Environmental Impact Assessment Report

Construction and Operation of Maniyafushi Field Station
Maniyafushi, Kaafu Atoll

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Prepared for: Ministry of Fisheries and Agriculture

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Land and Marine Environmental Resource Group Pvt Ltd, Maldives

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Consultants Declaration

I certify that to best of my knowledge the statements made in this Environmental Impact Assessment report for "Construction and Operation of Maniyafushi Field Station" are true, complete and correct.

Name: Hussain Zahir

Consultant Registration Number: EIA P04-2007

Signature:

Company Name: Land and Marine Environmental Resource Group Pvt Ltd

Date: 14th January 2018

Details of consultants participate in preparation of EIA report

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Project description	Hussein Zahir Mariyam Shujaath	P04-2007	
Project setting	Mariyam Shujaath		
Existing Environment	Hussein Zahir Mariyam Shujaath	P04-2007	
Impact, alternatives and Mitigation	Hussein Zahir Mariyam Shujaath	P04-2007	
Stakeholder consultation	Hussein Zahir Mariyam Shujaath	P04-2007	
Monitoring	Hussein Zahir	P04-2007	
Recommendation and Conclusion	Hussein Zahir	P04-2007	

Proponents Declaration

بسم الله الرحمن الرحيم

" ދިވެހިންގެ ކަނޑުތަކުގެ - ދިފާއިގެ ހަގަ "

MARINE RESEARCH CENTRE
Ministry of Fisheries and Agriculture
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ފިޝަރީސް ޕްލޭނިންގ ހިންގާ ދިވެހިރާއްޖެ
ފ - ފިލާވަރިވަށް

Ref: 30-MRC-ADM/203/2018/1

11 January 2018

Ibrahim Naeem
Director General
Environmental Protection Agency
Green Building
Male', Maldives

Subject: Proponents declaration and letter of commitment

Dear Sir,

As proponent of the project "Construction and Operation of Maniyafushi Field Station", we hereby confirm that we have read and understood the report, and to the best of our knowledge all the information with regard to the project description and other non-technical information provided in this EIA report are true.

We also confirm our commitment to execute and cover the cost of environmental mitigation and monitoring measures outlined in the EIA report.

Sincerely,

Shafiya Naeem
Aquatic Pathologist

1 Non-technical Summary

Background

The proposed project is a continuous project implemented by the MRC and executed by MOFA, which will seek funds for its continuation. The project is an extension of an existing mariculture research and development operation, focusing on research and development of mariculture techniques for the brown marbled grouper, milkfish, sandfish and local varieties of sea cucumbers such as the white teatfish. In addition, the project will target on establishing research and capacity for coral reef studies and reef fisheries.

In the immediate term, mariculture research and development capacity will be established to facilitate the establishment and development of a mariculture industry in the country. The project aims at establishing production capacity for approximately 25,000 pieces of fingerling size groupers per production cycle to pilot viability of grow out operations. Further, the project aims at developing research capacity for sea cucumber hatchery technology as well as the production of milkfish.

Key impacts, mitigation measures and alternatives

Impacts on the environment from various activities of the construction work and during the operation of the facility have been identified through interviews with the project management team, field data collection and surveys are also based on past experience of consultant in similar development projects. The impacts identified are also described according to their location, extent and characteristics. Mitigation measures have also been identified for impacts which are irreversible in nature.

Impact analysis was done using the Leopold matrix. Impact analysis showed that impact of highest significance is on seawater quality as majority of the project is established in the lagoon and sea.

The proposed development is expected to bring significant socioeconomic impacts on the locals, especially the island communities as the project will mainly focus on training Atoll communities interested in grouper and sea cucumber farming on a large scale. Since there is a high demand for export business of these two species, it will bring high economic benefits to the local communities. Moreover, it will create many job opportunities especially for the unskilled workers.

Mitigation measures are discussed in the report for potential impacts, including measures to minimize the impacts on seawater quality, such as regular change of water (by 25%) of the closed

hatchery system and avoiding trampling outside project boundary. Detailed mitigation measures are discussed in Section 11 of the report.

Alternatives have been considered for the specific location of the grow-out pens. The ‘no project’ alternative is also considered. If this alternative was to be chosen, this would mean that all negative environmental impacts which would arise due to construction would not be there. However, the ‘no-project’ scenario would take away an opportunity the local communities to explore a highly rewarding economic venture.

1. ހުލާސާ

ތައާރަފު

މި ހުލާސާއިން ދައްކައިދެނީ ވ. ވަނިހަފުރީގައި އެޅުމަށް ހަމަޖެހިފައިވާ ޕާއްމުންނަރު ފުނަ އާއި ވަނޭ އާލާކުރުމުގެ ދަސްކޮށްކަރާ ކޮށް ހަދައިދިނުމުގެ ގޮތުން ހަދާ ޑެރިކަލްވާ ފުސްޖިހު އަށުގެ ކުރިން ބައްޓަރީކޮށްފައިވާ ތިމާވެއްޓަށް އަސަރު ފޯރާން މިންވަރު ބަޔާންކޮށްފައިވާ ރިޕޯޓުގެ ހުލާސާއެވެ. މިޕްރޮޖެކްޓުގެ އެންމެ ބޮޑު ޝަރުތަކަކީ ރަށް ތެރެއަށް ހުރި ކަންކަމާއި ދަރާއިން ބަލައިލަނީ ދިރާސާކުރުމެވެ. އެދި ދިރިއުޅޭ އެއްޗެހި ކުރިމަތިވާ ދަރުސްތަކުގައި ދިޔަ ފަސޭހަކަމާ ވަރަށް ކުރެވިފައި ކުރިއަށް ހިނގަމުންދާ ހުރިހާ ސަބަބުތަކާއި ގުޅޭ ކަންކަމުގެ ތެރެއިން ކުރެވޭ ކަންކަމެވެ. މި ޕްރޮޖެކްޓުގެ ދަށުން މަސައްކަތްކުރާ ކުންފުނީގެ ފެންނަރާ ފީލާ ބަލާފައި ކުރުން ހިމެނެއެވެ.

ތިމާވެއްޓަށް ކޮށްފާނެ އަސަރު، އަދި މިއަސަރު ކުޑަކުރުމަށް އެޅިދާނެ ފިޔަވަޅުތަކާއި ބަދަލުގައި ކުރެވިދާނެ ކަންތައް

މިޕްރޮޖެކްޓުގެ ސަބަބުން ތިމާވެއްޓަށް ކުރާނެ އަސަރުތައް ބޭނުންކުރާ މަސައްކަތުގެ ހަރުކަށިކަމާއި ޖެހިގެން ވަރަށް ބޮޑު ދެރަ އަސަރުތަކެއް ކުރިމަތިވެދާނެއެވެ. މި ބާވަތުގެ އަސަރުތައް ބަލައިލުމުގެ ތެރޭގައި، ޕްރޮޖެކްޓުގެ މަސައްކަތް ނިމުނުއިރު ބަލައިލެވިދާނެއެވެ. މިއާއި ގުޅިގެން ކުރިއަށް ދާ މަސައްކަތްތަކުގެ ތެރޭގައި ކުރާ ހިންގުމަށް ފުރިހަމަ ގޮތެއްގައި ބަލައިލެވިދާނެއެވެ. މިއަދަދުން ރިޕޯޓުގައި އަސަރުކުރާ އަސަރުތަކާއި މަސައްކަތަށް، އަސަރުގެ ކުޑަ/ބޮޑުމިން އަދި އެހެނިހެން ސިފަތަކުގެ މައްޗަށް ބިނާކޮށްގެންނެވެ. އަދި މިއަސަރުތައް ކުޑަކުރުމަށް އެޅިދާނެ ފިޔަވަޅުތައް ބަޔާންކޮށްފައިވާނެއެވެ.

މިޕްރޮޖެކްޓުގެ ސަބަބުން ކޮންމެހެން އަސަރުތައް ކުރިމަތިވާނީ ރަށުގެ ތިމާވެއްޓާ ގުޅުންހުރި ސިފަތަކަށެވެ. މިޕްރޮޖެކްޓުގެ ސަބަބުން ކުރާނެ އެންމެ ބޮޑު އަސަރަކީ ކަނޑުގެ ފަރުގެ ދިރުންތަކަށް ކުރިމަތިވާ ކޮންމެ އަސަރުތަކެވެ. އެއީ ވަނަ އަހަރު ވަރަށް އެތައް ކަހަލަ އެއްޗެހި ދިރިއުޅޭ ކަނޑުގެ ތަރުކީބު އަސަރުކުރާ ކަމުގެ ހަމަ ދިރުންތަކަށް ކުރާ ކަމަށްވާނެއެވެ.

މިޕްރޮޖެކްޓުގެ ސަބަބުން ކުރާނެ ރަގަޅު އަސަރުތަކުގެ ތެރޭގައި އެންމެ ފައިދާ ބޮޑު އަސަރުކޮށްކަމަކީ ފެންނަނީ ދިރިއުޅުމާ ފަސޭހަކަމާއެވެ. އެއީ ވަށައިގެން ބޮޑެތި ދިރުމުގެ ފާހަގަކުރެވޭ ފާރަވެރިކަމެއްގައި ކަންތައް ކުރުމަށް ރާއްޖޭގެ ފުރުސަތު ހުޅުވިގެން ދިއުމެވެ. މީގެ އިތުރުން މީގެ ސަބަބުން ވަޒީފާ ލިބުން ހުރިހާ ފުރުސަތުތަކެއް ލިބިގެންދާނެ އަދި ފަރާތްތަކާއި ވަރަށް ބޮޑު ފުރުސަތުތަކެއް ފަހިވެގެންދާނެއެވެ.

މަޝްރޫޢުގެ ސަބަބުން ކުރާނެ އަސަރުތައް ކުޑަކުރުމަށް އެޅިދާނެ ފިޔަވަޅުތަކެއް މި ރިޕޯޓުގައި ބަޔާންކޮށްފައިވާނެއެވެ. މީގެތެރޭ މިޕްރޮޖެކްޓު ފެށުމަށްފަހު ކުރެވޭ ފެންނަ ކުރާ ހިނގާ އަސަރު ކުޑަކުރުމަށް ހުށަހެޅޭ ފެންގަނޑުގެ 25% ކުރެވޭ

ދުވަހަކުވެސް ބަދަލުވެކުރުން ހިމެނެއެވެ. ތިމާވެއްޓަށް ކުރާ އަސަރު ކުޑަކުރުމުގެ ގޮތުން އެކިދާއިރާ އިތުރު ފިޔަވަޅުތަކެއް ތަފްސީލް މިރިޕޯޓުގެ ސެކްޝަން 11 ގައި ބަޔާންކުރެވިފައިވާނެއެވެ.

މިމަޝްރޫޢުގައި މަސައްކަތް ކުރިއަށް ގެންދިއުމަށް ރޭވިފައިވާ ގޮތުގެ ބަދަލުގައި ކުރެވިދާނެ ކަނޑައެޅުން ތެރޭގައި ބަލާލުމުގައި ވަނީ ފާސް އާއި ވަނީ އާލާކުރާ ކުރިމަތިން ބަދަލުކުރުމަކީ އަނެއް ދިމާވާކަށެވެ.

މަޝްރޫޢު ކުރިއަށް ނުގެންދިއުމުގެ އެއްއަސަރުތަކެވެ. މިގޮތުން ހިޔާރުކުރެވޭނީ މިމަޝްރޫޢުގެ ސަބަބުން ތިމާވެއްޓަށް ކުރާނެ އަސަރުތަކަށް ނުކުރާނެއެވެ. އެހެންނަމަވެސް މިމަޝްރޫޢުގެ ސަބަބުން ލިބޭނެ ފައިދާތައް ބޮޑުވުމުގެ ސަބަބުން މިއީ ކުރުމާ ގޮތެއްކަމުގައި ފެނެއެވެ.

2 Introduction

The livelihood of Maldivians is highly dependent on tuna fisheries. The decline in tuna fisheries in the Maldives, has, over the past years, been affecting the livelihood of many island communities who were highly dependent on the income generated from this industry. To improve the situation, the Government of Maldives has initiated development of aquaculture or mariculture as an alternative source of livelihood which would reduce the pressure on natural stocks of tuna and reef related fishery activities.

Mariculture, however, is a new field in the Maldives and development of mariculture in the country requires transfer of technology from other countries and capacity building in research, biosecurity, aquatic animal health and provision of training and extensive services.

To initiate mariculture development in the country, some pilot activities have been carried out by the Marine Research Centre (MRC) of Ministry of Fisheries and Agriculture (MOFA). These activities include pilot scale half-round pearl culture, grouper culture, ornamental fish culture and seaweed culture. Efforts are being made to commercialize these activities. Currently, sea cucumber (sandfish) culture is being carried out on a commercial scale by the private sector.

To facilitate mariculture development and increase research capacity of MRC in fisheries and coral reef, a field station is being developed on Maniyafushi Island in South Male' Atoll. Currently the station has very limited facilities. With the available facilities some small scale research activities are being carried out in the station. The project "Construction and Operation of Maniyafushi Field Station" will establish the basic facilities of the station, which will improve the research capacities of MRC.

The estimated investment cost of the proposed project is MVR 31,317,925.00 Funding for the infrastructure component of the project will come from the Public Sector Investment Program (PSIP) implemented by the Government, and external sources. Funding for the operational phase research and development activities and mariculture activities is expected from the annual recurrent budget of the government and external sources.

2.1 Purpose of the report and need for the EIA

This document presents the findings of an Environmental Impact Assessment (EIA) for the construction and operation of Maniyafushi field station. Developers of such development projects are required to carry out EIA studies under the Environmental Act of Maldives. The

developer is required to obtain approval of the Environmental Protection Agency (EPA), prior to the implementation of any development activities on the island.

Land and Marine Environmental Resource Group Pvt Ltd won the bid for the project to prepare the EIA and to provide assistance in other environmental related activities. This EIA is prepared in accordance with Environmental Impact Assessment Regulations 2012 and the environmental policy and guidelines of the Government of Maldives.

3 Terms of Reference (ToR)

All development projects that have a socioeconomic environmental relevance and are listed in Appendix Raa of the EIA Regulations 2012 are required to submit an Environmental Impact Assessment report which forms the basis for project approval. As such, projects are required to follow a screening process identifying the environmental impacts associated with the project. Projects which are not listed in the above mentioned Schedule has to follow a screening process, based on which EPA decides whether the project requires the submission of an Initial Environment Evaluation report or an Environmental Monitoring report. Based on the findings of this report, EPA as the regulator makes a decision on whether the specified project further requires the submission of an EIA based on the impacts associated with the project.

In accordance with the regulations of Ministry of Environment and Energy, an EIA application form and project brief was sent stating the nature of the project and likely impacts associated with the environment. The scoping meeting was held at the Environmental Protection Agency (EPA) on the 14th of December 2017 with the project proponent, consultant and EPA officials. Based on the discussions at the meeting, draft TOR which had been submitted was finalized and approved by EPA on the 14th of December 2017 (see Appendix 2).

The EIA report is prepared as per the TOR given by EPA. All efforts have been made to address the requirements identified in the TOR.

4 Project Setting

The project conforms to the requirements of the Environmental Protection and Preservation Act of the Maldives, Law no. 4/93. The EIA has been undertaken in accordance with the EIA Regulation 2012 of the Maldives by a registered consultant. Furthermore, it adheres to the principles underlined in the regulations, action plans, programs and policies of the following Ministries of the Government of Maldives.

- Ministry of Environment and Energy (MEE)
- Ministry of Fisheries and Agriculture (MOFA)

These are discussed in detail in Table 1 below.

Table 1. Legislations pertaining to the project

Legislation	How does current project conform to legislation
Environmental Protection and Preservation Act (Law 4/93)	EIA undertaken as stipulated in the Act, which states that any developmental project which has a potential impact on the environment should have an EIA done prior to commencement of the project. List of such projects are given in the EIA Regulations 2012
Dewatering Regulation (2013/R-1697) – 31st January 2014	The Dewatering Regulation has been formulated to introduce measures so as to minimize impact on the environment and ecosystem due to dewatering which may be carried out as part of construction works or during other works. Any development which requires dewatering as part of the project, can only implement the dewatering phase after obtaining the required approval from the EPA, which is the implementing agency for the regulation. The regulation does not apply to dewatering which may be required for the installation/cleaning of a groundwater well for personal use or use of groundwater for agricultural purposes. Prior to carrying out dewatering the proponent of such projects have to submit an application form to EPA with required documents which are detailed in the regulation and application form. It is also the responsibility of the proponent to inform the relevant councils, if there are residential areas or agricultural lands within 100m radius of the site where dewatering will be carried out. The regulation further details what should be done with the water extracted during dewatering, and what actions should be taken should dewatering impact resource users within 30m radius of the site.

	The regulation further specifies fines which will be applicable if the regulation is not followed. The proposed project will conform to the regulation, by first submitting an application to carry out dewatering within the project site. The proponent will also carry out all the additional measures necessary to obtain the approval for EPA and to abide by the regulation.
Regulation on fuel storage and use (2015/ R-160)	The objective of this regulation is to: • Decrease the number of accidents due to fuel usage and storage and protect the people and their belongings from such incidences • Raise awareness regarding protective measures which should be in place when using/storing fuel • Establish means which would enable all places which sell fuel (currently established and in the future) to do so under proper protective measures The implementing agency for this regulation is the Ministry of Defense and National Security and enforcement of the regulation began on the day the regulation was published in the government gazette (12th August 2015). All current establishments which use and store fuel have to abide by the regulation and existing establishments were given grace periods of 6 months and 1 year to modify their setups so as to meet the criteria outlined in the Regulation. Future establishments should be set up as per the regulation, inclusive of firefighting and safety measures. Operation of new facilities can only commence once its been checked and approved by the implementing agency (MNDF). Existing facilities (at time of implementation of regulation) which had not prior obtained permission from MNDF should also continue their operations after getting the required approval. Appendix 6 of the Regulation states distance which should be left between the bund wall adjacent residential areas (inclusive of road). These distances are based on the capacity of the facility and MWSC fuel tanks have a capacity of 200 tonnes (approximately 6350 gallons) which as per the regulation means that there should be a distance of 15ft between the bund wall of the tank and other residential areas adjacent to the plot. There should

	also be a distance of 5ft between the bund wall and other properties within own plot. The implementing agency has the authority to make inspections at the facilities once every 6 months and this will be done in the presence of the owner of the facility. During such inspections, the implementing authority will advise if any changes have to be brought to the facility. In such instances the facility will be checked again after been given a time period to make this change.
Third National Environment Action Plan (2009 – 2013) (NEAP III)	This guide developed by the Ministry of Housing and Urban Development (MHUD, 2005) classifies islands into 5 different categories. Lh.Naifaru is classified as a Category B island, which includes inhabited islands that are not developed as Urban Centres. It states that the preparation of land use plans for such islands shall be supervised by the relevant government office, in this case, Ministry of Home Affairs, with the advice of Urban Development Department of MHI. When planning these islands, the relevant government office shall seek advice of MHI. The guidelines also refer to a minimum of 20m wide Environmental Protection Zone (EPZ), consisting of vegetation to be provided around the outer periphery of the island between the beach and rest of the island. However, it also states the EPZ's can be excluded from areas where the land use is for harbor frontage or for commercial use.
National Biodiversity Strategy and Action Plan (NBSAP)	The objective of NBSAP was to *"achieve biodiversity conservation and sustainable utilization of biological resources in the Maldives"* by integration of biodiversity conservation into all areas of national planning, policy development and administration (MHAHE, 2002). To achieve this objective, one of the first actions listed is "formulation and adoption of suitable development planning procedures, land use plans and strengthening of the EIA process". The current project conforms to this policy, by carrying out the EIA prior to commencement of the project, so as to minimize impact on the environment and to incorporate ways of environmental monitoring and management during the project works.
Waste Management Regulation (R-58/2013)	This Regulation was gazetted on the 5th of August 2013 and came into effect 6 months from the date, on 5th of February 2014. The main objective of this regulation is to implement the national policy on waste management. Article 8 of the regulation addresses management of hazardous waste, where Section Raa specifies that transport of hazardous waste from one location to

	another should be in a manner where the waste is packed in tightly sealed containers so as to prevent leakage. The Article further specifies that hazardous waste should not be dumped or burnt under any circumstance. Hazardous waste has to be separated and stored separately in a manner which ensures no leakage of waste. As per the regulation, hazardous waste generated during the project will be collected and stored separately and as per the regulation. Transportation will also be as per the Regulation.

5 Project Description

5.1 Project Proponent

The proponent of the proposed project is the Ministry of Fisheries and Agriculture.

5.2 The Project

The proposed project is a continuous project implemented by MRC and executed by MOFA, which will seek funds for its continuation. The project is an extension of an existing mariculture research and development operation, focusing on research and development of mariculture techniques for the brown marbled grouper (*Epinephelus fuscoguttatus*), milkfish (*Chanos chanos*), sandfish (*Holothuria scabra*) and local varieties of sea cucumbers such as the white teatfish (*Holothuria fuscogiva*). In addition, the project will target on establishing research and capacity for coral reef studies and reef fisheries.

In the immediate term, mariculture research and development capacity will be established to facilitate the establishment and development of a mariculture industry in the country. The project aims at establishing production capacity for approximately 25,000 pieces of fingerling size groupers per production cycle to pilot viability of grow out operations. Further, the project aims at developing research capacity for sea cucumber hatchery technology as well as the production of milkfish.

Proposed project has the following components:-

- Mariculture research and demonstration facility;
- Coral reef and fisheries research; and
- Coral reef and fisheries training

Mariculture research and demonstration facility component is highly targeted for the establishment of the mariculture industry in the country. It includes mariculture research and development, training, extension and demonstration. It is the major component of the station. The other two components are more general and addresses the coral reef fishery issues as they arise.

5.2.1 Existing facilities

Maniyafushi is an already established island as a training and demonstration facility for sea cucumber and grouper hatchery facility. Therefore, power generation, RO plant, hatchery,

seawater intake wells, pump stations, water intake and outfall pipelines, hatchery discharge, STP with sewer discharge, mosque, staff headquarters and jetty already exist on the island.

However, extension of some of these facilities are included in the proposed development which include the following:-

- Extension of existing powerhouse,
- Demolish and construct a four storey staff headquarter
- Warehouse/workshop
- Demolish existing mosque and reconstruction
- Road paving

The Land Use Plan (LUP) of Maniyafushi is attached in Appendix 3 of this report.

5.2.2 Construction phase

The construction phase will involve demolition of some of the existing infrastructure and the construction of all infrastructure required to complete the mariculture research and development facility. The infrastructure development will be planned to minimize the cutting down of existing trees.

The scope of this phase include the following:-

a) Demolition of existing staff accommodation building;
b) Construction of a 4-storey staff accommodation building with all necessary support services (195 m^2);
c) Construction of broodstock unit (195 m^2);
    i. Round concrete tanks (121 tons x 2 nos);
    ii. Rectangular concrete tanks (37 tons x 2 nos);
d) Construction of live feed culture unit (198 m^2);
    i. Fiberglass tanks rectangular for algae culture (1.6 tons x 10 nos);
    ii. Fiberglass tanks round for algae culture (0.5 tons x 6 nos);
    iii. Fiberglass tanks round for algae culture (1.5 tons x 4 nos);
    iv. Fiberglass tanks rectangular for rotifer culture (1.6 tons x 4 nos);
    v. Fiberglass tanks round for rotifer culture (0.5 tons x 4 nos);
    vi. Fiberglass tanks for rotifer enrichment (0.6 tons x 5 nos);
    vii. Fiberglass tanks for brine shrimp culture (1.5 tons x 2 nos);
e) Construction of 4-storey laboratory unit (68 m^2);
f) Construction of warehouse (65 m^2);

g) Deployment of square, High Density Polyethylene (HDPE) floating cages for grouper grow-out pilot (8 unit of 8 cages; dimensions: 3m x 3m/cage; with UV protected HDPE cage nets);
h) Deployment of square, HDPE floating cages for milkfish grow-out pilot (1 unit of 8 cages; dimensions: 3m x 3m; with UV protected HDPE cage nets);
i) Deployment of square, HDPE floating cages for grouper broodstock conditioning (2 unit of 3m x 3m cages with UV protected HDPE cage nets); and
j) Deployment of round, HDPE floating cages for milkfish broodstock conditioning (2 unit of 10m diameter cages with UV protected HDPE cage nets);

5.2.3 Operational phase

The operation will involve the following components:-

a) Grouper culture;
    i. Scaling up of an existing pilot research on breeding the brown marbled grouper (*Epinephelus fuscoguttatus*) to obtain a production of approximately 25,000 fingerling-sized animals in the hatchery, and trailing their grow-out in sea cages;
    ii. 22 locally sourced grouper broodstock will be maintained in 3m x 3m x 4m floating cages at a stocking density of 4.3 kgm^{-3}, fed daily and monitored for their health and spawning behavior;
    iii. Grouper broodstock will be fed with dark meat usually discarded from tuna processing factories;
    iv. The broodstock will be monitored for natural breeding in captivity, the cages will be lined just before spawning occurs, in order to catch the fertilized eggs;
    v. In addition, broodstock conditioning in in-land tanks will be tested as a method to achieve a more reliable, regular production;
    vi. Fertilized eggs will be scooped from broodstock cages and transferred to hatchery for incubation;
    vii. Egg incubation stocking density range from 50-100 eggs/liter;
    viii. The hatched larvae are transferred to larval rearing tanks for larval rearing 7 tons tanks are used at an initial stocking density of 20-30 larvae/liter;
    ix. Rotifer (*Brachionus plicatilis*), enriched with mixed microalgae cultures, will be introduced as live food organisms to 3 day old larvae, at a density of 3-5 individuals/ml. The larvae will be fed on rotifers until 28 days post hatch;
    x. Cultures of rotifer will be maintained continuously in the live feed culture units at adequate quantities to feed the first feeding larvae;

xi. The brine shrimp (*Artemia salina*) will be introduced on day 17 post hatch, at a density of 2-3 individuals/ml, and will be continued until the larvae are weaned on to artificial feeds at day 8;
xii. Brine shrimp will be cultured from cysts available off the shelf;
xiii. The larvae will then be introduced to imported, factory made micro pellet feeds, the sizes of which will be gradually increased according to the growth of the animals. The animals will be maintained on pelletized feed until they are transferred to sea cages for grow out production;
xiv. 70-90 day old grouper juveniles will be transferred to sea cages at a density of 150-200 m^{-3} for grow out production to market size;
xv. The stocking density will be reduced to provide adequate space for the animals;
xvi. During grow out, the animals will be fed with an imported, ready-made grow out pallet feed 5-10 mm.

b) Research on sandfish breeding and rearing;
   i. Broodstock obtained from a previous project will be maintained in in-land tanks designed for sandfish spawning;
   ii. Spawning trials will be carried out by providing the animals with a temperature shock to cue the animals starting to spawn;
   iii. The eggs will be scooped out of the broodstock tanks and a stocking density of 300 individuals per liter and fed with the diatom *Chaetoceros calcitrans* cultured on site;
   iv. The hatched larvae will be transferred to larval rearing tanks at a stocking density of 300 individuals per liter and fed with diatom *Chaetoceros calcitrans* cultures on site;
   v. When the larvae start to settle, substrate coated with the benthic diatom *Navicula* sp. will be introduced to the tanks to provide the settling larvae with food, as well as settlement substrate;
   vi. Sandfish larvae will be maintained in hatchery tanks for 60-70 days until they are ready to be transferred to grow out tanks and pens;
   vii. Experiments will be carried out in land based tanks as well as the sea pens to optimize conditions of grow out. These will include experiments on feed (both types and ration sizes) as we as stocking densities to assess the best combinations for optimal growth.

c) Development of breeding technologies for local varieties of sea cucumber;

i. Locally sourced sea cucumber broodstock will be conditioned in in-land tanks as well as in the shallow lagoon area of the island;
ii. Experiments will be carried out to optimize breeding and rearing techniques.

d) Milkfish broodstock conditioning and rearing;
   i. Milkfish broodstock obtained locally will be maintained and conditioned in sea cages. Spawning is expected to occur naturally without any external interventions;
   ii. Fertilized eggs will be incubated in in-land tanks, and the hatched larvae transferred to larval rearing tanks in the hatchery;
   iii. The larvae will be fed on live feeds (microalgae, rotifer and artemia) produced on site during the hatchery phase;
   iv. Milkfish hatchery phase is expected to be completed in 21 days, at which point the animals will be transferred to nursery tanks with adjusted stocking densities;
   v. The nursery phase is expected to take 4-6 weeks until the milkfish fry reach bait-size;
   vi. The fry will be fed on artificial feeds during the nursery phase.

e) Live feed culture and management;
   i. The live feed culture facility will produce the following species on site and at adequate quantities to allow for smooth aquaculture operations:
      i. Microalgae, *Nanochloropsis oculata*
      ii. Microalgae, *Isochrysis galbana*
      iii. Microalgae, *Chaetoceros calcitrans*
      iv. Benthic microalgae, *Navicula* sp.
      v. Microalgae, *Brachionus plicatilis*
      vi. Super small rotifer, *Nanochloropsis oculata*
      vii. Brine shrimp, *Artemia salina* (obtained as cysts, and cultured as and when needed).

f) Power generation;
   i. Diesel power generation will be primarily used, especially at the initial stages of the project.
   ii. The option of solar power generation will be studied, with the aim of integrating solar and diesel power in the future.
g) Training and demonstration;

i. Maniyafushi will be developed as a center that provides training and demonstration on aquaculture techniques, best practices, and aquaculture management.
ii. Training and demonstration works will include sea cucumber and grouper culture training, live feed culture and maintenance targeting the private sector.
iii. The maximum number of trainees at any given time is not expected to exceed 20, and the trainings will be held for a duration of 14 days.

5.3 Need for the Project

The livelihoods of Maldivians have always depended on the country's marine resources. These resources are shared by both fisheries and tourism sectors, the two main pillars of the country's economy. Tuna fishery has been the traditional fishery in the Maldives for years. However, reef fishery has recently become popular due to the demand created by the tourism industry. Today, the key fisheries are pole-and-line skip jack tuna fisheries, hand-line yellowfin tuna fisheries, grouper and other reef fish fisheries and lobster and sea cucumber fisheries.

The tuna fishery, which has traditionally been the main source of livelihood for the people, has declined in recent years. Some reef fisheries such as sea cucumber and grouper fisheries that serve as an additional source of livelihood have also declined, while the market for the living reef resources has widened due to the expansion of tourism in the country.

The declining fisheries have been affecting the livelihood of the island communities. To improve the situation, the government has started to develop marine aquaculture or mariculture in the country, which is seen as an alternative source of livelihood that reduces fishing pressure on natural stocks and contributes to the sustainability of reef related fisheries. However, mariculture is a new field in the Maldives.

5.4 Location and Extent of Site Boundaries

The locations proposed for the new grow-out pens are at the areas where existing grow-out pens are located. The proposed pens are larger than the existing pens. The locations are shown on Figure 1 below.

Figure 1. Sites selected for grow-out pens (image sourced from project brief provided by client)

5.5 Project management

5.5.1 Construction phase and schedule for implementation

The project duration for the construction and establishment of grow-out pens is estimated to last about 10 months. Listed below are the construction phases and detailed work schedule.

Table 2. Work schedule for the proposed project

Activity/Month	1	2	3	4	5	6	7	8	9	10
Preparation of land use plan										
Preparation of architectural drawings										
Refurbishment of hatchery										
Construction of powerhouse										
Preparation of electrical design study										
Construction of new infrastructure										

5.6 Major Inputs and Outputs

5.6.1 Inputs (description of the project in terms of raw materials, processes, equipment and work force)

5.6.1.1 Access to site, mobilization and material unloading

Construction material for the project, such as building material, galvanized iron pipes and nets will be brought to the island on bigger vessels. Materials will be unloaded to the island at the existing jetty. Sea pen construction will be carried out at the areas allocated for construction of the pens.

5.6.1.2 **Construction work**

Project inputs and outputs

Project inputs and source, as well as outputs and management is shown in Table 3.

Table 3. Major inputs required for the proposed project and their outputs

Inputs	Source	Outputs	Management
Cement	• Imported material, contractor may purchase locally or import directly	Building structure and walls	MRC
River sand	• Imported material, contractor may purchase locally or import directly	Building structure and walls	MRC
Aggregate	• Imported material, contractor may purchase locally or import directly	Building structure and walls	MRC
Gypsum board	• Imported material, contractor may purchase locally or import directly	Building ceiling	MRC
Wood	• Imported material, contractor may purchase locally or import directly	Building ceiling	MRC
GI pipes	• Imported material, contractor may purchase locally or import directly	Building ceiling	MRC
Corrugated sheets	• Imported material, contractor may purchase locally or import directly	Building ceiling	MRC

Construction methodology

- Flexy Type Floating Fish Cage

AquaTec Flexy Type Floating Fish Cage is the fourth generation of AquaTec floating fish cage. It is designed to be both strong and elastic to withstand 1.5 m high waves. Made of prime grade High Density Polyethelene (HDPE) with anti-UV. The cylindrical floating device is hydrodynamic, therefore, making the water circulation easier, which helps oxygen circulation and fish growth.

Each of AquaTec Floating Fish Cage components can be assembled and dismantled easily with simple tools. The connections between floating device and floating device joint use Stainless Steel grade 304 bolt equipped with ring and nylon lock nut.

Since the pens are proposed to be constructed in deeper areas of the lagoon, dredging of the lagoon for deepening will not be required.

Floating Device

The function is to use as a place where fish farming activity takes place. The cylindrical floating device is hydrodynamic, therefore making the water circulation easier, which helps oxygen circulation. The side wall thickness is 10-12 mm with a gross buoyancy of 100 kg/m in sea water. Both ends of the floating device are sealed with double waterproof layer. There are walking tracks with anti-slip patterns above the floating device. The walking tracks are fused to floating device.

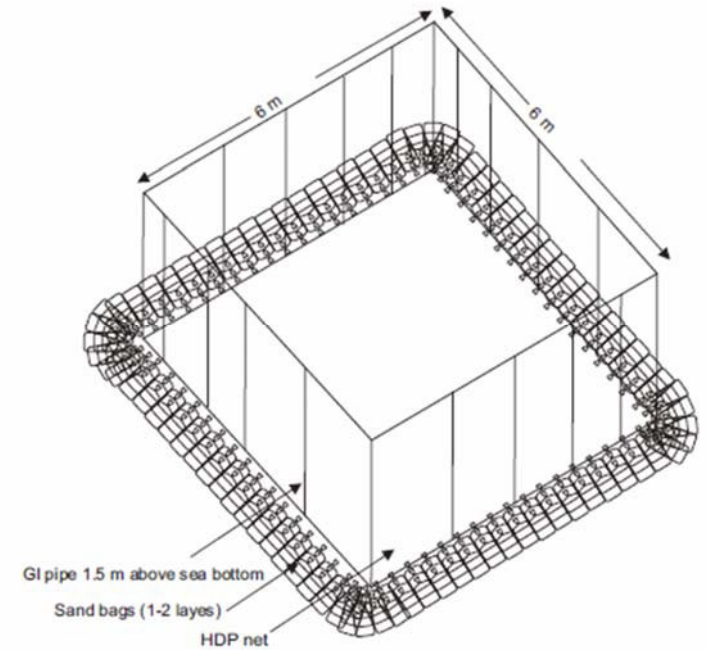

Figure 2. Proposed design of the sea cucumber grow-out pen

Sand for the filling of sandbags at the bottom of sea cucumber grow-out pens will sourced from local sand miners operating in Male'. The amount of sand will be minimal as only small scale experiments will be carried when the need arises.

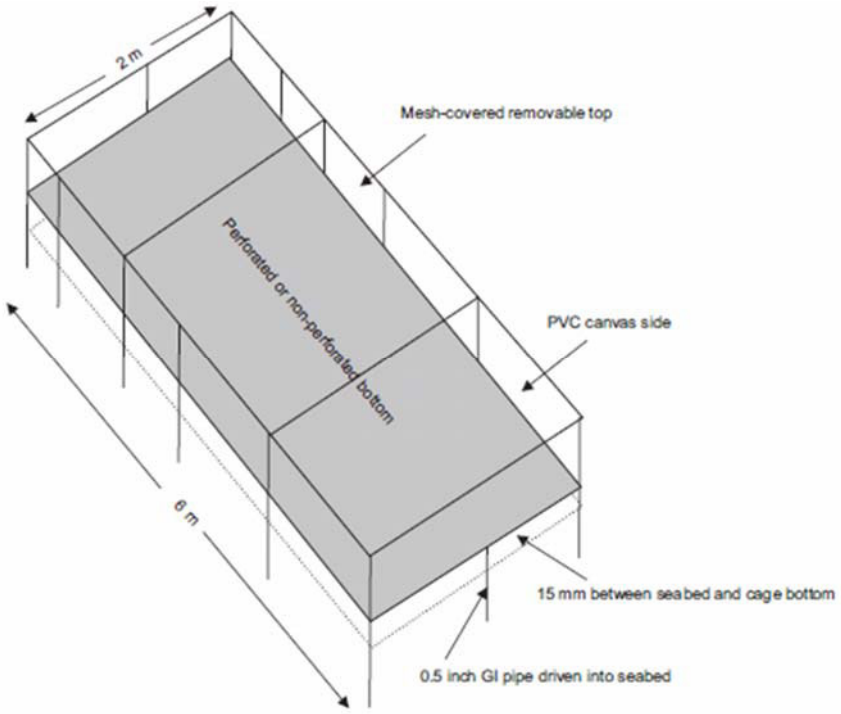

Figure 3. Off-bottom sea cucumber grow-out cage

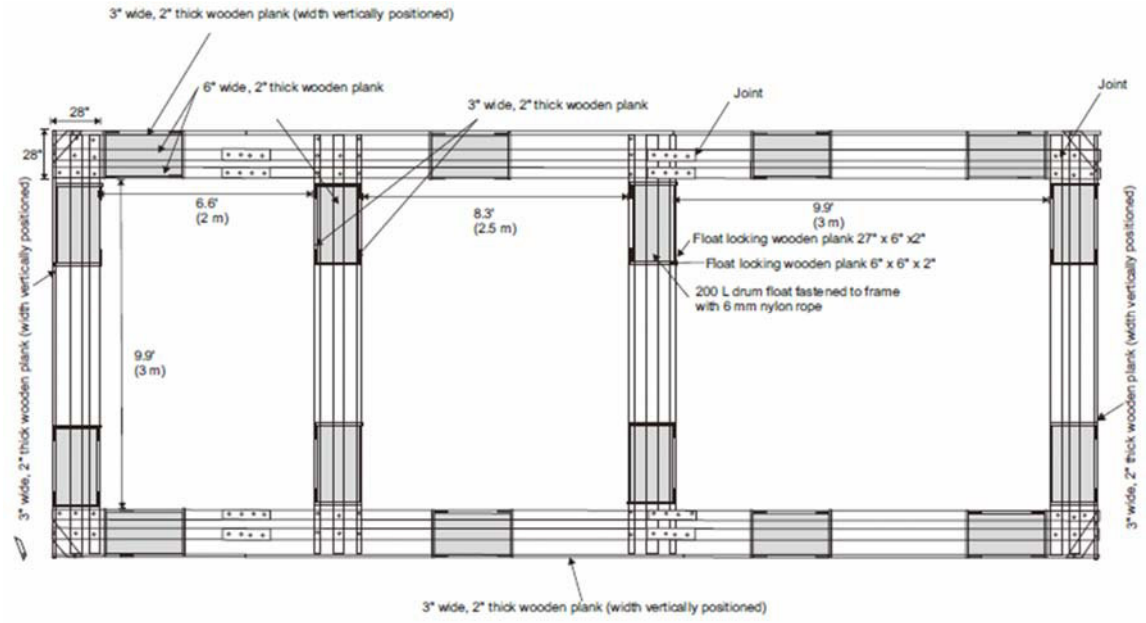

Figure 4. Top view of grouper cage

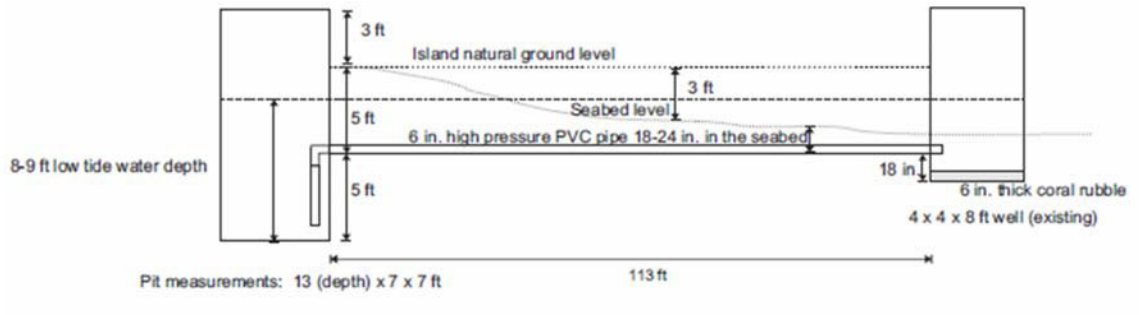

Figure 5. Sea water intake system

- Building construction

Conventional civil construction methods employed in Maldives will be used to construct the buildings and concrete tanks; concrete foundations, columns, beams and sheets, masonry walls, wall plastered. Building sizes of the facilities to be built under this project are provided on Table 4 below. Mobile concrete machine will be used for concrete mixing, only a limited heavy machinery will be mobilized due to small scale of the project. Water for construction will be sourced from existing RO plant on the island (groundwater is too saline for construction use).

Table 4. Building sizes of the facilities to be constructed under this project

Building	**No. of storeys**
Broodstock holding facility	Single
Live feed culture facility (FL area: 7.75 x 13.4 m = 104 m^2)	Single
Laboratory	Four
Hatchery/nursery	Single
Trainee/staff quarters	Four
Warehouse	Single
Powerhouse	Single

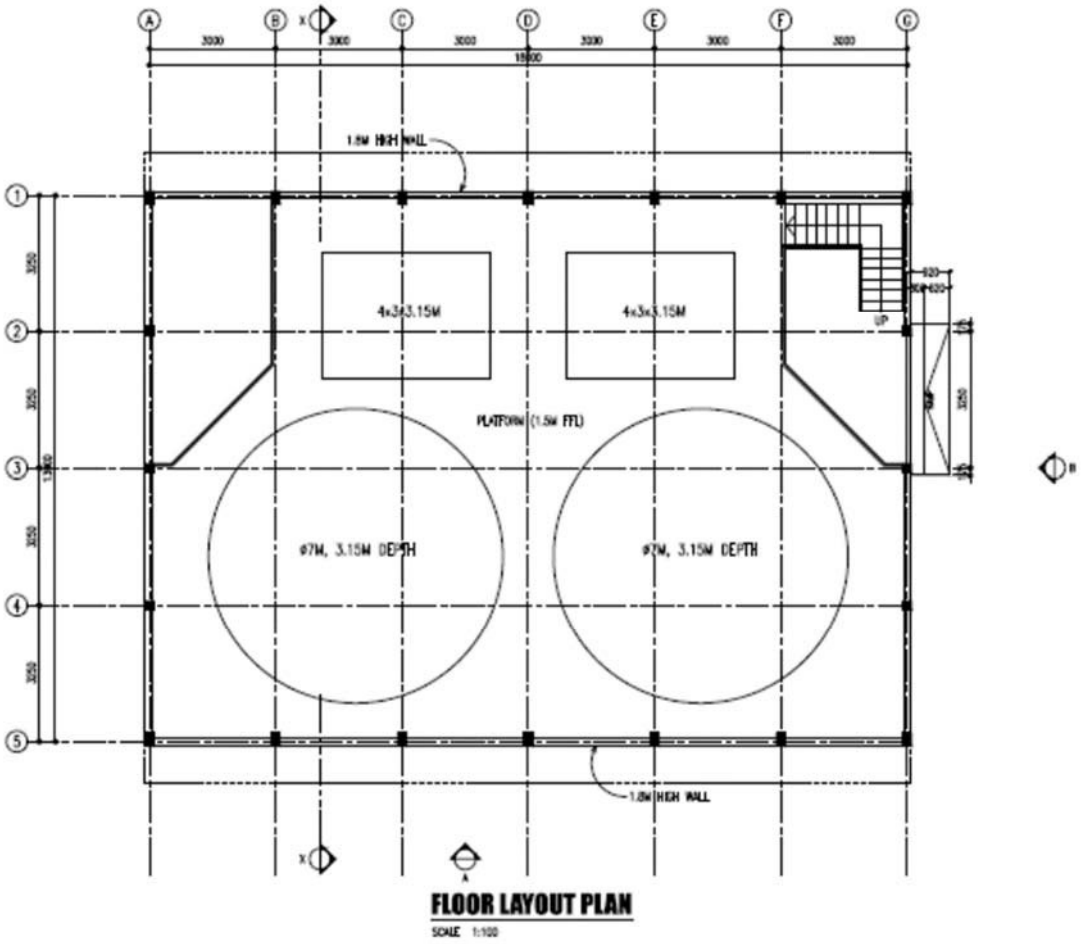

Figure 6. Floor layout plan of broodstock holding facility

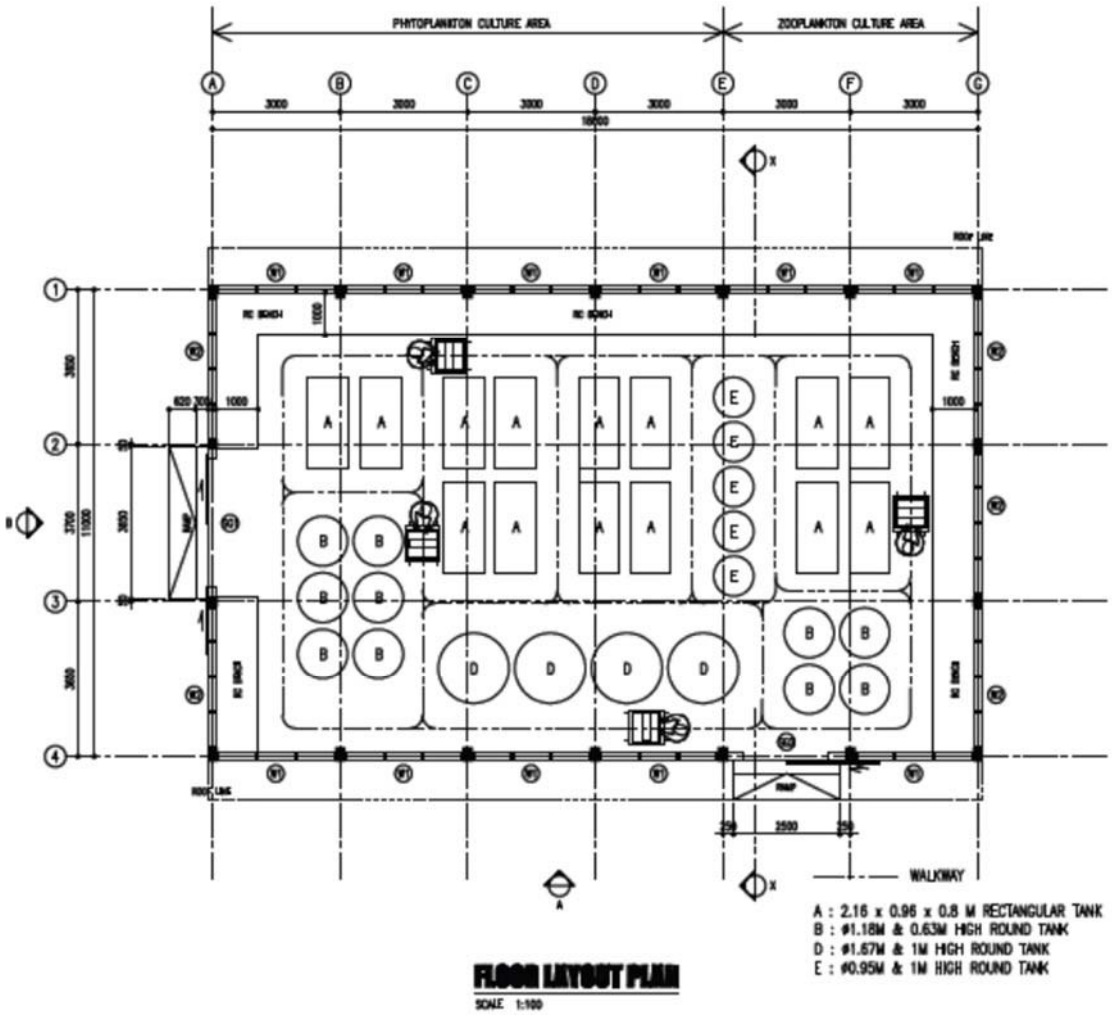

Figure 7. Floor layout plan of algae culture greenhouse

- Training

The main purpose of the facility is conduct demonstration activities for mariculture projects, providing training opportunities to Maldivians who are eager to engage in mariculture work.

In addition to the training programs, the facility will also produce fingerlings for prospective local farmers. Grouper and sand fish fingerlings will be reared at the facility.

5.6.1.3 **Workforce and temporary facilities**

The exact size of workforce, workers and their origin will be decided by the contractor. An estimate is provided in Table 5 based on the scale of the work needed for the construction of the field station. Temporary accommodation facilities will be made on land not used for

construction to station the workforce required for the project. Utilities will be provided by existing facilities on the island.

Table 5. Estimated workforce required for the project

Designation	Numbers
Project manager	1
Works manager	1
Project administrator	1
QA/QC/HSES officer	1
Dredging superintendent	0
Chief surveyor	1
Project engineer	1
Laborers: Mobilization and site preparation	10
Construction	40
Site cleanup	10

5.6.2 Power generation facility

Under the proposed project, the power generation facility will be upgraded as the existing electric power system is insufficient for its full operation as well as for the planned upgrading works. The load forecasts for staff accommodation and hatchery and other such infrastructure areas are developed for 10 years but for street light and lighting for public spaces are considered constant.

With the commissioning of the upgraded power system, reliable and cost effective power will be delivered throughout the day. Generating capacity of the power station would be further upgraded only on demand. With this strategy, the consumers on the island will benefit from low cost and reliable power for their consumption.

This project, if implemented as planned, will consolidate the infrastructure of the island and is an important means for developing K. Maniyafushi further. Stable, reliable and cost-effective electricity to this island will improve the life span of the general electrical appliance and as well as the most expensive machineries used in the island.

- Generator set sizing and main control panel board

For continuous operation of power system, minimum four generator sets, with total capacity of 97kW (1x35kW, 1x28kW, 2x17kW) shall be installed. The power house and control panel shall be large enough to accommodate the diesel generator sets sizes for the 10 year period. The panel board is a synchronizing panel board with automatic load sharing for two generator sets.

- Voltage drop

Main distribution cables are selected to limit the voltage drop to maximum 5% for the 10 year period and up to 2% for the consumer cables. Existing consumer and road light cables shall be used where possible and make joints where necessary to connect new/ existing distribution boxes.

- Powerhouse building

Existing power house is insufficient for the installation of additional generators and control panel thus a new powerhouse building is designed and constructed. The new powerhouse will be equipped with sound attenuators and rockwool insulated roofs to minimize noise. Refer to Appendix 4 for basic design of a new power house and distribution map.

- Fuel tank

A fuel storage tank with a capacity of 3,600 liters shall be constructed within the powerhouse premises. Refer to Appendix 5 for fuel tank and fuel line designs.

- Fire system and lightening protection

Fire extinguishers shall be installed at suitable locations of the powerhouse and in the premises. A fire alarm system with smoke and heat detectors shall be installed within the powerhouse.

The powerhouse will be facilitated with lightning protection terminals. Refer to Appendix 6 for lightning protection layout.

- Power distribution network

New power distribution network will be laid as part of proposed project. Trenching works will be done manually since the island is very small and buildings are closely stacked together. Cables will be laid 600mm below ground level. No dewatering will be required for the cable laying works.

5.6.3 Waste management

An area is designated as a waste yard where waste will be sorted and safely stored prior to transportation to Thilafushi for final disposal. The proposed site is indicated on the LUP given in Appendix 3 of this report. Waste will be transported to Thilafushi once a month.

5.6.4 Wastewater

Grey and black water from toilets and kitchen is connected to a septic tank (three chambers septic tank), the effluent is disposed at the northern side lagoon (existing system). Since the estimated population of the island is very small even at peak capacity (staff and trainees during training programs), sewage treatment is not necessary. The effluent disposal pipe line does not meet the wastewater disposal regulation; hence mitigation is provided for this component.

5.6.5 Safety measures during construction and operation

The safety measures to be followed during construction and operation phase of the project are outlined in Environmental and Social Management Plan (ESMP) attached in Appendix 7 of this report.

5.6.6 Outputs

Key outputs of the project include:

- sea-cucumber and grouper grow-out pens,
- research facilities including laboratory
- accommodation facilities and;
- upgraded powerhouse and power distribution network.

Secondary outputs as a result of the operation of the facility include venue for conducting mariculture related training for development of mariculture industry in the country and produce fingerling for prospective maricultural projects (mariculture development projects carried out by Ministry of Fisheries and Agriculture).

6 Methodology

The approach to data collection and compilation of this report includes;

- Consultation and discussion with the proponent with regard to design and work methodology that would be used to implement the proposed activities of the project,
- Examination of the existing environment to identify significant environmental components that are likely to be affected,
- Consultation with major stakeholders to exchange information on the project and to follow the EIA procedures required for the report, and
- Evaluation of available and relevant literature on environmental impacts associated with similar projects.

Information on existing environment was collected during the field visit to the project site in December 2017. General information on the existing environment was based on available secondary data, such as climatic data from the meteorological center at Hulhumale' Airport.

6.1 Physical surveys

6.1.1 Marine Environment

Figure 8. Sampling locations of marine environment and groundwater quality

Table 6. GPS Coordinates of marine and groundwater sampling locations

Name (sampling sites)	Latitude	Longitude
S1 (Marine survey)	4° 3'17.84"N	73°24'34.63"E
S2 (Marine survey)	4° 3'25.36"N	73°24'23.85"E
S3 (Marine survey)	4° 3'27.14"N	73°24'42.20"E
GW (Groundwater)	4° 3'20.34"N	73°24'39.65"E

6.1.2 Shoreline survey

Shoreline survey was carried out using Trimble Geo explorer 7 system; high tide, low tide, vegetation line and erosion line was mapped.

6.1.3 Bathymetric survey

Bathymetric survey of project area was carried out using Ohmex Sonarmite Echo sounder combined with Trimble Geo explorer 7 GPS system. The depth reading data collected was reduced to MSL using predicted tide data for Hulhule.

6.2 Water quality analysis

Samples for sea water quality were collected at the same locations surveyed for the reef environment analysis (Figure 8 and Table 6). General parameters were tested in situ using a Hanna multi probe water test meter (HI 9828) and the rest tested at MWSC Water Quality Assurance Laboratory.

Groundwater sample was collected from a well located at the project area (Figure 8 and Table 6) and tested in-situ using Hanna multi probe water test meter (HI 9828).

7 Existing environment

7.1 Geographic location of Maniyafushi

Maniyafushi is located at South Male' on the western side approximately 3.4km from the western peripheral reef. The island lies at coordinates of N 04° 03'21.05", E 73°24'39.54", approximately 15.9km south west of Capital Male' City. Nearest resort or island to Maniyafushi is Jumeirah Vittaveli Maldives (Bolifushi) located on the northwestern side approximately 4.3km away (see Figure 9).

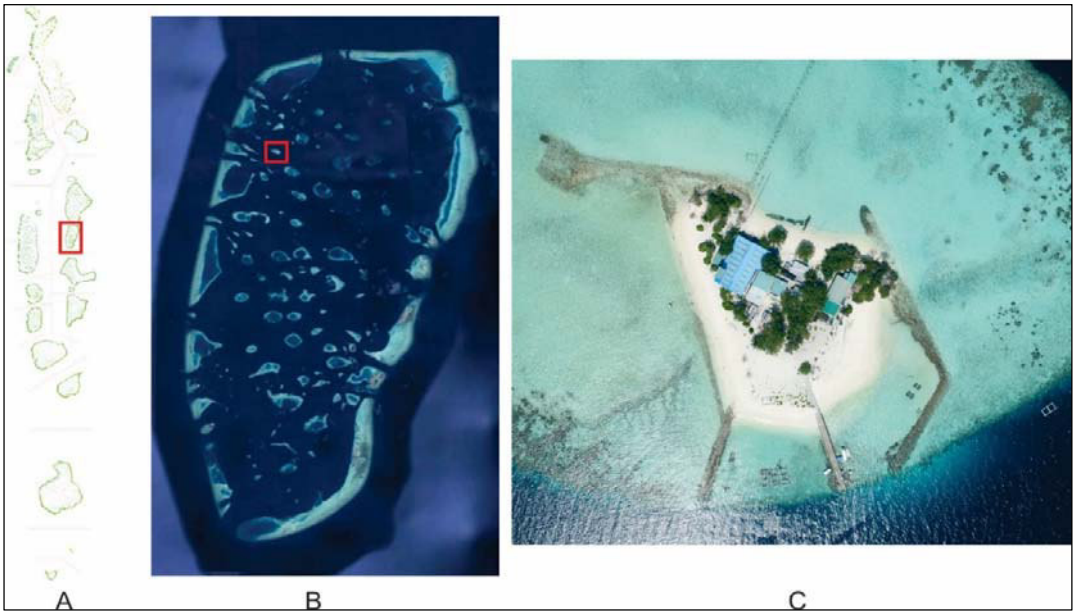

Figure 9. Location of South Male Atoll in Maldives archipelago (A), location of the Maniyafushi at South Male Atoll (B) and Drone image of Maniyafushi (C)

7.2 Geology and geomorphology

Earliest aerial image available of Maniyafushi is from 1969. The image shows the island is very small with distinct extending northwest and southwestwards, while the island is very narrow and elongated oriented northwest to south east wards. Aerial images taken during 1999 by Government of Maldives (Construction Ministry) shows the island has undergone significant coastal modifications. These include several coral rock breakwaters/revetments and small-scale reclamation. At present most of these breakwaters/revetments are gone with only low remnants remaining, a new access jetty is constructed by Marine Research Centre at old access jetty/rock mound. Beach rock formations are not observed, while erosion is observed at the northern and north eastern side of the island (mainly due to poor condition of the revetment structures).

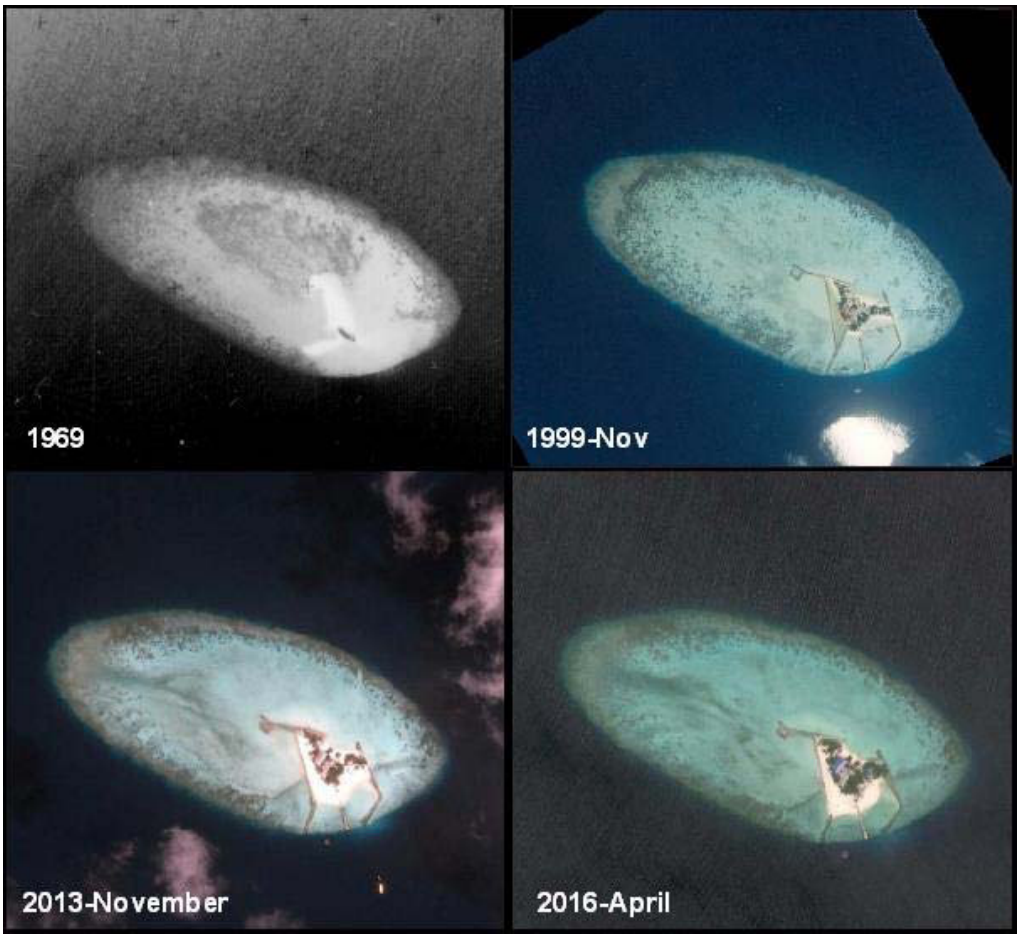

Figure 10. Aerial and satellite images of Maniyafushi showing changes to the shoreline and island over the years

7.2.1 Shoreline and vegetation

The island is largely reclaimed, with mostly replanted vegetation. Vegetation on the island are mostly Sea Hibiscus and Sea lettuce, and Coconut palms (11 Coconut palms). The island is void of proper vegetation buffer since it is largely reclaimed island. The high tide line at some areas are very close to building footprint (Hatchery south west corner).

Table 7. Summary of shoreline survey (taken from Land Area Registration Survey Report provided by Marine Research Centre)

Shoreline category	Perimeter (m)	Area (sqm)	Area under MSL (sqm) (average area under HWL and LWL)
High Water line	4,334	313,342	333,447
Low Water line	4,650	353,551	
Vegetation line	5,137	267,399	
Reef line	1,940	241,301	

Figure 11. Drone image showing beach on the southeastern side of the island

Figure 12. Erosion prone areas observed at the island

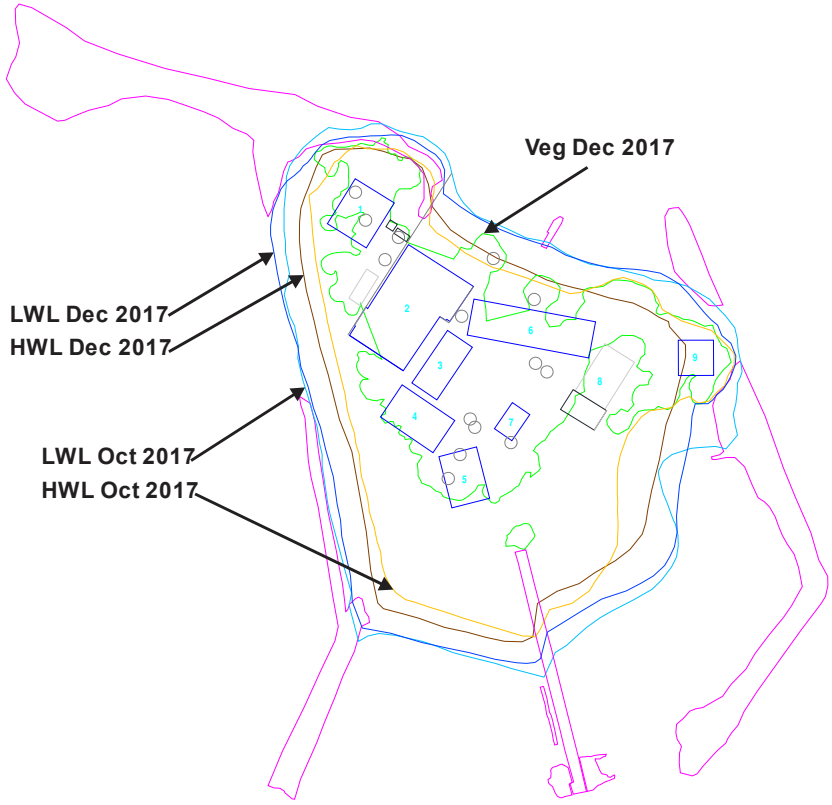

Figure 13. Schematic showing Low Water Line (LWL), High Water Line (HWL) and Vegetation line (Veg) at Maniyafushi taken during survey for Land Area Registration and for EIA data collection (larger scaled drawing is provided in Appendix 8)

7.3 Bathymetric survey

Bathymetric survey at Maniyafushi reef was done at project area (eastern segment of the reef including reef slope. The bathymetric survey shows that lagoon area at the southern side of the island is on average -1.4m MSL while the northern side is -1.6m MSL. The lagoon area where shallow pens are located has an average depth of -1.6m MSL. The deep water pen or cage location is near reef slope with a gradual reef slope (see Appendix 9 for bathymetric survey map).

7.4 Climate

7.4.1 Wind Climate

Wind climate in the Maldives is dominated by the Indian Ocean monsoon climate, with the South West (SW) monsoon and North East (NE) monsoon. The Indian monsoon system is one of the major climate systems of the world, impacting large portions of both Africa and Asia (Overpeck et, al., 1996). The monsoon climate is driven by the atmospheric pressure

differences that arise as a result of rapid warming or cooling of the Tibetan Plateau relative to the Indian Ocean. During the summer of northern hemisphere the Tibetan Plateau warms rapidly relative to the Indian Ocean which results in an atmospheric pressure gradient (Low pressure over Asia and high pressure over the Indian Ocean) between the Asian landmass and the Indian ocean, which drives the prevailing wind from south to westerly directions. The period during which prevailing winds are from south to westerly direction is known as the SW monsoon. In the winter of northern hemisphere the continent cools relative to the ocean. This reverses the pressure gradient (low pressure over the Indian Ocean high pressure over the Asian landmass) and the prevailing winds become northeasterly. The period during which prevailing winds are from northeasterly directions is known as NE monsoon. The transitions from NE to SW monsoon and vice versa are distinctly different from SW or NE monsoon. During these transition periods the wind becomes more variable.

The SW monsoon lasts between May and September while the NE monsoon lasts between December and February. The period between March and April is the transition period from the NE monsoon to SW monsoon known locally as the *Hulhangu Halha*, while the transition period from SW monsoon to NE monsoon is known as *Iruvai Halha*. *Iruvai halha* lasts from October to November (Table 8). The SW monsoon is generally rough and wetter than the NE monsoon. Storms and gales are infrequent in this part of the world and cyclones do not reach as far south as the Maldivian archipelago (Ministry of Construction and Public Works, 1999).

Table 8. The four seasons experienced in the Maldives

Season	**Month**
NE-Monsoon	December
	January
	February
Transition Period 1	March
	April
SW-Monsoon	May
	June
	July
	August
	September
Transition Period 2	October
	November

Since there were no site-specific wind data, wind regime around the island was assumed to be similar to that at the closest meteorological station, which is at K. Hulhule, approximately 20 km North of Maniyafushi. An analysis of the wind climate was done using hourly wind data

between the periods of May 2008 to December 2015 from the Hulhule meteorological station. In this analysis, wind rose diagram based on wind speed and direction and the frequency of speeds and direction was produced.

Wind rose plot (Figure 14) shows that winds from the western quadrant are dominant reaching speeds as high as 30 knots. Winds from the northern and eastern quadrant are less prevalent and with comparatively low speeds. Wind speeds above 18 knots were found to be a rare occurrence, and the instances when it does occur, wind direction was from the western quadrant (Table 9), thus indicating that this was during the SW monsoon, when winds are generally stronger.

Table 9. Hourly wind data from Hulhule Meteorological station

				Wind Speed (Knots)															
Wind Direction		Freq	Cum. Freq.	>0 - 2	>2 - 4	>4 - 6	>6 - 8	>8 - 10	>10 - 12	>12 - 14	>14 - 16	>16 - 18	>18 - 20	>20 - 22	>22 - 24	>24 - 26	>26 - 28	>28 - 30
22.5	NNE	3.9%	3.9%	0.005%	2.784%	0.964%	0.119%	0.020%	0.005%	0.008%								
45	NE	3.8%	7.7%		0.961%	1.777%	0.821%	0.211%	0.033%	0.015%	0.005%	0.003%						
67.5	ENE	5.1%	12.8%		0.882%	2.339%	1.111%	0.486%	0.191%	0.074%	0.015%	0.005%						
90	E	5.1%	17.9%		1.154%	2.146%	0.905%	0.511%	0.211%	0.104%	0.018%	0.003%						
112.5	ESE	1.1%	19.0%		0.501%	0.534%	0.069%	0.013%										
135	SE	1.0%	20.0%		0.440%	0.422%	0.086%	0.036%		0.003%	0.003%							
157.5	SSE	0.8%	20.8%		0.285%	0.346%	0.114%	0.041%	0.020%	0.003%								
180	S	1.1%	21.9%		0.338%	0.460%	0.168%	0.066%	0.028%	0.005%			0.003%					
202.5	SSW	2.2%	24.1%		0.702%	0.913%	0.358%	0.163%	0.064%	0.013%	0.005%							
225	SW	4.1%	28.2%		0.519%	1.312%	0.994%	0.661%	0.297%	0.226%	0.051%	0.010%	0.005%					
247.5	WSW	10.9%	39.0%		1.147%	3.216%	2.278%	1.996%	1.200%	0.653%	0.264%	0.074%	0.036%	0.005%	0.005%			
270	W	25.2%	64.2%		2.464%	6.349%	5.133%	4.884%	3.165%	2.153%	0.572%	0.211%	0.117%	0.043%	0.041%	0.013%	0.008%	0.003%
292.5	WNW	15.3%	79.5%		2.087%	4.131%	3.351%	2.520%	1.599%	1.078%	0.249%	0.117%	0.066%	0.033%	0.025%	0.008%	0.008%	0.003%
315	NW	9.2%	88.7%		2.174%	3.882%	1.775%	0.859%	0.305%	0.153%	0.046%	0.028%	0.008%	0.003%				
337.5	NNW	5.6%	94.3%		1.752%	2.771%	0.658%	0.287%	0.107%	0.043%	0.005%	0.013%						
360	N	5.7%	100.0%		2.303%	2.733%	0.481%	0.114%	0.023%	0.013%								
Cumulative %				0.005%	20.49%	34.30%	18.42%	12.87%	7.249%	4.543%	1.233%	0.463%	0.234%	0.084%	0.071%	0.020%	0.015%	0.005%

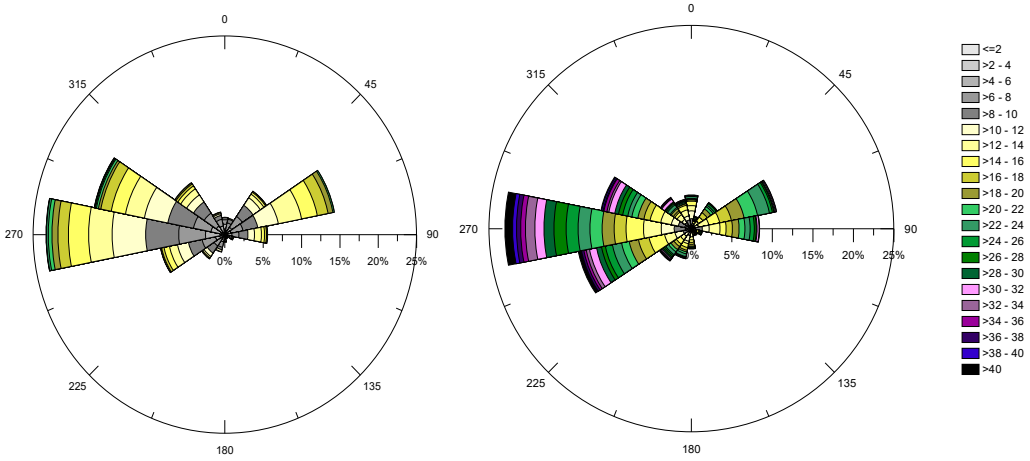

Figure 14. Wind rose plot for Hulhule' Meteorological station, based on mean daily wind data for the period of January 1998 to December 2015 (left) and maximum daily wind data (right) for the period of January 2008 to December 2015.

With regards to mean wind speeds per month, results from this analysis were contradicting with the traditionally defined monsoonal months. It is evident from Figure 14 that the SW monsoon lasts from April to October whereas it is traditionally defined that the SW monsoon of the Maldives commences in May and ends in September and the months March to April and October to November are transition periods. But clearly, during April, transition from NE to SW monsoon had already occurred as the winds were predominantly coming from the west, and NE winds were almost zero to negligible. Likewise, in October, the transition from SW to NE has not commenced yet as the winds was not only predominantly coming from the westerly direction but also at a strong speed. March and November can, however, be taken as the transition periods (Table 10).

Table 10.The traditionally defined seasons experienced in Maldives compared with the current analysis of seasonal winds per month

<table>
<tr><th>Month</th><th>Traditionally defined seasons</th><th>Seasons as per our analysis</th></tr>
<tr><td>December</td><td rowspan="3">NE monsoon</td><td rowspan="3">NE monsoon</td></tr>
<tr><td>January</td></tr>
<tr><td>February</td></tr>
<tr><td>March</td><td rowspan="2">Transition period 1</td><td>Transition period 1</td></tr>
<tr><td>April</td><td rowspan="6">Winds predominantly from the west</td></tr>
<tr><td>May</td><td rowspan="4">SW monsoon</td></tr>
<tr><td>June</td></tr>
<tr><td>July</td></tr>
<tr><td>September</td></tr>
<tr><td>October</td><td rowspan="2">Transition period 2</td></tr>
<tr><td>November</td><td>Transition period 2</td></tr>
</table>

Additionally, during the SW monsoon, winds are known to occur dominantly from the SW direction, however the results indicate that the strongest and most dominant winds occur from the west and the second most dominant frequency fluctuates between WSW and WNW directions. As for the NE monsoon, winds predominantly occur form the NE direction, agreeing with the traditional definition (Figure 15).

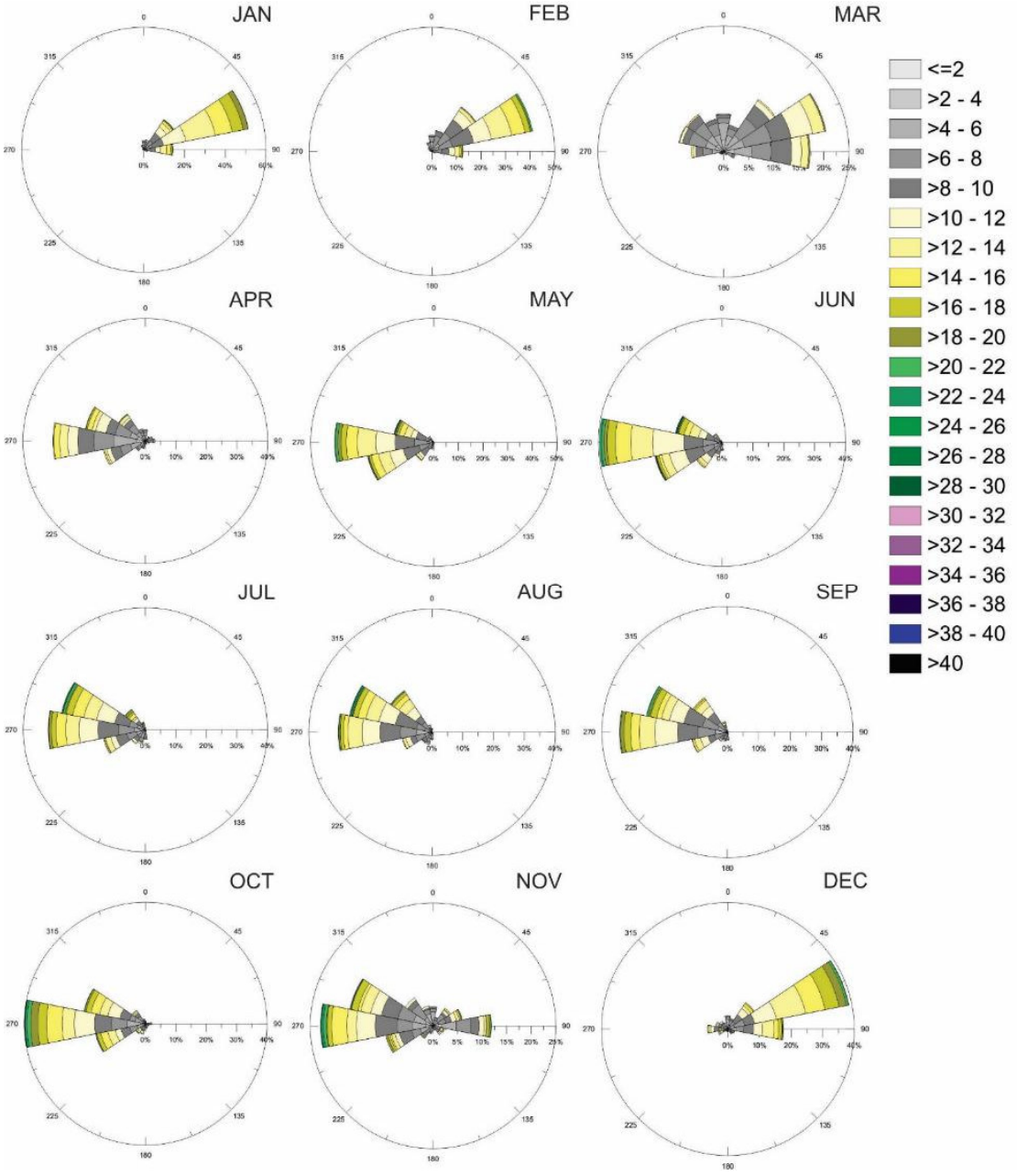

Figure 15. Monthly wind rose plots for Hulhule' Meteorological station, based on mean daily wind data for the period of January 1998 to December 2015

With reference to monthly maximum wind speeds, unlike the mean monthly winds speeds, only one transition period was observed from the wind rose analysis. A wind direction change abruptly from NE to W on April and a clear transition period from W to NE monsoon is observed in November which extends to December as well. The highest maximum wind speeds occur during July and January to March are generally the calmer months (Figure 16).

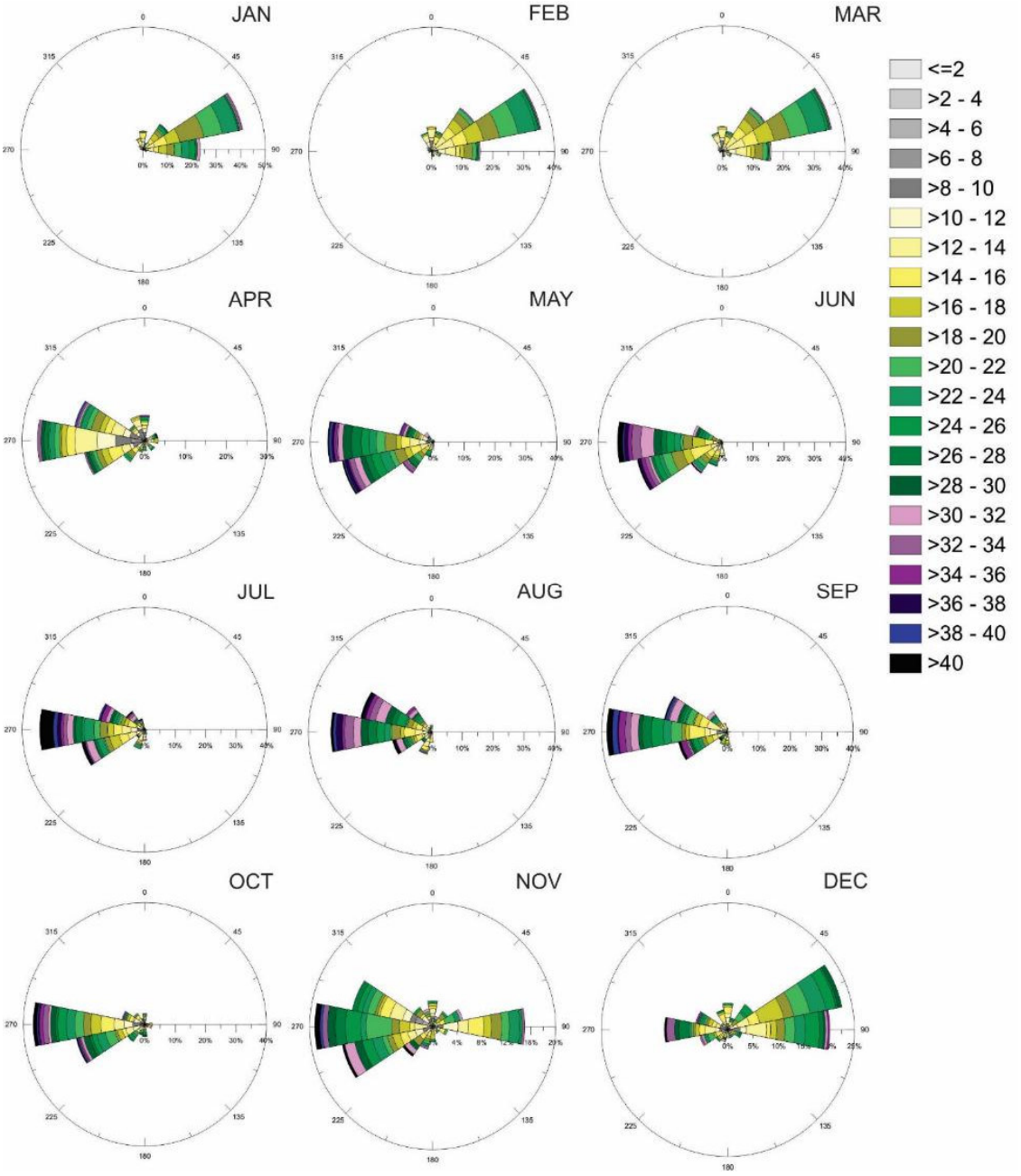

Figure 16. Monthly wind rose plots for Hulhule' Meteorological station, based on maximum daily wind data for the period of January 2008 to December 2015

7.4.2 Tide

Tides experienced in the Maldives are mixed semi-diurnal and diurnal with a strong diurnal inequality. A tide station at Ibrahim Nasir International Airport has continuous records of tide for over the past 30 years. The maximum tidal range recorded at this tide station is 1.20m. The

highest astronomical tide level is +0.64m (MSL) and the lowest astronomical tide level is -0.56m (MSL) (Table 11).

Table 11. Summary of tide level at Ibrahim Nasir International Airport, Male Atoll

Tide level	Water level referred to Mean Sea Level (MSL) (m)
Highest Astronomical Tide (HAT)	+0.64
Mean Higher High Water (MHHW)	+0.34
Mean Lower High Water (MLHW)	+0.14
Mean Sea Level (MSL)	0.0
Mean Higher Low Water (MHLW)	-0.16
Mean Lower Low Water (MLLW)	-0.36
Lowest Astronomical Tide (LAT)	-0.56

7.4.3 Wave and Current

Information on the deep water waves for Maldives is limited (Kench and Brander, 2006), but wave climate data for the Indian Ocean region surrounding the Maldives reported by Young (1999) indicate that the dominant swell approaches the Maldives from southerly quarters. Young (1999) reported that on a seasonal basis, swell reaching Maldives is from the south-southwest from April to November with a peak significant wave height (Hs) of 1.8 m in July, and from the southeast from December to March with a minimum mean Hs of 0.75 m in March.

General wave and current pattern around the Maniyafushi reef is assessed using available wind data. The dominant wind direction during NE monsoon for Male' atoll is from the eastern quadrant and from the western quadrant during the SW monsoon. The reef system also receives refracted swell waves from western and southern side (lesser extent). The main hydrodynamic factors affecting the currents at Maniyafushi reef system are wind wave induced currents and tidal currents (Figure 17).

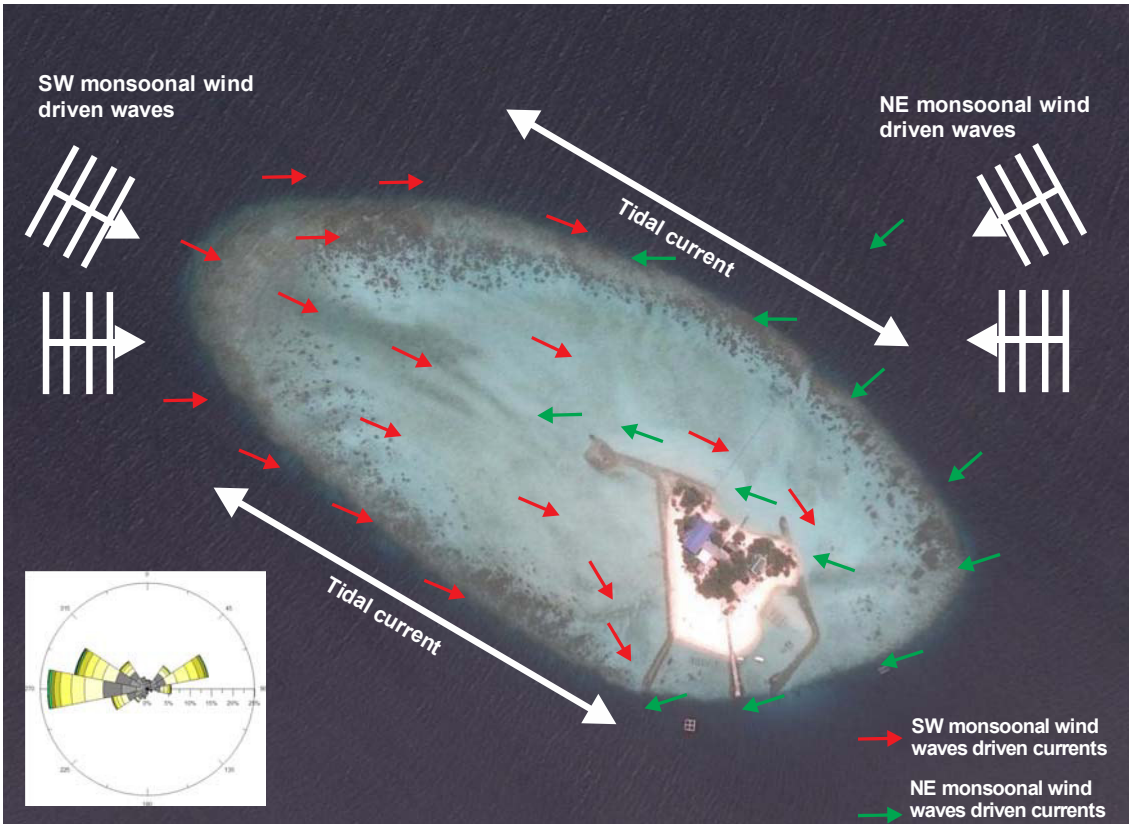

Figure 17. Schematic showing anticipated wave and current regime at the reef system

7.5 Marine environment

The proposed habitats for the grow-out pens are located at the deep lagoon area where smaller grow-out pens already exist. Under the proposed project the grow-out pens will be extended to a larger area as shown on Figure 1.

7.5.1 Reef survey

Following section describes the reef condition at the project location. Quantitative reef surveys were conducted at four sites (R1-R3) which will act as baselines in future reef monitoring. Refer to Figure 8 for aerial map of surveyed locations and Table 6 for their GPS Coordinates.

Figure 18 and Table 12 show the percentage composition of substrate forms at the three quantitative survey locations (R1-R3). Coral rock was noted as the most dominant substrate at all sites with a percentage cover ranging from 68.71% to 52.51%. Highest live cover was observed at location R1 with 14% coral cover, which comprised of Porites spp. and other

branching and encrusting coral forms. Live coral cover at R2 and R3 was comparatively low, with 2.35% and 0.34% respectively. A significant presence of dead coral covered in algae and coralline algal cover were recorded at all surveyed locations. Moreover, forms of macroalgae such as Halimeda were also recorded in significant numbers at R3.

Table 12. Details of substrate composition at sites R1-R3, as observed on 23 December, 2017

Substrate Categories	R1			R2			R3		
	Mean	±	Std. Error	Mean	±	Std. Error	Mean	±	Std. Error
Algae	1.67	±	1.67	1.02	±	0.59	1.01	±	0.58
Coral	14.00	±	7.51	2.35	±	1.88	0.34	±	0.34
Halomitra	-			0.34	±	0.34	-		
Other coral branching	0.33	±	0.33	-			-		
Other coral encrusting	0.33	±	0.33	0.34	±	0.34	0.34	±	0.34
Porites	11.33	±	7.54	1.68	±	1.21	-		
Sponges	1.00	±	0.58	0.33	±	0.33	-		
Macroalgae	0.67	±	0.67	2.03	±	1.17	6.04	±	2.68
Halimeda	-			0.34	±	0.34	5.70	±	2.36
Other macro algae	0.67	±	0.67	1.69	±	0.89	0.34	±	0.34
Ascidian	-			0.34	±	0.34	-		
Other live	-			1.69	±	1.21	-		
Dead coral covered with algae	8.00	±	2.52	9.06	±	3.81	27.07	±	3.98
Coralline algae	9.33	±	2.19	8.75	±	2.87	7.35	±	2.96
Rock, rubble, sand	65.33	±	6.06	74.43	±	4.10	58.20	±	0.76
Coral rock	55.00	±	7.57	68.71	±	3.43	52.51	±	1.26
Rubble	6.67	±	0.33	5.39	±	0.67	4.69	±	0.69
Sand	3.67	±	1.33	0.33	±	0.33	1.00	±	1.00

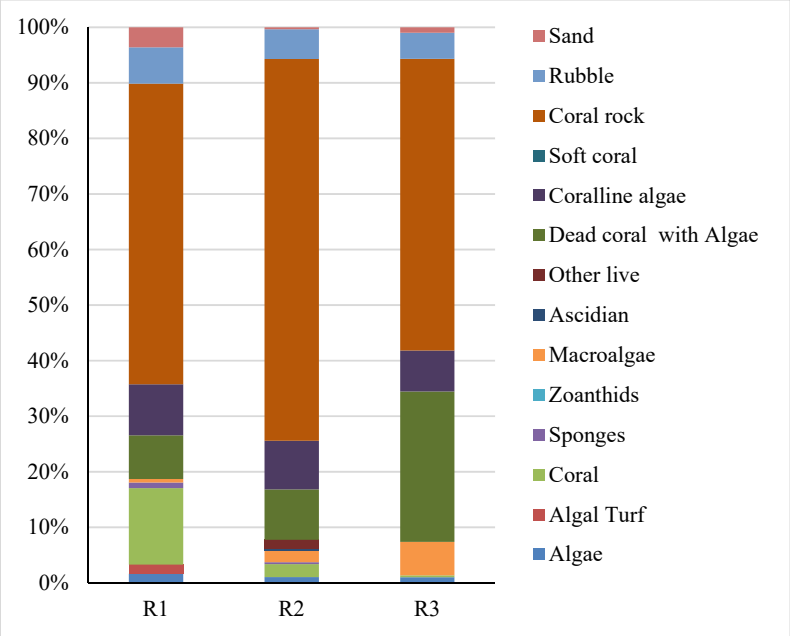

Figure 18. Percentage composition of live cover at sites R1 – R3, as surveyed on 23 December, 2017

7.5.1.1 **Site 1**

Location R1 was located on the southern side of the reef system. This site hosted the highest live coral cover accounting for 14% of the transect. This comprised of colonies of Porites spp. (11.33%) and other branching and encrusting hard coral forms. A significant presence of coralline algal cover (9.33%) were also recorded, followed by dead coral covered in algae, which accounted for 8% of the sampled area. Additionally, low occurrences of rubble (6.67%), sand (3.67%), macroalgae (0.67%) and sponges (1%) were also recorded (Refer to Figure 8 for aerial map of surveyed locations and Table 6 for their GPS Coordinates. and Figure 19 for representative photos of the site).

Figure 19. Representative photographs of site R1, as surveyed on 23 December, 2017

7.5.1.2 **Site 2 (Control)**

Location R2 was established as a control for comparison in future monitoring efforts. This site showed a similar dominance of rock as the main substrate with 68.71%, followed by dead coral covered in algae (9.06%) and coralline algae (8.75%). Low occurrences of live coral were also recorded, which comprised of Halomitra spp. (0.34%), Porites spp. (1.68%) and other encrusting coral forms. Additionally, macro algal cover, sponges and ascidian forms were also recorded (Refer to Figure 8 for aerial map of surveyed locations and Table 6 for their GPS Coordinates. and Figure 20 for representative photos of the site).

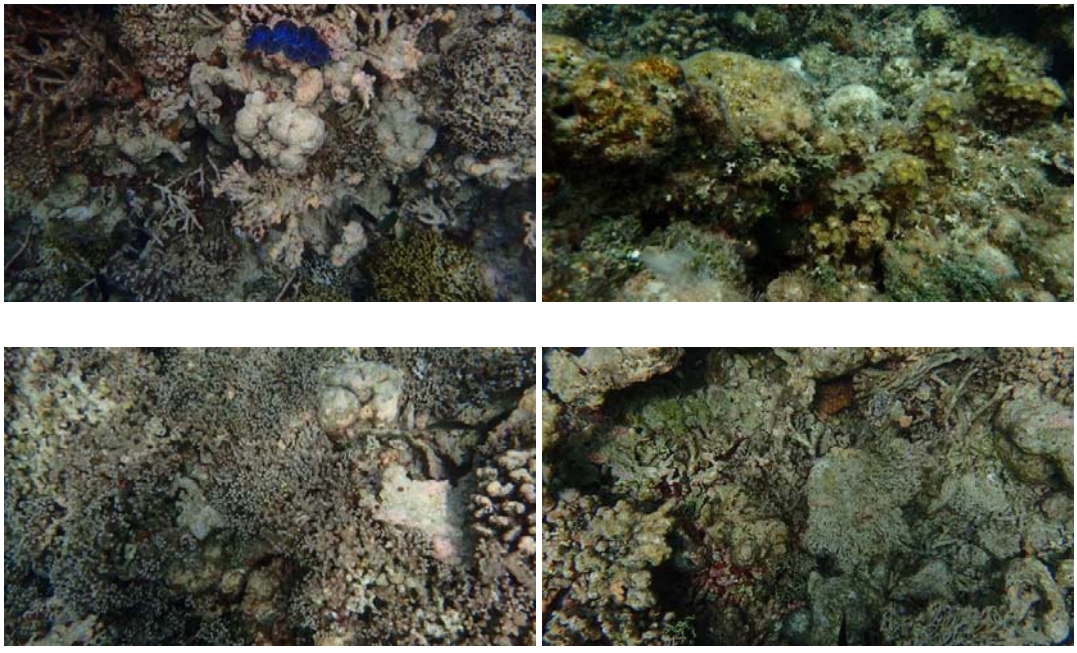

Figure 20. Representative photographs of site R2, as surveyed on 23 December, 2017

7.5.1.3 **Site 3**

Location R3 was located on the north eastern side of the island. This site showed a higher presence of dead coral covered in algae (27.07%) than the previous sites, with a comparatively lower presence of coral rock (52.51%). Also, higher occurrences in macro algal cover and Halimeda spp. (5.70%) were recorded at this location. In addition to these, comparable presence of coralline algae (7.35%) were recorded as well (Refer to Figure 8 for aerial map of surveyed locations and Table 6 for their GPS Coordinates and Figure 21 for representative photos of the site).

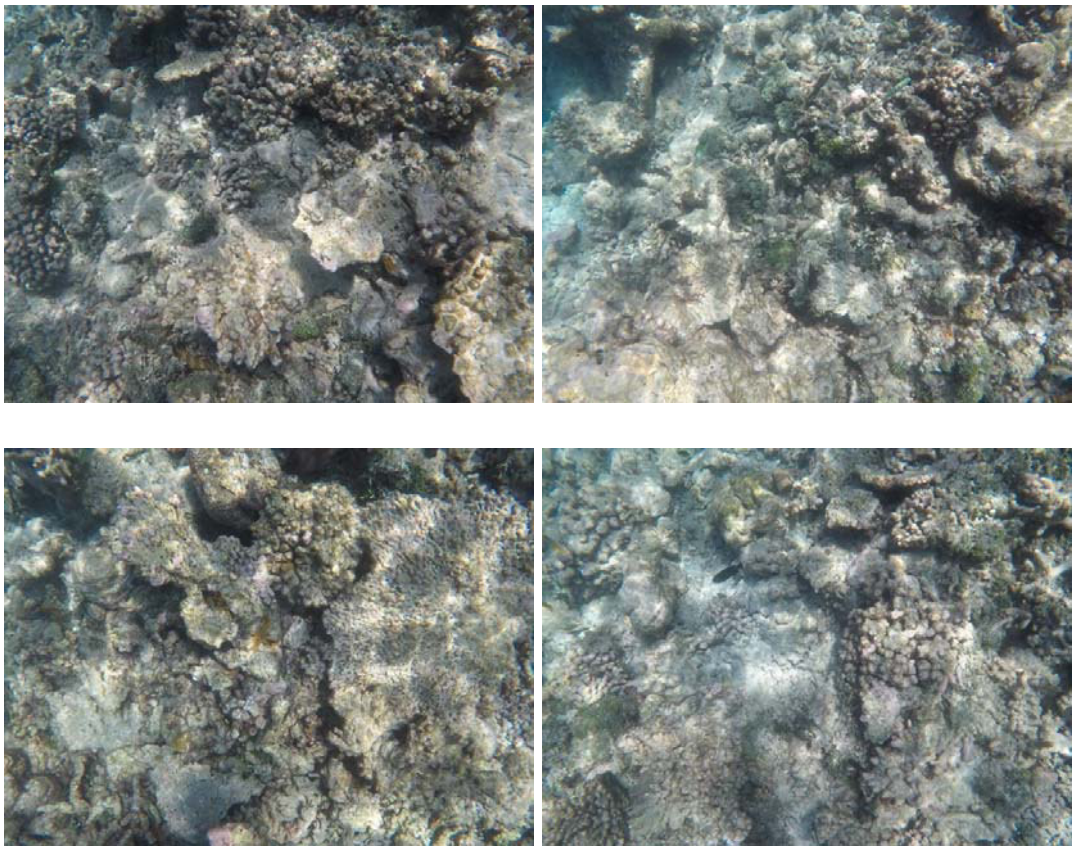

Figure 21. Representative photographs of site R3, as surveyed on 23 December, 2017

7.5.2 Seawater quality

The condition or quality of coastal water is important for ecological functioning of the organisms living in the habitat, for health and safety reasons and also for visual and aesthetic impacts. The water quality is generally determined by the level of nutrients. There are several sources that can lead to increased nutrients in coastal waters, e.g. sewage effluents and terrestrial storm water runoff. Sediment stir-up can also lead to release of nutrients within the sediments especially when there is excavation and dredging involved.

The most important nutrients of concern in coastal waters are nitrates and phosphates. In excessive quantities these can cause rapid growth of phytoplankton and result in algal blooms. Visual quality of the water is also important; a beach environment is much more attractive when the water is clean and one can see the sea bottom. However, even clear waters may sometimes be polluted.

It is worthwhile to note here that there is no direct input source of nutrients in the coastal waters during the construction phase. However, the operational phase and associated activities (grouper and sea cucumber rearing) has the potential to release a number of nutrients into waters. Moreover, sewerage discharge pipelines are already established on the island. Therefore, the purpose of the assessment of water quality is to establish a baseline for the seawater quality, taken as a standard to compare with any future water quality assessments. A list of parameters tested and their values for the three locations are given in Table 13 (test results from MWSC) and Table 14 (in-situ water testing done using Hanna HI9828 probe).

Table 13. Results of seawater quality tests performed by MWSC (lab reports in Appendix 10)

Parameter	Site 1	Site 2	Site 3
Physical appearance	Clear with particles	Clear with particles	Clear with particles
Nitrate (mg/l)	3.7	3.1	3.0
Nitrogen Ammonia (mg/l)	0.03	<0.02	<0.02
Phosphate (mg/l)	<0.05	<0.05	<0.05

Table 14. Results of seawater quality tests performed in-situ (using Hanna HI9828 probe)

Parameter	Site 1	Site 2	Site 3
Temperature	27.23	27.44	27.04
pH	8.06	8.11	8.09
Salinity (‰)	32.51	32.62	32.64
Turbidity (FTU)	0.00	0.10	0.00

7.6 Groundwater quality

Groundwater sample was analyzed in order to establish the baseline groundwater characteristic of the island. The groundwater quality was found to be highly saline with a salinity of 18.01 ‰ and a conductivity of 29.19 mS/cm. Water quality test results from the groundwater table on the island is shown on Table 15 below.

Table 15. Results of seawater quality tests performed in-situ (using Hanna HI9828 probe)

Parameter	Site 1
Temperature	27.04
pH	7.22
Salinity ($^{o}/_{oo}$)	18.01
Turbidity (FTU)	0.02
Conductivity (mS/cm)	29.19

8 Stakeholder consultation

8.1 Consultation with EPA

Consultation with EPA was held at the agency on the 3rd of January 2018 at 10am. Participants of the meeting are listed in Appendix 11. The representatives from EPA agree that the proposed project will benefit the community. Major concerns highlighted at the consultation meeting are listed below:-

- Existing sewer discharge is directly on the reef system, it is recommended to extend this out into the ocean.
- The corner of the hatchery building is very close High Water Line (HWL) on the north western side. Coastal protection measures are recommended.
- A landing craft shall be used in order to transfer any heavy equipment (if any) to the project site.
- Concerns about the size of the island being too small for such a facility was raised. This will limit the number of participants which could be accommodated at a time.
- Since there is very less vegetation on the island, they should be retained as much as possible.
- Waste should not be burnt or dumped to the sea.

8.2 Consultation with Health Protection Agency (HPA)

Consultation with HPA was held at the agency on the 3rd of January 2018. Participants of the meeting are listed in Appendix 11. Representative from HPA was consulted via telephone conversation and a project brief was emailed for comments. They had no concerns regarding the construction and operation of the field station at Maniyafushi as of now.

8.3 Consultation with Kaafu Atoll Council

The Vice president of the Kaafu Atoll council was consulted over the phone on the 3rd of Janyary 2018 and the following were highlighted:-

- During a recent tour around the Atoll, many parties interested in grouper and sea cucumber fishery came forward requesting for a similar facility.
- They would like to know when the facility will be open for enrolment.

NOTE: the TOR specifies consultation with Maldives Food and Drug Authority. However, MFDA stated that Consultation for this project should be carried out with HPA and not MFDA.

9 Environmental Impacts

9.1 Impact Identification

Various methods are available to categorize impacts and identify the magnitude and significance of the impact, such as checklists, matrices, expert opinion, modelling etc. Impacts on the environment from various activities of the project construction work (constructional impacts) and post construction (operational impacts) have been identified through interviews with the project management team, field data collection surveys and based on past experience in similar development projects. Data collected during field surveys can be used to predict outcomes of various operational and construction activities on the various related environmental components. This data can also be used as a baseline for future monitoring of the environment.

Possible impacts arising from the construction and operation works are described according to their location, extent (magnitude) and characteristics. They are also further categorized by intensity of impacts (negligible, minor, moderate and major) for identifying best possible remedial (mitigation measures) action to be taken. Below are the impact categories.

Table 16. Impact prediction categorized

Impact category	Description	Reversible/ irreversible	Cumulative impacts
Negligible	The impact has no significant risk to environment either short term or long term	Reversible	No
Minor	The impact is short term and cause very limited risk to the environment	Reversible	No
Moderate	Impacts give rise to some concern, may cause long term environmental problems but are likely short term and acceptable	Reversible	May or may not
Major	Impact is long term, large scale environmental risk	Reversible and Irreversible	Yes, mitigation measures has to be addressed

The concept of the Leopold Matrix (Leopold et. al., 1971) has been used to classify the magnitude and importance of possible impacts which may arise during the constructional and post constructional stage of the proposed project. This is one of the best known matrix methodology used for identifying the impact of a project on the environment. It is a two dimensional matrix which cross references between the activities which are foreseen to have potential impacts on the environment and the existing conditions (environmental and social) which could be affected.

The matrix has the actions which may cause an impact on the horizontal axis and the environmental conditions which may be impacted on the vertical axis. While the original Leopold matrix lists 100 such actions and 88 environmental conditions, not all are applicable to all projects. Hence the matrix used in the current assessment is a modified matrix customized to this project.

Each action which is evaluated is done so in terms of magnitude of impact on the environmental condition and significance of this impact. In addition to this probability of impact as well as duration of impact is also assessed and shown separately. All probable and significant actions, their magnitude of impact and duration of impact are further described in the text.

This version of the Leopold Matrix has been adopted from Josimovic et. al (2014) and the EIA adopts the grading scales used in the paper referred. Listing of these grading scales are shown in Table 17 below.

Table 17. Grading scales for the four impact evaluation criteria

Evaluation criteria	Designation	Scale
Impact Probability	M	Impact is possible (probability <50%)
	V	Impact is probable (probability >50%)
	I	Impact is certain (probability = 100%)
Impact Magnitude	0	no observable effect
	1	low effect
	2	tolerable effect
	3	medium high effect
	4	high effect
	5	very high effect
Impact significance	P	limited impact on project site (immediate site)
	I	Impact of importance at Island level
	A	Impact of importance at Atoll level
	N	Impact of national character
	M	Impact of cross-border character
Impact duration	P	Occasional/temporary
	D	Long term/permanent

The proposed project involves construction of grow-out pens for sea cucumber and grouper rearing at K. Maniyafushi. Development of the field station on the island is also included in the project. Both the constructional phase and operational phase of the project are expected to have impacts on the environment, especially the marine environment.

The severity of impacts is predicted by reviewing the design plans and construction methodologies. Mitigation measures are formulated in light of the information revealed by the project engineers.

9.2 Limitation or uncertainty of impact prediction

Uncertainty of impact prediction are mainly due to the lack of long term data, inherent complexity of ecosystem and lack of coordinated monitoring programs with consistent methodologies which can be used to predict outcomes or reliability of predictions of previous projects.

The impacts are predicted by reviewing the survey data collected during field visits and information revealed by the designers and engineers. The data collected during field visit is limited in terms of number of days to a week or few more, which limits the overall understanding of even the short term environmental conditions.

The time limitation of EIA field data collection and report preparation is also a hindrance to properly understanding the environmental factors dictating the conditions of the habitat.

9.3 Constructional Impacts

In any development project major direct impacts to the environment (either short term or long term) occur mainly during the construction phase. Potential direct or indirect impacts on the environment from the proposed works include:

- Loss of marine habitat
- Impact on shoreline
- Impact on seawater quality
- Pollution of the natural environment
- Impacts on groundwater

9.3.1 Loss of marine habitat

Sewer outfall, hatchery discharge and seawater intake well are already established at the project site. Therefore, pipeline laying work will not be required on this project. As such, constructional impacts on marine environment from outfalls is not anticipated.

As for the establishment of grow-out pens, the pens will be placed at deeper area of the lagoon which does not require deepening of the lagoon nor dredging by any means. Moreover,

the pens will be constructed from buoyant material, thus they will not touch the sea bottom. Therefore, impacts on marine environment due to construction of grow-out pens is expected to be very low. According to the impact analysis, this component scored an average value of 0.21 (Table 21).

9.3.2 Impact on shoreline/ shoreline and erosion

Maniyafushi is observed with sparse vegetation and void of proper shoreline vegetation belt. The project has been designed in such a way that limited vegetation need to be cleared from the site, any mature tree/palm that needs to be removed will be transplanted elsewhere on the island. The corner of the hatchery is very close the high tide line of the island, in the event of erosion building structure may be compromised. Although it not included in current project, it is recommended to place coastal protection measures on this side of the island.

9.3.3 Impacts on seawater quality

The construction phase of the project will have minor impact on seawater quality (due to stir up some sediment during construction of pens and transportation of pens from lagoon to reef slope area). However, average value of impact is envisaged to be 1.25 with impact being restricted to project site and for the construction period (hence short term).

9.3.4 Pollution of the natural environment

Such development projects have the potential to pollute the environment during the construction phase, through improper disposal of waste. All construction waste will be collected and transported to Thilafushi for proper disposal. Hence the impact potential for pollution is negligible to minor, with an average impact value of 0.14 being felt at the project site.

9.3.5 Impact on air quality and noise

Inherent to any construction project, impacts on air quality and noise level is expected to arise from constructional and demolishing activities of the buildings proposed in this project. Since the project site is far from urban areas or communities impact on air and noise is negligible.

9.3.6 Impacts on groundwater quality