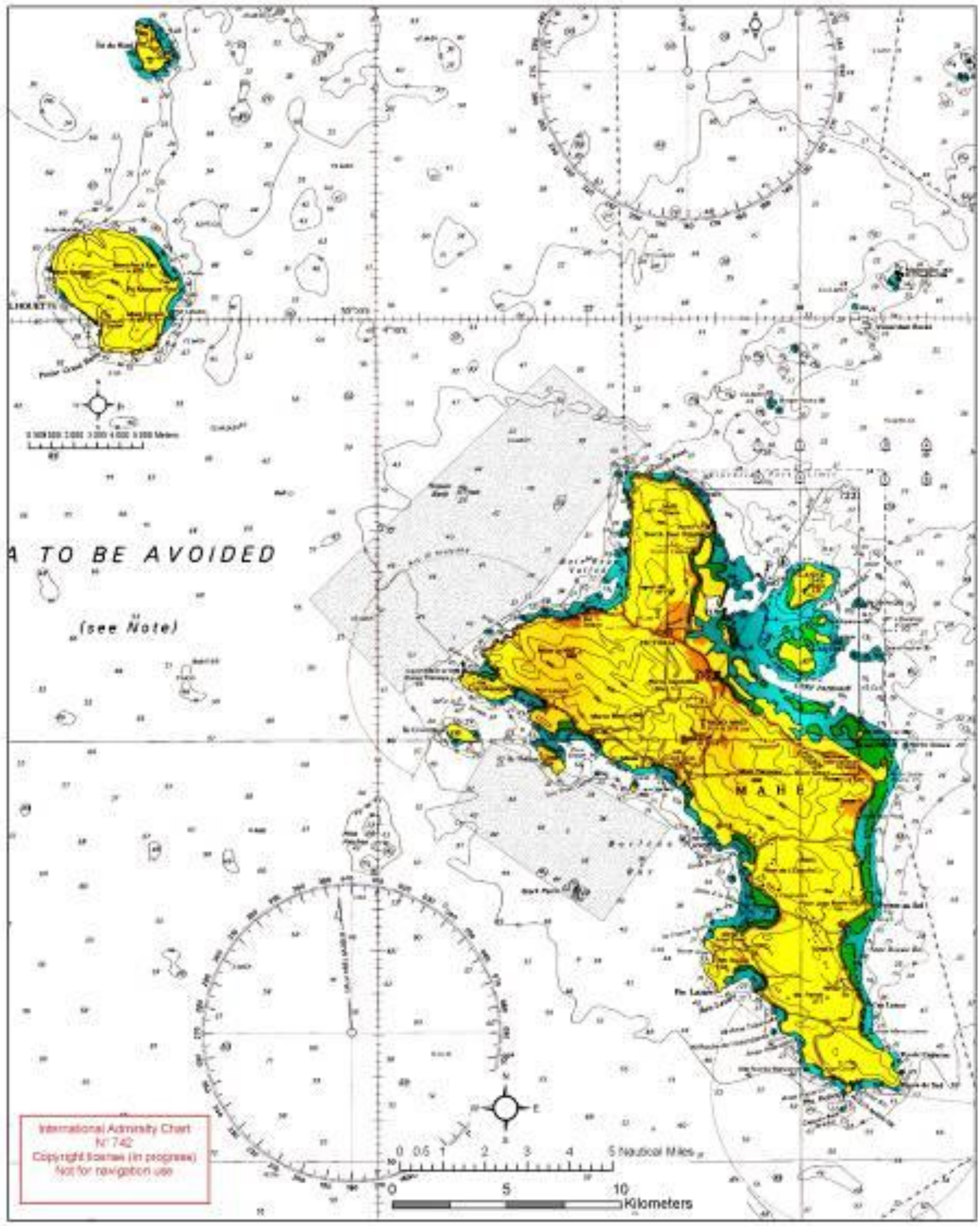

Figure 1: Sand burrow areas around Mahé (Source: iXSurvey 2010)

2.1.3 Salinity

The available salinity data indicates that the salinity of the proposed aquaculture zones is relatively consistent and well mixed throughout the water column (SFA, 2016). The NOAA World Ocean Database indicates a mean surface salinity of 35.13 PSU with a standard deviation of 0.7079 for the Seychelles. Site specific measurements have recorded lower values, for example, 32.72PSU at Beau Vallon and 32.7 to 34 PSU at Isle Therese (SFA, 2016).

The inshore waters of Mahé are however subject to periods of much lower salinities due to rainfall runoff, and this one of the reasons that the ADZs were chosen (SFA, 2016). Due the prevailing current regime, the salinity of the proposed ADZ sites in likely to be homogenous and suitable for cage aquaculture.

2.1.4 Primary Productivity

The tropical waters of the Seychelles are oligotrophic (nutrient poor) with low and variable algal productivity. Primary productivity varies with the Monsoon season, with the SE monsoon period being relatively more productive than the NW monsoon period (Cuching 1973 cited in UNEP Seas and Reports and Studies No.13, cited in SFA 2016). These conditions are favourable for aquaculture.

Nonetheless, harmful algal blooms (HABs) have been recorded on three occasions in Seychelles. SFA (2016) reports that significant phytoplankton bloom was recorded in August 2003 resulting in extensive macro-benthos and fish mortalities (Bijoux *et al*. 2003). Another harmful algal bloom (HAB) comprising the dinoflagellate *Cochlodinium polykrikoides* was recorded in October 2015 resulting in significant shallow reef fish mortalities. A further, smaller bloom (unknown species) occurred in December 2015 (SFA, 2015). In the absence of a monitoring programme, the incidence of these previous events at the proposed ADZ sites is unknown, and the risks associated with harmful algal blooms are yet to be fully established (ASCLME 2012).

However due to the exposed, open water situation of the proposed ADZs with the associated Mahé Plateau current regimes, their susceptibility to red tide will be lower than the more sheltered and nutrient rich inshore waters. The possibility of harmful algal blooms is thus regarded as a **low risk** to cage aquaculture development in the 12 ADZs.

2.1.5 Pollution and Terrestrial Nutrients

SFA (2016) reviewed information on marine pollution and nutrients and stated that ‘the coastal waters of Seychelles are generally low in nutrients with the exception of areas which receive significant inflow from rivers and food processing factories.’

His main findings relevant to aquaculture site selection were that:

- High nutrient inputs in populated and industrial areas such as Port Victoria have led to eutrophication and formation of algal blooms in certain periods of the year when hydrodynamic and climatic conditions are favourable;
- Pollution from pesticides and fertilizers is minimal as agricultural activities in Seychelles are primarily small-scale;
- Concentrations of heavy metals are low, with the exception of chromium, copper, lead and zinc in Port Victoria (Radegonde 2008 in ASCLME 2012); and
- There is little information on the incidence of coliform bacteria (*E.coli*) or hydrocarbons as the Seychelles does not yet have a regular ocean water quality monitoring programme.

Despite the lack of information on nutrients and pollution, the risk to aquaculture the ADZ sites can be considered minimal due to their distance from terrestrial sources of pollution and the open water nature of the sites which are exposed to the Mahé Plateau current regime.

2.1.6 Wind

The Inner Island ADZ sites are characterized by generally low to moderate winds, with occasional and very short windows of high wind speeds (Table 3). The wind regime is determined by the alternating South-east (April-October) and North-west (November- March) monsoon seasons. The mean wind speed during the SE and NW monsoons are 7.3 and 3.2 knots, respectively. The NW Monsoon wind blow predominantly from the NW and are light and very variable (Figure 2), whereas the SE 'trade wind' Monsoon, blow almost consistently, with little variation, from the SE. The wind speed is consistent and only increases to gale force for short periods normally <1.5 hour. (SFA, 2016, from Seychelles Meteorological Services data).

The wind regime is thus highly suitable for cage culture operations as access by work boats and personnel to service the sites is possible on most days. Furthermore, the consistent wind direction and velocity determines the current regime which will continually flush the cages thereby maintaining good water quality and effectively dispersing organic waste from fish feed and faeces.

Table 3: Average monthly wind speed (kts) at Seychelles International Airport (2000 to 2007) (Source: Seychelles Meteorological Services)

Month	Mean	SD	Min	Max
Jan	3.2	1.7	0.0	10.0
Feb	3.7	1.7	0.0	11.1
Mar	2.9	1.6	0.0	9.7
Apr	2.8	1.7	0.0	12.5
May	5.1	2.4	0.6	15.2
Jun	7.5	2.3	0.0	14.5
July	8.2	2.7	0.0	19.5
Aug	9.2	2.6	1.1	22.6
Sep	8.4	2.2	1.3	15.8
Oct	5.6	2.4	0.1	11.7
Nov	3.5	1.7	0.0	8.8
Dec	3.0	1.6	0.0	8.8

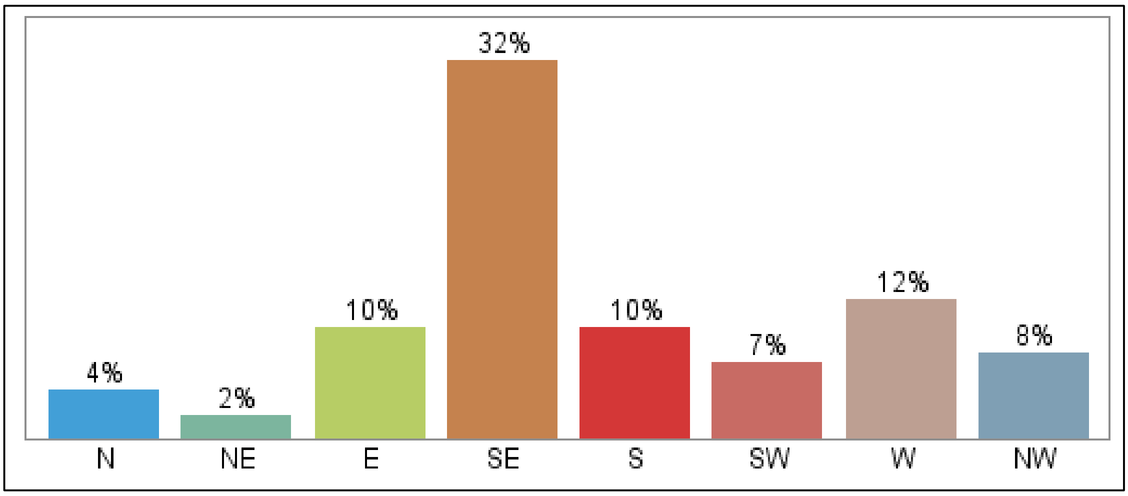

Figure 2: The fraction of time with the wind blowing from the various directions over the entire year. Values do not sum to 100% because the wind direction is undefined when the wind speed is zero. (From SFA, 2016; Source: https://weatherspark.com/averages/29137/)

2.1.7 Cyclones

The Seychelles is not affected by the Indian Ocean equatorial cyclone paths which affect other inhabited South West Indian Ocean Islands such as Reunion, Madagascar, Comoros, Mauritius and Rodrigues. This reduces the risks of cage aquaculture and provides a comparative advantage over cage aquaculture developments in the countries mentioned.

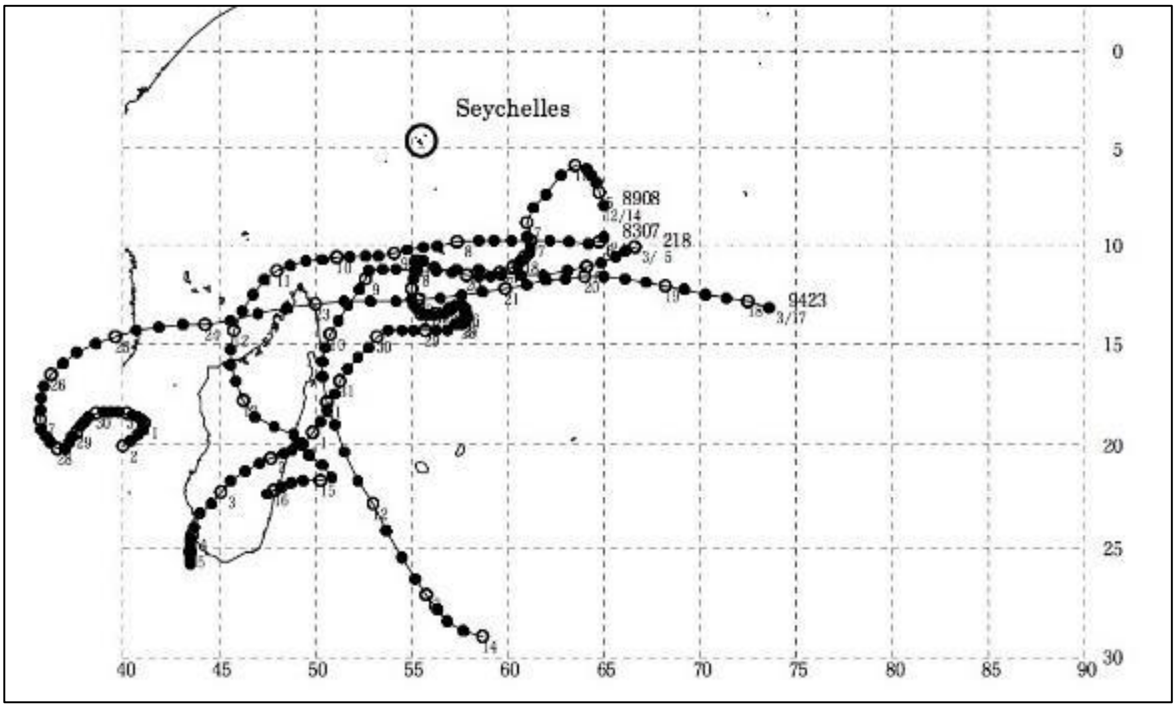

Figure 3: Cyclone routes 1945 – 2003 (JICA 2006, data source: Seychelles Meteorological Services)

2.1.8 Waves

The shallow Seychelles Mahé Plateau shields the Inner Islands from the brunt of long period (high energy) oceanic swells. The Inner Islands and ADZ sites are thus subject to relatively small SE swells and wind waves of short period (low energy) (Figure 4 and Figure 5). During the NW monsoon offshore waves generally approach from a N-NE direction with a significant wave height (H_s) of 1.2 m, and only 9.5% of the waves greater than 2m high. During the SE Monsoon, waves are predominantly from a S-SE direction and the significant wave height is higher (average H_s = 2.16 m with peaks up to 2.4 m) (SFA, 2016). A maximum wave height of 4-5m is experienced during the SE monsoons for short periods (ca. 0.5% of the period 2001-2004; Table 4).

The relatively benign wave regime is thus highly favourable for cage aquaculture in the proposed ADZ sites on the Mahé Plateau. The number of sea days lost due to high wave heights will be low, and the moorings of cages subject to relatively low forces reducing the risk of failure.

Figure 4: Significant wave height at Lat -4°: Lon 55° (SFA, 2016; Data source: Seychelles Meteorological Authority)

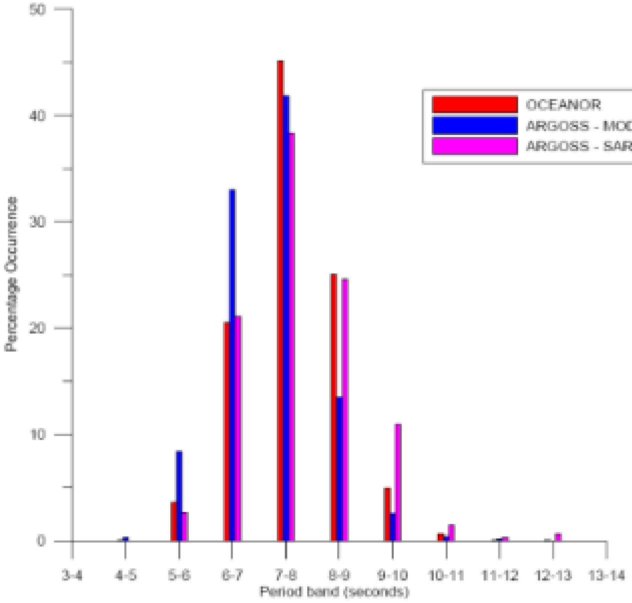

Figure 5: Satellite deduced offshore wave periods (SFA, 2016; Source: Vasco Consulting)

Table 4: Frequency of wave height and direction (Mar 2001 to Feb 2004) (SFA 2016; Source of data: JICA 2006)

WAVE DIRECTION	U.K.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	TOTAL
WAVE HEIGHT (M)																		
CALM	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0
0.00 - 0.50	0 .0	676 2.6	450 1.7	48 .2	45 .2	65 .2	330 1.3	1090 4.1	638 2.4	68 .3	9 .0	0 .0	0 .0	0 .0	0 .0	0 .0	22 .1	3441 13.1
0.50 - 1.00	0 .0	1004 3.8	728 2.8	40 .2	85 .3	16 .1	1088 4.1	2080 7.9	699 2.7	354 1.3	35 .1	0 .0	0 .0	27 .1	107 .4	91 .3	92 .3	6446 24.5
1.00 - 1.50	0 .0	774 2.9	254 1.0	14 .1	0 .0	1 .0	635 2.4	1771 6.7	719 2.7	320 1.2	25 .1	0 .0	17 .1	0 .0	75 .3	52 .2	85 .3	4742 18.0
1.50 - 2.00	0 .0	127 .5	3 .0	0 .0	0 .0	0 .0	799 3.0	2000 7.6	584 2.2	282 1.1	2 .0	0 .0	0 .0	17 .1	6 .0	42 .2	43 .2	3905 14.8
2.00 - 2.50	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	669 2.5	1583 6.0	661 2.5	237 .9	15 .1	0 .0	0 .0	5 .0	0 .0	3 .0	27 .1	3200 12.2
2.50 - 3.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	328 1.2	1363 5.2	647 2.5	213 .8	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	2551 9.7
3.00 - 3.50	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	90 .3	822 3.1	321 1.2	127 .5	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	1360 5.2
3.50 - 4.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	5 .0	253 1.0	183 .7	91 .3	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	532 2.0
4.00 - 5.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	27 .1	48 .2	45 .2	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	120 .5
5.00 - 6.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0
6.00 - 7.00	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0
7.00 -	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0	0 .0
TOTAL	0 .0	2581 9.8	1435 5.5	102 .4	130 .5	82 .3	3944 15.0	10989 41.8	4500 17.1	1737 6.6	86 .3	0 .0	17 .1	49 .2	188 .7	188 .7	269 1.0	26297 100.0

2.1.9 Tidal flux

The tidal range off Mahé is relatively small with mean high water spring of 1.63 above chart datum (Table 5). Nonetheless, the tides may have a marked influence on current velocity (Vasco Consulting, 2008). The low tidal range is conducive for cage aquaculture as the tension in the cage mooring lines will be relatively constant and not subject to strong tidal current flows.

Table 5: Seychelles mean tide levels (1993-2010) at Point La Rue, charted against a fixed Admiral Chart Datum (SFA, 2016; Data source: Seychelles Meteorological Authority)

Tide	Height (m) above chart Datum
Highest Astronomical tide (HAT)	2.10
Mean high water spring (MHWS)	1.63
Mean high water (MHW)	1.45
Mean high water neap (MHWN)	1.27
Mean Level	1.10
Mean Low water neap (MLWN)	0.81
Mean Low water (MLW)	0.63
Mean Low water Spring (MLWS)	0.45
Lowest astronomical tide (LAT)	0.20

2.1.10 Currents

The oceanic current regime influencing the Mahé Plateau is well understood, however site specific data for the proposed ADZ sites is very sparse (SFA, 2016).

The Seychelles current regime is determined by the alternating Indian Ocean monsoon regimes (Figure 6). During the NE monsoon, the flow patterns are determined the Indian Ocean Gyre the eastward flowing Equatorial Counter Current, with its two westward flowing counter currents. During the SE monsoon, the Equatorial Counter Current and North Equatorial Current disappear and major currents that drive the circulation within Seychelles region are the South Equatorial Current and the Somali Current (ASCLME 2012).

Current data for the proposed ADZ sites (with the exception of Beau Vallon) is only available from vessel drift survey measurements conducted during the site assessments (Table 6). Detailed current information on the Beau Vallon site is available as a result of an acoustic Doppler current profiler (ADCP) current monitoring done for the sand mining on the two sand burrows off the NW and the SW coast of Mahé (Vasco Consulting, 2008).

The data sources reviewed by SFA (2016) indicate that during SE monsoon current speeds ranged from 0.05 to 0.11m/sec and during the NW monsoon from 0.5 to 0.36m/sec. These ranges are within recommended international benchmarks for cage aquaculture (Cardia and Lovatelli, 2015) which provide for effective cage flushing to ensure good water quality and dispersal of organic wastes.

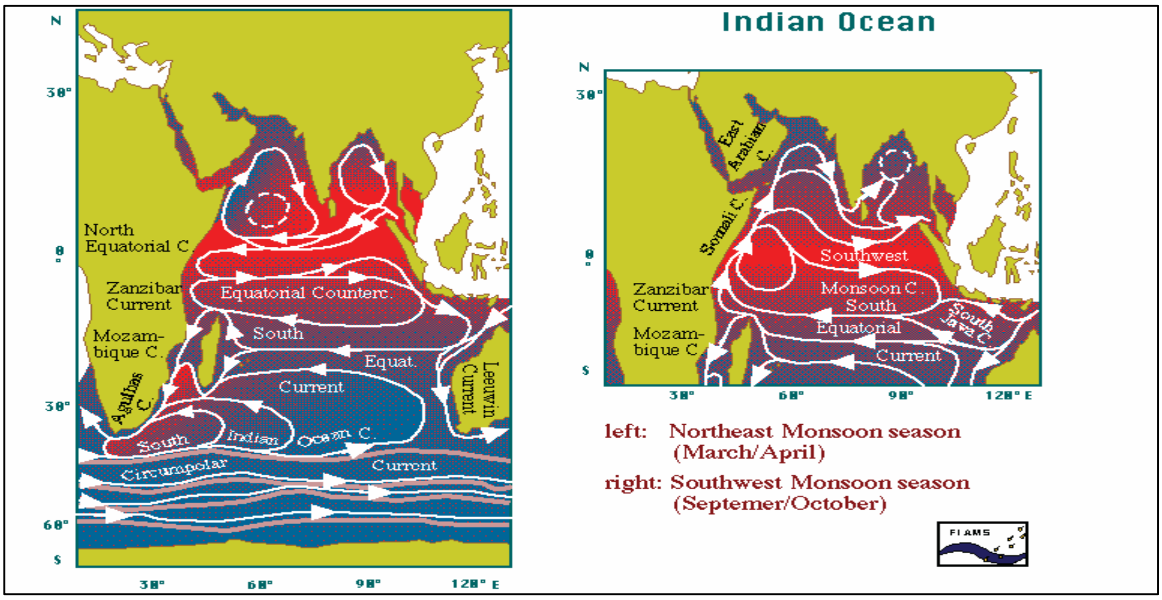

Figure 6: Indian Ocean major currents and monsoon seasonal reversal

Table 6: Vessel drift speed used as a proxy for current speed

Transect	Date	Wind	Sea condition	Time start	Time end	Seconds	Waypt start	Waypt end	Distance (m)	Drift m/sec	Depth m	Current speed m/s
1	27-Jan-09	Light air	Rippled	9.1	9.25	900	10	11			43-46	
2	27-Jan-09	Light air	Rippled	9.53	10.12	3540	12	13			42-43	
3	27-Jan-09	Light breeze	Wavelets	11.25	11.4	900	14	15	1050	1.17	42-48	
4	27-Jan-09	Light air	Rippled	13.2	13.25	300	16	17	500	1.67	38-44	
5	28-Jan-09	Calm	Glassy	17.15	17.22	420	20	21				
6	28-Jan-09	Calm	Glassy	8.3	8.35	300	22	23			45-50	
7	28-Jan-09	Calm	Glassy	9.04	9.18	840	24	25	205	0.24	39-43	0.24
8	28-Jan-09	Calm	Glassy	10.38	10.5	720	26	27	520	0.72	35-37	0.72
9	28-Jan-09	Calm	Glassy	11.56	12.11	3300	28	29	426	0.13	35-37	0.13
10	28-Jan-09	Calm	Glassy	13.2	13.32	720	30	31	245	0.34		0.34
11	28-Jan-09	Light air	Rippled	15.08	15.24	960	32	33	660	0.69	41-43	
12	29-Jan-09	Light air	Rippled	10.3	10.37	420	36	37	224	0.53	43-46	
13	29-Jan-09	Calm	Glassy	11.3	11.37	420	38	39	124	0.30	45-50	0.30
14	29-Jan-09	Calm	Glassy	12.05	12.18	780	40	41	180	0.23	46-47.5	0.23
15	29-Jan-09	Light air	Rippled	13.38	13.47	540	42	43	266	0.49	46-49	
16	30-Jan-09	Calm	Glassy	7.5	8	3000	50	52	45	0.02	34-35	0.02
17	30-Jan-09	Calm	Glassy	8.53	9	2820	53	54	245	0.09	36-40	0.09
18	30-Jan-09	Calm	Glassy	9.35	9.5	900	55	56	243	0.27	43-46	0.27
19	30-Jan-09	Calm	Glassy	10.37	10.5	780	57	58	345	0.44	36-37	0.44
20	30-Jan-09	Calm	Glassy	11.5	12.04	3240	59	60	184	0.06	44-46	0.06
21	30-Jan-09	Light air	Rippled	12.35	12.46	660	61	62	319	0.48	44-47	
22	30-Jan-09	Light breeze	Wavelets	13.4	13.55	900	63	64	484	0.54	36-38	
											Mean	**0.26**
											SD	**0.20**

2.1.11 Overall Environmental Suitability for Cage Aquaculture

Cage aquaculture is a well-established in many countries with benchmarks for classifying site characteristics (Table 7). Due to the location of the Seychelles ADZ sites, with their moderate wind and swell regimes, the most applicable category for Seychelles is the FAO “Off the coast category”. Based on wind speeds during the NW Monsoon the sea state would be classified as 2-3 (smooth-slight) and as 4-5 (moderate to rough) during the SE Monsoon period. In respect of aquaculture operation feasibility, this is a favourable classification as the cages are accessible on at least once daily basis, with ‘landing’ (workers on cages) usually possible.

Table 7: FAO site classification guide (Cardia and Lovatelli, 2015)

Feature	Coastal	Off the coast	Offshore
Location/hydrography	<500m from coast >10m depth at SLT Within sight of land Usually sheltered	0.5-3km from coast 10-50m depth at SLT. Often within sight of land. Somewhat sheltered	>2km from the coast Generally within continental shelf area, possibly open ocean >50m depth
Environment	Hs usually <1m Short wind fetch Localised coastal currents, Possibly strong tidal streams	Hs <3-4m Localised coastal currents, some tidal stream.	Hs 5m or more. Variable wind periods. Possible less localized current effect.
Access	100% accessible. Landing possible at all times	>90% accessible on at least once daily basis. Landing usually possible.	Usually >80% accessible, landing may be possible, every 3-10 days
Operation	Regular, manual involvement, feeding, monitoring	Some automated operations (e.g. feeding, monitoring).	Remote operations, automated feeding, distance monitoring system function

SFA (2016) notes that some of the proposed ADZ sites are semi sheltered from the SE Monsoon. These include the area on the NW coast off Beau Vallon, the SW coast (Bay Boileau), areas to the north of Silhouette and North Island, the area seaward of Baie Chevalier on Praslin, the area north of Curieuse Island and the area immediately north of the Les Soeurs Islands. All other areas are considered to be 'exposed' sites.

The environmental variable relevant to cage aquaculture in the Seychelles ADZs were summarised by SFA (2016), with comments on their suitability (Table 8). These average and maximum oceanographic conditions and the FAO site classification guide indicate that fish cage culture is highly feasible around the inner islands of the Seychelles.

Table 8: Summary of oceanographic conditions and their comparative suitability for cage culture (SFA 2016, based on the classification Cardia and Lovatelli, 2015)

Environmental variable	Unit	Typical zone value	Comment /Reference
Significant wave height	m	1.1 to 2.4 depending on season with mean H_s = 1.6	Small in comparison to othercage sites (Cardia and Lovatelli, 2015)
Max wave height	m	5m, but % frequency occurrence of 0.5% over 35 months	Small in comparison to other cage sites with waves of 6 to 8 m (Cardia and Lovatelli, 2015)
Current speed	cm/sec	Min=2, Max=35, Mean=18	Ideal (Price and Beck- Simpert, 2014)
Wind speed	m/sec	SE Monsoon = 7.3 NW Monsoon = 3.2	Wind is consistent and only increases to gale force for short periods normally <1.5 hour (Source: Seychelles Meteorological Services). Max wind speeds and wave heights result in moderate to rough seas. Wind speeds, Hs and wave period are all within very acceptable limits (Cardia and Lovatelli 2015, Benetti *et al*. 2010)

Environmental variable	Unit	Typical zone value	Comment /Reference
Depth	m	25 to 57	Ideal, >15 m free depth below bottom of cage (Beveridge, 2004, Cardia and Lovatelli, 2015, Price & Morris 2013)
Substrate		Sand and rubble (fine to course & shell grit)	Optimal for waste assimilation and cage moorings (Cardia and Lovatelli, 2015, Price & Morris, 2013)
Water temperature	^{o}C at 5m	Min=24.8, Max=30.5 Mean=27.7	Typical value for tropical waters
Dissolved oxygen	mg/L at 5m	Max=5.1, Min=4.5, Mean=4.8	Typical value for tropical waters (e.g. Glude, 1982)

2.1.12 Conclusions on Environmental Suitability of the ADZ for the Mariculture Master Plan

In conclusion, the present evaluation of the environmental sustainability of the Seychelles Mariculture Master Plan indicates that:

- Sufficient environmental information is available to assess the sustainability and operational viability of cage aquaculture at the 12 proposed ADZs;
- Similar environmental conditions prevail at the 12 sites due to their position on Mahé plateau, with its relatively homogenous oceanography, depth profile, sediment characteristics and well mixed water.
- The ADZ sites are highly suitable for cage aquaculture of tropical species due to:
  - The relatively low average swell and wind regime, allowing for daily operational access and the effective mooring of cages in open water.
  - The shallow Mahé Plateau (20-60m depth) which is ideal for mooring cages.
  - The well mixed water and consistent SE and NW monsoon current regimes which will effectively disperse organic nutrients from the sites. This is confirmed by the MOM Model of cage culture carrying capacity (Section 5.0 below).
  - The absence of cyclones in the Seychelles.
  - The narrow range of water temperature which coincides with the optimal growth temperatures for tropical species.
  - The low exposure to pollution and freshwater run off from land.
- The limited site surveys undertaken for the 12 ADZs revealed no ecological reasons not to proceed with the Mariculture Master Plan. However, **site specific survey and monitoring should begin before cages are positioned on site to verify that the site has a baseline with which to assess and model potential impacts.**

2.2 Site Selection / ADZs

2.2.1 Lack of ADZ Site Specific Environmental Data

The ADZ Site Selection report (SFA, 2016) acknowledges that site-specific environmental data for the 12 proposed ADZs are limited and that no long term baseline monitoring has been undertaken. This reduces the confidence in the Environmental and Social Impact Assessment of the sustainability of aquaculture at the ADZ sites. ADZ site surveys were undertaken by the Seychelles Fishing Authority using the research vessel

Amitie which comprised of ROV video transects, sediment grab sampling and current measurement. The survey process and data are documented in SFA (2016) and summarised in the following sections (Section 2.2.2). A strategy is thus required for how to address this shortcoming without slowing down the Mariculture Master Plan implementation time schedule.

The ADZ site selection report (SFA, 2016) and the above evaluation of the environmental suitability of the ADZs for cage aquaculture indicate that it is reasonable to assume that the 12 proposed ADZs share similar environmental characteristics due to theirlocation from shore and the fairly homogenous oceanography, depth and sediments of the Mahé plateau. This, seen together with the generally favourable conditions for cage aquaculture indicate no known ecological or technical reasons why aquaculture development should not proceed at any of the ADZs within the carrying capacity of the environment (social issues such as conflict of use are dealt with in report number 1543656-301742-1, Social Impact Assessment).

The requirement to improve the robustness of site specific ADZ environmental baseline data can be addressed in parallel with the MMP implementation process. Once an investor/developer is assigned a right to an ADZ area, the Seychelles Fishing Authority, in consultation with the investor/ developer, can use the Seychelles Aquaculture Standard for '*Responsible Finfish Cage Culture*' to **prescribe baseline and operational monitoring protocols for the proposed site**. Site survey and monitoring is proposed to begin at least six months before cage installation to check that there are no site specific ecological issues that will affect the sustainability of cage aquaculture at the site. Provision is made in the Mariculture Master Plan to adjust the site boundaries by up to one nautical mile should an ecological issue (such as a coral outcrop) require an adjustment to the cage farm positioning.

2.2.2 Marine ADZ sites

The appropriate site selection and positioning of cages is critical to minimise potential environmental impacts and to optimize fish health and performance. With the exception of the site selection, operators have little control over the oceanographic processes and environmental drivers (disused above).

The development of a new sector within Seychelles must also be harmonized with tourism and fisheries, which are currently the two primary pillars of the country's economy (SSDS 2012-2020). Therefore, identifying ADZs that are socially acceptable, commercially and ecologically viable as well as sustainable, is complex. In addition to the oceanographic processes and environmental drivers (discussed above), good information on societal perceptions, marine spatial planning data as well as detailed information of contiguous multi-sectoral planning information and activities needs to be considered (Benetti *et al*. 2010).

The Seychelles Aquaculture Standard for '*Responsible Finfish Cage Culture*' states that site selection must amongst others take the following into consideration:

i) In order to prevent cumulative environmental impacts, farms that produce more than 500 tonnes of fish per annum must be separated by at least 500m. The distance between smaller farms will be determined by the Regulator on a case specific basis;

ii) A "Farm Site Plan" that maps the location of the cages, mooring and feeding systems must be prepared and submitted as part of the license application procedure. Cages and anchors must be mapped using Global Positioning System (GPS) or latitude/longitude coordinates in decimal degrees. The Farm Site Plan must be maintained, updated and available for inspection by the Regulator during compliance inspections;

iii) Sites should have good water exchange and a depth of at least 2 times the depth of cages. The ideal depth for cage farming is between 25 and 50m with a current velocity of between 20 and 40cm /second, but not exceeding 1m / second; and

iv) Sites should have a sandy or sandy/muddy substrate.

It is well documented that the environmental impacts potentially associated with aquaculture in the open ocean are considerably lower than in inshore coastal areas because the water is deeper and currents are stronger (Benetti *et al*. 2010, Price and Morris 2013). For this reason and the fact that stakeholder engagement (conducted in 2009) raised concerns about the potential inshore environmental impacts and user conflicts of inshore aquaculture, a suggested 2km exclusion zone was accepted by the MMP team as a valuable contribution towards establishing the sector on the back of the precautionary principle.

As the process of selecting sites is an iterative one, the starting point was to map out potential development zones for aquaculture at a desktop level. This mapping considered Seychelles Navigational Chart for orientation purposes and to avoid hazards and shipping lanes. The mapping further considered the 2km exclusion zone around the coast of inhabited islands, a 1km exclusion zone around MPAs, mitigating visual conflict (such as hotels and resorts), avoiding conflict with the recreational diving sector and artisanal fisheries, avoiding restricted areas such as fibre optic cable corridors, selection of areas with a suitable sand dominated seabed, avoiding coral reefs and seagrass meadows and other sensitive areas, choosing areas with a suitable depth and bathymetry, and seeking partial protection from the SE Monsoon winds.

The criteria listed in Table 9 were used to broadly delineate the ADZs.

Table 9: Primary selection criteria for fish cage culture ADZs

Item	Parameter	Criterion	Reason	Reference or source
1	Bathymetry	Flat or low profile areas	■ Currents not deflected or slowed down. ■ Preferred for cage moorings.	■ Navigational Chart. ■ Cruise 1 data.
2	Depth	Range = 25 – 65m (Isobaths shown on GIS maps)	■ Min. free water depth below cages > 10m ■ Impact on sediment is reduced with depth. ■ Avoids possible harmful feedback from wasted material accumulated on the seabed.	■ Perez *et al*., 2003. ■ Cardia & Lovatelli, 2015.
3	Distance from shore	> 2km from inhabited islands, where appropriate.	■ Open Ocean cage culture minimizes impacts. ■ Mitigates visual impact.	■ Proposed by Dept. of Environment and Tourism Bd. (2009).
4	Location	Reduced visibility from tourism infrastructure, if possible	■ Mitigate visual impact.	■ Proposed by Dept. of Environment and Tourism Bd. (2009).
5	Suitable seabed type	Sand, rubble dominated areas. Sandy areas with patches of macro-algae	■ High assimilation capacity.	■ Price & Morris, 2013.
6	Unsuitable seabed type	All areas dominated by coral reefs and extensive seagrass meadows were excluded	■ Ecologically sensitive area.	■ Price & Morris, 2013.
8	Shipping lanes	All shipping lanes excluded (shown on GIS maps)	■ Marine safety.	■ Seychelles Maritime Safety Administration.
9	Sport and recreation	All sport diving spots excluded (shown on GIS maps)	■ Mitigate conflict.	■ GPS locations obtained from private operators.
10	Fishing grounds	All artisanal fishing areas excluded (shown on GIS maps)	■ Mitigate conflict.	■ Christophe, 2006.
11	Restricted areas	Marine protected areas (MPAs) and restricted zones excluded Fibre optic cable area excluded (shown on GIS maps).	■ High conservation value. ■ Security / Safety	■ Seychelles National Parks Authority. ■ Seychelles Maritime Safety Administration.

The following notes on the selection criteria were applicable:

- The 2km distance from shore criterion was applied only where the shore (in direct line of sight) was inhabited;
- Locations not in the direct line of sight of tourism infrastructure were few and far between and this was the reason why the sector suggested a 2km buffer zone;
- All coral reef areas were excluded but isolated corals were not;
- Shipping lanes included the southern and northern approaches to Mahé and the southern approach to Praslin; and
- Restricted areas included the 1000m buffer zones around Marine Protected Areas (MPAs) as well as the “Dredging Prohibited” zone around the fibre optic cable that lands on Beau Vallon beach, Mahé. It was excluded for cage culture because of the possible damage that cage moorings could cause.

Four ‘aquaculture zone selection’ cruises were then undertaken by the SFA “R/V *Amitie*”. The first cruise (Cruise 1) was of an exploratory nature to gain an understanding of the bathymetry of the seabed in those areas identified during the mapping exercise. Furthermore, the cruise aimed to identify the largest soft bottom seabed areas in which more specific areas for cage aquaculture could be isolated.

Cruise 1 (01/2009) was accomplished by sailing a zigzag track, 2km from the shore, in areas roughly between the 20m and 50m isobaths and noting the bathymetry and bottom type (hard or soft) on the echo sounder (Furuno FCV 1200L, MU-101C – 28-200Hz) of the *R/V Amiti.*

The second cruise (Cruise 2 = 02/2009) had a narrower focus and was geared towards identifying more specific areas within the broader, low profile, soft bottom areas as identified during the first cruise (Cruise 1). During this cruise a SeaViewer camera was used to collect video footage to assess the nature of the seabed. To validate this sediment samples were taken using an Ekman Grab. The sediment collected was used to broadly classify the ‘sediment categories” (i.e. grain size), and macrobenthic organisms.

Cruises 3 (09/2013) and 4 (10/2013) made use of a Remote Operated Vehicle (ROV) to validate seabed conditions in terms of sand, coral, seaweed and rubble. During Cruise 4, several conductivity, temperature and depth (CTD) profiles were recorded using a YSI Sonde.

From this process 16 ADZs were initially selected. Of the original 16 aquaculture development zones (Figure 7) 25% were ultimately rejected, mainly because of the presence of coral. The remaining 12 zones were sand dominated and were not affected by the exclusionary criteria detailed above and are shown below in Figure 7 and detailed in Table 10.

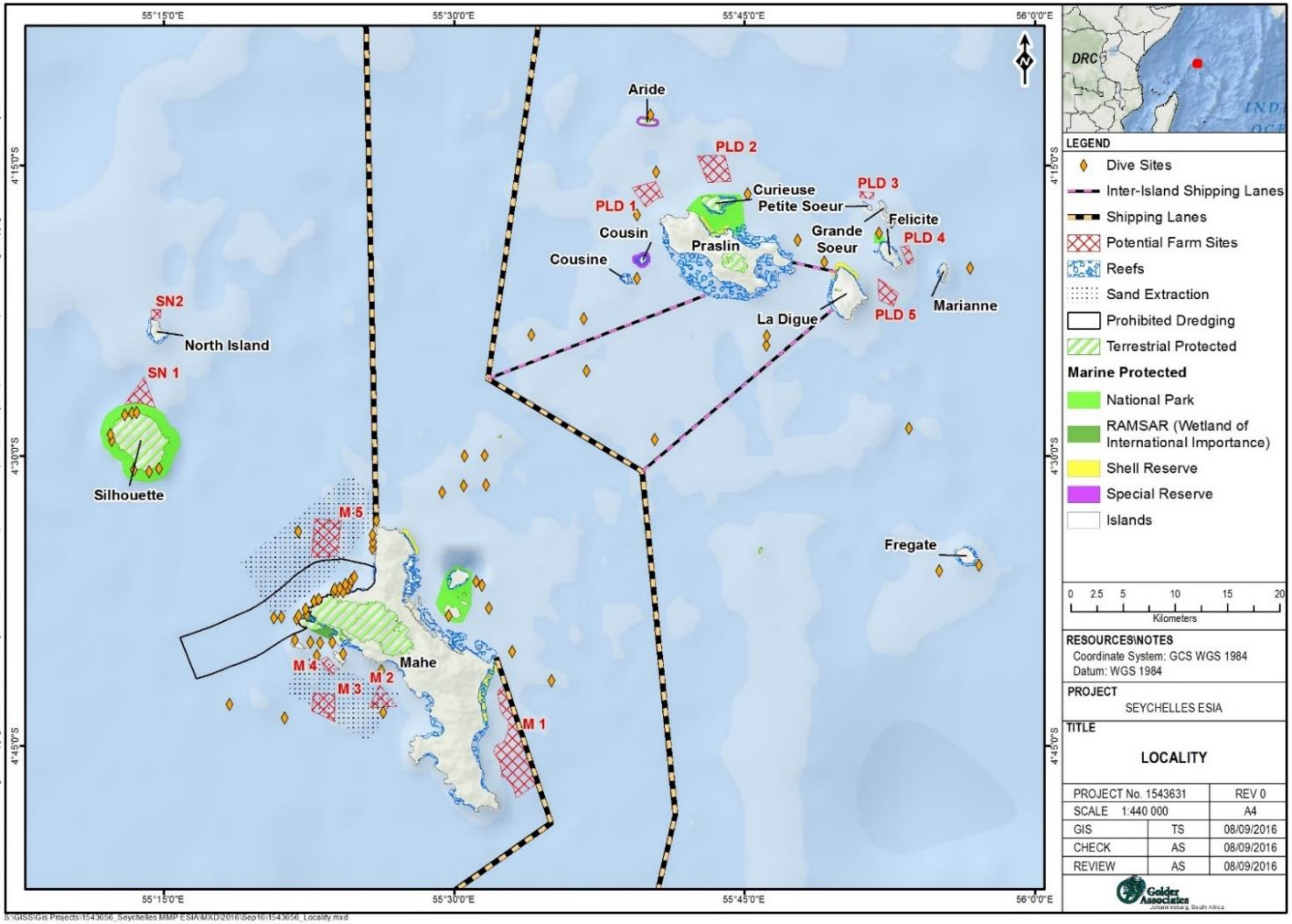

Figure 7: Locality of proposed ADZs

Table 10: Summary features of final 12 ADZs

ID No.	ADZ	ADZ Name	Max Depth (m)	Area (ha)	Ave Temp (ºC)	Ave Salinity (psu)	Seabed Echo	Seabed (ROV survey)	Seabed (grab samples)	>2km offshore	Depth (m)	Benthos	Sheltered from SE Monsoon
1	PLD1	Baie Chevalier	40.1	390.42	27.96	33	Soft	Sand	Medium sand	Yes	25-40	No macrobenthos	Yes
2	PLD2	Curieuse North	44.5	614.45	28.03	33	Soft	Sand	Medium sand	No - uninhabited	30-45	Bivalves, small polychaetes	Yes
3	PLD3	Petite Soeur	47.7	75.23	28.00	33	Soft	Sand	Medium sand	No - uninhabited	46-48	No macrobenthos	Yes
4	PLD4	Felicite East	--	116.31	--	--	Mainly soft	tbd	Fine sand	Yes	36-42	Polychaetes	Partly
5	PLD5	La Digue East	--	292.52	--	--	Soft and hard	tbd	Fine / medium sand	Yes	41-43	Shrimp, polychaete.	No
6	M1	Mahé South East	53	1872.77	27.63	33.4	Mainly soft	tbd	Medium sand / shell grit	Yes	32-52	Sponge, Brittle star, gastropod, bivalve, sand anemone	No
7	M2	Trois Banc	41.4	284.56	26.95	34	Soft	Sand	Coarse sand Shell grit	Yes	29-41	Crab, bivalve, polychaete	Yes
8	M3	Stork patch	48.3	346.04	26.88	34	Mainly soft	Sand/ Macro algae	Fine sand / shell grit	4,6 km offshore	42-48	Sea urchin remains, crab, bivalves, brittle star	Yes
9	M4	Ile Therese	40	106.02	27.09	34	Mainly soft	Sand/ Macro algae	Medium / coarse sand	No - uninhabited	25-40	No macrobenthos	No
10	M5	Beau Vallon	43.1	858.51	27.40	33.7	Soft	Sand	Medium & fine sand and silt	3,5 km offshore	40-43	Anemone, bivalves, crabs, polychaete	Yes
11	SN1	Silhouette North	62.2	305.27	27.7	32.7	Mainly soft	Sand	Coarse sand / shell grit	No, 1km MPA zone	32-62	No macrobenthos	Yes
12	SN2	North Is. North	48.5	50.71	28.13	32.9	Mainly soft	Sand	Shell grit	No (to hide from hotel beach)	35-48	Bivalves	Yes

Average depth of the sites is 40m (range 25-62m). Prevailing current profiles are more than adequate to ensure dispersal of dissolved and solid wastes from the fish cages (1543656-308203-7 and 1543656-308204-8). The 12 zones provide a total of 53.2km^2 for the initial development of the sector. Eight (8) of the 12 sites are relatively well sheltered from the SE Monsoon, one (1) is partly sheltered and three (3) are not protected.

For the purpose of the sector establishment, the 12 sites were further divided into Tier 1 and Tier 2 sites (Table 11). Tier 1 sites are supported by the fact that sand mining has occurred, resulting in some level of substrate disturbance. The sites that overlap with previously mined areas include sites M2, M3 and M5. Site PLD 2 was selected as it is sufficiently screened by Curiese Island and offers developers who wish to base themselves at Praslin and/or La Digue the opportunity to invest in the MMP. Tier 1 sites should ideally be developed over the first 10 years of the new aquaculture sector, where after monitoring and an increased understanding of the potential environmental impacts operators may access Tier 2 sites.

It should be noted that due to the existence of the vast sand mining areas (Figure 7), the ADZs that occur over this area have some flexibility with regards to size and location within this area owing to the fact that the substrate within these areas has already been disturbed. Based on this historical disturbance, Tier 1 sites will be prioritized in terms of pre-approval for development by the Ministry of Environment, Energy and Climate Change as detailed above.

It should be noted that the ADZs are not fixed in space and could be shifted within a 1 nautical mile zone around their currently proposed locations to find sandy substrate in cases where unsuitable substrate (such as isolated coral, seagrass or macro-algae patches), should these occur. This is important from an industry development perspective.

Table 11: For purposes of the ESIA, the following sites were classed as Tier 1 and Tier 2 sites respectively

Tier 1 Sites	Tier 2 Sites
■ Site M 2; ■ Site M 3; ■ Site M 5; and ■ Site PLD 2.	■ Site M 1; ■ Site M 4; ■ Site PLD 1; ■ Site PLD 3; ■ Site PLD 4; ■ Site PLD 5; ■ Site SN 1; and ■ Site SN 2.

2.2.3 Land based ADZ Sites

With a total land area of approximately 455km^2 the Seychelles faces an obvious constraint of land availability, imposed by nature. The need to strike a balance between meeting the economic and social needs of its population and maintaining environmental integrity is challenging on a small island and as a result, the Seychelles Ministry of Land Use and Housing strives for synergies by bringing key stakeholders and institutions together. (Land Use and Housing, 2016).

The land based zone for the MMP (Phase 1) implementation includes the Broodstock Quarantine & Acclimation Facility (BQAF), the Pilot project Cage Site, both located at Providence, and the Research and Development (R&D) Facility located at the University of Seychelles (UNISEY), Anse Royale (Figure 8).

Figure 8: Pilot Project, Broodstock Acclimation Facility and R&D Facilities located on Mahé

The Seychelles Broodstock Quarantine and Acclimation Facility will be a multi-species quarantine and acclimation facility that provides quarantine treatments for wild-caught broodstock. The site is located at the Providence Harbour adjacent to the shoreline providing convenient access to water supply and cost-effective pumping with minimal head (water pressure) (Figure 9). Bulk infrastructure including port infrastructure, unused existing warehousing, electricity and fresh water is available at this site which also has existing road access. Facilities including ablutions and offices are also available on site. This site also has the benefit of being located adjacent to the SFA Providence Office, as well as the Maritime Training Facility.

The planned Pilot Project forms a strategic link between the activities of the R&D Facility and the commercial scale projects. The Pilot project is scaled at 200 tonnes per annum and aims to grow-out candidate species to a marketable size in order to prove and refine the lifecycle within the Seychelles environment. The product produced will be sold in the domestic market and used as product samples to target international markets. The Pilot Project cage site is also located at Providence (Mahé), approximately 340m offshore in a sheltered area east of the Providence port (Figure 10).

The Seychelles Aquaculture Research and Development (R&D) Facility at Anse Royale (herafter referred to as the R&D Facility), Mahé will be a multi-species tropical fish hatchery, science hub and visitors centre. The facility aims to provide technical support, research, and training to develop and advance the Seychelles aquaculture industry while promoting public awareness and education for this new sector. The R&D Facility will recognise the importance of providing support to both small- and large scale aquaculture operators while ensuring the sustainable development of the sector. This will be achieved through contemporary and relevant research programmes aimed at investigating the aquaculture potential of different species, improving fish health and production, empowering small scale operators with research into diverse aquaculture strategies, training and capacity building of Seychellois in aquaculture, and ongoing environmental monitoring. In addition to technical support, the R&D Facility will have an educational mandate with aquarium displays of a variety of broodstock species, information boards, and views of a working marine hatchery.

The R&D Facility is located 8km from the Mahé International Airport, and 18km from the capital Victoria. The site is on the southern grounds of the University of Seychelles (UNISEY) and is easily accessible and well serviced by road networks (Figure 11). The area has a very gentle slope and is situated next to a drainage line. The drainage flows into a canal that in turn flows under the East Coast Road, into the sea, offering good access for water supply and waste discharge pipes from the facility into the sea with minimal environmental or aesthetic impacts.

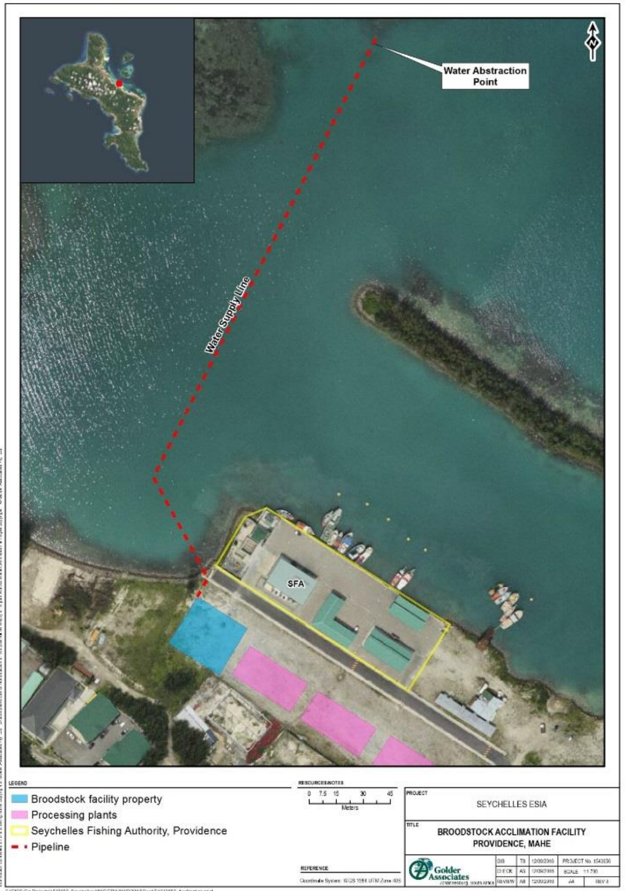

Figure 9: Broodstock Acclimation Facility, Providence

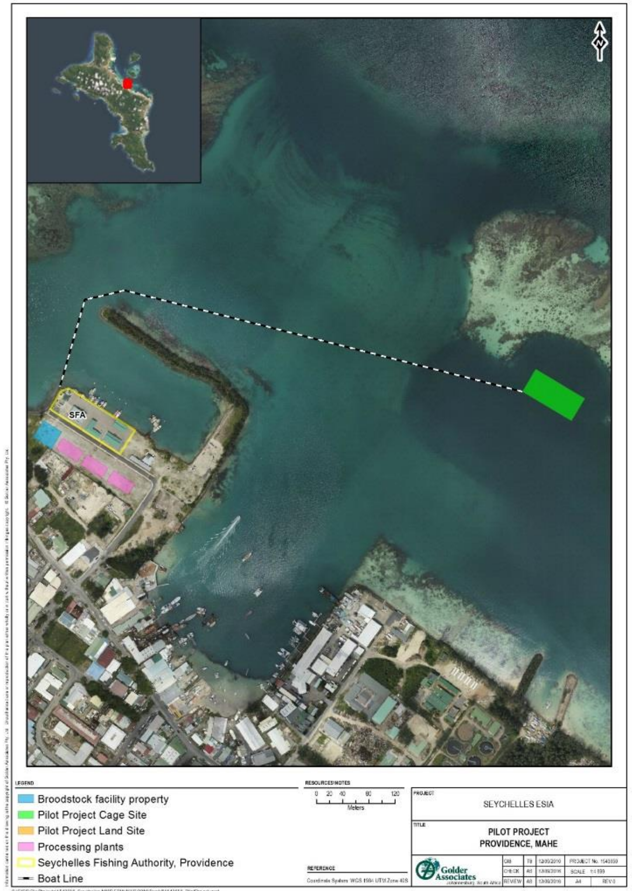

Figure 10: Pilot Project Cage Site

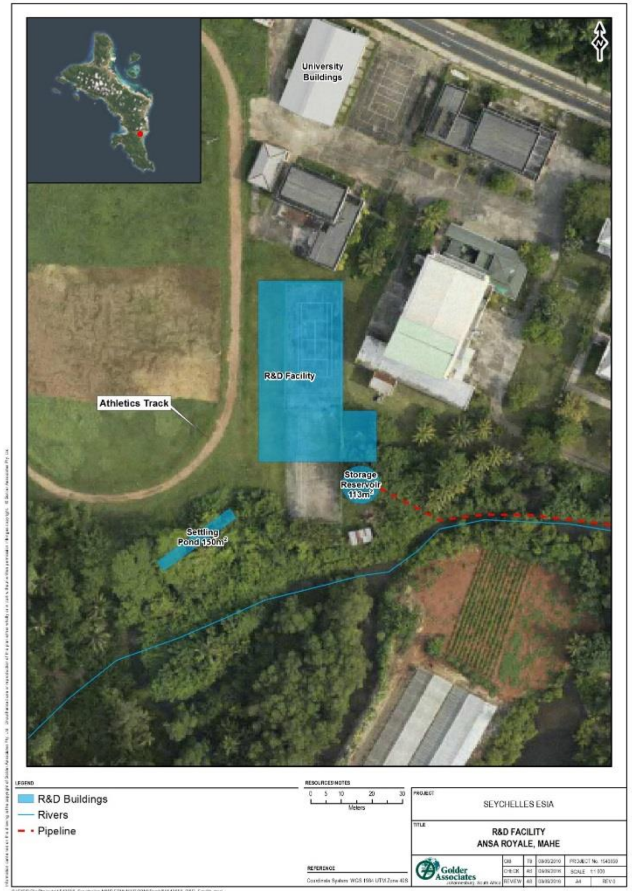

Figure 11: The land based components of the R&D Facility

3.0 SPECIES SELECTION

Species selection is fundamental to the success of an industry as it is the foundation on which the Mariculture Master Plan is built. The species selected will in turn determine the infrastructure, human resources, marketing and support industries required.

For aquaculture to be successful certain desirable characteristics need to be achieved before one considers the economic factors and marketability of the chosen species. In selecting species, the following criteria should be considered:

- **Biological features / Tolerance**: A selected species should have a tolerance to a wide range of environmental parameters such as salinity, temperature and oxygen. The breeding and feeding habits under different types of culture should be known as well as the natural geographic distribution.
- **Disease Resistant**: Species selected should be resistant to disease and able to handle the stress of being farmed in high concentrations and controlled environments (hatcheries, ponds and cages).
- **Growth Rate**: A faster growth rate is preferable.
- **Feed**: Readily available, cost effective and acceptance of compounded feeds for the desired species.
- **Food conversion Ratio**: The more efficient the food conversion ratio, the better the selected species will be at converting food mass into body mass (desired output).
- **Breeding**: The success of breeding the desired species in captivity.
- **Maturation**: Manipulation early maturation and spawning cycles can be beneficial.
- **Fecundity**: The higher the fecundity of female fish, the more material for hatchery production of seed and opportunity for selection.

Based on selection of candidate species from the above criteria, basic economic models can then be created to determine if there is a business case and if the species are economically suitable for development within the project area. Economic modelling must take into account the consumer acceptance and marketability, cost of production, domestic consumption versus export as well as potential investors (producers).

The Seychelles MMP outlines a selection process with two key objectives. The first objective aimed to identify potential species according to key selection criteria detailed below:

Key Selection Criteria:

- Species for whom aquaculture production techniques are well established; and
- Species that are naturally distributed in the Seychelles waters (*Species non-native to Seychelles were eliminated from the selection process).*

The second objective then assessed the species market potential looking at both the market availability and price. This refinement allowed for a more focused assessment of the regulatory, environmental, technical and economic factors on selected species.

The selection criteria can be summarized as follows:

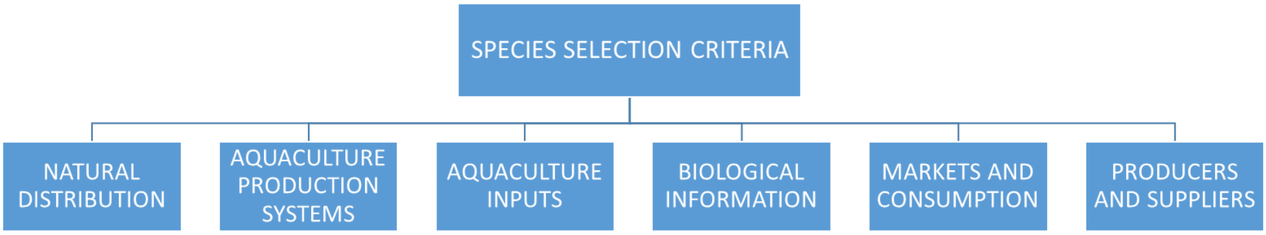

Figure 12: Graphical representation of approach to species selection

This process of selection resulted in a list of thirty (30) potential species, made-up of twenty-two (22) finfish species, three (3) species of sea cucumber, two (2) species of oysters, one (1) species of urchin, one (1) species of crab and one (1) species of prawn.

Further refinement of this list resulted in four (4) candidate aquaculture species - which have natural distributions in Seychelles and are currently being cultivated in a number of regions at various scales (small-scale and commercial production) - and twenty-seven (27) other species for aquaculture research and development (APPENDIX B).

The four (4) species selected in line with the production objectives for the R&D Facility and Pilot Project, as well as the long-term sustainability of the Seychelles economy, and that will initially be targeted for the MMP include:

- Brown-marbled grouper (*Epinephelus fucoguttatus*);
- Mangrove river snapper (*Lutjanus argentimaculatus*);
- Emperor snapper (*Lutjanus sebae*);
- Snubnose pompano (*Trachinotus blochii*); and
- Other target species identified as part of the MMP*.

**It should be noted that during the development of the MMP and the establishment of the industry new information on species lifecycles, markets and investors may come to light. In such situations the correct species profiles and market overview should be conducted to assess the suitability for inclusion within the Seychelles MMP post ESIA.*

This ESIA is directed at the assessment of the finfish cage culture within ADZs and the Research & Development facility, Broodstock Quarantine & Acclimation facility and pilot cage site. Therefore, the components and activities related to these project components will be described further for purposes of this ESIA and for the purpose of this report the following species will be assessed in more detail.

3.1 Brown-marbled Grouper (*Epinephelus fuscoguttatus*)

Distribution and Biology

Brown-marbled grouper, *Epinephelus fuscoguttatus* (Forsskål, 1775), are widely distributed throughout the tropical and subtropical waters of the Indo-Pacific, from the east coast of Africa to the oceanic islands in the Pacific Ocean (Figure 13). However, it is absent from the Persian Gulf, Hawaii and French Polynesia. Like many of the groupers, the brown-marbled grouper lives in rich clear waters close to coral or rocky reefs, lagoons and external slopes from the surface up to 60 metres (200 ft.) depth.

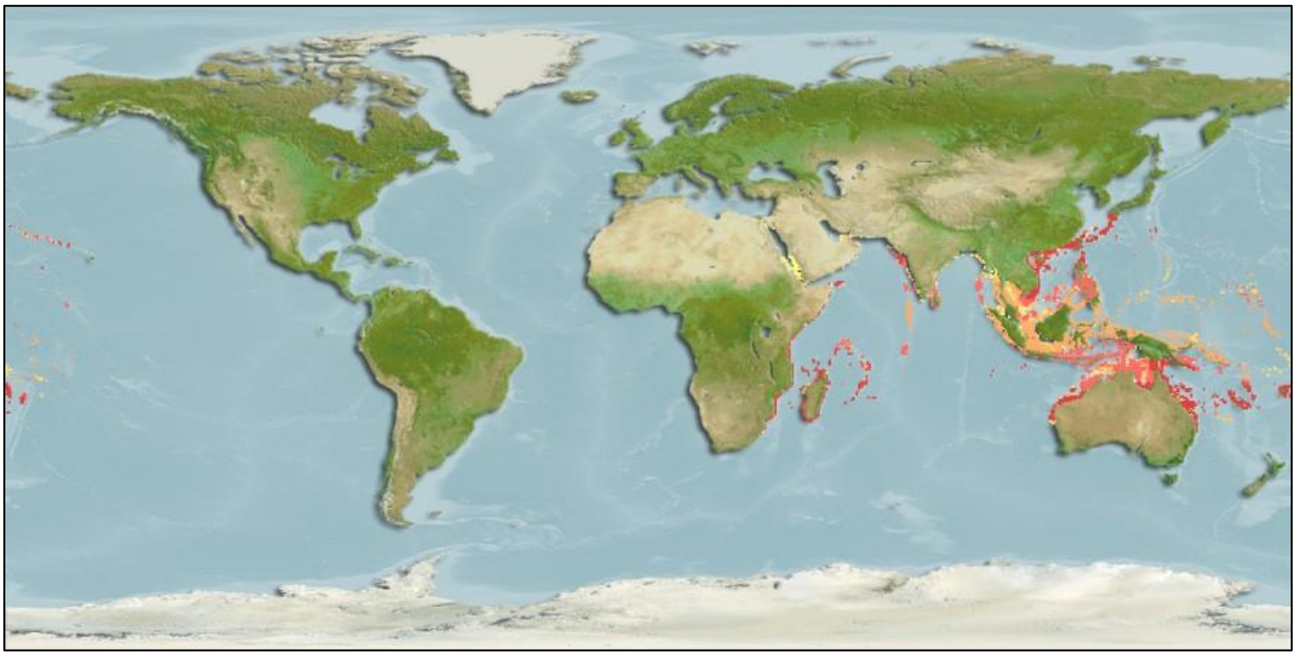

Figure 13: Brown-marbled grouper (Epinephelus fuscoguttatus) Distribution (Kaschner, et. al., 2016 - AquaMaps)

"The brown-marbled grouper is a robust marine fish, with a pale yellowish-brown, scaled body, covered with large, irregular, dark brown blotches. The head, back and sides are also covered with close-set tiny brown spots. The head profile is slightly indented at the eye, and then curves out towards the start of the dorsal fin. The tail, or caudal, fin is rounded" (Heemstra and Randall, 1993) (Figure 14).

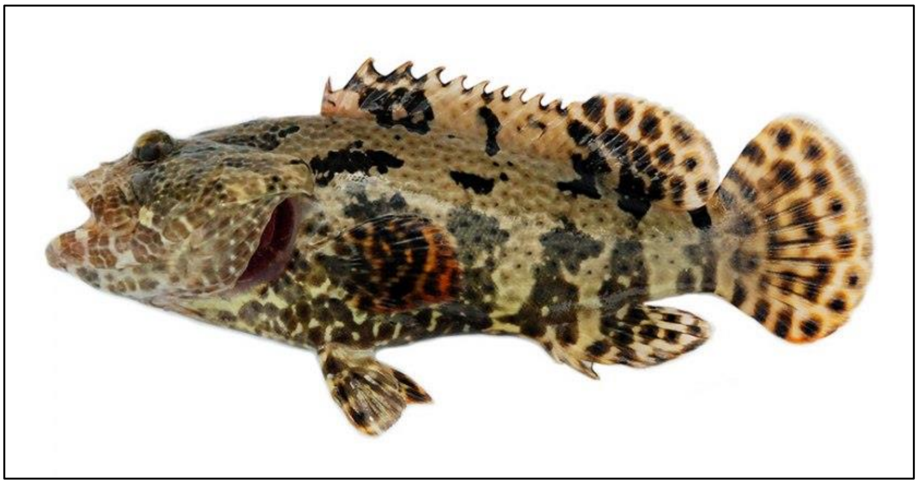

Figure 14: Brown-marbled grouper (Epinephelus fuscoguttatus) (WEB魚図鑑, 2011)

Groupers are some of the top predators on coral reefs, and tend to be K-strategists demonstrating slow growth, late reproduction, large size and long life-spans which make them vulnerable to overexploitation (Tupper and Sheriff, 2008).

Brown-marbled grouper are inherently vulnerable to fishing and heavily sought for the live reef food fish trade and as a result is listed as **Near Threatened** (NT) on the International Union for Conservation of Nature Red List (IUCN, 2016-2). The NT designation is intended to be precautionary and to signal that this species is inherently vulnerable to fishing (it is a large species and aggregates to spawn). Spawning aggregations have been historically targeted by fisheries due to easy catch returns of large volumes of fish (Pierre *et al*. 2008)

(SCRFA 2014). This has seemingly led to certain aggregations being under threat and some to have disappeared completely. Contributory factors to their vulnerability include; a long growth period to reach sexual maturity and the targeting of juveniles by fisheries for live trade. Sex change typically occurs in females at 68 cm total length, although not all females will change sex. Large spawning aggregations are formed that last for several months during spawning season (SCRFA 2014). Sexual maturity of 50% of population is reached at 56-57 cm and approximately 9-10 years of age (SCRFA 2014).

Aquaculture Production

Brown-marbled grouper can be cultured by hatcheries but is still extensively taken from the wild as small juveniles and grown out to market size in captivity. These fish are often collected from spawning aggregation. Recent research suggests that the ecological footprint of capture-based grouper aquaculture is large (Mous *et.al,* 2006).

Insufficient wild seed supply led to extensive research into full life-cycle hatchery production during the early 1970s with mixed success. Techniques have since been undergoing a process of refinement, particularly in Asia, where demand for grouper is highest. China and Taiwan are the world's biggest producers of grouper; they successfully started breeding grouper as far back as the 1980's. Taiwan "is currently able to produce grouper seeds on a commercially viable basis and to supply fertilised grouper eggs and seeds for export markets" with 38 million grouper fry produced annually (OECD 2010: 252).

Market

The global demand and production of grouper has seen a steady increase in the past decade, particularly in South East Asia where it is regarded as a high value species. The grouper market can be divided into two categories, the live reef trade and fresh or frozen products. The live reef trade has traditionally been supplied with wild harvested groupers from as early as the 1970's. With wild stocks declining, the fishing range has increased to include the whole of South East Asia and the coral triangle. The limited supply has caused a sharp increase in value of live groupers; species which are less common often have the highest prices. This has led to an increase in the aquaculture production of grouper to supply markets like Hong Kong and Singapore. It is estimated that the current global grouper demand is approximately 300 000 tonnes and will move to 500 000 tonnes by 2020. Although grouper have high demand and above average prices, the global aquaculture production is currently only about 96 000 tonnes per annum (FishStatJ, 2015). There is also concern over the accuracy of the wild caught grouper numbers in South East Asia, due to poorly recorded catch landings, but the current global figure is approximately 300 000 tonnes. Compared with other marine species such as Yellowtail, Bream, Cobia and Salmon; grouper aquaculture is still in its infancy and needs to address production issues of healthy fingerling supply, disease control and optimum feed types (Aquanue, 2014).

The majority of grouper produced through aquaculture are sold at the live reef trade in South East Asia. According to Kongkeo *et al* (2010) grouper aquaculture is now replacing wild caught groupers in supplying the live reef trade. Prices vary depending on the market, with prices in Malaysia ranges from 8 US$/kg to about 12 US$/kg. In Indonesia, the price for grouper in Sumatra averages 14 US$/kg, yet in the province of Kalimatan, a lower price of 4 US$/kg may suggest that a local fresh or frozen product does not have the same value as the exported grouper. Hong Kong proves to be the best market for brown-marbled grouper with 500 tonnes sold in 2014 at a price of 25 US$/kg. It is reported that wild brown-marbled grouper have one of the highest prices in the market at approximately 45 US$/kg. As with most commodities, the market indicates that with higher tonnage in the market, the lower the price.

3.2 Mangrove Red Snapper (*Lutjanus argentimaculatus*)

Distribution and Biology

The Mangrove Red Snapper, *Lutjanus argentimaculatus* (Forsskål, 1775) also known as a River Snapper, is an important food fish in Southeast Asia with a wide distribution in the Indo-West Pacific from Samoa and the Line Islands to East Africa, and from Australia northward to Ryukyu Island, Japan (Allen, 1985 in Emata, 2003) (Figure 15). Although a marine species, Mangrove Red Snapper fry and juveniles are found in brackish estuaries and the lower reaches of freshwater streams (Emata, 2003). Offshore migrations to deeper reef areas sometimes penetrate depths exceeding 100 m (Leu *at al*., 2003).

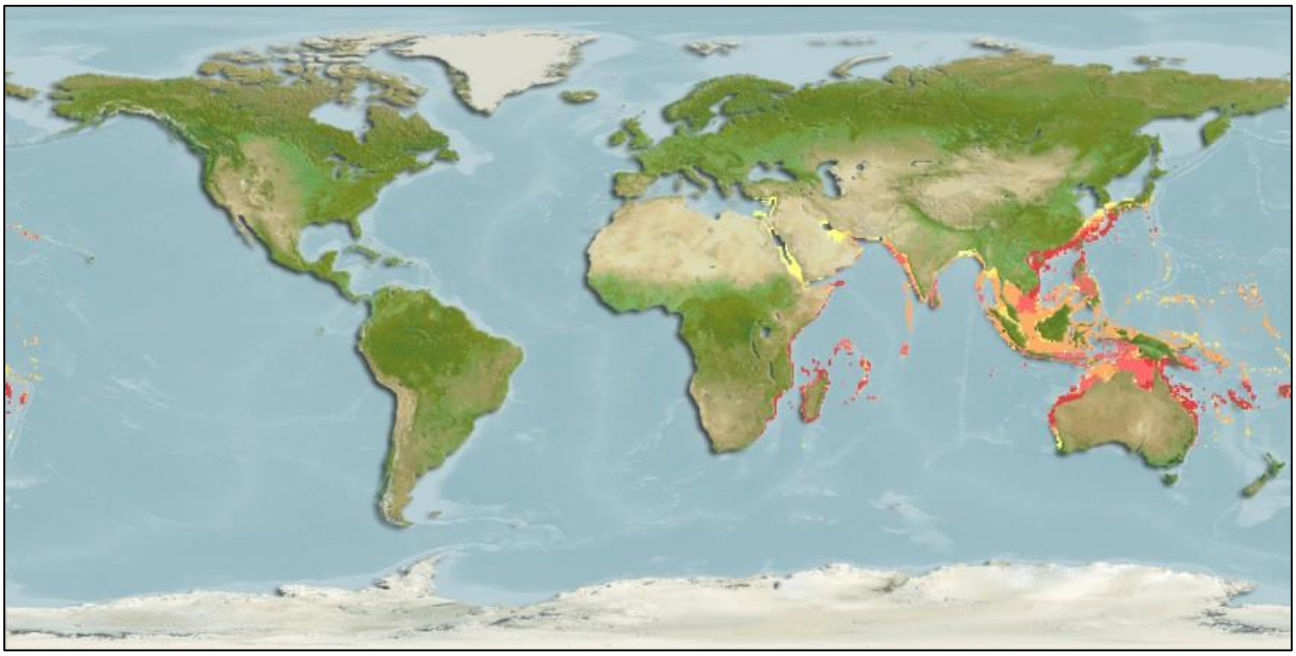

Figure 15: Mangrove Red Snapper (Lutjanus argentimaculatus) Distribution (Kaschner, et. al., 2016 - AquaMaps)

Body moderately deep (greatest depth 2.5 to 3.1 times in standard length), with a somewhat pointed snout and caudal fin emarginate to nearly truncate (FAO, 1985). Generally greenish brown on back, grading to reddish on sides and ventral parts, with a silvery/white belly (FAO, 1985, Froese and Pauly, 2016). Juvenile fish have a series of about eight whitish bars crossing sides, and 1 or 2 blue lines across cheek (Figure 16).

Figure 16: Mangrove Red Snapper (Lutjanus argentimaculatus) (Photo from MitoFish, 2012)

Aquaculture Production

Mangrove Snapper do have good resistance to diseases and bacteria, which makes them suitable for Aquaculture. Snapper can spawn naturally in captivity, as well as be artificially induced to spawn, typically being cultured in sea cages and brackish ponds. Culture predominantly relies on wild caught fry for aquaculture. This is perceived to be a major inhibitor to stable and successful snapper culture, as sourcing wild stock can be seasonal and inconsistent. It is also seen to be an unsustainable method of aquaculture due to the limited nature of wild stocks (Emata, 2003). The capture culture industry (wild caught and then further reared in captivity), together with wild caught fisheries, place pressure on wild populations.As a result of this pressure on wild populations, attempts have been made to establish the reliable breeding and successful larviculture development of snapper since the mid 1980's. South East Asia and Australia have both made advancements in full cycle snapper hatchery production, in a bid to support their respective aquaculture industry's with high-quality, mass fingerling supplies.

Market

The Mangrove Red Snapper fetches a high market price and is a popular food fish. The global aquaculture production of snapper is focused in Malaysia, where approximately 8000 tonnes per annum are produced. A further 2 000 tonnes per annum of snapper are produced in Indonesia.

The total global production of wild caught snapper is approximately 250 000 tonnes, compared to the aquaculture production on only 8 000 to 10 000 tonnes. From these figures it is clear that the snapper market is still dominated by wild caught fish.

The wholesale price for snapper from Malaysia ranges from 3 US$/kg to about 8 US$/kg, where comparably retail price for snapper in Malaysia ranges from 4 US$/kg to about 9 US$/kg (it is also unknown if these are for whole fish or filleted products, or are for live reef fish or processed product). The price for aquaculture produced snapper in Indonesia has ranged from 3 US$/kg to 5 US$/kg from 2009 to 2012.

3.3 Emperor Snapper (*Lutjanus sebae*)

Distribution and Biology

The Emperor Snapper, *Lutjanus sebae* (Cuvier, 1816), is distributed through the Indo-West Pacific, occurring in the southern Red Sea and East Africa to New Caledonia, north to southern Japan and south to Australia (Figure 17).

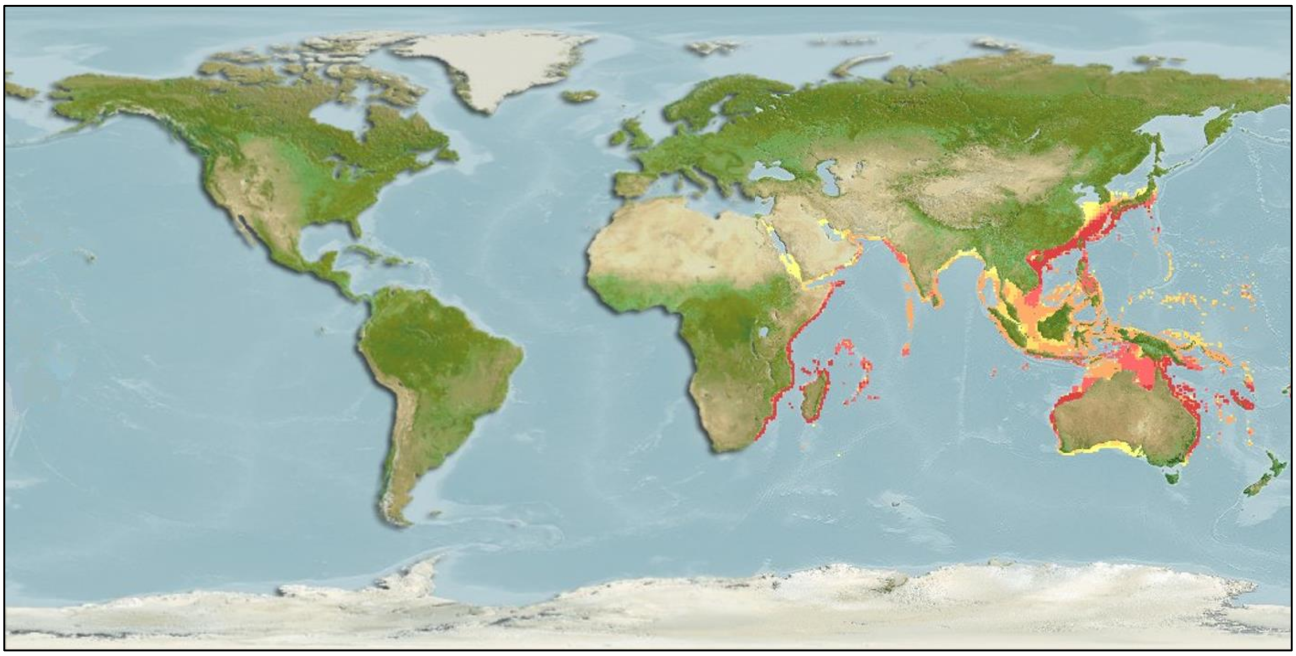

Figure 17: Emperor Snapper (Lutjanus sebae) Distribution (Kaschner, et. al., 2016 - AquaMaps)

Dorsal profile of head steeply sloped. Preorbital bone broad. Preopercular notch and knob moderately developed. Scale rows on back rising obliquely above lateral line. Generally red or pink, darker on the back; fins are red except the pectorals which is pink. Juveniles and small adults have a dark red band from first dorsal spine through eye to tip of snout; a 2nd band from mid-dorsal fin to pelvic fin; a 3rd from base of last dorsal spine to caudal peduncle. Large adults become uniformly red (Lieske and Muers, 1994) (Figure 18).

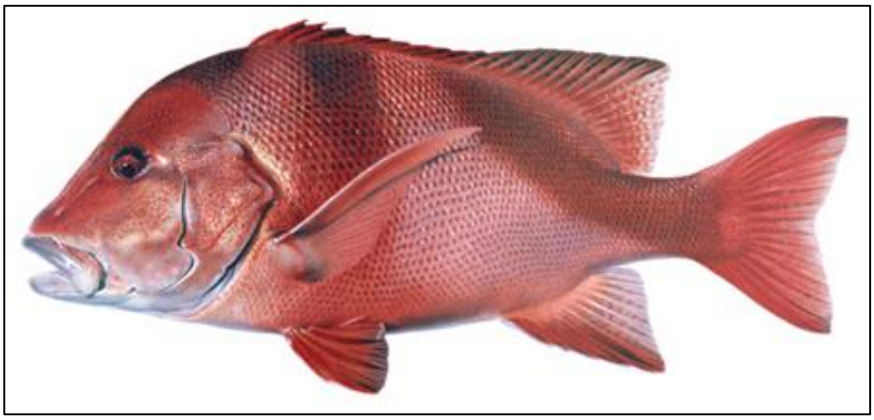

Figure 18: Emperor Snapper (Lutjanus sebae) (Photo from Suncrest Austraila, accessed 2016)

Aquaculture Production

In 2012, a New Caledonian farm started research on the technical feasibility of Red Emperor Snapper seed production and sea cage grow out, as part of 5 year program (Ducrocq and Noguerra, 2015). The feasibility studies reported that broodstock spawned spontaneously and that growth, feed conversion ratios and survival rates were being refined further. Small scale market trials were conducted during July and August 2015, with fish averaging 500 grams in weight. The New Caledonian Centre for Development and Transfer in Marine Aquaculture (CCDTAM) stated that they “are close to mastering larval and fingerlings production techniques for commercial production purposes, but grow out operations need more research work” (Dekoninck, *et.al*., 2016).

Market

Known locally as the ‘*Bourzwa*’, the Red Emperor Snapper is a fish associated with Seychelles cuisine, even being referred to as the 'icon of 'Seychelles dinner table'. With wild stocks under pressure

Studies conducted by the SFA show that the recent dramatic increase in catches of Bourzwa is threatening the viability of the wild stocks and requires immediate management attention. The study went on to say that there is a high proportion of immature individuals being caught, meaning they have yet had the opportunity to reproduce.

In January 2016, Red Emperor Snapper were being sold at a Hong Kong market for 14 US$/kg for wild caught and 7.70 US$/kg for cultured specimens. At selected fishmongers and supermarkets in Sydney, Australia, Red Emperor Snapper were being sold at 22 US$/kg.

3.4 Snubnose Pompano (*Trachinotus blochii*)

Distribution and Biology

The Snubnose Pompano, *Trachinotus blochii* (Lacepède, 1801) is a pelagic species that occurs in tropical waters in the Indian Ocean, from the east coast of Africa including the Red Sea, to the Indo-west Pacific, north to Japan and south to Australia, to the Central Pacific, including central volcanic islands (Figure 19).

“Juveniles inhabit sandy shorelines and shallow sandy or muddy bays near river mouths while adults move out in schools to clear seaward coral and rock reefs. Juveniles are in small schools, while adults are usually solitary. Adults feed primarily on sand molluscs and other hard-shelled invertebrates” (Froese and Pauly, 2015).

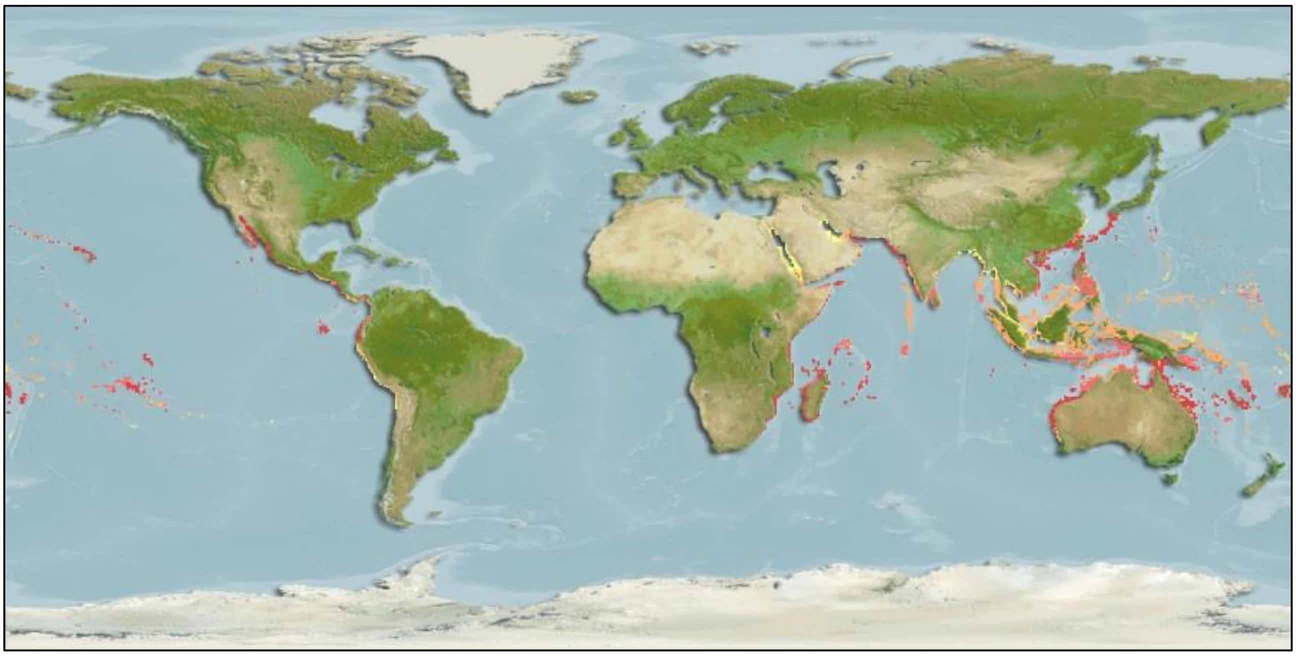

Figure 19: Snubnose pompano (Trachinotus blochii) Distribution (Kaschner, et. al., 2016 - AquaMaps)

Trachinotus blochii is a compressed fish with a steep, blunt snout that is broadly rounded. The dorsal and anal fins have very long leading fin rays, while the caudal fin is strongly forked. The species grows to 110 cm total length (TL) and has attained a maximum published weight of 3,4kg (Figure 20).

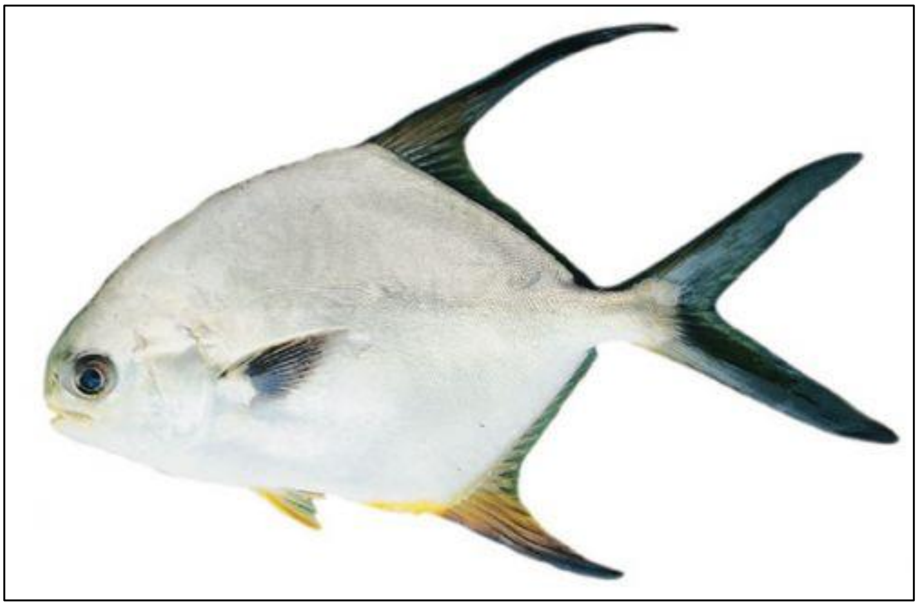

Figure 20: Snubnose pompano (Trachinotus blochii) (Photo from Queensland Dept. of Agriculture and Fisheries, 2012)

Aquaculture Production

Aquaculture of *Trachinotus blochii* produces more than commercial catches, based on the habitat preferences and biological nature of *Trachinotus blochii* making it an uncommon commercial catch. Most of the aquaculture production comes from China and Indonesia.

Trachinotus blochii is an 'open water, sub-stratum egg-scatterer', which does not guard its eggs. Fertilisation of eggs occurs externally (Froese and Pauly, 2016). In captivity, pompano are typically induced to spawn with hormone injection techniques and control of photoperiod and thermal exposure. Utilising established techniques lead to predictable spawning of *Trachinotus blochii* in captivity (Gopakumar 2012).

Due to market demand, the subsequent development of *Trachinotus blochii* was successfully established in many Asian-Pacific countries, such as Taiwan and Indonesia, although only certain countries have established fingerling production, for instance, Malaysia's aquaculture of *Trachinotus blochii* relies on importing fingerlings from Taiwan (Ransangan *et al*. 2011).

Market

Trachinotus blochii is recognised as a high-medium-end restaurant food fish and premium species for mariculture due to its attractive appearance, fast and uniform growth rate, adaptability to culture environments, acceptability of formulated feed, tolerance of differing salinities, firm white flesh (Groat, 2002; Chavez *et al*., 2011; Gopakumar 2012).

The demand for pompano in Hong Kong is limited to household use and medium priced restaurants (Louise, 2000). The limited supply of wild caught pompano however, means that a wild caught pompano in the market can reach higher than average prices, sometimes more than snapper. There is however, at best, limited information on the total tonnage of live pompano consumed in Hong Kong.

Retail price for a fresh gilled gutted 600g pompano can reach 6 US$/kg. Large quantities of frozen whole gutted pompano have resulted in prices of 2 US$/kg but normally the range is between 2 US$/kg to 4 US$/kg.

4.0 TECHNICAL AND OPERATIONAL ASPECTS

A brief description of cage culture technology and operations is provided in order to identify issues requiring operational attention, and that are of relevance to the environmental impact assessment and management plan. The Seychelles aquaculture Standard for Sustainable for '*Responsible Finfish Culture*' provides comprehensive operational specifications to ensure that cage culture operations conform to the highest environmental management standards.

4.1 General description of cage aquaculture

Modern offshore cage culture operations are relatively simple and highly mechanised.

Offshore cages systems generally employ round High Density Poly-Ethylene (HDPE) ringed collars with a suspended net (Figure 21). The rings are held together by plastic or galvanized steel stanchions that hold the cage structure together. The most common cage net types are polyester or nylon nets with variable mesh sizes (dependent on the size of fish stocked and stage of outgrowing). Nets are usually impregnated with an antifouling compound, probably a copper based product, to prevent excessive biofouling of the mesh.

While cage sizes and configurations vary a great deal, in the Seychelles Mariculture Master Plan site selection report, a generic farm configuration is provided. It is proposed that a typical farm is likely to comprise of two rows of cages (20m diameter with 12m deep nets), spaced 16m apart. Cages are moored in linked arrays anchored to the sea bottom (Figure 22). The servicing of offshore cages is performed vessels equipped with equipment for feeding, changing nets and removing fish from the cages (Figure 23 and Figure 24).

Figure 21: Typical HDPE cage configuration with bird predator netting cover. Source: www.tradekey.com.

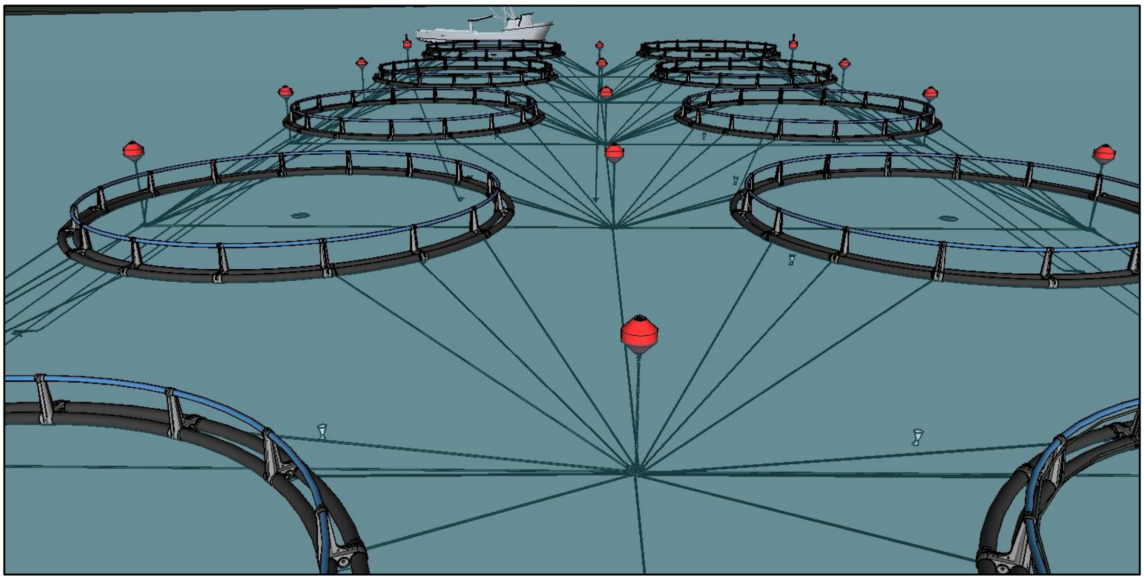

Figure 22: Mooring array configuration for fish cages. Marker buoys are used to indicate the position of the moorings and the perimeter of the farm. Source: Akuakare Aquaculture Equipment Limited http://eng.akuakare.com/moorning/

Figure 23: Service vessel for an offshore cage aquaculture site. Source: www.marineharvestireland.com.

Feeding of fish in cages is usually performed daily by hand on smaller farms, thus requiring suitable sea conditions for the landing of personnel on the cages. On larger cages farms, automated feeding is performed from moored feed barges or service vessels.

Figure 24: Service vessel applying feed to a cage. Source FAO/Aquaculture photo library/F.Cardia

4.2 Operational Issues

Operational issues relevant to the environmental management of a cage aquaculture operation are considered below.

4.2.1 Workable sea days

Sea conditions determine whether it is possible to safely i) access the cage site with service vessels and ii) land personnel on the cages.

It is necessary to feed fish daily, check cages and predator nets for damage, and remove mortalities. Cage nets are usually changed once a month using a service vessel with a crane. Nets are cleaned of fouling organisms on shore and repaired as required. Fish are stocked, sorted and harvested using ‘well boats’ with special pumps and holding tanks. Daily feeding can be undertaken in relatively rough conditions, particularly if it is from a vessel and personnel do not have to be landed on the cages to hand feed. The changing of nets and harvesting of fish requires calm conditions.

The relatively moderate wind and swell conditions that prevail over the Mahé Plateau make it possible to access cages and land personnel on most days of the year, despite the open water situation of the ADZ sites. The ADZ sites which are sheltered from the stronger SE monsoon winds and swell on western sides of the Inner Islands will probably be favoured by investors due to the ease of operations.

4.2.2 Operations and maintenance

As cage farms are situated in remote locations in a high energy and ecologically sensitive marine environment, there is a high risk of equipment failure which can pose a risk to the environment, human safety and economic viability of the operation. A very high specification of operational and maintenance is thus required utilising appropriately trained and skilled personnel. The Seychelles Aquaculture Standard for Responsible Cage Culture requires the following operational and maintenance provisions:

- Farmers must develop Standard Operating Procedures (SOP) for each component of the farm and conduct annual, systematic reviews of their operations against the specific SOP and have these available for inspection by the Regulator.
- When considering modifications to existing farming practices, procedures or structures, farmers must conduct a review of the type and extent of probable environmental impacts that may occur as a result of the new methods and amend their existing operational practices and procedures to mitigate potential impacts.
- When conducting activities such as stocking/seeding, harvesting, feeding, grading, thinning, transfer, cleaning, gear maintenance or fallowing, all standard operating procedures must include diligent efforts to minimise probable environmental impacts.
- Comprehensive stocking and production strategies that optimise production while minimizing environmental impacts must be used. Production planning must include a systematic review of any probable and cumulative environmental impacts that would be associated with a particular production plan or method.
- Nets and moorings must be maintained in a whole and intact condition.
- No gear may be abandoned and storage of nets or gear on the bottom is prohibited.
- Any net or gear accidentally dropped or lost during storm events that is not recovered immediately shall be tagged with a float, positioned using GPS, and reported to Regulator within 24 hours. The lost net or gear shall be recovered within 30 days of the date lost. The Regulator shall be notified on the date the net or gear is recovered.

- Nets, mooring and rigging lines, and anti-predator equipment must be stretched tight and held taut and maintained in a manner to diminish the likelihood of entangling finfish, decapod crustaceans, sea birds, marine mammals, and sea turtles.
- Maintain an Entanglement Log for finfish, sea birds, marine mammals and sea turtles. The log should identify the species, size, number, date of entanglement, and disposition of the species and be submitted to the Regulator on an annual basis.
- Consider potential impacts on water circulation patterns when installing cages and their associated mooring systems. Gear deployment must optimize circulation patterns and maximize water exchange through the pens, thereby improving fish health and reducing benthic impacts.
- Design and operate harvest procedures and equipment in a fashion that reduces any associated discharges. Harvest and post-harvest vessel and equipment clean-up procedures must minimize wastes discharged overboard.
- Consider the practicality of polyculture using scallops or sea cucumbers on the seabed to reduce the contribution of nutrients and particulate matter to waters outside the farm lease.
- Farm support vessels must be fuelled at designated fuelling stations.
- All fuel or oil spills must be reported as required by law to the appropriate authorities. Appropriate clean-up and repair actions must be initiated as soon as possible.
- Farm support vessels of the appropriate size must have approved Marine Sanitation Devices on board. All human wastes must be disposed of according to the applicable maritime regulations.

4.2.3 Safety and Security

A cage farm is an industrial work place and thus appropriate measures need to be in place to ensure safety of personnel and alert vessels in the area to the navigational hazard.

Buoys and navigation lights are thus positioned around the perimeter of the farm. Workers need wear appropriate protective clothing and life jackets.

The Seychelles Aquaculture Standard for Responsible Finfish Cage Culture requires the following measures:

- Maritime regulations require that the areas occupied by cage farming equipment are marked by surface buoys complying with a prescriptive standard, and include lights which are visible at night up to a prescribed distance.
- All cage culture areas are clearly marked on navigation charts.
- Non-fish farm vessels may not come closer than 50m from the cages.

4.2.4 Health Management, Medications and Chemicals

The fundamental principle of fish health management is the minimisation health risk factors such as stress which may compromise the fishs' immune system and result in susceptibility to pathogens. This is achieved by means of efficient feeding, handling and operational procedures. If fish are stresses, it may be necessary to treat with medications and dips in cages. Medications such as antibiotics prescribed by veterinarian are usually included in the feed.

Ectoparasitic infections may need to be treated externally by means of a dip. A tarpaulin is drawn around the cage and the chemical introduced to treat the fish for a period of time before being allowed to disperse into the environment. The aquaculture industry is moving away from external oganophosphate dips to more natural remedies such as vaccines and cleaner fish.

The Seychelles Aquaculture Standard for '*Responsible Finfish Cage Culture'* provides comprehensive guidance on cage culture fish health management.

4.2.5 Control of Interactions with Piscivorous Animals

Fish in cages may attract marine predators such as seals, sharks, birds and fish. Operations need to install nets designed to minimise these interactions. For example,

- Mortalities should be removed from cages daily so as not to attract predators.
- Bird netting over the fish cages is standard to prevent birds from eating the fish food and the young fish.
- If the cage farm attracts large predators such as seals and sharks, it may be necessary to install a heavy perimeter predator net around the farm.
- During harvesting and killing of fish ensure that minimal blood enters the water.
- Maintain a record of incidents with large predators.

4.2.6 Entanglement of Cetaceans

Cetacea are an order of aquatic, chiefly marine mammals, including the whales and dolphins.

If whales are present in the cage farm site there is a small possibility of entanglement in the cage moorings. Southern right whales, humpbacks and short-finned pilot whales occur in the Seychelles and thus farms should have equipment on service vessels to cut mooring lines should an entanglement incident occur.

4.2.7 Site Fallowing

Cage culture operations in sheltered waters such as fjords with little water exchange may periodically move their cages to allow for 'fallowing', that is recovery from the build-up of organic of the sediments below the cages. As the Seychelles ADZ sites are in open water with very good flushing, the MOM waste dispersion model (Section 5.0 below) indicates that there will be no build-up of organic waste below the cages.

In line with best management practices of the Seychelles 'Marine Aquaculture and Sea-Ranching Regulations' states:

> *In keeping with the ethics of conservation and sustainable development as outlined in the Environment Protection Act 1994, the Environmental Management Plan of Seychelles 2000 - 2010 and the Seychelles Sustainable Development Strategy, offshore and nearshore cage farming sites will be fallowed 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*.

4.2.8 Feed Management

As fish feed is the biggest organic input into the environment, efficient feed management to minimise particulate and dissolved waste to the environment is essential. As feed constitutes the single biggest operational cost input, there is a strong economic incentive for farmers to manage feeding very carefully.

The Seychelles aquaculture Standard for Sustainable for '*Responsible Finfish Cage Culture*' provides comprehensive guidance on feed management:

- Optimize all operations related to feed delivery, storage and handling methods to minimise waste and the creation of fines (feed dust).
- Where applicable use feeding tables provided by the manufacturer.
- Maintain feed conversion ratio records by using feed and fish biomass inventory tracking systems.
- Where possible use species specific formulations designed to enhance nitrogen and phosphorus retention efficiency, and reduce metabolic waste output.

- Feed manufacturer labels, or copies thereof, must be retained for a period of two years. Labels must be made available to the Regulator during compliance inspections.
- Use efficient feeding practices, monitor active feed consumption, and reduce feed loss.
- Feed pellet size should be appropriate for the size of fish being fed.
- Feeding behaviour must be observed to monitor feed utilization and evaluate health status.
- Maintain and properly operate feeding equipment.
- Conduct employee training in fish husbandry and feeding methods to ensure that workers have adequate training to optimize feed conversion ratios.
- Interactive feedback feeding systems such as video or “lift-ups,” should be used to optimise feed consumption and to reduce feed waste.
- The feeding of wet feeds (ground or whole fish or shellfish and other raw meat or plant materials) is not normally permitted. If wet feeds are to be used, then special permission will have to be sought from the Regulator.
- Physical disturbance of the bottom such as harrowing, dragging or other mechanical means shall not be used to mitigate the benthic impacts of feed or fish excretion.

4.2.9 Escape Management

The escape of fish to the environment is a major economic risk and potentially a genetic risk to wild fish populations. Daily cage inspection and repairs, scheduled maintenance and effective handling of fish is thus essential to minimise the possibility of escape. The Seychelles aquaculture Standard for ‘*Responsible Finfish Cage Culture’* provides comprehensive guidelines to minimise escape management.

4.2.10 Cage, Net, Mooring and Anchoring

To minimise operational and environmental risk, it is essential that the specification of the cage systems is appropriate to the sea conditions in the ADZs, and that they are maintained according to scheduled protocols by appropriately trained and equipped personnel.

The larger cage manufacturers provide ancillary services and recommended consultants to ensure that clients are provided with the back-up they require to install and operate their cage systems effectively. The Seychelles Aquaculture Standard for ‘*Responsible Finfish Cage Culture*’ provides a detailed standard to which cage systems need to comply.

4.2.11 Solid Waste Management and Disposal

As cage farming constitutes and industrial activity on the sea and a work place, strict guidelines are required to ensure that solid wastes do not enter the marine ecosystem. This is provided for in Seychelles Aquaculture Standard for ‘*Responsible Finfish Cage Culture*’, which states:

- Cage operators must develop a Solid Waste Management Plan that is compliant with the relevant legislation. This plan must identify all wastes generated on a site or from an aquaculture facility. The Solid Waste Management Plan must be available for inspection by the Regulator and must be implemented rigorously.
- Cage operators on the outer Islands must ensure that their solid waste, where appropriate, is taken off the Island and returned to Mahé for proper disposal.
- Mortalities will attract predators and contribute to fish health problems. Mortalities must be collected **daily** (weather permitting) to avoid accumulation at the cage bottom.

- Farmers must use collection and removal methods that do not stress remaining animals or compromise net integrity. Mortalities must be stored and transported in closed containers with tight fitting lids. Mortalities must be returned to shore, disposed of and noted in accordance with the Regulations.
- Farmers must avoid the discharge of substances associated with *in situ* net cleaning. Instead farmers should implement gear and management strategies to reduce biofouling that will minimise or eliminate the need for on-site net cleaning. Strategies may include, but not be limited to: stocking mullet (Mugil spp.), or similar native species in the cage to biologically control fouling, use of fouling resistant materials (e.g., copper alloy netting or other materials), net changing, rotating cage designs.
- On-site mechanical cleaning must include methods to prevent the accumulation of solids on the sea floor or the release of solids that cause or contribute to water quality impairment.
- The use of antifouling coatings on nets or the use of biocidal chemicals for cleaning nets on site is prohibited
- Farm support vessels of the appropriate size must have approved Marine Sanitation Devices on board. All human wastes must be disposed of according to the applicable maritime regulations.

5.0 ENVIRONMENTAL CARRYING CAPACITY FOR CAGE AQUACULTURE - MOM MODEL

The Seychelles Aquaculture Standard for ADZ cage aquaculture requires that the production of fish does not exceed the environmental carrying capacity for assimilating organic waste. The interactions between the caged biomass of fish and the surrounding environment are well understood based on the experience of various cage culture industries. It is now generally accepted that before aquaculture is established in a certain area, the environmental carrying capacity should be estimated using appropriate models together with representative observational data from the area and the local environmental quality standards in force and appropriate farm water quality standards (Stigebrandt, 2011).

The Seychelles Mariculture Master Plan Site Selection Report (SFA, 2016) used the widely accepted Norwegian MOM (Modelling-Ongrowing fish farm -Monitoring) Model to determine the carrying capacity of the 12 ADZ sites and to set precautionary production biomass limits. The MOM model estimates the monthly maximum production of fish that can be sustained given a set of environmental conditions, feeding regimes, and sea cage arrangements. The MOM model uses following conditions to determine farm biomass carrying capacity, visibly

1) **There must be living benthic fauna beneath the cages**. This means that the loading with organic matter must not be so high that the benthic fauna disappears. The maximal biomass fulfilling this condition is called Carrying Capacity ($CC_{benthos}$).

2) **There should be good water quality in the cages.** The corresponding farm water quality standard indicate that the oxygen concentration is sufficiently high and the concentration of waste (UIA = unionized ammonia) is sufficiently low. Based on these two farm water quality standards, the carrying capacity for dissolved oxygen (CC_{DO}) and carrying capacity for unionised ammonia (CC_{UIA}) are be calculated. The smallest of $CC_{benthos}$, CC_{DO}, CC_{UIA} determines the carrying capacity of the location (Stigebrandt, 2011).

3) **The farm is not allowed to exert an unacceptable negative impact on larger scales** (regional scale), i.e. away from the farm area. The maximum biomass that fulfils this condition is CC_{reg}. The regional impact is however measured, by a monitoring programme on operational farms, as (i) a reduction in the Secchi depth in the surface layer and (ii) a reduction in the minimum oxygen concentration in the deep water.

The MOM model for the Seychelles ADZ sites was based on available information for two grouper species, viz. *Epinephelus malabaricus* and *E. tauvina*, which are similar to the preferred aquaculture candidiate species for the Seychelles *E. fuscuguttatus* (SFA, 2016).

The carrying capacity of the ADZ sites was modelled for optimistic, realistic and worst case scenarios for the key model parameters, visibly depth, dissolved oxygen concentration, current speed, and the efficiency of feed conversion into fish biomass ('food factor' – which provides an estimate of waste feed not consumed) (Table 12). The other parameter input values were obtained from various sources.

With these inputs, the model predicts (Table 13) that the maximum annual production of fish that can be sustained under all model scenarios was 4292 tonnes per annum per square kilometre (42.9 tpa/ha). The limiting factor determining this value was the Carrying Capacity$_{DO}$ due to the relatively low ambient oxygen concentration on the Mahé plateau waters. This production level is thus below the threshold level that would have an impact on the benthos or result in unfavourable NH_3 levels in the cages. Under all current speed scenarios the results show that the carbon flux to the sediment was 0 gC/m^2/year, due to the relatively high current sigma value of >3.5 cm/s. A further factor influencing the impact of fish farm food and faecal waste on the environment is the direct consumption of these organic particulates by fish. As cages are known to act as 'fish-aggregating-devices', it is likely that a high proportion of the waste will be directly consumed and not reach the benthic environment.

The Seychelles Mariculture Master Plan has proposed precautionary production limit of 1000 tonnes per annum per square kilometre (10 tpa/ha) which is <u>significantly lower</u> than the modelled environmental carrying capacity. This is a very conservative production limit given the output of the MOM model. The Site Selection Report (SFA, 2016), cites other two other cage situations (Algoa Bay, South Africa and Macquarie Harbour, Tasmania) where a carrying capacity of 30tpa/ha has been set. The Site Selection Report concludes by saying: "*Nevertheless, it is recommended that the precautionary principle prevail and that the limit is not exceeded until actual farm monitoring data become available that may support an increase in the rate of production per unit area*."

It can thus be concluded with a high degree of confidence that cage aquaculture in the Seychelles ADZs at the proposed production limit is well within the carrying capacity of the environment, and will not negatively affect the local benthic environment or regional water quality.

Table 12: Input data for the Seychelles MOM ver 3.2 model

Model runs	25A	25B	25C	35A	35B	35C	55A	55B	55C	Reference or comment
Locality data										
Water depth (m)	**25**	**25**	**25**	**35**	**35**	**35**	**55**	**55**	**55**	Within observed depth range
Current standard deviation (cm/s)	12.1	8	4	12.1	8	4	12.1	8	4	Baseline StDev of ADCP data from NW and SW Mahé coast during NE and SE Monsoon (Vasco consulting 2009)and then reduced to worst case scenario
Salinity (ppt)	33	33	33	33	33	33	33	33	33	Average CTD measured salinity (0-45m)
Dissolved oxygen bottom layer (mg/L)	**4.67**	**4.67**	**3**	**4**	**4**	**3**	**3.98**	**3.98**	**3**	Observed DO levels at various depths and reduced to worst case scenario
Ammonia level in environment (mg/L)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	Mengesha *et al*. 1999
Dimensioning current surface layer (cm/s)	**12**	**12**	**6**	**12**	**12**	**6**	**12**	**12**	**6**	Model equation Stigebrandt et al. (2004)
Dimensioning current bottom layer (cm/s)	**6**	**4**	**2.5**	**6**	**4**	**2.5**	**6**	**4**	**2.5**	Estimated at 50% of dimensioned surface current and reduced to worst case scenario
Critical concentrations										
Lowest acceptable DO in cages (mg/L)	**4.2**	**4.2**	**3.5**	**4.2**	**4.2**	**3.5**	**4.2**	**4.2**	**3.5**	Refer to DO levels in text
Highest acceptable NH3 in cages (mg/L)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	Halide *at al*. 2008
Lowest acceptable DO at the bottom (mg/L)	**4**	**4**	**2.5**	**4**	**4**	**2.5**	**3.8**	**3.8**	**2.5**	Halide *et al* (2008) set the lowest level at 2mg/L
Farm data										
Maximum biomass (tonnes)	650	650	650	650	650	650	650	650	650	Standard see text
Cage length (m) or √ area circular cages	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	20m diameter circular cages
Depth of cages (m)	12	12	12	12	12	12	12	12	12	Standard ranges from 8 to 16
Distance between cages (m)	16	16	16	16	16	16	16	16	16	Standard ranges from 10 to 20m
Reduction factor through flow (0-1)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7 = default value Despite low biofouling levels (SFA, 2012) we used the default value of 0.7
Food factor (real)	**1.4**	**1.8**	**2.0**	**1.4**	**1.8**	**2.0**	**1.4**	**1.8**	**2.0**	Ranges recorded for Tiger Grouper
Number of cage rows	2	2	2	2	2	2	2	2	2	
Fish and food data										
Food protein content (0-1)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	Commercial Grouper pellet (Team Feeds, Indonesia)
Food fat content (0-1)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
Food CH content (0-1)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
Food Ash content (0-1)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	
Food sinking speed (cm/s)	7	7	7	7	7	7	7	7	7	
Fish start weight (g)	15	15	15	15	15	15	15	15	15	
Fish end weight (g)	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Fish protein content (0-1)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	Gooch *et al.* 1987, Anbarasu *et al*. 2015

Fish fat content (0-1)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	Gooch *et al*. 1987, Anbarasu *et al*. 2015
Faeces sinking speed (cm/s)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	Used proxy value for *Sparus aurata* (Magill *et al*. 2006)

Table 13: MOM ver. 3.2 model outputs for inputs described in Table 12 above

Model outputs	**Case 25A**	**Case 25B**	**Case 25C**	**Case 35A**	**Case 35B**	**Case 35C**	**Case 55A**	**Case 55B**	**Case 55C**
General									
Time to reach end weight (days)	206	206	206	206	206	206	206	206	206
Median weight of fish (g)	248	248	248	248	248	248	248	248	248
Max carbon flux to sediment (gC/m2/yr)	0	0	0	0	0	0	0	0	0
Dissolved wastes to cages									
Nitrogen (kg)	55	55	55	55	55	55	55	55	55
Phosphorous (kg)	9	9	9	9	9	9	9	9	9
Particulate waste to sediment									
Nitrogen (kg)	13	43	58	13	43	58	13	43	58
Phosphorous (kg)	2	7	10	2	7	10	2	7	10
Faeces (kg)	236	236	237	236	236	236	236	236	236
Wasted food (/tonne production)	71	472	671	71	471	671	71	471	671
Max production potential (tonnes)	4292	4292	4292	4292	4292	4292	4292	4292	4292
Production limiting factor	O2 in cages	O2 in cages	O2 in cages	O2 in cages	O2 in cages	O2 in cages	O2 in cages	O2 in cages	O2 in cages

6.0 IMPACT ASSESSMENT AND MITIGATION MEASURES

The environmental impacts of finfish cage farming are well documented and internationally accepted best practise guidelines exist to establish operations that are ecologically, socially and economically sustainable (Ross *et al,* 2013; Soto, *et al,*, 2007). The Seychelles Mariculture Master process used these guidelines in planning the proposed aquaculture industry. This MMP includes development plans, ADZ site selection to minimise impacts, setting of environmental carrying capacities and the promulgation of aquaculture standards and regulations. This strong supporting institutional framework reduces environmental risk as adds confidence to the assessment of impacts and the implementation of mitigation measures.

A brief description of the potential environmental impacts of finfish cage culture followed by the impact assessment with recommended mitigation measures.

6.1 Approach to Impact Assessment

This ESIA impact assessment complies with the environmental law requirements of the Seychelles and is aligned with best practice guidelines such as FAO ‘ecosystem approach to aquaculture’.

Key principles contained in the ESIA methodology include:

- Sustainability – development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs;
- Mitigation hierarchy – The mitigation hierarchy describes a step-wise approach (BBOP, 2009) that illustrates the preferred approach to mitigating adverse impacts as follows (the governing principle is to achieve no net loss and preferably a net positive impact on people and the environment as a result of the project):
  1) The preferred mitigation measure is avoidance;
  2) Then minimisation;
  3) Then rehabilitation or restoration; and
  4) Finally offsetting residual, unavoidable impacts.
- Developers have a duty of care towards the environment.

The assessment of the impacts of the proposed activities has been conducted within the context provided by these principles and objectives.

6.2 Impact Significance Rating Methodology

The significance of the identified impacts has been determined using the approach outlined below (terminology from the South African 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)

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 (Beyond EEZ)	10 - Very high/don't know (Modifications have reached a critical level and the system has been modified complete with an almost complete loss of natural habitat and/or biota / don't know)
4 – National (The Seychelles EEZ)	8 – High (The loss of natural habitat, biota and basic ecosystem functions has occurred)
3 – Regional (The inner islands)	6 – Moderate (Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged)
2 – Local (The ADZ extent)	4 – Low (Largely natural with few modifications, a small change in habitat or biota has taken place but the ecosystem functions are essentially unchanged)
1 - Site only (The farm footprint)	2 – Minor (no noticeable change to habitat or species, ecosystem functions are unchanged)
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 significant	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 condition

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).

6.2.1 Project Phasing for this ESIA

It is anticipated that the following timeframes apply to each of the project phases:

- **Construction Phase**: The BQAF and R&D facilities are likely to be constructed and ready for hand-over to the operational teams after a period of approximately 12 months. This includes the installation of the pilot project cages and grow-out cages associated with individual fish farm operators. It should be noted that floating cages can be assembled and commissioned in a very short period of time (a couple of days to weeks), and as such may occur at different stages when needed as more operators enter the aquaculture sector.
- **Operational Phase**: The operational phase of the aquaculture industry for purposes of this ESIA has been set at 25 years, however, it is very possible that the sector develops into a stable sector that continues for many more years.
- **Decommissioning Phase**: This phase is not described in detail in this ESIA, as imminent closure and decommissioning of the aquaculture sector is not anticipated. However, this phase would involve the removal of infrastructure such as the cages, moorings and boats from the waters, with the land based facilities being utilised for alternate purposes. This would require removal of aquaculture equipment and infrastructure activities.

This ESIA has assessed impacts linked to the above phasing of the aquaculture sector for the land based components described as well as the establishment of fish farms in ADZs. The inshore and offshore components of the MMP and larger potential aquaculture sector, is subject to separate ESIA's that will address each of these specific components.

6.3 Impact identification

The following potential aquaculture impacts related to the technical components of MMP, and that may occur during the construction, operational and decommissioning phases of the proposed aquaculture sector development have been identified.

6.3.1 Construction Phases / Implementation Phase

The construction phase impacts as a result of the industry establishment are limited to those caused by the placement of cages and mooring infrastructure on the sites, as well as the construction activities of land based facilities (i.e. the BQAF, the R&D facility as well as their associated abstraction and discharge infrastructure). The establishment of cages may have a negative impact (mortalities, loss of habitat) on benthic communities, but this will be covered under the benthic assessment report (ORI Report No. 332, 2016).

6.3.1.1 Importation of genetically distinct fingerlings that are not from the Seychelles inner islands populations.

The Pilot Project will be required to bring in Grouper fingerlings from Asia for the first season or until such a point that the bloodstock facility and hatchery is up and running. This may have disease and genetic impacts on the local fish populations.

The disease risk is potentially high as 1) alien species pathogens not present in the Seychelles ecosystem might be introduced and 2) pathogens with acquired drug resistance due to repeated exposure under aquaculture conditions may be introduced.

The fish would also originate from a related but genetically distinct regional population and escapees could have an impact on wild fish genetics if they successfully breed.

In general, the aquaculture industry is moving away from translocations for biosecurity reasons. However, should a transfer be done strict biosecurity and quarantine protocols will minimise the risk of disease introduction. Mitigation measures include risk assessment, authorisation with conditions by the regulator, a health certificate from exporting country, prophylactic treatment of imported fish for parasites, quarantine and monitoring for parasites and diseases, and application of ICES Code of Practise on the Transfer and Introduction of Marine Species (ICES, 2005). The Seychelles Aquaculture Standard: '*Hatchery Biosecurity Protocol*' and '*Responsible Finfish Cage Aquaculture*' provide protocols for biosecurity measures to minimise disease transfer to wild populations.

The potential disease impact is assessed '**high**' without mitigation and 'moderate' with mitigation.

It should be noted that the importation of any biological matter, such as ova, fingerlings or broodstock at a latter stage during the development of the sector, would carry with it the same risks and hence the same impact rating. Thus the importation of any biological matter at any time would constitute a "high" impact without mitigation.

The potential genetic impact of farmed fish on wild populations is dealt with in Section 6.3.2.1 below. The potential disease impact is assessed '**high**' without mitigation and 'moderate' with mitigation (Table 14, Table 15 and Table 16).

6.3.1.2 *Importation of genetically distinct broodstock fish that are not sourced from the Seychelles Inner Islands*

The Pilot Project will be required to bring in Grouper broodstock from the outer island populations. This may have disease and genetic impacts on the local fish populations. The disease and genetic risk is not considered as high as the importation of cultured fingerlings from Asia because the fish are part of the Seychelles Indian Ocean ecosystem. Therefore 1) the parasite and potential disease vectors are likely to present in inner island wild populations and 2) the farmed and wild fish are likely to be more similar genetically. As the wild brood fish have not been subject to husbandry conditions they are less likely to carry parasites and disease vectors that are drug resistant. The impacts and risks associated with genetic contamination and disease transfer to wild stocks are discussed more fully below in sections 6.3.2.1 and 6.3.2.2.

Mitigation measures include disease risk assessment, authorisation with conditions by the regulator, prophylactic treatment of imported fish for parasites, quarantine and monitoring for parasites and diseases, and application of ICES Code of Practise on the Transfer and Introduction of Marine Species (ICES, 2005). The Seychelles Aquaculture Standard: '*Hatchery Biosecurity Protocol*' and '*Responsible Finfish Cage Aquaculture*' provide protocols for biosecurity measures to minimise disease transfer to wild populations.

The potential disease impact is assessed 'moderate' both before and after (Table 14, Table 15 and Table 16).

The potential genetic impact is assessed 'moderate' without mitigation and 'low' with mitigation (Table 14, Table 15 and Table 16).

6.3.1.3 *Impact on sensitive benthic habitats with cage installation.*

Placing cages in areas that are sensitive, such as coral reefs or in shallow waters where currents are not strong to disperse organic waste away from the site could pose a risk to the sustainability of the operation and receiving environment.

The ADZ site selection protocol however anticipated these issues and areas with coral reefs were deemed unsuitable as ADZ sites. Furthermore, as demonstrated by the MOM model all ADZ sites selected have current speeds that will disperse organic wastes and not result in a build-up or organic waste in the sediments.

The ADZ site survey indicated that all have sandy/silty sediments. However, due to the lack of detailed data on the ADZ sites, it is possible that some sensitive habitats may be present. To mitigate the possibility of cage placement over sensitive habitats, any potential developer is **required to undertaken site survey and monitoring at least six months prior to cage installation**. Proposed ADZ sites may be moved by up to one nautical mile, should sensitive habitats be revealed.

The likelihood of cages being situated over sensitive benthic habitats during the construction phase is the minimal and the impact is ranked as 'low' with mitigation (Table 14, Table 15 and Table 16).

6.3.2 Operational Phase

6.3.2.1 *Genetic contamination of wild stocks*

Farmed fish spawned from a small number of broodstock tend to have reduced genetic diversity compared to wild stocks. Furthermore, farmed fish are genetically selected for and typically preferred traits such as fast growth and high meat yield. Farmed fish are thus genetically distinct and their breeding with wild stocks may have a negative effect on the fitness of the population (Hershberger, 2002; Naylor *et al*., 2005; Ford and Myers 2008).

Despite being confined to sea cages, it is inevitable that some fish will escape from the farms and possible breed with wild populations. Even in countries with advanced sea cage farming industries such as Norway, fish escapes are a regular occurrence with an estimated 1.5 million escaped salmon present in Norwegian fjords at any one time (Heuch, *et al*., 2005).

It should be noted that the significance of the impact of genetic contamination of escaped farm fish on wild stocks is largely determined by the extent of genetic differentiation between farmed and wild stocks, as well as the survival and reproductive success of escaped fish (Falconer and Mackay, 1996). If the farm broodstock population is made of a genetically representative selection of wild caught fish, and a 'no selection' policy is adopted in order to maintain the wild genetic profile, the effects of escapees interbreeding with the wild population will be low. If farmed fish are subject to a high level of genetic selection and inbreeding for production traits (e.g. fast growth rate), they will be genetically more differentiated from the wild population. Farm escapees could have a greater genetic impact on the wild population – depending on the scale of escape and their proportional contribution to the wild spawner stock.

The impact of farmed fish on the population genetics of the preferred aquaculture species, the Brown-marbled grouper (*Epinephelus fuscoguttatus*) is a potential issue as it is listed as 'Near Threatened' due to the over utilization and targeting of adults at spawning aggregations (IUCN, 2016-2). Large numbers of escape wild fish could thus make a significant contribution to spawning and recruitment. There is however insufficient information available to assess the magnitude of this risk. The size of the Brown-marbled grouper population within the Seychelles inner and outer islands would need to be determined to fully understand the risk of possible genetic alteration at population level. There have been studies on the spawning aggregations of grouper within Seychelles (Robinson *et al.*, 2008), but these studies provide a high level of detail within a very small area.

Precautionary mitigation measures to reduce the risk of genetic alteration of wild populations through breeding with escapees could include a 'no selection policy', use of wild brood stock only and brood stock rotation. Once a better understanding of *E. fuscoguttatus* population genetics is obtained, and the risk of escaped fish affecting their genetics understood and minimised, it may be possible to selectively breed for traits that enhance stock productivity (stock improvement).

The Seychelles Aquaculture Standard for Responsible Finfish Cage Culture deals with "Escape Management', whereby it details proactively reducing the potential causes of escape and recommended escape response actions.

The impact of genetic contamination is ranked as 'moderate' without mitigation and 'low' with mitigation (Table 14, Table 15 and Table 16).

6.3.2.2 Disease and parasite transmission to wild fish stocks

Intensive fish farming involves high density stocking of fish per unit area which increases stress and the incidence and prevalence of infectious diseases and parasites (Lipton, 1994). Farmed fish are therefore inherently more prone to these disease vectors inducing pathogenic symptoms. Infectious diseases and parasites are regarded as the single biggest threat to aquaculture, for example, 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).

Maintaining proper environmental conditions, selecting healthy fish, quarantining new broodstock, providing a nutritious diet, minimising stress, vaccinating fish, and rapidly diagnosing, isolating, and treating disease outbreaks are important aspects of good husbandry.

Under natural conditions, potential disease causing organisms are not normally pathogenic as they have co-evolved with the host fish species and are less concentrated than those confined to cages. Furthermore, wild fish exercise natural parasite shedding behaviours. The transmission of diseases from farmed fish to wild stocks may take place when wild fish are in close proximity to cages (fish may be attracted to the cages as a result of excess food), or simply as a result of the much higher concentration of pelagic parasite life history stages arising from intensive fish farming.

In cases where farmed fish species are not indigenous, the risk of wild fish becoming infected with new disease causing organisms to which they have no natural resistance is indeed high. One of the key criteria in species selection for the Seychelles MMP was "*Species that are naturally distributed in the Seychelles waters*". Thus as only indigenous fish species form part of the MMP (notwithstanding the potential for bringing in an initial batch of fingerlings for the Pilot Project) and the associated disease causing organisms and parasites will originate from the wild fish populations and pose a lower risk due to the natural resistance of the wild fish.

Although treatment of cultured stock to control disease and parasite outbreaks is possible (unlike wild stocks), chemical treatment is not without further environmental impacts, whilst build-up of antibiotic and chemical resistance is becoming increasingly problematic (Staniford, 2002).

Modern best management practise is to reduce stress through good husbandry practise and to implement an on-farm preventative fish health management programme under supervision of a veterinarian. This involves ongoing baseline monitoring of fish health status including:

- Nutritional status;
- Parasite load;
- General condition;
- Growth performance; and
- Pathogenic symptoms.

The Seychelles Aquaculture Standards for '*Fish Health Management*', '*Biosecurity Protocols for Hatcheries*' and '*Responsible Finfish Cage Culture*' provide for biosecurity and fish health management based on internationally accepted best management practices. From the training of staff, identification of risks, through to the daily management, monitoring, contingency plans and treatment, these documents cover the detail required to compile a standard operating procedure (SOP) for Biosecurity and Fish Health Management.

Biosecurity in aquaculture is of critical importance. The control of pathogen entry and proliferation is an essential aspect of any intensive animal production unit and is one of the most difficult challenges facing the industry worldwide. Therefore, strict biosecurity measures should be adhered to in hatcheries, including restricted access, hand washing and foot baths. Should new broodstock be introduced then these should be appropriately quarantined to ensure disease free status. The Seychelles Aquaculture Standard for Responsible Cage Aquaculture provides for the following biosecurity measures:

- Cage farms must maintain documentation identifying the source of all eggs, fry, fingerlings or adult fish in each cage.
- All purchases of live fish, regardless of life stage, must be accompanied by an accredited veterinarian signed "Certificate of Veterinary Inspection" attesting to the good health of the fish.
- Limit contact among groups of animals, workers, and equipment through disinfection/decontamination procedures.
- Facilities that use different life stages in the production process must, where necessary, implement quarantine or disinfection procedures to reduce the risk of pathogen transfer.
- The veterinarians approved by the Regulator must be informed of diseases or pathogens observed in cultured stocks, and before disposing of fish that manifest disease symptoms.
- Health management records must be archived for at least two years to document behavioural changes, clinical signs of disease, treatment procedures, or unusual mortality rates. These records will be made available for inspection by the Regulator.

The impact of disease transfer to wild fish is ranked as 'moderate' without mitigation, however remains 'moderate' even with mitigation due to the magnitude of the impact. (Table 14, Table 15 and Table 16).

6.3.2.3 Organic waste pollution from finfish cages

The potential for the deterioration of water quality in the receiving ecosystem as a result of fish farm intensification is potentially high if no mitigation and monitoring is implemented.

This potential deterioration of water quality as a result of organic fish farm effluents include eutrophication, sedimentation, increased Biological Oxygen Demarnd (BOD) and Chemical Oxygen Demarnd (COD) (Staniford, 2002). These effects are most severe in sheltered waters with low exchange rates (e.g. fjords), and become less intense in open waters where currents and winds disperse the organic waste. As the waste is organic, the fish faeces and food waste compounds will assimilate into the ecosystem food chain, provided that the assimilation capacity of the local environment is not exceeded.

Aquaculture organic waste originates from the metabolism and excrement of the fish, as well as from waste feed. The particulate and dissolved waste is rich in carbon, nitrogen and phosphorous. Studies have documented increased dissolved nutrients and particular components (POC and PON) both below, and in plumes downstream, of fish cages (Pitta *et al*. 2005). These wastes impact both on the benthic environment and on the water column.

Sediments and benthic invertebrate communities under fish farms usually show chemical, physical and biological changes attributable to nutrient loading. Elevations in carbon, ammonia and hydrogen sulphide concentrations are frequently observed (Carroll, *et al.* 2003; Heggoey, *et al.,* 2005). Nutrient enrichment and resulting eutrophication of sediments under fish cages is regarded as a serious issue in area with low water exchange rates (Staniford, 2002). Impacts on benthic habitats below fish cages do, however, tend to be localized. Most studies indicate that the effect is contained within a few hundred meters (Porrello, *et al.* 2005; Merceron, 2002 and Kempf *et al.,* 2002), but one Mediterranean study was able to detect changes up to 1000 m away (Sara, *et al.* 2004).

It is thus important to determine the fish biomass carrying capacity of farm sites to ensure that the organic waste produced is assimilated by the local ecosystem without negative ecological impacts (Ross, *et al,* 2013). The MOM model described in section 5.0 above a modelling tool that determines safe production volumes based on three key indicators (i) benthic fauna at a farm site does not disappear due to organic sediment accumulation, (ii) the water quality in the sea cages must be kept high, and (iii) the water quality in the areas surrounding the farm must not deteriorate (Stigebrand*t et al*, 2004).

Due to rapid dispersal of wastes predicted by the MOM model and the precautionary production limit of 10t/ha year, the impact of organic waste pollution is ranked as 'low' without mitigation and 'low' with mitigation
(Table 14, Table 15 and Table 16).

6.3.2.4 Chemical pollution arising from finfish cages

Disinfectants, antifoulants and therapeutic chemicals (medicines) are typically used in sea cage fish culture. Some of these chemicals may be toxic to non-target organisms and may remain active in the environment for extended periods. For this reason, the Seychelles Aquaculture Standard for '*Responsible Effluent and Waste Management*' stipulate that the use of hormones and anti-biotics in the Seychelles will be restricted to land based facilities under supervision of a state veterinarian.

Biofouling of cage nets in the Seychelles is considered low due to the oligothrophic nature of the tropical waters (SFA, 2012). The Seychelles MMP provides for strict control of antifoulants to minimise their potential toxic effects on the receiving environment. The Special Conditions for the Seychelles Marine Aquaculture Licence for Finfish Grow-out in Cages, Section 8 (a) states, "*The License Holder shall ensure that the Regulator approves any anti-fouling product used on the net pen material*", and the Seychelles Aquaculture Standard for Finfish states (7.7) "*The use of antifouling coatings on nets or the use of biocidal chemicals for cleaning nets on site is prohibited*".

Chemical use at sea is thus expected to be minimal in the Seychelles ADZs. The impact chemical pollution is ranked as 'low' with appropriate mitigation measures (Table 14, Table 15 and Table 16).

6.3.2.5 Accidental entanglement of cetaceans in finfish cage culture infrastructure

They Seychelles is home to resident and migratory populations of dolphins and whales. Southern right whales, humpbacks and short-finned pilot whales occur common in the Seychelles with a number of other species having been recorded. There is thus a small risk of entanglement in cage moorings.

Entanglement of marine mammals in fish cage infrastructure has been reported internationally but are rare events (Kemper & Gibbs 2001; Wuersig & Gailey 2002).Cetaceans and other marine animals may be able to avoid lethal effects associated with entanglement in fish cage infrastructure, but the mere presence of sea cages may well adversely affect habitat use and may have chronic negative effects on populations (as well as ecotourism activities) (Wuersig & Gailey 2002).

Cetaceans may be able to avoid lethal effects associated with entanglement in fish cage infrastructure, but the presence of sea cages may adversely affect habitat use and ecotourism activities (Wuersig & Gailey 2002).

Given the rarity of reported cetacean entanglement events, the impact is considered 'low' with mitigation for the Seychelles ADZs (Table 14, Table 15 and Table 16).

6.3.2.6 Piscivorous marine animals interacting with finfish cage culture operations

Piscivorous (fish eating) marine animals including mammals, sharks, bony fish and birds are naturally attracted to the fish cages (Wuersig & Gailey 2002, Vita, *et al.* 2004). The cages act as natural Fish Aggregating Devices (FADs) and it is common to have a community of small fish associated with the cages for purposes of shelter and food. Both the fish in the cages and associated small fish community tend to attract larger, predatory marine animals. Their attempts to get at the stock may induce a stress response with consequent decreased growth rates and resistance to disease. Furthermore, predators can damage the cage nets, allowing fish to escape.

While a certain level of interaction between the farmed fish and wild fauna is unavoidable, such as the small fish seeking shelter and feeding on waste feed and faeces, the interaction with larger marine piscivores should be minimised through appropriate mitigation measures. For example, mortalities should be removed daily as they may attract wild fish and birds which may become tangled in nets. Apart from harm or death to the predator, this may result in damaged nets leading to escapes and stress or harm the cultured stock. The attraction of piscivorous marine animals may alter natural foraging behaviours. Farmers tend to kill problem predators or use acoustic deterrents.

There are various measures to mitigate the effect of fish cages on piscivorous marine animals. Bird netting over fish cages is standard to prevent entry, and the above water 'jump nets' around the circumference of the cage prevent the caged fish from escaping as well as wild fish and seals from jumping into the cage.

The impact on marine piscivores is ranked as 'low' with appropriate mitigation (Table 14, Table 15 and Table 16).

6.3.2.7 Impacts on fishing, yachting and recreational vessels

The establishment of fish farms with the proposed ADZs will exclude other vessels from the fish cage area. This is essential for personal and navigational safety and farm security. The ADZ sites have been selected to avoid shipping lanes, diving reefs and fishing grounds and so are thus not expected to conflict with these activities. The main impact is will on the movement of fishing, yachting and recreational vessels.

The main effects will be on vessels 1) having to detour around the fish farm sites and 2) a potential open water navigational hazard.

Mitigation measures would include navigational lights on the cages, buoys delineating the fish farm boundaries, listing the fish farm sites on navigational charts and educating vessel operators about the fish farm presence. It should be possible to traverse the ADZ sites between the demarcated fish farms.

The impact on fishing, yachting and recreational vessels is ranked as ‘low’ with appropriate mitigation (Table 14, Table 15 and Table 16).

6.3.3 Decommissioning Phase

6.3.3.1 Farm operations cease

All businesses have a life cycle and closure is a normal phase of operation. Aquaculture businesses tend to have a high failure rate because the technology is new, markets are rapidly changing and environmental factors introduce a high element of unpredictability into performance.

Farm closure and decommissioning should thus be planned for. The environmental impacts of decommissioning can range from severe – if the farm infrastructure is abandoned, to negligible if all equipment is removed and responsibly disposed of.

If the cage culture operation is abandoned as a result of business failure, a number of harmful environmental effects are possible. These could include:

- Entanglement of marine animals such as turtles, birds, cetaceans and large fish in the netting; and
- A navigational hazard to vessels.

The impact rating of ceasing farm operations is rated as ‘moderate’ without mitigation and as ‘low’ with mitigation.

Mitigation measures could include a public liability insurance policy or an invetsment fund to provide for site rehabilitation should an operation be abandoned.

6.3.4 Cumulative impacts

The cumulative impacts of an aquaculture industry will be similar to those listed, but may be exacerbated as a result of more operators farming within a certain area. Potential impacts include:

- Genetic Contamination.
  - A larger industry with more players, will likely attract new species, sources of seed and competition to produce artificially selected species.
- Disease and parasite transmission to wild fish stocks.
  - With more fish being farmed the potential for disease breakout is increased, furthermore the implications of such a breakout would likely be more significant and harder to manage across farms and operators.
- Degraded water quality as a result of organic wastes (Golder Reports: 1543656-308203-7 and 1543656-308204-8).
  - More intensive farming has the potential to degrade water quality as a result of higher nutrient inputs.
- Chemical pollution arising from finfish cages.
  - Higher volumes of fish produced as a result of multiple farms within a unit area, will result in more stringent treatments to avoid disease and as a result more intensive farming has the potential for chemicals to accumulate.

The Seychelles Mariculture Master Plan is however designed to space ADZs and farms so that they operate within the carrying capacity of the environment. If the prescribed Aquaculture Standards and Regulations are adhered to, with effective monitoring and feedback into the management and regulatory processes, there should not be cumulative impacts.

6.4 Mitigation Measures

The EMP and specific mitigation measures and monitoring actions for the identified impacts in Sections 6.3 are presented in this section. The mitigation measures associated with each of the construction/implementation, operational and decommissioning phases are described Table 14.

Table 14: Mitigation and Monitoring

Activity	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/ party	Monitoring and Reporting Frequency
Construction/ Implementation Phase						
Importation of genetically distinct fingerlings	Introduction of new diseases and parasites	To prevent infection of wild stocks with a new disease or parasite	Imported fish free from parasites and disease vectors	■ Prior to the commencement of any aquaculture activities, use of the target species must be authorised by the regulator (currently the SFA). ■ Health certificate from exporting country. ■ Prophylactic treatment of imported fish for parasites. ■ Quarantine and monitoring for parasites and diseases. ■ Follow ICES Code of Practise on the Transfer and Introduction of Marine Species.	State Veterinarian and contracted veterinary service providers	Monthly report on health and disease status of imported fingerlings
Escape of farmed fish	Escapees from cages contaminate wild fish genetic profile	No alteration of wild fish genetic profile	No escapees	■ Operational measures to minimise escapement according to Seychelles Aquaculture Standard for Responsible Finfish Cage Aquaculture.	Farm management under supervision of Seychelles Fishing Authority	Incident reporting of any escapees. Annual summary report to Seychelles Fishing Authority
Importation of genetically distinct broodstock fish that are not sourced from the Seychelles Inner Islands	Introduction of new diseases and parasites	To prevent infection of wild stocks with a new disease or parasite	Broodstock fish and offspring free from parasites and disease vectors	■ Prior to the commencement of any aquaculture activities, use of the target species must be authorised by the regulator. ■ Native species should not be introduced to an area where they do not already occur. ■ Prophylactic treatment of imported fish for parasites. ■ Quarantine and monitoring for parasites and diseases.	Veterinarian	Initial treatment of fish for parasites followed by six monthly health screening

Activity	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/ party	Monitoring and Reporting Frequency
Escape of farmed fish	Escapees from cage farms contaminate wild fish genetic profile	No alteration of wild fish genetic profile	No escapees	■ Adequate steps must be taken to prevent the escape of production organisms, especially from the hatchery environment where individual organisms may be very small. ■ Escape barriers may include netting, grids, sand and other filters, predator ponds, chemical treatment areas, soak away systems, etc. ■ Barriers should be adequate to prevent escape during flooding, overflows and during other unforeseen circumstances.	Farm management	Incident logging and annual reporting to Seychelles Fishing Authority.
Cage installation	Impact to sensitive benthic habitats	No damage to sensitive benthic habitats such as coral reefs and sea grass beds	No impact on sensitive benthic habitats	■ Pre-installation site survey to verify benthic habitat type and select sandy/muddy bottom.	Independent service provider	ADZ Site survey at least six months prior to cage installation
Operational Phase						
Cage Aquaculture of Finfish	Genetic contamination of wild populations	No measurable genetic contamination of wild stocks	Minimise farm fish escapees	■ Adequate steps must be taken to prevent the escape of production organisms, especially from the hatchery environment where individual organisms may be very small. ■ Escape barriers may include netting, grids, sand and other filters, predator ponds, chemical treatment areas, soak away systems, etc. ■ Barriers should be adequate to prevent escape during flooding, overflows and during other unforeseen circumstances.	Farm management	Daily inspection.
Hatchery and Cage Aquaculture of Finfish	Disease and parasite transmission to wild fish stocks	To maintain health fish within the farm and protect wild stocks	No breakout or spread of disease	■ Staff trained in fish health management and disease recognition. ■ Implement a Fish Health Management Programme.	Farm management under veterinary oversight	Six monthly veterinary health assessment Maintain comprehensive records of all pathogens and parasites detected as

Activity	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/ party	Monitoring and Reporting Frequency
				■ Apply aquaculture best management practices. ■ Maintain strict bio-security measures within hatchery, holding tanks and sea cages. ■ Ensure all fry undergo a health examination prior to stocking in sea cages. ■ Regularly inspect stock for disease and/parasites as part of a formalised stock health monitoring programme. ■ Take necessary action to eliminate pathogens through the use of therapeutic chemicals or improved farm management. ■ Research into the identification, pathology and treatment of diseases and parasites infecting farmed species. ■ Treat adjacent cages simultaneously even if infections have not yet been detected in these cages.		well as logs detailing the efficacy of treatments applied Annual health management programme report to Seychelles Fishing Authority
Hatchery and Cage Aquaculture of Finfish	Organic Pollution from fish faecal and feed waste	To prevent the build-up of nutrients within the water column	Dissolved and particulate organic nutrients below specified levels in the vicinity of the fish farm	■ Bio filtration of shore based hatchery effluent. ■ Set production carrying capacity limits for cage sites. ■ Cage location in areas with current >2m/s. ■ Ongoing MOM modelling and feedback into management measures.	Independent service provider	Sampling and reporting every six months
Cage Aquaculture of Finfish	Chemical pollution arising from finfish cages	No chemical pollution of the environment	No measurable chemical pollution in the environment	■ Utilise professional fish health services and/or veterinary expertise to diagnose disease prior to initiating any disease treatment.	Farm management and veterinarian	Incident logging if any chemicals are released to the environment. Annual incident log summary report to

Activity	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/ party	Monitoring and Reporting Frequency
				■ No veterinary therapeutic-products and medicinal premixes for inclusion in fish feeds may be applied to fish unless they are approved for use. ■ Follow manufacturer's/veterinarian's instructions regarding dosage, frequency and duration. ■ Keep a current copy of the veterinarian's written recommendation. ■ Use environmentally-friendly detergents. ■ Ensure all chemicals and drugs are secured to prevent unauthorised use. ■ Dispose of unutilised therapeutic agents and medicines according to conventional hazardous waste disposal practices.		Seychelles Fishing Authority Annually
Cage Aquaculture of Finfish	Entanglement of cetaceans in finfish cage infrastructure	No entanglement of cetaceans	No cetacean entanglement incidents	■ Do not locate ADZs in important cetacean habitats and migration routes. ■ Ensure all mooring lines and nets are highly visual. ■ Keep all lines and nets tight through regular inspections and maintenance. ■ Ensure that mesh size on primary and secondary nets does not exceed 16 cm stretched mesh.	Farm Management	Incident logging if any entanglement events occur. Annual incident log summary report to Seychelles Fishing Authority Annually
Cage Aquaculture of Finfish	Piscivorous marine animals interacting with finfish cage culture operations	Minimal interaction between piscivores and cage fish	Minimal interaction between piscivores and cage fish	■ Install and maintain suitable predator nets (sufficient strength, visibility and mesh size, above and below water line). ■ Install visual deterrents (e.g. tori line type deterrents for birds).	Farm Management	Incident logging interactions with piscivoros animals. Annual incident log summary report to

Activity	Potential impact	Objectives	Performance Criteria	Mitigation measure(s)	Responsible person/ party	Monitoring and Reporting Frequency
				■ Store feed so piscivores cannot access it, and implement efficient feeding strategy. ■ Remove any injured or dead fish from cages promptly. ■ During harvesting of stock, ensure that minimal blood or offal enters the water. ■ Implement mitigation measures as for entanglement impacts (see above). ■ Develop a protocol for dealing with problem piscivores in conjunction with experts and officials (SFA).		Seychelles Fishing Authority Annually.
Cage Aquaculture of Finfish	Impacts on fishing, yachting and recreational vessels	No impact on other vessels and activities	No incidents or activities which impact negatively on other vessels	■ Install navigational markers and lights as required by SAMSA regulations. ■ Include position of ADZs on navigational charts. ■ Ongoing consultation with user groups to keep them informed of the ADZ developments.	Farm management	Incident logging of incidents with other sea users. Annual incident log summary report to Seychelles Fishing Authority Annually.

6.5 Impact Significance Determination

Using the above criteria, the results of the impact significance assessment before and after mitigation, for the construction, operations and decommissioning phase impacts, are presented in Sections 6.5.1 and 6.5.2.

6.5.1 Construction / Implementation Phase

Table 15 below summarises those impacts directly related to the Construction Phase of the proposed project, and provides a significance rating for each impact before and after mitigation. The construction period will be approximately 12 months for the BQAF and R&D facility each respectively. The construction and assembly of the pilot project cages and grow out cages for individual farms will be a couple of weeks at most and may occur at different times as new operators enter the aquaculture sector and begin setting up fish farms.

6.5.2 Operational Phase

Table 16 below summarises those impacts directly related to the Operational Phase of the proposed project, and provides a significance rating for each impact before and after mitigation. The operational period will be a minimum of 25 years, possibly much longer, although it is anticipated that the overall growth of the aquaculture sector and associated operations of fish farms will grow gradually over this period.

6.6 Cumulative Impacts

Table 17 below summarises the cumulative impact identified for the proposed project in Section 6.3.4, and provides a significance rating for each cumulative impact before and after mitigation.

Table 15: Environmental Impact Assessment Matrix for the construction phase of the proposed Seychelles MMP

POTENTIAL ENVIRONMENTAL IMPACT: CONSTRUCTION PHASE	ENVIRONMENTAL SIGNIFICANCE											
	Before mitigation						After mitigation					
	Magnitude	Duration	Scale	Probability	Significance Points	Rating	Magnitude	Duration	Scale	Probability	Significance Points	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	2	2	1	1	5	Low	2	1	1	0	0	Low

Table 16: Environmental Impact Assessment Matrix for the operation phase of the proposed Seychelles MMP

POTENTIAL ENVIRONMENTAL IMPACT: OPERATIONAL PHASE	ENVIRONMENTAL SIGNIFICANCE											
	Before mitigation						After mitigation					
	Magnitude	Duration	Scale	Probability	Significance Points	Rating	Magnitude	Duration	Scale	Probability	Significance Points	Rating
Genetic Contamination	8	5	3	4	64	Moderate	6	5	3	2	28	Low
Disease and parasite transmission to wild fish stocks	10	2	3	5	75	Moderate	8	2	2	3	36	Moderate
Degraded water quality as a result of organic wastes	4	2	2	2	16	Low	4	2	1	1	7	Low
Chemical pollution arising from finfish cages	6	4	2	2	24	Moderate	4	2	1	3	21	Low
Entanglement of cetaceans	2	1	1	2	8	Low	2	1	1	1	4	Low
Interactions with piscivorous marine animals	2	1	1	5	20	Low	2	1	1	2	8	Low
Impacts on fishing, yachting and recreational vessels	2	1	1	4	16	Low	2	1	1	2	8	Low

Table 17: Environmental Impact Assessment Matrix for the cumulative impacts associated with the proposed Seychelles MMP

POTENTIAL ENVIRONMENTAL IMPACT:DECOMMISSION PHASE	ENVIRONMENTAL SIGNIFICANCE											
	Before mitigation						After mitigation					
	Magnitude	Duration	Scale	Probability	Significance Points	Rating	Magnitude	Duration	Scale	Probability	Significance Points	Rating
Farm operations cease	6	3	2	4	44	Moderate	2	2	1	1	5	Low

7.0 CONCLUSIONS

The Seychelles provides an attractive location for cage aquaculture due to the constant tropical environmental conditions, shallow water (20-50m depth) with generally soft/sandy sediments, low average wind and swell regimes, and no cyclones.

The species that have been selected to launch the aquaculture sector, have been selected as a result of being naturally distributed in the Seychelles waters and the fact that the aquaculture production techniques are well established. Furthermore, they are economically viable due to their marketability and price. The technologies and carrying capacities calculated for the MMP ensure that any adverse environmental impacts and diseases are minimised by adopting a precautionary approach. Standards for responsible aquaculture and fish health further ensure that the industry will be operated according to international best practises to ensure sustainability.

The predicted impacts that were evaluated include: genetic contamination of wild stock; disease and parasite transmission to wild fish stocks; organic waste pollution, chemical pollution; entanglement of cetaceans; interactions with piscivorous marine animals and impacts on fishing, yachting and other recreational vessel activity.

Due to the comprehensive Seychelles Mariculture Masterplan process these impacts were anticipated and planned for with appropriate mitigation and management strategies, including the identification of sustainable ADZ sites, the setting of aquaculture production carrying capacities, Aquaculture Standards and Regulations and institutions and government capacity to support industry development.

Only two impacts, imported fish genetic contamination of wild stock and disease and parasite transmission to wild stock, were rated as ‘moderate’ impact without mitigation. All other issues were ranked as ‘low’ impact without and with mitigation.

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APPENDIX A

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APPENDIX B

Aquaculture Species Selection Screening

	Species Pre Screening			
Criteria				
1	Evidence of Aquaculture			
2	Indigenous to Seychelles			
Scientific Name	**English Name**	**Local Seychelles Name**	**Evidence of Aquauculture**	**Indigenous to Seychelles**
Abalistes stellatus	Starry triggerfish	Bours		
Acanthocybium solandri	Wahoo	Wahoo		
Acanthurus bleekeri	Bleekers Surgeonfish	Sirizyen		
Acanthurus xanthoptexus	Yellowtail Surgeonfish	Sirizyen		
Aetobatus narinari	Spotted eagle ray	Lare Sousouri		
Alectis indicus	Indian Threadfin	Karang plim		
Amblygaster sirm	Spotted Sardinella	Lafles		
Anyperodon leucogrammicus	Slender Grouper	Seval Dibwa		
Aphareus rutilans	Red Smalltooth Job	Zob Zonn		
Aprion virescens	Green Jobfish	Zob Gri		
Atherinomorus lacunosus	Hardyhead Silverside Pret	Penba		
Bodianus bilunulatus	Tarry Hogfish	Domeng		
Bodianus macrourus	Black Banded Hogfish	Domeng		
Bolbometopon muricatum	Green Humphead Parrotfish	Filanbaz		
Caesio caerulaureus	Blue and Gold Fusilier	Makro Kannal		
Caesio caeruleus		Makro Ble		
Caesio xanthonotus	Yellowfin Fusilie	Makro Zonn		
Carangoides chrysophrys	Longnose Trevally	Karang Monik		
Carangoides fulvoguttatus	Yellowspotted Trevally	Karang Plat		
Carangoides gymnostethus	Bludger	Karang Balo		
Carangoides malabaricus	Malabar Trevally	Karang Monik		
Caranx ignobilis	Giant Trevally	Karang Ledan		
Caranx melampygus	Bluefin Trevally	Karang Ver		
Caranx sexfasciatus	Bigeye Trevally	Karang Ledan		
Carcharhinus albimarginatus	Silvertip Shark	Reken Waro		
Carcharhinus amblyrhnchos	Grey Reef Shark	Reken Bar		
Carcharhinus brachyurus	Bronze Whaler	Bronze Whaler		
Carcharhinus brevipinna	Spinner Shark	Reken nennen pwent		
Carcharhinus longimanus	Oceanic Whitetip	Reken Kannal		
Carcharhinus melanopterus	Blacktip Reef Shark	Reken Nwanr		
Carcharias milberti	Sand Bar shark	Reken Blan		
Carcharhinus sorrah	Spot Tail shark	Reken nennen pwent		
Carcharias tjujot	White Cheek Shark	Reken nennen pwent		
Cephalopholis argus	Peacock Grouper	Vyey Kwizinyen		
Cephalopholis miniata	Vermilion Seabass	Vyey Zannanan		
Cephalopholis sonnerati	Tomato Hind	Msye Angar		
Chano chanos	Milkfish	Libine		
Cheilio inermis	Cigar wrasse	Pies Madanm		
Chelinus fasciatus	Red Breasted Wrasse	Kalam		
Coryphaena hippurus	Common dolphinfish	Dorad		
Crenimugil crenilabis	Fringelip Mullet	Mile Soter		
Cryptotomus spinidens	Spinytooth parrotfish	Kalam		
Decapterus macarellus	Mackerel Scad	Mawan		
Decapterus macrosoma	Shortfin Scad	Mawan		
Diagramma pictum	Painted Sweetlips	Kaptenn di Por		
Egalatis bipinnulata	Rainbow runner	Galate		
Epinephelus areolatus	Aerolated Grouper	Vyey		
Epinephelus Chlorostigma	Brown Spotted Grouper	Vyey Makonde		
Epinephelus fasciatus	Redbanded Grouper	Madanm Dilo,		
Epinephelus faveatus	Bigspot Grouper	Vyey Sat		
Epinephelus flavocaeruleus	Blue & Yellow Grouper	Vyey Plat		
Epinephelus Lanceolatus	Giant Grouper	Vyey Krab		
Epinephelus fuscoguttatus	Brown Marbled Grouper	Vyey Goni		
Epinephelus morruha	Contour Rockcod	Tioffe		
Epinephelus multinotatus	White Blotched Grouper	Vyey Plat		
Epinephelus malabaricus	Malabar Grouper			
Epinephelus polyphekadion	Marbled Grouper	Vyey Mashata		
Epinephelus tauvina	Greasy grouper			
Epinephelus tukula	Potato Grouper	Vyey Tukula		
Etelis carbunculus	Ruby Snapper	Job la Flamm		
Etelis marshi	Ruby Snapper	Job la Flamm		
Euthynnus affinis	Kawakawa	Bonit Fol		
Galeocerdo cuvieri	Tiger Shark	Reken Demwazel		
Ginglymostoma brevicaudatur	Shorttail Nurse Shark	Landormi		
Ginglymostoma ferrugineum	Tawny Nurse Shark	Landormi		
Gnathanodon speciosus	Golden Trevally	Karang Saser		
Gymnocranius griseus	Grey Large-eye Bream	Sousout		
Gymnocranius robinsoni	Bluelined Large-eye Bream	Kaptenn Blan		
Gymnosarda unicolor	Dog Tooth Tuna	Ton Ledan		
Halichoeres scapularis	Zigzag Sandwrasse	Tanmaren		
Hamantura uarnak	Honeycomb Stingray	Lare boukle		
Herklotsichthys punctatus	Sardine Herring	Sardin Ordiner		
Herklotsichthys quadrimaculat	Blueline herring	Sardin Ordiner		
Hipposcarus harid	Candelamoa Parrotfish	Kakatwa Brino		
Istiophorus platypterus	Sailfish	Sailfish		
Isurus Oxyrinchus	Short fin Mako	Moro		
Katsuwonus pelamis	Skipjack Tuna	Skipjack		
Leptoscarus vaigiensis	Marbled Parrotfish	Marare		

Lethrinus borbonicus	Snubnose Emperor	Toloy		
Lethrinus conchyliatus	Red Axel Emperor	Gel de Ven		
Lethrinus crocineus	Yellowtail Emperor	Laskar		
Lethrinus elongatus	Longface Emperor	Gel long		
Lethrinus enigmaticus	Blackeye Emperor			
Lethrinus harak	Blackspot Emperor	Ziblo		
Lethrinus lentjan	Redspot Emperor	Zekler		
Lethrinus mahsena	Mahsena Emperor	Madanm Beri		
Lethrinus microdon	Small Tooth Emperor	Bek Long		
Lethrinus miniatus	Trumpet Emperor	Poul Kouve		
Lethrinus nebulosus	Spangled Emperor	Kaptenn Rouz		
Lethrinus variegatus	Variegated Emperor	Baksou		
Loxodon macrorhinus	Sliteye Shark	Reken Pisar		
Lutjanus argentimaculatus	Mangrove Red Snapper	Karp		
Lutjanus johnii	Golden /Johns Snapper	Ziebelo		
Lutjanus bengalensis	Bengal Snapper	Madras		
Lutjanus bohar	Twospot Red Snapper	Vara Vara		
Lutjanus coccineus	Humphead Snapper	Bordmar		
Lutjanus fulviflama	Black-Spot Snapper	Ziblo		
Lutjanus gibbus	Humpback Red Snapper	Terez		
Lutjanus kasmira	Bluelined Snapper	Madras		
Lutjanus monostigma	Onespot Snapper	Semiz		
Lutjanus rivulatus	Scribbled Snapper	Bourzwa de Zil		
Lutjanus sebae	Emperor Red Snapper	Bourzwa		
Makaira indica	Black Marlin	Espadron		
Makaira mazara	Blue Marlin	Espadron		
Monodactylus argenteus	Natal Mony	Lime		
Naso hexacanthus	Blacktongue Unicornfish	Korn Blan		
Octopus vulgaris	Octopus	Zourit		
Oedalechilus labiosus	Foldlip Mullet	Mile Laronn		
Ondontaspis tricuspidatus	Sand Tiger Shark			
Paracaesio xanthurus	Yellowtail Blue Snapper	Makro Zonn		
Parupeneus barberinus	Dash and Dot Goatfish	Rouze Tas		
Parupeneus cinnabarinus	Cinnabar Goatfish	Rouze Lokal		
Parupeneus porphyreus	Rosy Goatfish	Rouze Rouz		
Platax orbicularis	Orbicular Batfish	Poul Do		
Plectorhinchus gaterinus	Balckspotted Rubberlip	Kaka Matlo		
Plectorhinchus orientalis	Oriental Sweetlips	Vyey Sesil		
Plectorhinchus schotaf	Minstrel	Marmite		
Plectropomus laevis	Spotted Coral Trout	Vyey Babonn Sesil		
Plectropomus maculatus	Leopard Coral Grouper	Vyey Zannannan		
Plectropomus punctatus	Marbled Coral Grouper	Babonn Fey Koko		
Priacanthus hamrur	Moontail bullseye	Lapo Soulye		
Pristipomoides filamentosus	Bluespotted Jobfish	Batrikan, Kalkal		
Pristipomoides multidens	Striped Jobfish	Sagresyen		
Rhabdosargus sarba	Goldlined sea bream			
Ranina ranina	Spanner crab	Crab Giraf		
Rachycentron canadum	Cobia			
Rastrelliger kanagurta	Indian Mackerel	Makro Dou		
Rhynchobatus djiddensis	Giant Guitarfish	Reken Violon		
Sarda orientalis	Striped Bonito	Brosadan		
Scarus falcipinnis	Sicklefin Parrotfish	Kakatwa Ver		
Scarus ghobban	Yellowscale Parrotfish	Kakatwa Blan		
Scarus rubrioviolaceus	Ember Parrotfish	Kakatwa Rouz		
Scolopsis frenatus	Seychelles Moncle	Batgren		
Selar crumenopthalmus	Bigeye Scad	Makro Gro Lizye		
Seriola rivoliana	Almaco Jack	Somon		
Siganus argenteus	Streamlined Spinefoot	Kordonnyen Soulfanm		
Siganus canaliculatus	Whitespotted Spinefoot	Kordonnyen Brizan		
Siganus corallinus	Bluespotted Spinefoot	Kordonnyen Lafimen		
Siganus stellatus	Brownspotted Spinefoot	Kordonnyen Margrit		
Siganus sutor	Shoemaker Spinefoot	Kordonnyen Blan		
Sphyraena barracuda	Great Barracuda	Tazar		
Sphyraena bleekeri	Sawtooth Barracuda	Bekin Vera		
Sphyraena forsteri	Bigeye Barracuda	Bekin		
Sphyraena jello	Pickhandle Barracuda	Bekin Karo		
Sphyraena obtusata	Obtuse Barracuda	Bekin Gomon		
Sphyrna lewini	Scalloped hammerhead shark	Reken Marto		
Taeniura lymma	Bluespotted Ribbontail ray	Lare Bannann		
Taeniura melanospilos	Blotched Funtail Ray	Lare Brizan		
Trachinotus blochii	Snubnose Pompano	Pampe		
Thunnus albacares	Yellowfin Tuna	Ton Zonn		
Thunnus obesus	Bigeye Tuna	Ton Gro Lizye		
Variola albimarginata	White-edge lyretail Grouper	Gran Queue		
Variola louti	Lyretail Grouper	Krwasan		
Zebrasoma veliferum	Sailfish	Tang Taba		

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