Feasibility Study for the Decarbonisation of Pulau Satumu

Final Report

Maritime and Port Authority of Singapore

Final Report

July 2024

This report has been prepared under the DHI Business Management System
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Feasibility Study for the Decarbonisation of Pulau Satumu

Final Report

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1 Introduction

Based on Letter of Acceptance (Ref. MPA000ECI23000521 / 1) received from Maritime and Port Authority of Singapore (MPA) dated 28th November 2023, DHI Water & Environment (S) Pte. Ltd. has been appointed to provide specialist consultancy services for the ***Feasibility Study for the Decarbonisation of Pulau Satumu (the Project).***

1.1 Background and Objectives

The Maritime and Port Authority of Singapore ("MPA" or "the Authority") is seeking to carry out a Conceptual Design for the proposed installation of a ground-mounted Solar Photovoltaic (PV) System, Energy Storage System (ESS), power management (PM) system, desalination unit(s), and all other necessary provisions on Pulau Satumu. This will henceforth be referred to as "the Project".

Pulau Satumu currently operates on a diesel-based power generation system. Pulau Satumu also does not currently possess facilities or pipelines capable of providing a ready supply of fresh, potable water. Therefore, the freshwater and fuel needs of personnel stationed on the island are at present, met by the routine transportation of diesel and potable water by bunker barge and water boat to the island.

Accordingly, the Project has been planned to meet a set of bifold goals. Firstly, the Project aims to fully decarbonise operations on Pulau Satumu through generation and utilisation of renewable energy, which is in line with WOG target to attain net-zero emissions by 2045. Secondly, the desalination initiative is intended to satisfy the freshwater needs of personnel on the island and reduce the need for extraneous transport of potable water. The proposed desalination units would be powered by renewable energy generated from the solar PV system. Overall, the proposed solarisation and desalination initiatives would eliminate the need to regularly transport fuel and water to the island so as to reduce the output of additional carbon emissions.

Thus, a bifold study ("the Study") has been commissioned by MPA. Firstly, the study aims to develop a practical concept design that maximises the generation of green electricity and provision of sufficient energy storage systems to ensure uninterrupted electricity supply for all facilities and operations on Pulau Satumu. The study will also concurrently assess the installation of desalination unit(s) on the island. Secondly, the study seeks to identify possible environmental impacts as a result of the proposed Project.

This Report has been prepared to document the methodology, results, and discussion for the proposed biodiversity study of the terrestrial and intertidal habitats, as well as the conceptual design of the PV, ESS, PM systems and desalination unit(s), for the necessary TA's review and concurrence.

1.2 Biodiversity Study Objectives

The objectives of this Biodiversity Study are:

- To identify and determine the baseline conditions of biodiversity and to formulate a biodiversity inventory and distribution map;
- To assess the potential impacts caused by the construction of the proposed Project based on the Conceptual Design; and

- To propose suitable mitigation measures and recommend an Environmental Monitoring and Management Plan (EMMP) if necessary for the construction phase of the Project.

1.3 Report Structure

The present Report has been prepared based on DHI's contracted scope of work, other general experience from similar studies, and specific knowledge of the project area. The Report is structured as follows:

- Section 1 – Introduction
- Section 2 – Project Description
- Section 3 – Relevant Environmental Laws, Standards, and Guidelines
- Section 4 – Biodiversity Study Approach
- Section 5 – Ecological Baseline
- Section 6 – Impact Assessment Framework
- Section 7 – Prediction and Evaluation of Environmental Impacts (Pre-construction & Construction Phase
- Environment Management and Monitoring Plan
- References
- Appendices
    - Appendix A– Baseline Survey Species List
    - Appendix B – Locations of Flora of Interest

2 Project Description

2.1 Project Area

Pulau Satumu is Singapore's southernmost island and is home to Singapore's second oldest lighthouse still in operation – the Raffles Lighthouse. The island is adjacent to the Main Strait sea passage. Covering an area of approximately 0.4 ha, the main vegetation on the project site includes managed turf and planted fruit trees, particularly Coconut (*Cocos nucifera*). Given that these vegetation types are managed, they are generally considered to be of low ecological value.

However, the intertidal and marine environment surrounding the project site are hotspots for marine biodiversity. A study by Tay et al. (2012) demonstrated that three islands within the southern cluster (Pulau Sudong, Pulau Pawai and Pulau Senang), located just north of Pulau Satumu, are robust sources of coral larvae which seed the reefs amongst the Southern Islands, indicating this island group's importance in the resilience of coral species regionally.

The proposed activities are to take place within the land area of Pulau Satumu, which is currently dominated by managed turf and planted fruit trees.

2.2 Project Works and Activities

This section will provide a brief description of the type of works that will be carried out for proposed installation of a ground-mounted Solar PV System, ESS, power management system, small desalination unit(s), and other associated works. Since the Project is still in the concept design phase, some of the methodologies described may utilise typical

construction activities adopted by the industry. It should be noted that, the actual construction methods may vary based on actual site conditions and awarded Contractor's proposal.

2.2.1 Pre-Construction and Site Preparation Phase

A detailed construction method and programme is not available at this stage of the Biodiversity Study. A brief description of the likely works which will be carried out is given below.

Assessment of Barge Mooring Area

An intertidal assessment of optimal barge mooring areas along the island's rock revetment will be conducted so that a suitable location can be found to minimise the potential impact to the coral reef surrounding Pulau Satumu, during the transportation of equipment and supplies from barges to the shore. The size of the barges used and methodology of mooring and operation, will affect the extent of the area that needs to be studied.

Soil Investigation

To facilitate the detailed design, soil investigations would be carried out to determine the geotechnical characteristics within the project site. An example of a widely used soil investigation technique is the Standard Penetration Test (SPT), which is an in-situ dynamic penetration test utilized to determine the geotechnical properties of soil layer at varying depth.

Site Preparation

Tree felling works and debris clearance will be the primary activity occurring to prepare the project site for installation of the proposed solar PV, ESS and PM System. Vehicles and/or heavy machinery could also be transferred to the island via barges to assist with other necessary site preparation works, which could include minor earthworks to level the project site.

2.2.2 Construction Phase

Marine transportation of equipment and supplies

All equipment and supplies will be transported to the island via means of marine transportation such as barges with mobile cranes and/or ramps. The actual mode of marine transportation will be assessed and determined by the appointed Contractor during the construction phase. Where practical, the Project's equipment and supplies (such as PV panels, mounting structures, electrical components, cables, etc) will be stored in containers during marine transportation. It is envisaged that these containers and the containerised ESS units will be transferred from the barge to the temporary staging area on the island using mobile cranes to a temporary staging area on the island. Heavy machinery and/or vehicles may be deployed on the island to facilitate the construction activities.

Installation of PV, ESS & PM system infrastructure

Minor excavation works will be required for the installation of the concrete foundation on which ground-mounted PV panels and ESS will be installed upon. An over-site clearance of 500-750mm of sand/soil will be removed as needed to facilitate the installation of said concrete foundation at pre-defined locations. In addition to this, minor trenching, concrete hacking and excavation works will be carried out to facilitate the laying of underground cable conduits as part of the proposed microgrid network to integrate the PV system and ESS on the island. The final layout will be confirmed once due diligence has been done to

map any existing subterranean infrastructure, such as power, telecommunication cables and gas/water mains.

Installation of Desalination Unit(s)

Small-scale desalination unit(s) are planned to be installed on Pulau Satumu to generate clean water in order to meet the water consumption needs on the island. The inlet pipe would be installed at a suitable foreshore location, while the outlet pipe is envisaged to be installed along the jetty infrastructure to facilitate rapid mixing and dilution of saline effluent.

Working Hours

Construction works are expected to primarily take place during daylight hours. Nightworks will be refrained from to avoid interfering with the function of the lighthouse as a navigation aid, thereby ensuring navigational safety and to avoid causing disturbances to nocturnal fauna. Barge works, which involves the transfer of project equipment and supplies to-and-from the island will be restricted to daylight hours. Once the necessary loading/offloading activities are completed, the barge will be towed to an anchorage offshore or returned to its harbour in the mainland.

2.2.2.1 Post-construction Phase

During the post-construction (operational) phase, the Project will occupy a physical footprint of around 4000 m^2, the majority of which will consist of the ground-mounted PV panels. The desalination units are planned to produce around 2 cubic metres of clean water per day. Details on its long-term use remains under planning.

2.3 Project Timeline

The works for deployment of solar photovoltaic, energy storage system and power management system including desalination unit(s), on Pulau Satumu, are indicatively expected to commence construction in the 4th quarter of 2024, subject to planning approval by Urban Redevelopment Authority (URA) and Ministry of National Development (MND). Works are estimated to last for a period of 6 to 8 months.

Table 2.1 Indicative Project timeline for the Project.

Work progress	Timeline
Commence construction	December 2024
Completion of construction, commencement of testing and commissioning	May 2025
Completion of testing & commissioning	July 2025

3 Relevant Environmental Laws, Standards and Guidelines

3.1 Local Legislative and Administrative Requirements

At present, there is no specific legislation in Singapore for Biodiversity Studies. However, potential environmental impacts of development proposals are usually assessed internally or collectively by relevant government agencies, as part of planning approval process. Under the Planning Act, statutory permissions and conditions can be imposed for the conduct of environmental studies and investigations into biodiversity. National management requirements pertaining to biodiversity protection that are applicable to the Project are found in several Acts, Regulations and Guidelines as listed in Table 3.1.

Table 3.1 List of applicable laws, standards and guidelines relevant to the Project

Ecological Aspect	Applicable Acts, Regulations & Guidelines
Wildlife Protection and Welfare	• Wildlife Act, 2000 • Singapore Red Data Book, Second Edition, 2008
Habitat Protection/ Conservation of Protected Areas	• Parks and Trees Act, 2006 • Parks and Trees Regulations, 2006 • Parks and Trees (Preservation of Trees) Order, revised 1998 • Guidelines on Greenery Provision and Tree Conservation for Developments (NParks, 2023) • Biodiversity Impact Assessment Guidelines (NParks, 2021)
Importation of Animals and Plants	• Endangered Species (Import and Export) Act, 2008 (Chapter 92A) • Animals and Birds Act, 2002, Chapter 7 • Control of Plants Act, 2000, Chapter 57A

As per standard protocol, consultation with the various government technical agencies including the National Parks Board, National Environment Agency, Singapore Food Agency, Maritime & Port Authority and Urban Redevelopment Authority was carried out through Form A submission, with agency's comments being addressed throughout this report. All technical agencies have given no objection through Form B replies.

3.2 International Standards and Guidelines

3.2.1 Ecological Impact Assessment Guidelines (EIANZ and CIEEM)

The Ecological Impact Assessment Guidelines published by the Environment Institute of Australia and New Zealand Inc. (EIANZ) is a set of guidelines aimed at providing a framework for the practice of ecological assessment in Australia and New Zealand.

A similar set of guidelines has also been published by the UK Chartered Institute of Ecology and Environmental Management (CIEEM). These guidelines will be used as a reference and adapted to the Singapore context where necessary and available.

4 Biodiversity Study Approach and Methodology

4.1 Overall Process

DHI has carried out this Biodiversity Study by adopting components of the standard Environmental Impact Assessment (EIA) framework that were deemed to be relevant to an assessment of biodiversity and associated ecological receptors. The requirements of the EIA process are stipulated by URA and MND and form a formal part of the planning approval process (Figure 4.1).

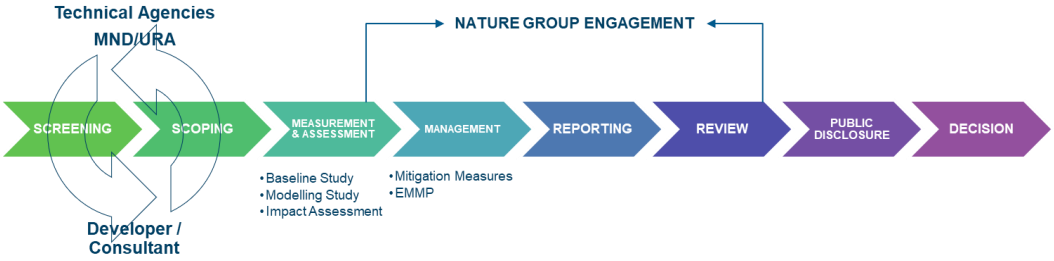


Figure 4.1 An illustration of EIA procedures in Singapore. Stakeholder engagement is project dependent, may take place at multiple stages of the study.

In accordance with the aforementioned EIA framework, a screening process was pursued with the relevant technical agencies between December 2023 to February 2024 (Form A/B process). It was concluded from this phase that the Biodiversity Study in question was required.

This report documents outcomes of the subsequent stages – Scoping, Measurement, Assessment and Management. DHI's approach to these tasks is illustrated in Figure 4.2 and outlined below. After the reporting stage, DHI, together with MPA as the Developing Agency, will consult the Technical Agencies, stakeholders and the public before final decisions are undertaken by URA and MND.

- **Scoping** – to propose and obtain consensus on the objectives, spatial and temporal scales, and parameters of the Biodiversity Study as well as all the assessment criteria and methodologies.
- **Measurement (Baseline Study)** – to study and fully describe the baseline for the assessment, either through field surveys or desktop literature searches, and predict potential changes in environmental parameters as a result of the Project, either qualitatively or quantitatively.
- **Assessment** – to classify the significance of the environmental pressures and their influence on sensitive environmental receptors, through the Rapid Impact Assessment Matrix (RIAM) methodology.
- **Management** – to identify measures to manage the impacts to a reasonably practicable level and outline a monitoring program to ensure that impacts are managed accordingly. Impact significance will be re-evaluated on the basis that mitigation measures are implemented, to derive the Residual Impact significance.

More details of these steps are discussed in the sub-sections to follow.

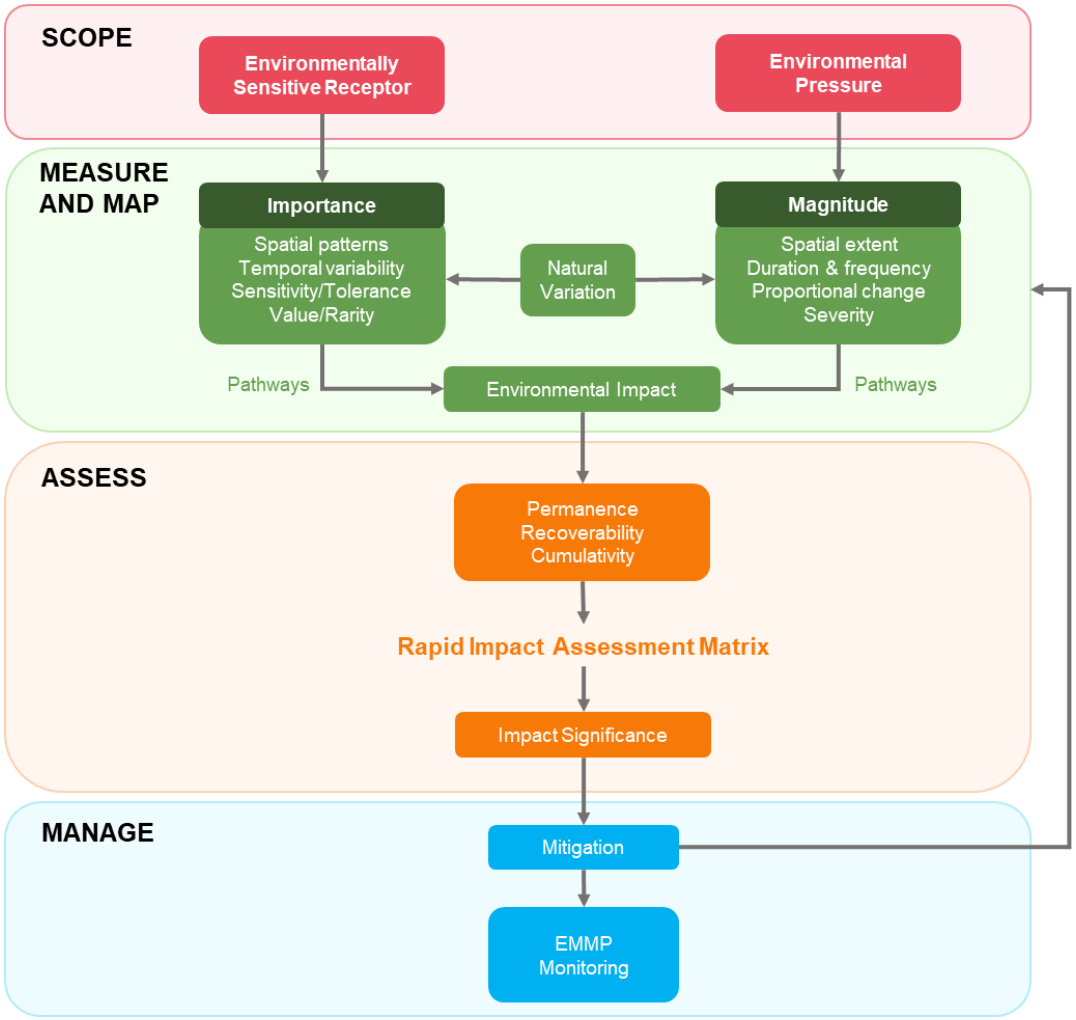


Figure 4.2 Overall workflow for the impact assessment process.

4.2 Scoping

Scoping is a critical step in the preparation of a Biodiversity Study that defines the Spatial scope of the study (henceforth known as the 'Study Area'), and to delineate the material requirements of the study, including relevant parameters, receptors and assessments that are to be undertaken. This process requires a clear understanding of (i) potential changes, or *pressures*, that will arise from the proposed Project, (ii) presence of environmental sensitive features, or *receptors*, in its potential impact zone and (iii) impact processes, such as ecosystem processes and linkages. An impact process is a description of how a specific receptor is affected by a specific type of impact: Pressure > Pathway > Receptor. All three elements are required for there to be an impact. For example, if there is no pathway from the source to the receptor, then no impact will eventuate; and if there is a source but no receptor, then there will also be no impact.

During this stage, DHI works closely with MPA and the Engineering Consultant to understand the project design and possible construction methodologies, in order to identify potential environmental pressures, taking into consideration the comments and requirements laid out by the various technical agencies. DHI also conducts an extensive desktop study of the Study Area, in combination with consultation with relevant agencies (URA and NParks), to understand the existing and future land use, ecological habitats and socio-economic receptors in the area. The pressures and receptors are then

tabulated in a Scoping Matrix and interactions between them are sought and to be assessed in the Biodiversity Study.

4.2.1 Identification of Study Area

The Study Area in this Biodiversity Study will be understood to encompass the Project footprint, and up to 100m of buffer distance beyond this. It was determined that these parameters would sufficiently allow for the assessment of Project impacts on relevant ecological receptors that could be related to the eventual scope of construction and operational activities. These decisions were guided by expert judgement, along with an adherence to the Biodiversity Impact Assessment (BIA) Guidelines stipulated by the relevant governing bodies (NParks, 2021).

4.2.2 Identification of Potential Environmental Pressures

Based on project information described in Section 2.2, the following environmental pressures on the biological receptors and the environment are expected:

Construction Phase:

- Loss of habitat, flora, and fauna, including within affected terrestrial, intertidal and subtidal areas
- Physical disturbances from construction works (including underwater noise pollution, and suspension of marine sediments)
- Pollution from improper site management and construction equipment (Spills and leaks)

Post-construction Phase:

- Changes in water quality from desalination effluent discharge

4.2.3 Identification of Sensitive Receptors

With the pre-defined focus, in this report, Ecological Sensitive Receptors (ESRs) only include ecological and biodiversity sensitive receptors as seen in Table 4.1.

Table 4.1 List of ESRs and the sub-categorizations covered within. (adapted from BIA guidelines)

Domain	Ecological Sensitive Receptors (ESR)		Description
Terrestrial ecology and diversity	Flora		Native species, including trees, palms, shrubs, herbs, ferns, climbers, epiphytes, vines and lianas
	Fauna	Mammals	Native mammals, including bats
		Avifauna (Birds)	All non-invasive birds, both resident and migratory
		Herpetofauna	Native reptiles and amphibians
		Butterflies	Native butterflies
		Odonates	Native dragonflies and damselflies

Domain	Ecological Sensitive Receptors (ESR)	Description
Marine ecology and diversity	Coral	Subtidal and intertidal coral communities around Pulau Satumu.
	Macrobenthos	Soft-bottom seafloor macrobenthos around Pulau Satumu
	Intertidal habitats	Rocky shores and sandy beach at Pulau Satumu. Many of these habitats are dominated by intertidal corals
	Marine Fauna	Fish, molluscs, crustaceans, plankton, shorebirds, etc
	Marine megafauna	Turtles, sharks, cetaceans

4.2.4 Identification of Potential Environmental Impacts – Scoping Matrix

Subsequent to the investigation of potential pressures and sensitive receptors, DHI systematically examines the potential interactions between them. The Scoping Matrix for impacts during the construction phase and operational phase are detailed in Table 4.2.

Table 4.2 Potential environmental impacts on ecological sensitive receptors (S = Impacts are Short-term, L = Impacts are Long-term)

Ecological Pressures / Ecological Sensitive Receptors	Construction Phase				Operational phase
	Injury or Mortality to ecological receptor	Loss of habitat	Disturbance from construction activities*	Pollution	Deterioration of coastal water quality
Flora	S	L			
Avifauna (Birds)	S	L			
Herpetofauna (Reptiles and Amphibians)	S	L			
Butterflies	S	L			
Odonates	S	L			
Coral			S	S	L
Macrobenthos			S		
Intertidal Habitats			S		
Marine Fauna			S	S	L
Marine Megafauna			S	S	

*** Refers to Construction activities that would alter existing habitat conditions, and includes airborne and underwater noise, suspension of marine sediments and boat-strikes , dust and vibrations which would cause distress to wildlife**

4.3 Baseline Study

The primary objectives of the biodiversity baseline study are to understand the identified sensitive receptors and establish baseline conditions, in order to utilise the baseline data for subsequent impact assessments.

The scope of this baseline study has been developed based on the sensitive receptors identified (Table 4.1) and the relevant impacts (Table 4.2) to be assessed in this Biodiversity Study. Baseline conditions will be established through a combination of desktop study (secondary data) and field surveys (primary data). An overview of field surveys conducted for this study is presented in Table 4.3.

The sources of secondary data have been elaborated upon in Section 4.3.1.

Table 4.3 Overview of surveys conducted

Date	Survey Type
06/03/2024	Flora surveys
06/03/2024	Diurnal Terrestrial Fauna Transect surveys
23/02/2024	Nocturnal Terrestrial Fauna Transect surveys
23/02/2024	Intertidal Habitat surveys

4.3.1 Desktop Review

A desktop review was conducted to obtain secondary ecological data pertaining to Pulau Satumu. This review includes, but is not limited to, going through past EIAs or environmental baseline reports, published literature, historical land-use information, along with other publicly available information. The inference of secondary ecological data will largely be spatially limited to findings of habitats and/or conservation significant species which overlap with Pulau Satumu and its waters, with qualitive or non-geospatial inferences made (e.g. ecological connectivity) where available and presented as part of the desktop review findings.

While the secondary ecological data collected are more dated than the typical 2-year validity period that NParks considers to be useable as baseline data, they still remain as a valuable retrospective reference. This is especially true for baseline fauna data, given the stochastic nature of sightings for most species, which increases based on the rarity of a species. A temporally robust dataset thus improves the ability of this study to estimate true species richness and capture all conservation significant species.

Intertidal Fauna

Pulau Satumu is the southernmost islet of Singapore, approximately 23km southwest of the mainland (NLB, 2014). Reclamation was conducted in the 1970s, which increased the land mass of Pulau Satumu to about 1.5 hectares (MPA, 2021; NLB, 2014; Tan & Low, 2022).

Reefs at Pulau Satumu feature a greater tidal range and stronger water circulation as compared to reefs closer to ports on the mainland. This, coupled with the restricted

access to the island, makes its fringing reef one of Singapore's most ecologically significant marine habitats. (Guest et al., 2007; Jaafar et al., 2018; Reef Ecology Lab, 2024).

Out of approximately 276 species of scleractinian coral present in Singapore (NParks, 2023), 143 species were found on Pulau Satumu (Guest et al., 2005; Huang et al., 2009), 23 of which are of local conservation significance (NParks, 2023). There were also significantly more locally critically endangered giant clams (Tridacna squamosa) found at Pulau Satumu (Guest et al., 2007), as compared to other reefs in the Southern Islands.

Terrestrial Fauna

A desktop review conducted revealed that there have been no former baseline studies conducted for terrestrial fauna on Pulau Satumu. As such, the primary surveys conducted as part of this study now form the first known inventory of terrestrial fauna from Pulau Satumu surveyed during this study. The full inventory of terrestrial fauna and their conservation statuses are documented in Appendix A.

4.3.2 Primary Data Collection (Ecological Field Surveys)

Terrestrial Flora

The field surveys conducted to obtain flora baseline data consist of habitat and vegetation mapping, general walking floristic surveys, and tree mapping and measuring, which are elaborated in subsequent sections. These were carried out on 6 March 2024 in the Study Area.

General Walking Floristic Surveys

All plants observed in the Study Area during floristic surveys were identified to species level whenever possible. A checklist of all the plant species recorded from the present floristic surveys was compiled and detailed (Appendix A). The nomenclature, native and conservation status of plants observed followed that of NParks (2023) for native plants, and Lindsay et al. (2022) for non-native plants. Other information on the plant species was also cross referenced with online databases, namely, the National Parks Board Flora and Fauna Web (NParks, 2024) and The Biodiversity of Singapore (LKCNHM, n.d.-a).

For plants that could not be immediately identified with certainty in the field, photographs and/or voucher specimens were taken. They were then identified using identification keys, taxonomic descriptions, online plant photo databases, with the help of taxonomic experts, and/or by matching the pressed and dried collected specimens with existing specimens in the Singapore Botanic Gardens' Herbarium (SING).

Flora Species of Conservation Significance

The assessment of whether flora species recorded were considered to be of conservation significance is elaborated in Section 4.3.3. For flora specimens of conservation significance, their geographic locations were marked using a Global Positioning System (GPS) receiver (Garmin GPSMap® 79s), which records locations within an accuracy of ± 4 m, during floristic surveys. For herbaceous plants that cover a large area, the boundaries of their extent is provided.

Terrestrial Fauna

The diversity and distribution of terrestrial fauna was assessed via Rapid Line Transect Surveys (Figure 4.3). Rapid Line Transect surveys are a form of distance sampling which involve walking along a planned, continuous 200m transect and recording fauna observations up to a specified distance. The surveys were conducted in accordance with periods of taxa-specific activity in diurnal and nocturnal phases. All fauna species within the target fauna groups observed on the island were recorded.

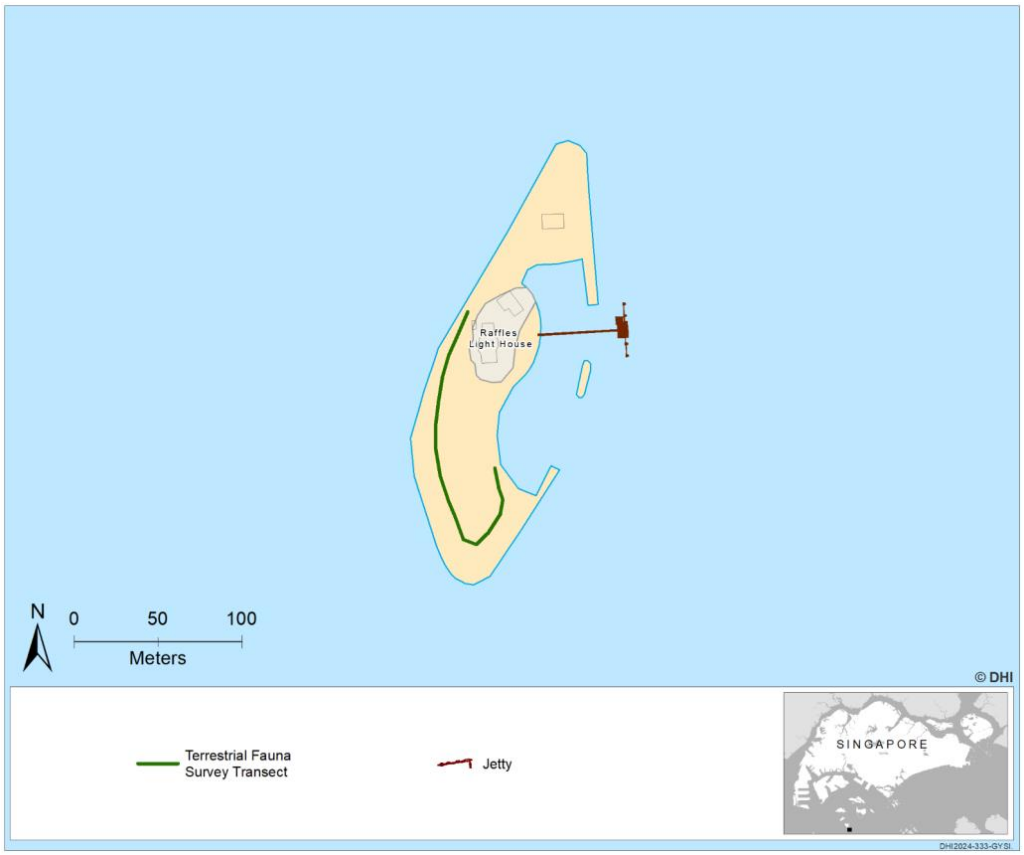


Figure 4.3 Location of the planned 200m terrestrial fauna transect

A summary of the relevant survey durations, lengths and observation ranges for different fauna groups is tabulated in Table 4.4. The observational data was analysed quantitatively and summarised in a checklist cataloguing all identified species alongside their relative abundance and conservation status. The locations of fauna species of conservation interest were also mapped and observations on habitat use within the island was recorded.

Table 4.4 Observation times, observation range, and survey types used for different fauna groups (NParks, 2021).

Survey Type	Taxon	Timing (h)	Duration	Sampling Unit	Technique
Diurnal transect surveys	Butterflies	0900-1600	20–30 minutes per transect; two cycles	200-m continuous transects along a sampling route	Visual only; up to 25 m left, right, and front of surveyor
	Odonates (damselflies and dragonflies)				
Diurnal and nocturnal transect surveys	Herpetofauna (amphibians and reptiles)	0700–1000 2000–2300	20–30 minutes per transect; two cycles	200-m continuous transects along a sampling route	Visual and auditory; up to 50 m left, right, and front of surveyor
	Avifauna (Birds)				
	Mammals				

Intertidal Habitat Surveys

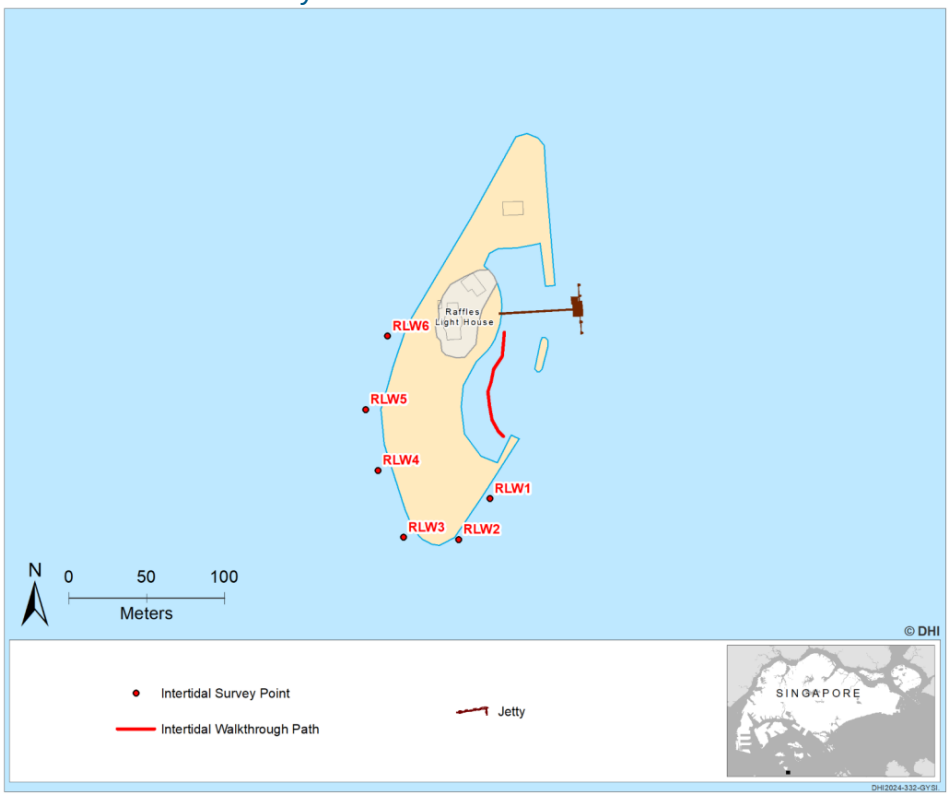


Figure 4.4 Location of intertidal survey points (VQP) & walk-by survey path

The intertidal habitat is generally dominated by organisms adapted to fluctuations in water level, e.g. mangroves and seagrasses that thrive in sites sheltered from wave action with suitable substrate or where water is entrapped during low tides, protecting the seagrasses from desiccation at low tide (Mckenzie et al., 2016). Singapore's intertidal area is also home to a variety of other flora and fauna such as algae, hard corals, sponges and numerous macrobenthic organisms.

DHI carried out intertidal surveys along both the exposed shoreline of Pulau Satumu (Figure 4.4) as well as along the sandy beachfront. These surveys included an evaluation of the mangrove, seagrass, sandy, mudflat and rocky intertidal habitats that might have been present. Alongside habitat evaluation, the surveys documented the floral and faunal diversity of the listed habitats using appropriately recognised and designed survey techniques.

Intertidal surveys concerning the former region remain the primary focus, as the rock revetment is where vessels are expected to anchor and berth as they transport equipment and supplies onto the island for the Project. Accordingly, the impacts from these activities are expected to be the heaviest. Thus, the surveys employed the quantitative Visual Quadrat Point Sampling method.

In contrast, the latter region is mainly expected to be affected indirectly by the construction activities, for example, via runoff from displaced substrata and other secondary impacts. Thus, intertidal surveys conducted along the latter region were qualitative in nature, to the extent that a reasonable prediction of potential impacts may be accurately achieved.

Visual Quadrat Point Sampling (VQP)

The Visual Quadrat Point (VQP) technique was the primary survey method adopted by DHI to conduct the quantitative assessment of the intertidal habitats. The VQP follows a

similar concept to the Visual Quadrat Transect method developed by Duarte and Kirkman (2001). Six 0.25 m^2 replicate quadrats will be placed randomly at predetermined points appropriately distributed across the sites to ensure adequate representation of the area (Figure 4.5). The following characteristics will be documented within each quadrat:

- Percentage cover of the major benthic categories (Table 4.5)
- Counts of individual motile organisms from major faunal classes (Table 4.6)
- Identification of intertidal biodiversity to the lowest taxonomic level possible.

Subsequently, the conservation status of intertidal flora and fauna was assessed in accordance with the Singapore Red Data Book (3rd edition) (NParks, 2023). Additional biodiversity observed beyond the quadrats was also recorded and assessed.

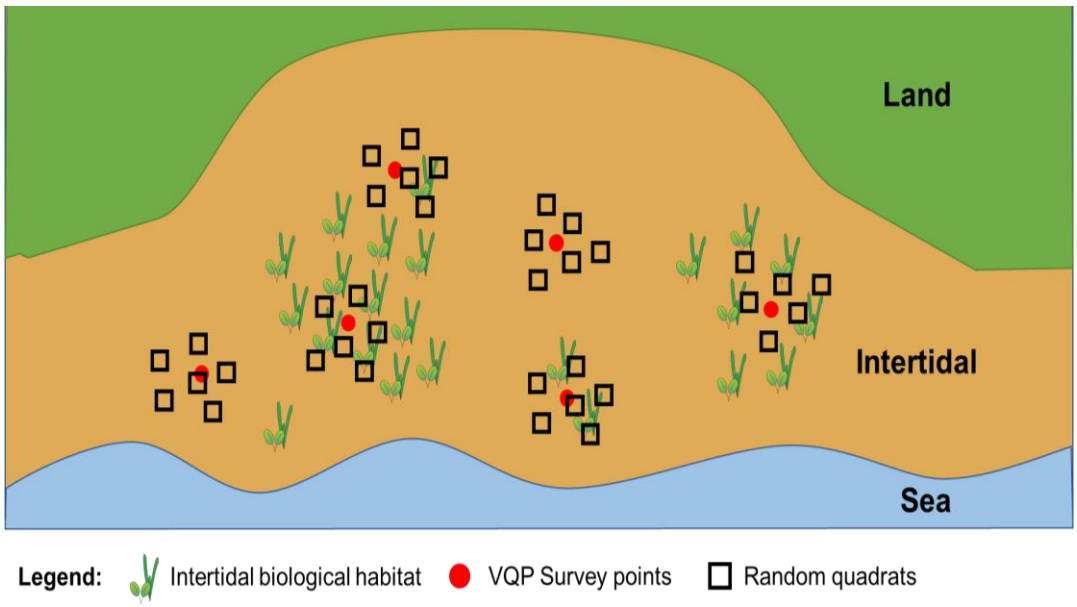


Figure 4.5 Placement of six, 0.25 m^2 quadrats within the irregular rocky intertidal area based on the VQP method. Red dots: Survey location (s) marked by GPS; Squares: Quadrats randomly placed around survey location.

Table 4.5 Major benthic categories used in the intertidal surveys

Major Benthic Category	Description
Hard Coral	Reef building scleractinian and non-scleractinian stony corals, e.g. *Favia* spp.
Seagrass	Marine flowering plants e.g. *Thalassia hemprichii*
Soft coral	Non-reef building fleshy corals without a supporting axis of horny and/or calcareous material e.g. *Sinularia* spp.
Sponge	Sessile multi-celled animals of the phylum Porifera that have many water intake and outlet openings connected by chambers e.g. *Xestospongia* spp.
Zoanthid	Colonial or solitary anthozoans, e.g. *Platythoa*, *Protopalythoa*
Other Fauna	Ascidians, anemones, gorgonians, giant clams etc.

Algae	Turf algae, coralline algae, all macroalgae (green, brown, red), algal assemblages, *Halimeda*
Abiotic	Non-living material such as dead coral, rubble, rock, soft benthos (sand/silt) and debris

Table 4.6 Fauna grouped according to taxonomic level of Phylum and Class and its corresponding components (Adapted from Allen and Steene, 2007)

Phylum	Class	Description
Annelida	Polychaeta	Segmented worms
Arthropoda	Crustacea	Barnacles, shrimps, crabs etc.
Echinodermata	Ophiuroidea	Brittle stars and basket stars
Echinodermata	Holothuroidea	Sea cucumbers
Echinodermata	Asteroidea	Sea stars
Echinodermata	Echinodea	Sand dollars and sea urchins
Hemichordata	Enteropneusta	Acorn worms, live in sand or silt bottoms
Mollusca	Bivalvia	Clams, oysters, mussels etc.
Mollusca	Gastropoda	Cowries, cone shells, nudibranch etc.
Nermetea	Anopla	Un-segmented, ribbon worms
Platyhelminthes	Turbellaria	Flatworms
Sipuncula	Sipunculidea	Peanut worms

Qualitative Walk-by Survey

Due the potential area of influence of the proposed works, DHI carried out a qualitative visual walk-by of the sandy shoreline. This survey was carried out during low tide to capture the intertidal area.

Coastal vegetation and habitats encountered were recorded and documented according to their type and conservation status (i.e. the Singapore Red Data Book 3rd Edition, 2024). A handheld Global Positioning System (GPS) was used (Garmin GPSMap® 79) to mark flora and fauna of interest (e.g., keystone species), which are of conservation significance and to track the survey route.

4.3.3 Native Status and Origin of Individuals

The nomenclature and native and conservation status of flora species observed followed that of NParks (2024) for native plants, and Lindsay et al. (2022) for non-native plants. The native status for flora is categorised as native, non-native or cryptogenic (Table 4.7), and native conservation statuses are discussed further in Section 4.3.4. Non-native flora species are further classified into casual, naturalised, and cultivated-only species (Table 4.8).

Table 4.7 List and definitions of native status terms for flora species used in this report.

Native Status	Definition (adapted from Lindsay et al., 2022)
Native	Originated or arrived in Singapore without intentional or unintentional involvement of human activities
Non-native	Presence in Singapore is because of intentional or unintentional involvement of human activities
Cryptogenic	Uncertain whether presence in Singapore is from natural dispersal or as a result of human activities

Table 4.8 List and definitions of non-native status terms for flora species used in this report.

Non-native Species Categories for flora (adapted from Chong et al., 2009 and Lindsay et al., 2022)	
Casual	Non-native species that do not maintain self-sustaining populations
Naturalised	Non-native species that maintain self-sustaining populations
Cultivated-Only	Species not naturally found in the wild in Singapore that are planted by humans and/or maintained by horticultural techniques

Individuals surveyed on site may have originated as planted individuals for aesthetic or for food purposes across past land use history or may have been dispersed and established on site spontaneously. These definitions refer to the status of plant individuals, not at species level, and may provide further clarity on the prioritisation for the allocation of resources for the retention and conservation of individuals. The definitions of the origins of the individuals on site are provided in Table 4.9.

Table 4.9 List and definitions of origin of individuals used in this report.

Origin of Individuals on Site	Definition	Native Status Of Species	Description
Planted	Individuals that were intentionally planted by humans for a specific purpose. Usually propagated and purchased from other countries, and therefore not from the native gene pool.	**Native**	Overwhelming numbers of individuals of native species have been purchased from Malaysia over the last several decades for the greening of Singapore, therefore the assumption is that they are likely from the non-native gene pool.
		Non-Native	Non-native species fall into one of the three sub-categories in Table 4.9.
Spontaneous	Individuals that were not intentionally planted by humans for a specific purpose. Usually self-dispersed and established on their own, and likely to be from the native gene pool if it is a native species.	**Native**	If they are not of the same native species planted in the site and its surrounding areas, they are likely to be of the native gene pool. They usually occur as weeds or small, herbaceous plants.
		Non-Native	Non-native species fall into one of the three sub-categories in Table 4.9.

4.3.4 Conservation Status

The Singapore Red Data Book (SRDB) is the main reference for local faunal conservation status, with the most recent SRDB (2nd Edition) being published in 2008 (Davison et al., 2008). Since then, multiple independent scientific studies have been carried out in preparation for an updated SRDB (3rd edition) to be published in the future with latest conservation statuses. These updated statuses (SRDB3) are already published for several taxa, including herpetofauna, odonates and flora on NParks Species List (Red Data Book List) (NParks, 2023). For this study, local conservation status for fauna was determined using the latest available status for each respective taxon as published on the NParks Species List. The classification of threatened species is presented in Table 4.10.

Table 4.10 List of local and global conservation statuses used to determine a species as conservation significance

Conservation Status	Definition
Local (Flora) - Lindsay et al., 2022	
Vulnerable (VU)	Between 250 to 1000 mature individuals estimated in Singapore
Endangered (EN)	Between 50 and 250 mature individuals estimated to be in Singapore, with no evidence of decline or fragmentation of populations
Critically Endangered (CR)	Fewer than 50 mature individuals estimated to be in Singapore; or if more than 50 but fewer than 250 mature individuals, with evidence of rapid decline or decline and fragmentation of populations
Presumed Nationally Extinct (NEx)	Not recorded in Singapore within the last 30 years. Endemic species that are presumed nationally extinct will consequently also be presumed to be globally extinct
Globally Extinct (EX)	Globally extinct
Data Deficient (DD)	Not enough information available to assess the risk of extinction
Local (Fauna) – NParks Red Data Book Species List, 2024	
Vulnerable (VU)	Species with <1,000 mature individuals and >250 total individuals
Endangered (EN)	Species with <250 mature individuals
Critically Endangered (CR)	Species with <50 mature individuals or <250 total individuals
Presumed Nationally Extinct (NE)	Flora and fauna not recorded within the last 30 and 50 years, respectively
Globally Extinct (EX)	Globally extinct, including in captivity or through cultivation
International/Global (Fauna) - IUCN Red List	
Vulnerable (VU)	Species facing a high risk of extinction in the wild
Endangered (EN)	Species facing a very high risk of extinction in the wild
Critically Endangered (CR)	Species facing an extremely high risk of extinction in the wild
Extinct in the Wild (NW)	Species that only survives through cultivation, captivity or as a naturalized population(s) outside its natural range
Extinct (EX)	Globally extinct, including in captivity or through cultivation

4.4 Impact Assessment

4.4.1 Assessment method

All the identified impacts will be assessed using the Rapid Impact Assessment Matrix (RIAM), originally developed by Pastakia & Jensen (1998). RIAM allows for a holistic, rapid and easily comparable presentation and summary of the overall project impacts, which ultimately aids in pinpointing the most significant impacts predicted. Besides the reduction in assessment subjectivity as compared to other methodologies, RIAM also accounts for the presence of impacts that may be cumulative in nature. The Biodiversity Impact Assessment (BIA) Guidelines of Singapore (NParks, 2020) recommends the use of RIAM as one of three approved methods for assessing and summarizing the overall significance of impacts.

RIAM translates qualitative standard definitions of evaluation criteria into semi-quantitative ordinal scores which are then used to calculate Environmental Scores (ES), via the formula:

$$Environmental\ Score\ (ES) = I\ \times M\ \times (P + R + C)$$

The five evaluation criteria (variables) used in the formula are defined as:

(I) Importance – This defines the importance of the sensitive receptor identified, which is assessed against spatial or political boundaries, socio-economic value, intrinsic quality, or the degree of rarity.

(M) Magnitude – Impact Magnitude or Magnitude of change is based on the relationship between the analysed physio-chemical, biological, or socio-economic deviation from baseline conditions and the relevant environmental standards, benchmarks, guidelines, or tolerance limits. Importantly, the Magnitude value should reflect the magnitude of change experienced at a particular sensitive receptor. In this way, the impact pathway is considered, i.e., whether there is a spatial and/or temporal overlap between the environmental change and receptor. Positive or negative impacts are represented though positive or negative ordinal scores for Magnitude respectively.

(P) Permanence – This defines whether an impact is temporary or permanent, i.e. a measure of the temporal status of the loss/change.

(R) Recoverability – The score expresses whether the receptor can recover from the impact, either unassisted or via mitigation measures. Recoverability is also a measure of the control over the effect (i.e., can it be mitigated).

(C) Cumulative Impact – This is a measure of whether the effect will have a single direct impact or whether there will be a cumulative effect over time.

The approach of RIAM is therefore to couple the potential impact Magnitude experienced at the sensitive receptor(s) of interest, with a concurrent assessment of receptor Importance, impact Permanence, Recoverability, and Cumulative potential.

Multiplication of Magnitude and Importance in the formula ensures that the weight of each evaluation criteria is expressed and individually able to significantly influence the resultant ES. The summation of Permanence, Importance, and Cumulative ensures that these criteria are represented collectively, but do not have as large an influence on the score

The standard (generic) definitions of each evaluation criteria, and the associated ordinal scores used to calculate ES, are shown in Table 4.11.

Table 4.11 Evaluation criteria and the associated standard definitions and ordinal scores used in the calculation of Environmental Scores.

Evaluation Criteria	Standard Definitions	Ordinal Score
Importance	Important to national/international interests	5
	Important to regional/national interests	4
	Important to areas immediately outside the local condition	3
	Important to the local conditions (within a large direct impact area)	2
	Important only to the local condition (within a small direct impact area)	1
Magnitude	Major positive benefit or change	+4
	Moderate positive benefit or change	+3
	Minor positive benefit or change	+2
	Slight positive benefit or change	+1
	No change/status quo	0
	Slight negative disadvantage or change	-1
	Minor negative disadvantage or change	-2
	Moderate negative disadvantage or change	-3
	Major negative disadvantage or change	-4
Permanence	Temporary or short-term change	2
	Permanent change or long-term; value and/or function unlikely to return	3
Recoverability	Recoverable or controllable through EMMP	2
	Irrecoverable	3
Cumulativity	Impact can be defined as not having cascading effect on other receptors over time	2
	Presence of obvious cumulative/cascading effect on other receptors over time	3

For each identified environmental impact affecting a sensitive receptor, an ES will be calculated. The ES are then banded together and ranked in range bands as presented in Table 4.12, which are then translated to Impact Significance – the reported output of the impact assessment process.

Table 4.12 Range bands of ES and the associated Impact Significance used in RIAM.

Environmental Scores (Range Bands)	Impact Significance Translated from Environmental Scores
116 to 180	Major positive change/impact
81 to 115	Moderate positive change/impact
37 to 80	Minor positive change/impact
7 to 36	Slight positive impact
-6 to +6	No impact/Status quote/Not applicable
-7 to -36	Slight negative change/impact
-37 to -80	Minor negative change/impact
-81 to -115	Moderate negative change/impact
-116 to -180	Major negative change/impact

4.5 Proposed EQOs

A set of Environmental Quality Objectives (EQOs) have been proposed for the Project and will be subject to approval by the Technical Agencies:

- No more than Slight Impact on the following receptors in the study areas:
  - Coral habitats located within 100 m of Pulau Satumu
  - Macrobenthos located within 100 m of Pulau Satumu
  - Intertidal habitats on Pulau Satumu
  - Marine Fauna within 100 m of Pulau Satumu
  - Marine Megafauna within 100 m of Pulau Satumu
  - Marine Water Quality around Pulau Satumu
  - Terrestrial fauna within 50m of Pulau Satumu
  - Terrestrial flora located within Pulau Satumu

4.5.1 Management of Environmental Impacts

Mitigation is typically required at least for identified environmental impacts predicted to be Moderate or Major. Mitigation measures are recommended and designed to reduce the impact down to an as-low-as-practicable level. Slight or Minor impacts also require mitigation, but it may also be enough to manage by having appropriate environmental procedures in place.

The term “mitigation measures” includes operational controls as well as management actions. These measures are often established through industry standards and may include:

- Changes to the design of the Project during the design process
- Engineering controls and other physical measures applied (e.g., noise barrier)
- Operational plans and procedures (e.g., noise pollution control management plan)
- Provision of like-for-like replacement, restoration, or compensation

The mitigation hierarchy concept is presented in Figure 4.6. In developing mitigation measures, the first focus is on measures that will avoid or minimise impacts through the design and management of the Project followed by those that restore or offset. Where impacts cannot be avoided, environmental mitigation measures will also be incorporated into the final detailed construction design and specified for appropriate construction methodology.

It is important to note that not all impacts are necessarily negative. There are actions that can be recommended to create net positive gains. Avoidance, minimisation and/or restoration alone are generally not enough to achieve a net gain and some form of offset is also necessary.

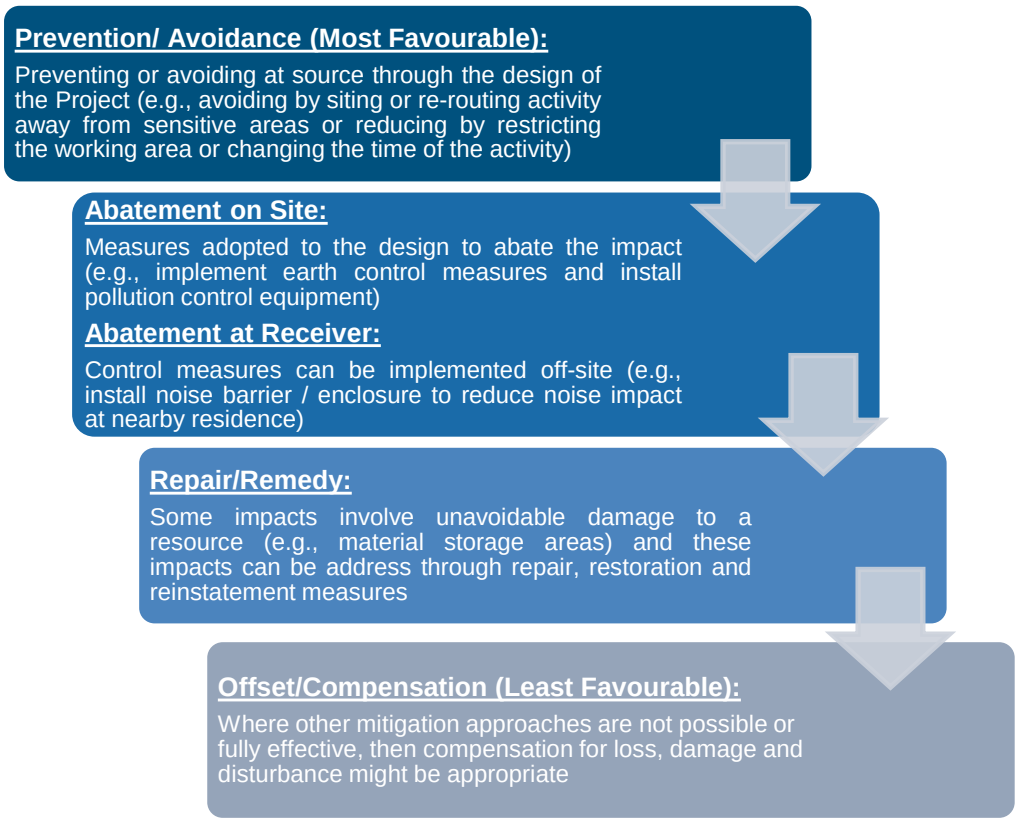


Figure 4.6 Hierarchy of mitigation strategy adopted in this Biodiversity Study.

5 Ecological Baseline

5.1 Terrestrial Habitats

The Study Area encompasses two major terrestrial habitat types, a central area of urban vegetation bounded by rock revetments on the western and southern ends, the lighthouse to the north and a strip of coastal vegetation defined by sandy beach on the eastern shore. The urban vegetation area consists of a large Cow grass (*Axonopus compressus*) and No mow grass (*Zoysia matrella*) planted lawn interspersed with various non-native and wind-dispersed weeds, with many old Coconuts (*Cocos nucifera*) and several smaller Fish killer trees (*Barringtonia asiatica*) forming the tree layer across this habitat. The sandy beach coastal habitat is mostly dominated by coastal specialists such as Beach morning glory (*Ipomoea pes-caprae*) and *Cyperus pedunculatus*.

Figure 5.1 A: Urban vegetation at the central part of the Study Area, with coastal vegetation at the right (red arrow). Coconuts are the dominant planted species in the habitat. B: Closeup of *Cyperus pedunculatus* at the coastal vegetation area.

5.2 Terrestrial Floral Biodiversity

A total of 21 flora taxa were recorded within the Study Area, all of which had been identified to species level (Table 5.2). Out of the 21 identified species, 12 species were native (57.2%) and 9 species were non-native/exotic (42.1%) (Table 5.1). Of the 12 native flora species recorded, 2 (9.6%) were considered threatened. There were 47 individuals of Coconuts (*C. nucifera*) that had 1 m girth or more, and 5 Fish Killer Trees (*Barringtonia asiatica*) that were mapped and measured (Appendix B).

Table 5.1 Summary of surveyed flora species. Native statuses and national conservation statuses were determined by taking reference from National Parks Board (2024) and Lindsay et al. (2022).

Origin	National conservation status	No. of Species	Percentage of Species
Native	Least Concern (LC)	10	47.6%
	Vulnerable (VU)	1	4.8%
	Critically Endangered (CR)	1	4.8%
	Total	**12**	**57.2%**
Exotic	Naturalized	5	23.8%
	Casual	1	4.8%
	Cultivated only	3	14.2%
	Total	**9**	**42.8%**
Total Number of Species		**21**	**100%**

5.2.1 Conservation Significant Flora

Out of the 12 native species, there were 2 conservation significant species (in **bold**, Table 5.2). The Critically Endangered *B. asiatica* is of planted origin, likely planted on the island in the past for aesthetic purposes and the ability to withstand coastal conditions. Due to the non-native origin of the individuals, this species is of low actual conservation significance. However, the other conservation significant species was *C. pedunculatus*, which is a Vulnerable self-dispersed coastal groundcover that thrives in full sun and sandy media (Figure 5.2). This species was found to be distributed across a 35 m^2 area on the eastern edge of the Study Area. This species is also known from several other Southern Islands such as Pulau Sudong, Pulau Semakau and Lazarus Island.

Table 5.2 List of flora species. Native statuses and national conservation statuses were determined by taking reference from National Parks Board (2024) and Lindsay et al. (2022). The origin of individuals on site was assessed using Table 4.9. The conservation significant species are in bold.

Species	Native Status	National Conservation Status	Origin of Individuals on site	Family	Form
Barringtonia asiatica	**Native**	**CR**	**Planted**	**Lecythidaceae**	**Tree**
Cyperus pedunculatus	**Native**	**VU**	**Spontaneous**	**Cyperaceae**	**Herbaceous Plant**
Alysicarpus vaginalis	Native	LC	Spontaneous	Fabaceae	Herbaceous Plant
Chrysopogon aciculatus	Native	LC	Spontaneous	Poaceae	Herbaceous Plant
Emilia sonchifolia	Native	LC	Spontaneous	Asteraceae	Herbaceous Plant
Fimbristylis dichotoma	Native	LC	Spontaneous	Cyperaceae	Herbaceous Plant
Grona triflora	Native	LC	Spontaneous	Fabaceae	Herbaceous Plant
Ipomoea pes-caprae	Native	LC	Spontaneous	Convolvulaceae	Creeper
Ischaemum muticum	Native	LC	Spontaneous	Poaceae	Herbaceous Plant
Scaevola taccada	Native	LC	Spontaneous	Goodeniaceae	Shrub
Wollastonia biflora	Native	LC	Spontaneous	Asteraceae	Herbaceous Plant
Zoysia matrella	Native	LC	Spontaneous	Poaceae	Herbaceous Plant
Axonopus compressus	Non-Native	Naturalised	Planted	Poaceae	Herbaceous Plant
Cocos nucifera	Non-Native	Naturalised	Planted	Arecaceae	Palm
Mimosa pudica	Non-Native	Naturalised	Spontaneous	Fabaceae	Herbaceous Plant
Tridax procumbens	Non-Native	Naturalised	Spontaneous	Asteraceae	Herbaceous Plant
Youngia	Non-	Naturalised	Spontaneous	Asteraceae	Herbaceous

Species	Native Status	National Conservation Status	Origin of Individuals on site	Family	Form
japonica	Native				Plant
Garcinia mangostana var. *mangostana*	Non-Native	Casual	Planted	Clusiaceae	Tree
Hibiscus sabdariffa	Non-Native	Cultivated Only	Planted	Malvaceae	Shrub
Moringa oleifera	Non-Native	Cultivated Only	Planted	Moringaceae	Tree
Musa sp.	Non-Native	Cultivated Only	Planted	Musaceae	Herbaceous Plant

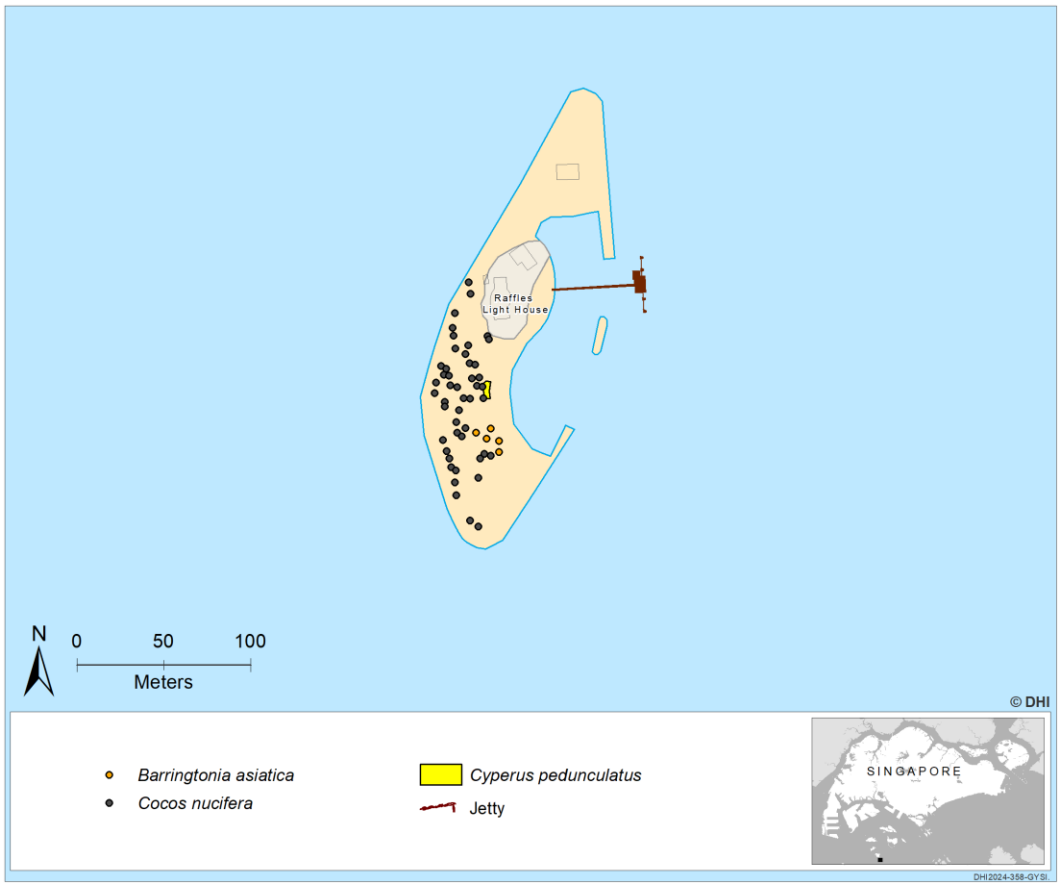


Figure 5.2 Locations of Coconuts (*C. nucifera*), Fish killer trees (*B. asiatica*) and the extent of *C. pedunculatus* found on Pulau Satumu in the Study Area.

5.3 Terrestrial Fauna Biodiversity

Terrestrial fauna surveys revealed a total of 24 species, which comprised of 12 bird, 3 reptile, 4 butterfly and 5 odonate species (Table 5.3). A full list of terrestrial fauna found during the survey can be found in Appendix A. Of all species observed, 3 species were of conservation significance, all of which were avifauna (Table 5.3).

The majority of species (21 species, 87.5%) were observed during diurnal surveys, whilst fewer species (9 species, 37.5%) were observed during nocturnal surveys. Species identified exclusively during diurnal surveys included all recorded butterfly and odonate species, as well as 6 species of avifauna. The remaining 6 bird species were observed across both diurnal and nocturnal periods. All 3 herpetofauna species were exclusively observed during nocturnal surveys. The Hawksbill turtle (*Eretmochelys imbricata*), although not sighted during baseline surveys, is known to nest on the sandy beach of Pulau Satumu.

No mammals and amphibians were observed over the course of the diurnal and nocturnal surveys. The low diversity of terrestrial fauna was expected, since the large stretches of sea between Pulau Satumu and other biodiverse land masses effectively functioned as barriers to dispersal for these largely terrestrial clades. The generally limited diversity of terrestrial fauna were largely limited to volant species with larger, known ranges.

Table 5.3 Terrestrial faunal checklist of all species observed at Pulau Satumu during Fauna line transect surveys.

Taxon	All species	Conservation significant species	Fauna line transect surveys	
			Diurnal	Nocturnal
Odonates	5	0	5	0
Butterflies	4	0	4	0
Herpetofauna	3	0	0	3
Amphibians	0	0	0	0
Reptiles	3	0	0	3
Birds	12	3	12	6
Mammals	0	0	0	0
Non-volant	0	0	0	0
Bats	0	0	0	0
Total	24	3	21	9

5.3.1 Avifauna

A total of 12 avifauna species were observed in and around the perimeter of Pulau Satumu, all of which were native species. Of these, 8 species were considered to be residents to Singapore, whilst the remaining 4 species were migratory visitors (Table 5.4).

Three of the migratory species, namely, the Greater crested tern (*Thalasseus bergii*), Lesser crested tern (*Thalasseus bengalensis*) and the Common sandpiper (*Actitis hypoleucos*) were of conservation significance. The remaining migratory species, the Eurasian whimbrel (*Numenius phaeopus*), was not of conservation significance, but was considered to be 'Near Threatened'. All of the native resident species were not of conservation significance (Table 5.4) (NParks, 2024).

Table 5.4 Checklist of avifauna species and abundance observed on and around Pulau Satumu. International and national conservation statuses take reference from IUCN (2024) and National Parks Board (2024) respectively. Conservation significant species are bolded.

Species name	Common name	IUCN	SRDB3	Abundance
Actitis hypoleucos	**Common Sandpiper**	**LC**	**VU**	**2**
Anthus rufulus	Paddyfield Pipit	LC	LC	2
Cinnyris jugularis	Olive-backed Sunbird	LC	LC	1
Haliaeetus leucogaster	White-bellied Sea Eagle	LC	LC	1
Haliastur indus	Brahminy Kite	LC	LC	4
Hirundo tahitica	Pacific Swallow	LC	LC	1
Numenius phaeopus	Eurasian Whimbrel	LC	NT	2
Passer montanus	Eurasian Tree Sparrow	LC	LC	33
Pycnonotus goiavier	Yellow-vented Bulbul	LC	LC	5
Spilopelia chinensis	Spotted Dove	LC	LC	18
Thalasseus bengalensis	**Lesser Crested Tern**	**LC**	**EN**	**34**
Thalasseus bergii	**Greater Crested Tern**	**LC**	**EN**	**8**

5.3.2 Herpetofauna

Herpetofauna is a term utilised to encompass the combined group of reptiles and amphibians. Herpetofauna identified on and around Pulau Satumu was exclusively comprised of reptiles. The absence of amphibians is unsurprising, as the island lacks and is distant from the freshwater bodies which are necessary for many amphibian species. All 3 species were members of the Gekkonidae family, and none were of conservation significance (Table 5.5) (NParks, 2024).

These gecko species may be classed as urban adaptors or exploiters that are often found around and benefit from centres of human activity. Due to limitations in their terrestrial locomotion, the presence of these geckos on Pulau Satumu was likely the result of their having been transported as hidden stowaways on various vessels that frequent the island.

Given that sea turtles come on land only during the nesting period, the locally and globally Critically Endangered Hawksbill turtle (*Eretmochelys imbricata*) was a notable absence from baseline surveys. However, the presence of this species on Pulau Satumu is well documented, with nesting events recorded on Pulau Satumu periodically (NParks, 2020). Several nesting occurrences have taken place over the past year on Pulau Satumu (MPA, pers. comms.) Thus, the Hawksbill turtle will be considered as part of the herpetofauna diversity on Pulau Satumu during an evaluation of impacts on biodiversity (Section 7.2.1).

Additionally, the locally Vulnerable Yellow-lipped sea krait (*Laticauda colubrina*) was absent from the baseline survey, though this species has been noted to utilise the island for shelter and reproductive activities (NParks, pers. comms.), and will be considered as part of the herpetofauna diversity on Pulau Satumu during an evaluation of impacts on biodiversity (Section 7.2.1).

Table 5.5 Checklist of herpetofauna species and abundance observed on and around Pulau Satumu. International and national conservation statuses take reference from IUCN (2024) and National Parks Board (2024) respectively. Conservation significant species are bolded.

Scientific name	Common name	IUCN	SRDB3	Abundance
Gehyra mutilata	Four-clawed gecko	LC	LC	2
Hemidactylus frenatus	Spiny-tailed gecko	LC	LC	31
Lepidodactylus lugubris	Maritime gecko	LC	LC	7
Eretmochelys imbricata	**Hawksbill turtle**	**CR**	**CR**	**-**
Laticauda colubrina	**Yellow-lipped sea krait**	LC	**VU**	**-**

5.3.3 Odonates

Odonates is a term utilised to encompass the combined group of dragonflies and damselflies. Three dragonfly species, the Scarlet skimmer (*Crocothemis servilia*), Coastal glider (*Macrodiplax cora*) and Yellow-barred flutterer (*Rhyothemis Phyllis*) as well as 2 species of damselfly, namely the Common bluetail (*Ischnura senegalensis*) and Blue sprite (*Pseudagrion microcephalum)* were recorded on and around Pulau Satumu. None of the species observed were of conservation significance (Table 5.6) (NParks, 2024).

Due to the distance between Pulau Satumu and other terrestrial habitats, the odonate diversity on Pulau Satumu reflects the presence of species which have been known to travel across larger distances.

Table 5.6 Checklist of odonate species and abundance observed on and around Pulau Satumu. International and national conservation statuses take reference from IUCN (2024) and National Parks Board (2024) respectively. Conservation significant species are bolded.

Scientific name	Common name	IUCN	SRDB3	Abundance
Crocothemis servilia	Scarlet skimmer	LC	LC	2
Ischnura senegalensis	Common bluetail	LC	LC	1
Macrodiplax cora	Coastal glider	LC	LC	9
Pseudagrion microcephalum	Blue sprite	LC	LC	1
Rhyothemis phyllis	Yellow-barred flutterer	LC	LC	1

5.3.4 Butterflies

Four butterfly were observed on and around Pulau Satumu. None of the species observed were of conservation significance (Table 5.7) (NParks, 2024).

Table 5.7 Checklist of butterfly species and abundance observed on and around Pulau Satumu. International and national conservation statuses take reference from IUCN (2024) and National Parks Board (2024) respectively. Conservation significant species are bolded.

Scientific name	Common name	IUCN	SRDB3	Abundance
Acraea terpsicore	Tawny coster	N/A	LC	1
Eurema hecabe contubernalis	Common grass yellow	N/A	LC	2
Junonia orithya wallacei	Blue pansy	N/A	LC	2
Zizina otis lampa	Lesser grass blue	N/A	LC	53

5.4 Intertidal biodiversity

The intertidal survey by DHI was completed on the 23rd of February 2024 at a low tide window between 0.3 – 0.5 mCD from 1600H to 2000H, with a quantitative Visual Quadrat Point (VQP) Survey being conducted along the intertidal zone of the western rock revetment and a qualitative Visual Walk-by Survey conducted along the eastern sandy beach intertidal area.

Figure 5.3 Intertidal area at Pulau Satumu

5.4.1 Visual Quadrat Point (VQP) Survey

Biotic components at Pulau Satumu accounted for the majority of substrata percentage cover (63.08 ± 7%), with abiotic components occupying the remaining area (36.91 ± 4.39%) (Table 5.8).

Biotic coverage of the substrata was almost entirely composed of sessile fauna with the predominant coverage being of hard coral (57.58 ± 4.21%), followed by zoanthids (1.94 ± 1.17%), soft corals (0.56 ± 0.56%) and finally, sponges (0.47 ± 0.31%) (Table 5.8).

Macroalgal components of biotic coverage were minimal (2.53 ± 0.6%). These comprised of Brown macroalgae (Phylum Ochrophyta, 2.08 ± 0.49%), Green macroalgae (Phylum Chlorophyta, 0.39 ± 0.20%) and Red macroalgae (Phylum Rhodophyta, 0.06 ± 0.06%) being the lowest. No seagrasses were recorded within and beyond quadrats set during the survey (Table 5.8).

Abiotic components (Table 5.8) comprised of rock (25.83 ± 4.21%), then rubble (5.08 ± 1.10%), sand (4.33 ± 1.41%) and finally, dead coral with algae (1.67 ± 0.60%).

Table 5.8 Mean percentage cover and standard error (SE) of biotic and abiotic components observed during the intertidal VQP surveys at Pulau Satumu.

Functional Group		Sub-category / Species	Selat Sengkir	
			Mean Cover (%)	SE
Biotic	Seagrass	-	-	-
	Algae	Brown macroalgae	2.08	0.49
		Green macroalgae	0.39	0.20
		Red macroalgae	0.06	0.06
		Algal assemblage	-	-
		Calcareous algae	-	-
	Sessile fauna	Ascidian	-	-
		Anemone	-	-
		Hard coral	57.58	4.21
		Soft coral	0.56	0.56
		Sponge	0.47	0.31
		Zoanthid	1.94	1.17
		Other fauna	-	-
Total biotic cover (%)			**63.08**	
Abiotic		**Dead Coral with algae**	1.67	0.60
		Rock	25.83	4.21
		Rubble	5.08	1.10
		Sand	4.33	1.41
		Silt	-	-
Total abiotic cover (%)			**36.91**	

Table 5.9 Mean density of intertidal fauna observed during the intertidal VQP surveys at Pulau Satumu.

Phylum	Class	Density(No./m^2)	SD	SE
Arthropoda	Polychaeta	0.00	0.00	0.00
Arthropoda	Arachnida	0.00	0.00	0.00
	Hexanauplia	0.00	0.00	0.00
	Malacostraca	2.89	4.34	0.72
	Ostracoda	0.00	0.00	0.00
Echinodermata	Asteroidea	0.00	0.00	0.00
	Echinoidea	0.00	0.00	0.00
	Holothuroidea	0.56	2.17	0.36
	Ophiuroidea	0.44	1.59	0.27
Mollusca	Bivalvia	0.00	0.00	0.00
	Gastropoda	4.56	11.16	1.86
Others	Others	0.00	0.00	0.00
SUM		**8.45**		

Several species of conservation significance were observed, such as the locally Vulnerable Red-eye reef crab (*Eriphia ferox*) and locally Endangered Burrowing giant clam (*Tridacna crocea*) among others (NParks, 2024) (Table 5.10). A full list of fauna found during the survey can be found in Appendix A.

5.4.2 Qualitative Visual Walk-by Survey

The qualitative Visual Walk-by Survey revealed the presence of significant intertidal biodiversity originating from several different taxa and genera. Notable finds include the locally Vulnerable Floral egg crab (*Atergatis floridus*) and locally Endangered Black long sea cucumber (*Holothuria leucospilota*) among others (NParks, 2024) (Table 5.10). A full list of fauna found during the survey can be found in Appendix A.

Table 5.10 List of conservation-significant fauna found during quantitative VQP surveys and qualitative visual walk-by surveys. A cross in the boxes indicates an observation of said species during the conduct of each survey.

Scientific name	Common name	SRDB3	Occurrence	
			VQP	Walk-by Survey
Atergatis floridus	Floral egg crab	VU	x	x
Eriphia ferox	Red-eyed reef crab	VU	x	x
Carcharhinus melanopterus	Blacktip reef shark	EN	x	
Holothuria leucospilota	Black long sea cucumber	EN	x	x
Tridacna crocea	Burrowing giant clam	EN	x	x

6 Impact Assessment Framework

6.1 Importance Rating of Sensitive Receptors

The generic criterion used to evaluate the Importance of ecological and biodiversity receptors, as stipulated in the BIA Guidelines (NParks, 2021), is adapted here (Table 6.1) following a customisation that considers the context-specificity of Singapore's ecological landscape, and its constituent biodiversity, habitat types, and conservation values. The evaluation of the Importance of identified receptors here utilised findings from the baseline surveys, the team's expert judgement, available scientific literature, and experience from similar Project within Singapore. The evaluation of Importance scores also considers the sensitivity or susceptibility of ecological receptors to the environmental pressure being assessed (e.g. airborne noise and air pollution).

Table 6.1 Evaluation Framework for Importance Scoring for identified ecological and biodiversity sensitive receptors, sorted in descending order of importance.

Score	Specific Criteria	
	Habitat/Vegetation types	**Fauna/Flora**
5	• Nationally or internationally designated habitat/sites of biological and ecological importance, e.g. designated Nature Reserves, Nature Areas, ASEAN Heritage Parks • Unrecognised habitat/sites of equivalent ecological value to designated and protected nature areas i.e. Primary forest, Freshwater swamp forests, Mangrove forests with distinct intertidal zonation • Natural freshwater streams within deep canopy cover • Highest ecological importance, near-inexistent potential for substitution, suis generis habitat nationally; many species with a highly restricted spatial distribution	• Contains species that are deemed to be Critically Endangered based on local (SRDB3) and global (IUCN) conservation assessments • Critically Endangered species found onsite demonstrate high site fidelity and/or narrow habitat specificity • Proportion of conservation-significant taxa/species between 40-50% of all species, e.g. listed in Singapore Red Data Book and IUCN conservation assessments as Vulnerable and above • Presence of species with keystone ecological functions i.e. bamboo clusters where there are bamboo bats
4	• Nationally or regionally recognised sites of biological and ecological importance • Large, forested sites (≥20 ha) with closed canopy cover, outside of designated nature reserves, nature areas and other legally protected areas including Native-dominated, old secondary forest, Coastal forests and Mangrove relic forests • Natural freshwater streams, marshes or ponds within open canopy cover • High ecological importance with limited potential for substitution; core habitat nationally; many species with	• Contains species that are deemed to be Endangered based on local (SRDB3) and Critically Endangered based on global (IUCN) conservation assessments • Endangered species found onsite demonstrate high site fidelity and/or Critically Endangered species with lower site specificity • Proportion of conservation-significant taxa/species between 30-40%, e.g. listed in Singapore Red Data Book and IUCN conservation assessments as Vulnerable and above • Presence of species with important

Score	Specific Criteria	
	Habitat/Vegetation types	**Fauna/Flora**
	restricted spatial distribution	ecological functions – Fig wasps for specific *Ficus* species
3	• Medium forested sites (5-20 ha) with closed canopy cover, outside of designated nature reserves, nature areas and other legally protected areas • Native-dominated, young secondary forest, Exotic-dominated secondary forest, and restored Mangrove forests • Naturalised streams, marshes or ponds with riparian vegetation • Moderate ecological importance with some potential for substitution, important habitat nationally; uncommon species with limited spatial distribution	• Contains species that are deemed to be Vulnerable based on local (SRDB3) and Endangered based on global (IUCN) conservation assessments • Proportion of conservation-significant taxa/species between 20-30%, e.g. listed in Singapore Red Data Book and IUCN conservation assessments as Vulnerable and above • Presence of species with defined ecological functions – most pollinators, food source for many species
2	• Smaller forested sites (1-5 ha), unmanaged vegetation under open canopy cover, such as Grassland or Shrubland habitats • Modified-urbanised streams with soft landscaping features, e.g. ABC projects • Modest ecological importance with the potential for substitution; important habitat locally, harbours common, non-urban species	• Contains species that are deemed to be Least Concern based on local (SRDB3) and Vulnerable based on global (IUCN) conservation assessments • Proportion of conservation-significant taxa/species between 10-20%, e.g. listed in Singapore Red Data Book and IUCN conservation assessments as Vulnerable and above
1	• Non-forested sites with urban vegetation • Highly modified or fragmented habitats; managed turf, streetscapes • Low to non-existent ecological importance, highly substitutable	• Species of no national importance • Urban adapting or exploiting species

6.2 Identified Sensitive Receptors and Importance

The relevant ecological sensitive receptors are limited to marine habitats, marine fauna, terrestrial fauna and terrestrial flora. Their associated importance scores and justifications are detailed in Table 6.2.

Table 6.2 Importance Score for identified ecological and biodiversity sensitive receptors.

Ecological Sensitive Receptors	Importance Score
Urban Vegetation	1
Flora	3
Avifauna (Birds)	3
Herpetofauna (Reptiles and Amphibians)	5
Butterflies	2
Odonates	2
Intertidal Habitat	3
Coral	5
Macrobenthos	2
Marine Fauna	3
Marine Megafauna	5

7 Prediction and Evaluation of Environmental Impacts (Pre-construction and Construction Phase)

This chapter analyses the predicted ecological impacts and assesses their significance during the pre-construction and construction phases of the Project and proposes suitable mitigation measures.

7.1 Loss of Terrestrial Flora

The diversity and structure of terrestrial flora found on site demonstrates an underlying structure of primarily urban vegetated species, with only one conservation significant species, *C. pedunculatus*, of non-cultivated origin. Thus, the Importance score of 3 reflects this relatively depauperate floral diversity.

The clearance of terrestrial flora from the entirety of the Study Area is likely to be necessitated to maximise the area occupied by the solar panel system, thereby ensuring that the solar energy generated within the constraints of the island can meet the island's energy need. Additionally, the implementation of the solar panels will inadvertently obscure the level of light available to the various low-lying grasses and weeds that currently function as ground cover for the island. However, as the installation of solar panel structures is likely to involve a nominal amount of alteration to the existing substrate, it is likely that various weeds and grasses will grow between the panel structures, assuming a sufficient level of light permeates into these areas.

While these conditions would entail the clearance of trees, including Coconut (*C. nucifera*) and Fish killer trees (*B. asiatica*), these tree species were planted, and not considered a sensitive ecological receptor. The herbaceous vegetation found on the site, including *C. pedunculatus*, are likely to continue to persist in some degree. Additional measures can also be introduced to ensure that the patch of *C. pedunculatus* is safeguarded (Section 0). Therefore, it is conservatively assessed that the magnitude of change to terrestrial flora is -3, with some potential declines in the extent of vegetated ground cover.

Although the presence of the solar panels is expected to be permanent, the current patch of *C. pedunculatus* is found at the eastern edge of the turfed area, where the direct impact due to the solar panel footprint can be avoided. Therefore, this impact can be deemed to be non-permanent and recoverable. Also, given the relatively urban structural composition of the vegetation on site, and the extensive barriers of dispersal between Pulau Satumu and other vegetated areas, these impacts are unlikely to be cumulative.

Thus in totality, the loss of terrestrial flora is likely to constitute a Minor Negative impact.

7.2 Loss of Terrestrial Fauna

The absence of complex vegetated habitat also reveals itself in the fauna diversity within the Study Area. Overall, a relatively low number of species were found during baseline surveys, of which, only 3 species of migratory avifauna, were conservation significant. Based on these considerations, an Importance score of 3 was attributed to avifauna, whilst the remaining observed taxa (herpetofauna, butterflies and odonates) were all given an Importance score of 2.

The clearance of vegetation may potentially lead to the injury and mortality of some of the terrestrial fauna. However, the vast majority of terrestrial fauna (avifauna, butterflies,

odonates) found within the Study Area exhibit the ability to fly, reducing the probability in which incidences of mechanical injury are likely to happen. Species found that are unable to fly include all gecko species on site. However, all of these species are nevertheless at least urban adaptive, if not urban exploitative species that were mostly found centred around pre-existing urban structures on the island, and are thus likely to be left relatively unaffected, at the fringes of the construction activity.

However, the removal of the established vegetation on site is likely to reduce the inhabitability of the site thereafter. The reduction of resources is also a meaningful source by which the abundance of population of terrestrial fauna may be affected. Whilst the removal of mature trees are likely to dissuade some avifauna, such as the Spotted doves (*S. chinensis*), which were observed moving actively between the canopy layers of the trees on site, others such as the Eurasian tree sparrows (*P. montanus*) already favour the urban dwellings on site. Importantly, the three conservation significant species were all spotted off the coast within the observational distances indicated (Section 4.3.2), feeding on fishes. By their very migratory nature, these species have been accustomed to moving substantive distances, and are likely able to identify and relocate to alternative habitats. Similarly, the various grassland favouring butterflies and odonates are expected to see a population reduction, but the continued persistence of these weeds is likely to exclude their extirpation from the island. Therefore, it is conservatively assessed that the magnitude of change to terrestrial fauna is -2.

The permanent eventual presence of the solar panels means that the loss of terrestrial flora is expected to be both permanent and non-recoverable. However, the small reductions in resource availability, the presence of alternative vegetated habitats and low probability of injury or mortality mean that these impacts are unlikely to be cumulative. Consequently, the impact significance of the loss of terrestrial fauna is expected to be a Minor Negative for avifauna, and a Slight Negative for all other taxa, including herpetofauna, butterflies and odonates.

7.2.1 Disturbance to Sea turtles

This subsection has been written to separately evaluate the impacts of planned construction activities on sea turtles, given their status as a Critically Endangered species at both national and international levels. This critical need for conservation is exacerbated by their unique tendency to return to their birth sites to nest. Their conservation significance and high habitat fidelity necessitates an Importance score of 5.

Although planned construction activities are to be limited to the mostly urban vegetated areas beyond the sandy beach front, the range of their disruptive effects may extend beyond this footprint and result in disturbances to sea turtles. These include the possibility of mechanical injury to incoming turtles, their nests and their eggs as well as functioning as a deterrence for warier individuals. Thus, the magnitude of change to sea turtles is -2.

The expected disturbances are not expected to be permanent since intrusive activities are expected to be limited to the construction phase. Similarly, the source of disturbances is believed to be self-correcting, and thus their associated impacts are expected to be recoverable. However, the impact of possible disturbances to sea turtles are expected to be cumulative, given the pre-existing backdrop of species scarcity and Pulau Satumu being known as a nesting site for the species.

All in all, the impact significance of disturbances to sea turtles is expected to be a Minor Negative.

7.2.2 Loss of sea krait habitat

This subsection has been written to separately evaluate the impacts of planned construction activities on Yellow-lipped sea kraits.

Planned construction activities are presently expected to result in the complete removal all vegetation within the Project footprint, including the Coconut trees noted in Section 5.3.2 to be utilised as nesting sites (NParks, pers. comms.). Various forms of terrestrial vegetation and other features, including tree holes and crevices function additionally as shelter and refuges (Shetty & Prasad, 1996), as well as repositories of freshwater (Liu et al., 2012) for this particular terrestrial species (Brischoux et al., 2012). However, no exclusivity of habitat niches has previously been prescribed for this species to Coconut trees. Whilst the majority of vegetation within the footprint will be removed, potential nesting sites and terrestrial refuges for Yellow-lipped sea kraits remain present in other parts of Pulau Satumu. These areas include the rock revetment that encircles majority the island and pre-existing trees that will remain untouched beyond the construction footprint. Taking these considerations into account, a magnitude score of -2 is appropriate.

The removal of pre-existing Coconut trees within the project footprint is expected to be permanent. However, the creation of alternative nesting sites through replacement planting and other forms of supplementary environmental niche creation are possible; and thus, makes the recovery from such an impact possible.

In totality, the impact on Yellow-lipped sea kraits are expected to be Minor Negative.

7.3 Disturbance from Pre-construction and Construction Activities

Based on secondary data, it is noted that the corals reefs around Pulau Satumu are one of Singapore's most ecologically significant marine habitats (Guest et al., 2007; Jaafar et al., 2018; Reef Ecology Lab, 2024) and feature high coral species richness (143 species out of 276 scleractinian coral present in Singapore) (Guest et al., 2005; Huang et al., 2009), including 23 species which are of local conservation significance (NParks, 2023). Hence the Importance score of corals reefs is 5.

The intertidal surveys reveal that rocky shore and sandy beach habitats harboured high coral and other sessile cover (Table 5.8) and some species of conservation significance (Appendix A). Additionally, the sandy beach is known to be a nesting site for the Critically Endangered Hawksbill Sea turtle. Therefore, the Importance score of the rocky shore and sandy beach habitats is 3.

The macrobenthic areas without coral were assessed to have an Importance score of 2. In general, macrobenthic areas around Pulau Satumu have a similar composition to other nearby Southern Islands such as Pulau Senang and Pulua Biola, with high replaceability.

The marine fauna found around Pulau Satumu are similar to those of Pulau Senang and Pulau Biola due to proximity. However, the intertidal surveys showed that there were some marine species of conservation significance (Appendix A). Therefore, the Importance score of marine fauna is 3.

Secondary information (DHI internal database and NParks) highlighted that marine megafauna such as dolphins and critically endangered Hawksbill Sea turtles were observed around Pulau Satumu. Therefore, the Importance score of marine megafauna is 5.

7.3.1 Loss of Marine Habitat during Equipment transportation

Before the installation of the ESS and solar PV panels on the island, equipment will be lifted by a crane from the barge and placed on a temporary staging area on Pulau Satumu to facilitate the movement of equipment to the construction site. The barge is expected to move close to the island but will remain at a distance from the shore. Therefter, anchors and/or spud legs could be deployed to stabilise the barge before utilizing its crane to transfer equipment onto the island. This precaution is necessary as the depths around the island are shallow and intertidal coral cover is extensive around the island.

Habitat losses during equipment transportation are described below:

- **Potential keel scouring of seabed**: While the barge remains at a distance and could be stabilised in position with anchors and/or spuds before transferring equipment, there still exists a potential risk of the barge's or other supporting vessels' keels scouring the seabed during their manoeuvres. If such an event occurs, it is anticipated that there will be a complete loss of habitat (coral or macrobenthos) at the impact zone.
- **Potential collision with the shoreline**: Similarly, there exists a potential for the barge to collide with the rocky shore and sandy beach habitats. If such an event occurs, the habitat will be damaged at the impact zone.
- **Spudding**: While deploying spuds to ensure stability and safety during equipment transportation, there will be a complete loss of habitat (coral or macrobenthos) within the footprint of the spuds.

The effects of suspension of marine sediments resulting from the above is further detailed in Section 7.3.4.

Therefore, it is conservatively assessed that the magnitude of change to macrobenthos, rocky shore and sandy beach, and coral is -2, because of the potential habitat area that may be lost or damaged. Permanence is scored at 2 given that this can only occur in the construction phase. Recoverability is scored at 2, given that lost coral cover and other habitats can recover over time. Cumulatively is scored at 2, as it is a non-cumulative impact.

Consequently, the Impact Significance of equipment transportation-linked loss of habitat on macrobenthos, rocky shore and sandy beach, and coral is predicted to be Slight Negative, Slight Negative, and Minor Negative respectively. With mitigation measures, the Magnitude of change can be reduced to -1, assuming the utilisation of smaller diameter spuds, selection of area with lower coral cover and sufficient depth for the mooring of the vessel, and slow and careful manoeuvring of the vessel. Therefore, Residual Impact Significance is also predicted to be Slight Negative for all three receptors (Table 7.2).

7.3.2 Boat strikes on marine megafauna

The physical presence of vessels associated with construction works in the area are expected to affect marine wildlife found within the vicinity of Pulau Satumu. Although there are already existing vessels that travel to Pulau Satumu or are going pass by the island, it is anticipated that there will be increased vessel traffic associated with the Project during the Construction Phase.

One of the key aspects related to greater presence of vessels in an area is a greater potential for occurrences of boat-strike incidents. This is particularly an issue for air breathing species such as cetaceans, dugongs, otters, and marine turtles. Of these

marine megafauna, dolphins and turtles are known to be present around the Pulau Satumu. Turtles may be at higher risk as they are slower, especially to fast-moving transport vessels.

Vessels associated with the Project during construction are expected to consist of barge/s, tugboat/s, and transport vessels. The barge and tugboat will be present around the mooring area, while transport vessels will be heading to the island's jetty for picking up or dropping off passengers.

It is conservatively assessed that the magnitude of change of boat strikes on marine megafauna is -1 as the probability of boat strikes occurring is low. Permanence and Recoverability is scored at 2 given the temporary nature of construction works. Cumulatively is scored at 2, as it is a non-cumulative impact.

Consequently, the Impact Significance of boat strikes on marine megafauna is predicted to be Slight Negative. With mitigation, the Magnitude of change still remains at -1, given that the risk of boat strikes occurring cannot be avoided. Therefore, Residual Impact Significance is also predicted to be Slight Negative for marine megafauna (Table 7.2).

7.3.3 Underwater noise disturbance from construction vessels

Underwater noise generated from the construction vessels may result in disturbance to marine wildlife. Sources of underwater noise for this Project will include construction vessel machinery and engines during vessel movement and unloading of equipment, as well as during spud deployment to stabilise the barge during equipment unloading.

Regarding marine megafauna in the area, dolphins and sea turtles are known to frequent the area and its surroundings. Fish are expected to be present in the Study Area, although fish surveys were not prioritized during the baseline campaign of this Study.

The duration of exposure to underwater noise generated from construction vessel machinery and engines, as well as spudding, is expected to be limited. This is because the unloading of equipment and supplies from transporting vessels will be conducted from a mooring area, owing to the shallow waters surrounding the island and precautions taken to avoid damaging the vessels and seabed. Additionally, the number of marine transportation trips will be minimised as far as practically possible during the construction phase.

Upon closer exposure to sources of underwater noise (e.g., when a vessel is approaching the rock revetment), it is expected that marine fauna will move away from the disturbance area following the onset of noise detection and return after the pressure ceases. It is conservatively assessed that the magnitude of change to marine fauna and megafauna is -2. Permanence is scored at 2 given that underwater noise generation will only occur during the Construction period. Recoverability is scored at 2, given that marine fauna will return to the area after the noise pressure ceases. Cumulatively is scored at 2, as it is a non-cumulative impact.

Consequently, the Impact Significance of underwater noise disturbance for marine fauna and marine megafauna is predicted to be Slight Negative and Minor Negative respectively. With mitigation, the Magnitude of change can be reduced to -1, assuming the utilisation of smaller vessel with smaller engine, options for muffling are implemented and smaller diameter spuds are used to anchor the vessel. Therefore, Residual Impact Significance is also predicted to be Slight Negative for both marine fauna and marine megafauna (Table 7.2).

7.3.4 Suspension of marine sediments

As described in Section 7.3.1, during equipment transportation there may be accidental scouring of the seabed and spudding. These events will cause marine sediments on the seabed to be suspended, however their effects will be very much dependent on the amount of suspended sediment released and the hydrodynamic conditions influencing their spread and dispersal.

Below, potential effects of the suspension of marine sediments are briefly described. However, unlike dredging or land reclamation works, it is noted that the activities associated with this project are unlikely to result in significant release of suspended sediment:

- **Shading of photosynthetic organisms (coral, seagrass, etc**): Suspended sediments can shade benthic photosynthetic organisms, reducing light availability to them, affecting their photosynthetic ability. These can lead to effects like reduced growth or mortality should the photosynthetic organisms be exposed to the suspended sediments shading over a long period.
- **Physiological effects on marine organisms**: Elevated suspended sediments can directly clog the respiratory and feeding apparatus of corals and other filter feeding organisms. Similarly, for fish, it can cause physiological damage such as damage to their gills and induce behavioural responses such as avoidance of areas with high suspended sediment concentrations.
- **Burial of benthic organism**: Elevated levels of suspended sediments can directly bury benthic organisms, leading to increased energy expenditure to compensate or resulting in mortality.

It is conservatively assessed that the magnitude of change of suspension of marine sediments to coral and marine fauna is -1. Permanence is scored at 2 given that suspension of marine sediments resulting from construction activities can only occur during the Construction period. Recoverability is scored at 2, given that coral and marine fauna can recover and/or will return to the area after the pressure ceases. Cumulatively is scored at 2, as it is a non-cumulative impact.

Consequently, the Impact Significance of suspension of marine sediments on marine fauna, and coral is predicted to be Slight Negative, even after mitigation (Table 7.2) as the risk of accidental suspension of marine sediments cannot be fully eliminated and a small amount of marine sediment will be released during spudding.

7.4 Pollution from improper site management

7.4.1 Oil spills and leaks

Due to the nature of the project which increases overall vessel traffic to Pulau Satumu, there is an increased risk of oil spills and leaks. Oil spills and leaks can occur during vessel collisions or improper maintenance of equipment. The most likely liquids to be spilt include fuel and diesel products. Hydrocarbons generally float as a layer on top of the water when released into the environment, and as such are a particular concern for air breathing marine species including marine reptiles, cetaceans, sirenians, and marine birds. Also, when spilt hydrocarbons reach the shoreline, they are deposited in the intertidal area, often causing smothering impact to in-fauna, intertidal habitats, as well as affecting other littoral species and animals which feed in these areas including shoreline birds and reptiles. Oil may be distributed through the water column if an emulsion with water is formed; this is more likely in high energy environments.

Spills of oil and petrochemicals can impact marine ecology through both physical and chemical (toxic) effects. The longer-chain compounds, such as those found in the fuel oil, have higher viscosities, and will coat surfaces and smother organisms. Shorter-chain hydrocarbons, such as diesel and unsaturated and aromatic hydrocarbons are primarily associated with toxicity impacts (UK Marine SACs Project 2001).

Certain ecological processes, including those that involve reproduction, development and certain behaviours are very sensitive to oil pollution. Generally, marine organisms in early life stages are more sensitive than full grown adults.

In the event of a spill, the effects will be very much dependent of the volumes released, environmental conditions (weather and tides), and physical properties of the spilt hydrocarbon such as toxicity, persistence in the environment, and bioavailability. Potential effects on the key habitats and species are discussed below:

- **Shorebirds**: Shorebirds may come in contact with oil spills while foraging in the intertidal areas. Oil causes mortality through destroying the waterproofing and insulating capabilities of feathers, leading to death from hypothermia. Other effects of direct oil exposure, generally from ingestion, include dehydration, starvation, infections, eye irritation, and reduced reproduction. Birds ingest oil when preening of oiled feathers. Whilst birds are highly mobile and can move to avoid patches of oil contamination and prolonged exposure, short-term exposure could still be detrimental. Furthermore, there is also a toxicity risk to these species through the consumption of contaminated food.

- **Corals and other marine invertebrates**: Oil spills can cause lethal or sublethal effects on corals and invertebrates, attenuating of interfering the physiological process such as faeces or pesudofaeces production, net carbon flux, feeding activity, and filtration rate (Shigenaka 2001; Zhou et al., 2019). Individual responses differ between species, with some more tolerant to oil spill disturbance than others. For example, crustaceans as a group are among the most vulnerable marine invertebrates to oil spills and suffer high mortalities, behavioural disorders, and reduced recruitment (Keesing et al., 2018). Similarly, many studies have documented extensive mortalities of echinoderms after oil spills (Keesing et al., 2018). However, there can also be variation within the faunal group. For example, the 2002 Prestige oil spill caused the disappearance of three species (one brittle star and two sea urchins) for two to four years, whereas a sea star and sea cucumber were either minimally or not impacted by the spill (Keesing et al., 2018).

- **Marine megafauna**: Oil affects marine megafauna through inhalation, ingestion, and dermal pathways, with each pathway causing a suite of physiological responses that potentially compromise health and long-term survival and reproduction. Like birds, marine megafauna are highly mobile and can move to avoid patches of oil contamination and prolonged exposure, although short-term exposure could still be detrimental. Similarly, marine megafauna are also exposed to toxicity risk through the consumption of contaminated food.

While the risk is relatively low, the environmental consequences of an oil spill can be significant. As such, the risk of an accidental spill must be managed to reduce the likelihood of such an event. It is conservatively assessed that the magnitude of change of spills and leaks to marine fauna, marine megafauna, and coral is -2, because the potential volume of oil spilt will only be limited to a few construction vessels at most and spill events are not common. Permanence is scored at 2 given the temporary nature of construction works. Recoverability is scored at 2, given that recovery can occur over time after a spill. Cumulatively is scored at 2, as it is a non-cumulative impact.

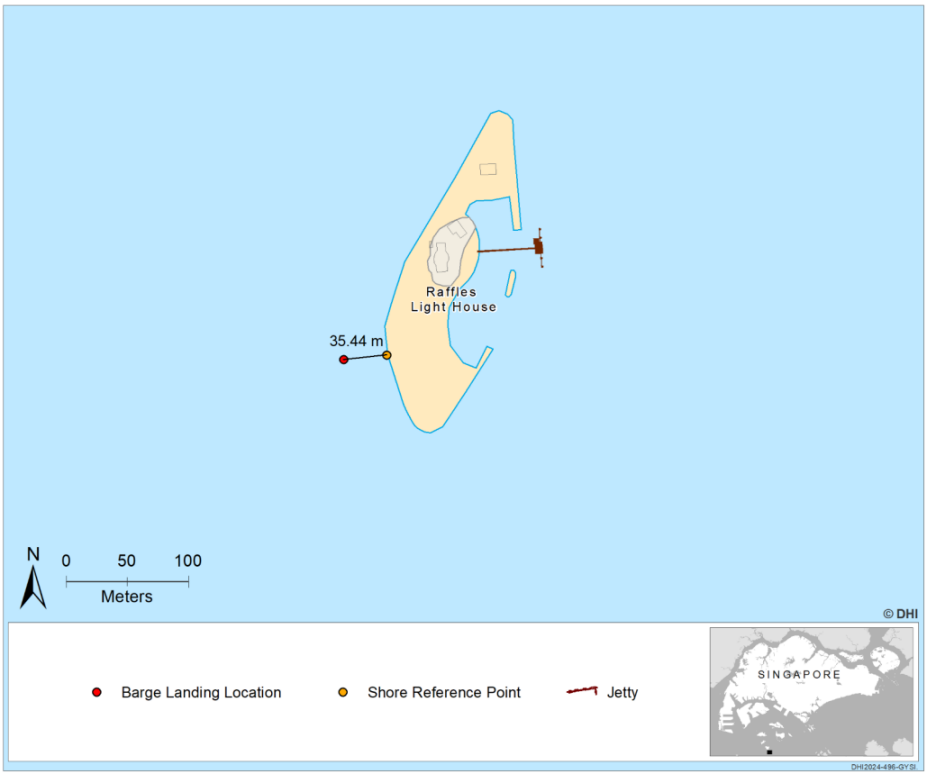
Consequently, the Impact Significance of oil spills and leaks on marine fauna, marine megafauna, and coral is predicted to be Slight Negative, Minor Negative, and Minor

Negative respectively. With mitigation, the Magnitude of change can be reduced to -1, assuming the adoption of a spill response plan. Therefore, Residual Impact Significance will be Slight Negative for marine fauna, marine megafauna, and coral (Table 7.2).

7.5 Proposed Mitigation Measures

The measures proposed to mitigate the impacts on ESRs during the construction stage is detailed in Table 7.1.

Table 7.1 Proposed measures to mitigate the impacts on ESRs during the Construction phase, ordered by mitigation hierarchy (priority).

Mitigation Hierarchy	Mitigation Measures
Avoidance	Avoid using a barge mooring area with higher coral cover, instead, choose a mooring area with lowest subtidal and intertidal coral cover. Areas with high coral cover should be avoided. Mooring of the barge should be far enough offshore to avoid spuds landing on subtidal coral (Figure 7.1).  Figure 7.1 The recommended mooring position situated ~30m from the rock revetment, within the barge crane's reach, but outside of the subtidal coral zone The transportation of equipment and supplies is to be restricted to daylight hours from the specific mooring point. Once daily loading/offloading works have ceased, transportation barges are not to remain at the mooring point, and instead should be towed to an offshore anchorage or mainland harbour to await subsequent deployment. Nightworks will be avoided to prevent interference with the function of the lighthouse as a nocturnal navigational aid and avoid affecting the behaviour of nocturnal megafauna around the island.

Mitigation Hierarchy	Mitigation Measures
	Where possible, minimise working during the coral spawning season. The coral spawning season in Singapore occurs on a monthly basis, typically during and up to four days after a full moon. During this time, the conduct of all activities that may involve a disturbance or alteration to the marine environment, including the movement of vessels, generation of surface runoff, underwater noise, vibration or intrusive lightning should be halted. The conduct of construction activities during the season may result in a disruption to the spawning process. Where possible, minimise working during the sea turtle nesting season, which lasts between June to September of each year. The conduct of works during this time risks the potential interference with nest-making, egg laying behaviours and the possibility of injurious encounters. Should works during the sea turtle nesting season be necessary, construction activities should be restricted to daylight hours to prevent the disruptive influence of lighting on sea turtle activity. A relocation plan for errant hatchlings or stray adults should be in place. Any access to the sandy beach should be avoided during the sea turtle nesting season.
Minimization	Identify a mooring location where with the least amount of coral cover to engage in barge spudding. When practical, consider using smaller vessel/s and barge/s with shorter keels and smaller engines, and explore options for muffling the engine where feasible to reduce underwater noise. Additionally, utilise spuds with a smaller diameter. Aim to execute equipment unloading works from the optimal vessel mooring area to minimise the potential disruptive effects. Aim to complete equipment unloading to the temporary staging area in as few tidal cycles as practically possible, this minimises the potential of damaging intertidal and shallow subtidal coral habitats and minimise the occurrence of spudding and anchoring during barge mooring. Construction crew to assign staff to keep active lookout of marine megafauna during operations. Vessels to slow down when marine mammals or marine reptiles are observed within 100 m and when approaching the island. Additionally, vessels are to actively avoid marine megafauna until the animal(s) have left the immediate observation zone. An emergency spill response plan and related equipment for the project site to be developed to ensure a maximum response time of 60 minutes after detection of leak or spill while the slick is mostly localised to the release site. Vegetation clearance should be preceded by the obtainment of NParks approval and in accordance with the following protocols: Trees that are marked to be felled should be physically tagged; Pre-felling Wildlife Inspections should be conducted to assess the presence of arboreal fauna and habitats (e.g. bird nests, bee hives, tree burrows). Tree-felling works are not to proceed should any fauna or active bee hives be found on the trees. If bird nests are found on the trees, visual confirmations are required to ensure that the nests are not actively occupied, and if they are, tree felling can only proceed when the birds or fledglings have left the nest. A Wildlife Management Plan should be concocted as part of an EMMP, with the engagement of an NParks-Certified Animal Management Specialists, proper fauna response protocols should wildlife be encountered or trapped on the site. NParks (Wildlife Management Division) should be sought for specific direction on what to do with wildlife encountered on site. Utilise Erosion Control Blankets (ECBs) where applicable to prevent the extent of

Mitigation Hierarchy	Mitigation Measures
	surface runoff into adjacent intertidal sites. The selection of ECBs should limited to the fully biodegradable versions, to minimise the likelihood of entrapping fauna when the ECBs are inadvertently left on site following completion of construction works. ECBs should be checked daily by the Environmental Control Officer (ECO).
Restoration	Replanting of low-rise coastal vegetation along the perimeter of the construction area to be considered. Allow for salvaging of conservation-significant flora species by NParks.
Offsets	The clearance of pre-existing vegetation within the project footprint can be offset by replanting of select species of coastal shrubbery and other forms of vegetation around the perimeter of the island, serving both as a coastal protection measure, as well as a substitute habitat for displaced fauna. Waste material such as wood originating from felled trees can be reused to design the planter beds and to form substitute habitat and shelters for animals i.e., sea kraits. Additionally, the wood can be chipped to be used as a substrate topper for the planter beds.

7.6 Impact Summary

Following implementation of the abovementioned mitigation measures, the residual impact significance for the impacts on ESRs are predicted to be Slight Negative for all identified impacts (Table 7.2).

Table 7.2 Pre-construction SI works and construction phase impact assessment for ESRs. The change in impact Magnitude following mitigation (if any), and the residual impact Significance is also shown. (I = Importance; M = Magnitude; P = Permanence; R = Reversibility; C = Cumulative; ES = Environmental Score)

Predicted Impact	Sensitive Receptors	Predicted impacts without mitigation measures							With mitigation measures		
		I	M	P	R	C	ES	Impact Significance	M	ES	Residual Impact Significance
Loss of terrestrial flora	Terrestrial flora	3	-3	2	2	2	-54	Minor Negative	-1	-18	Slight Negative
Loss of terrestrial fauna	Avifauna	3	-2	3	3	2	-48	Minor Negative	-1	-24	Slight negative
	Herpetofauna	2	-2	3	3	2	-32	Slight Negative	-1	-16	Slight negative
	Butterflies	2	-2	3	3	2	-32	Slight Negative	-1	-16	Slight negative
	Odonates	2	-2	3	3	2	-32	Slight Negative	-1	-16	Slight negative
Disturbance to Sea turtles	Sea turtles	5	-2	2	2	3	-70	Minor Negative	-1	-35	Slight negative
Loss of sea krait nesting sites	Yellow-lipped sea kraits	3	-2	3	2	3	-48	Minor Negative	-1	-24	Slight Negative
Loss of habitat during equipment transportation	Coral	5	-2	2	2	2	-60	Minor Negative	-1	-30	Slight Negative
	Rocky Shore and sandy beach	3	-2	2	2	2	-36	Slight Negative	-1	-18	Slight Negative
	Macrobenthos	2	-2	2	2	2	-24	Slight Negative	-1	-12	Slight Negative
Boat Strikes	Marine Megafauna	5	-1	2	2	2	-30	Slight Negative	-1	-30	Slight Negative

Predicted Impact	Sensitive Receptors	Predicted impacts without mitigation measures							With mitigation measures		
		I	M	P	R	C	ES	Impact Significance	M	ES	Residual Impact Significance
Underwater Noise Disturbance from construction vessels	Marine Fauna	3	-2	2	2	2	-36	Slight Negative	-1	-18	Slight Negative
	Marine Megafauna	5	-2	2	2	2	-60	Minor Negative	-1	-30	Slight Negative
Suspension of marine sediment	Coral	5	-1	2	2	2	-30	Slight Negative	-1	-30	Slight Negative
	Marine Fauna	3	-1	2	2	2	-18	Slight Negative	-1	-18	Slight Negative
Chemical spills and leaks	Coral	5	-2	2	2	2	-60	Minor Negative	-1	-30	Slight Negative
	Marine Fauna	3	-2	2	2	2	-36	Slight Negative	-1	-18	Slight Negative
	Marine Megafauna	5	-2	2	2	2	-60	Minor Negative	-1	-30	Slight Negative

8 Prediction and Evaluation of Environmental Impacts (Operational Phase)

Overall, the conservation value of the habitats and biodiversity found, particularly within the marine environment of the Study Area, appears to be important within Singapore's context, given the high species richness and the high proportion of species of conservation significance. Additionally, Pulau Satumu is an important habitat for coral recruitment, and is home to a substantial size of coral habitat in the southern area of Singapore waters.

8.1 Evaluation Framework

The evaluation framework for the impact assessment for changes to ecology and biodiversity follow that as described in Section 6. The relevant sensitive biodiversity and ecological receptors are limited to marine habitats and fauna. Their associated Importance scores and justifications are detailed in Sections 6.1 and 6.2.

8.2 Predicted Impacts and Assessment of Impact Significance

8.2.1 Changes to Marine Water Quality

The Project would include the proposed installation of small-scale desalination unit(s). Desalination units take in marine water and through a process known as reverse osmosis, extract dissolved salts and minerals, for the generation of potable freshwater. The extraction of dissolved salts and minerals results in the production of brine which can have an impact on marine habitats and fauna when released into the sea. Further investigation of these impacts is explored in the sections below.

The desalination units are intended to fulfil the island's freshwater needs, such as producing potable water for the lighthouse keepers stationed on the island and are envisaged to be small-scale units. Consequently, their potential effluent generation capacity will be limited. The small volume of brine effluent discharged is anticipated to swiftly mix and disperse upon discharge into the sea. Localised increases in salinity will be detectable within the small mixing zone during discharges. However, this small mixing zone is also subjected to being rapidly flushed because of the high current speeds* around Pulau Satumu.

Therefore, it is conservatively assessed that the magnitude of change to marine fauna and coral is -1, because of the limited volume of brine effluent potentially discharged and the effective flushing of the area^. Permanence is scored at 3 given that this will be a regular occurrence when the desalination units are operational. Recoverability is scored at 2, given that recovery can occur once desalination operations cease. Cumulatively is scored at 2, as it is a non-cumulative impact. The salinity modelling was performed as part of this assessment and incorporate the modelling results to conclude the associated impacts.

* Records from DHI's internal database indicate current speeds around the vicinity of the jetty range from 0.6 – 1.0 m/s.
^ Effective flushing around Pulau Satumu is owed to it being situated within an open water area with high current speeds.

The Impact Significance of changes to marine water quality from desalination operations for marine fauna and coral is predicted to be Slight Negative, even after mitigation (Table 7.2), as the impact cannot be fully eliminated until desalination operations are ceased.

8.2.1.1 Modelling Approach

In this study, the MIKE 21 hydrodynamic model of Singapore has been used to simulate the potential salinity impact on sensitive receptors arising from the proposed installation and operation of desalination unit(s) on Pulau Satumu.

The model simulations cover a 14-day tidal cycle within the inter-monsoon season in May 2023. This simulation period is representative of a relatively weaker seasonal tidal regime, which was chosen as a conservative scenario to evaluate the potential impact of saline discharge during periods of poor flushing.

To promote rapid mixing and dispersion of saline effluent, the desalination units' outfall pipe is recommended to be situated at Pulau Satumu's jetty. Based on the expected clean water production rate, the maximum saline effluent discharge is 1 m^3/h with a maximum salinity concentration of 90,000 ppm. In the model simulation, the saline effluent was being released with a constant discharge at 1 m^3/h throughout the entire 14-day simulation period.

Changes to salinity due to Proposed desalination unit(s) were assessed through the following:

- Mean salinity.
- Maximum (95th Percentile) salinity.

8.2.1.2 Change in Salinity

The modelling results indicate that there is '**No Change**' to the mean and 95th percentile salinity concentration arising from operating the proposed desalination units on Pulau Satumu, as illustrated in Figure 8.1. The increase in the mean and 95th percentile salinity is less than 0.1 PSU for both descriptors. The change in salinity at the proposed monitoring location at various time stamps, such as immediately after discharge, after ebb-flood cycle during neap and spring conditions, is less than 0.1 PSU over a 14-day period. No cumulative increase in salinity over the 14-day period is anticipated, which can be attributed to the area being well flushed.

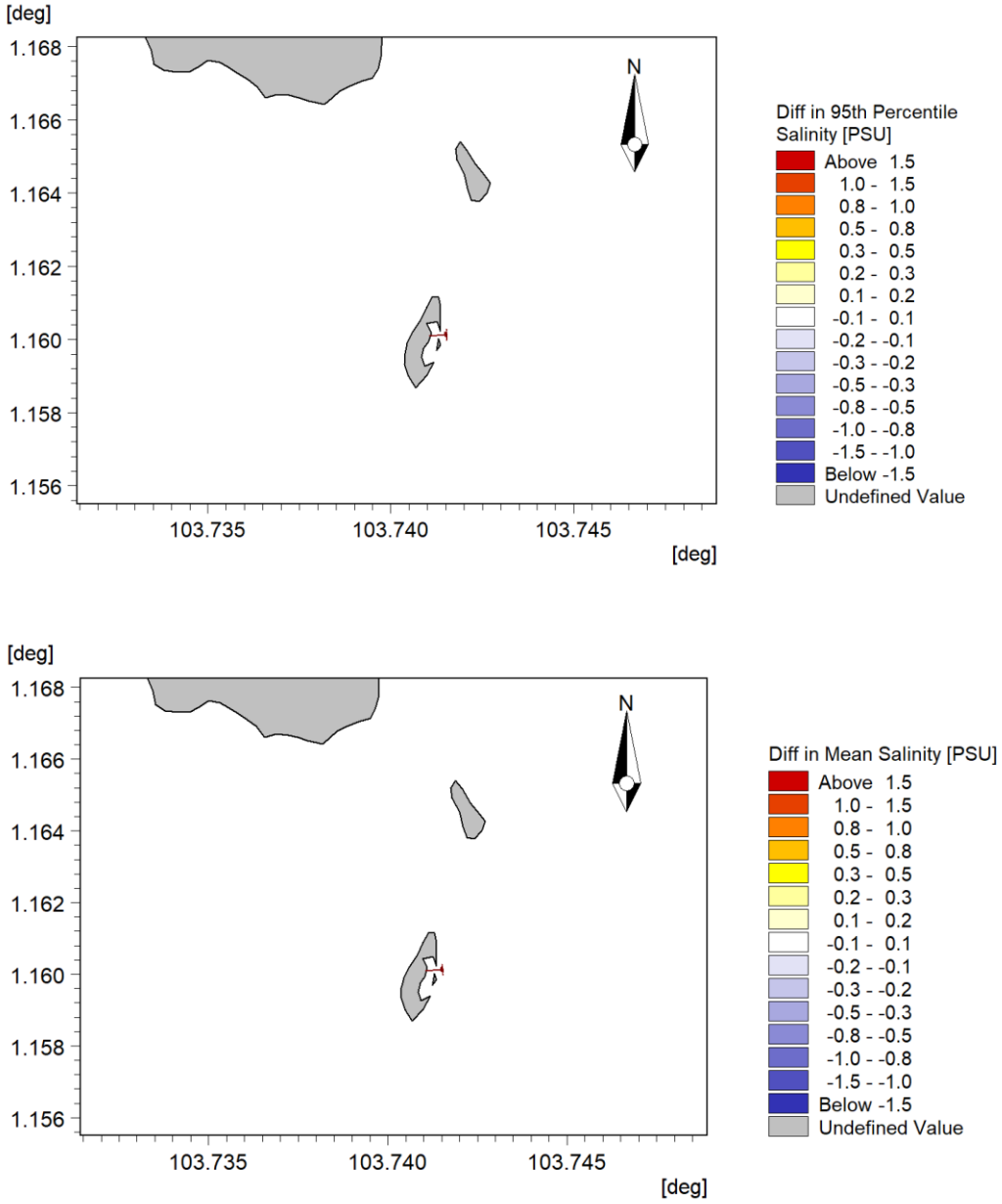


Figure 8.1 Variation in Salinity concentration due to saline effluent discharge from proposed desalination unit(s).

8.3 Proposed Mitigation Measures

The measures proposed to mitigate the impacts on ESRs during the operation stage is detailed in Table 8.1.

Table 8.1 Proposed measures to mitigate the impacts on ESRs during the Operational phase, ordered by mitigation hierarchy (priority).

Mitigation Hierarchy	Mitigation Measures
Avoidance	The discharge points of hypersaline water enriched via the desalination process should be directed away from areas in which the presence of corals has been recorded, particularly where species sensitive to changes in salinity persist.
Minimization	Discharge of desalination effluents is to be performed in areas or during periods in which there is high current flow and flushing, to promote the rapid dispersal of highly saline brine.

8.4 Impact Summary

Table 8.2 Operation phase impact assessment for ecological and biodiversity sensitive receptors. The change in impact Magnitude following mitigation (if any), and the residual impact Significance is also shown. (I = Importance; M = Magnitude; P = Permanence; R = Reversibility; C = Cumulative; ES = Environmental Score)

Predicted Impact	Sensitive Receptors	Predicted impacts without mitigation measures							With mitigation measures		
		I	M	P	R	C	ES	Impact Significance	M	ES	Residual Impact Significance
Salinity increases from desalination effluent discharge	Corals	5	-1	3	2	2	-35	Slight Negative	-1	-35	Slight Negative
	Marine Fauna	3	-1	3	2	2	-21	Slight Negative	-1	-21	Slight Negative

9 Environmental Management and Monitoring Plan

This section outlines the monitoring and management measures that are recommended for the Project.

9.1 EMMP Roles and Responsibilities

For the implementation and sustained success of the EMMP, there are many different parties that must commit to ensure that the impacts to ecology and biodiversity of the proposed Project construction activities will be mitigated to the lowest practicable level,

with on-going monitoring designed to maintain this optimum level of mitigation for the duration of the proposed Project.

9.1.1 Employer

It will be the responsibility of the Employer to ensure implementation of the EMMP by the Contractors or any third party during the construction periods of the proposed Project. References within the EMMP to the “Employer” are to MPA as the proposed Project Developing Agency. References to the “Contractor” are to the main contractors for the construction phase and also include any sub-contractors under their control.

9.1.2 Contractor

The Contractor will be responsible for establishing an Environmental Team that comprises different environmental specialists to work with the regulatory authorities in Singapore to comply with regulations, policies and guidelines related to environmental affairs. The Contractor’s team shall include an EMMP consultant and comply with the EMMP developed by the EMMP consultant. The Contractor shall ensure that all staff are familiar with the relevant parts of the EMMP.

While the EMMP sets out the requirements for environmental management during the construction phase, and the responsibilities for meeting them, the details of the actions to be taken in order to implement each aspect of the EMMP will need to be developed and specified by the Contractor in method statements. These method statements demonstrate how compliance with the requirements of the EMMP is to be achieved. These method statements need to be submitted to the EMMP consultant and Employer for approval and distribution to relevant regulatory authorities as appropriate.

The Contractor will also be responsible for the provision and installation of all monitoring instruments required under the EMMP specifications, together with the necessities to ensure smooth operation and accurate data and results, such as power supply, mounting, protective or weather-proof casing. The data from the monitoring instruments shall be shared with the EMMP consultant for EMMP monitoring requirements.

The Contractor will be responsible for developing and training staff in Emergency Management Procedures that cover potential incidents such as spills and leaks.

EMMP consultant

The Contractor can procure an EMMP consultant. The EMMP consultant shall formulate an EMMP that covers all proposed construction activities during the Project. It is important to note that the EMMP for the Project in this Biodiversity Study only covers mitigation to ecological and biodiversity impacts.

The EMMP consultant is responsible for conducting regular inspections of the site to monitor Contractor’s implementation of EMMP measures, and audit of environmental monitoring data provided by the Contractor. Where audit findings highlight a non-conformance, there will be an investigation and appropriate corrective action taken. All environmental audits will be clearly documented and filed internally. The EMMP consultant is responsible for the overall quality and effectiveness of the EMMP, organising the EMMP audits and provision of comment clarifications and presentations when required with stakeholders and authorities.

Biodiversity Specialists (Ecologist)

The EMMP consultant’s team shall include a sufficiently experienced Ecologist to conduct a pre-clearance wildlife inspection as and when required by the relevant Authorities. The Ecologist is responsible for ensuring wildlife encountered during pre-clearance

inspections are reported to the EMMP consultant and advising the EMMP consultant on further actions to mitigate fauna injury or mortality.

The EMMP consultant will be responsible for developing and training the Contractor and any sub-contractors in compliance with the EMMP, and incidents of human-wildlife conflicts.

9.2 Impact Mitigation and Monitoring

This section presents some key impact management measures and the monitoring regime recommended for the construction phase of the Project.

9.2.1 Mitigation

Construction Phase

The mitigation strategy for the project encompasses four sequential levels: avoidance, minimization, restoration, and offsets. For the marine impacts, priority should be placed on avoidance measures, such as selecting barge mooring areas with minimal coral cover and conducting thorough reconnaissance before conducting equipment transportation. Minimization efforts include careful operation planning and manoeuvring to reduce boat strikes, underwater noise generation, potential damage to marine habitats, and sediment released. Additionally, an emergency spill response plan is to be implemented. Upon the confirmation of barge mooring areas, should there be significant losses in coral habitat at the barge mooring areas, coral restoration should be performed. Briefly, this involves the removal of suitable coral fragments from the affected site, transplanting them to an artificial nursery, before transplanting them back to the affected site once all disruptive activities have ceased. Terrestrial impact mitigation will focus on the avoidance of impacts on sensitive receptors, particularly the patch of *C. pedunculatus*, as well as the sea turtle nesting area.

Through the systematic implementation of these measures, the project's potential impacts can be mitigated.

Operational Phase

During the operation of desalination units on the island, the objective is to minimise the potential impact to marine habitats arising from the saline discharge. In general, the saline effluent can be discharged during periods of high flushing to ensure rapid dispersion.

9.2.2 Monitoring

The following sections describe the basic components of the EMMP. The final specifications, however, depend upon the final Environmental Quality Objectives (EQOs) as determined by the relevant Authorities, specific construction schedule and finalised methodology adopted during the detailed design stage, and subsequently utilised by the Contractor.

Marine Water Quality Monitoring

Marine water quality will need to be monitored during the Baseline, Construction, Testing and Testing Audit phase. The two major water quality points, that will be monitored at varying periods of the project, are the Barge Mooring monitoring point (Figure 9.1) and Desalination Discharge monitoring point (Figure 9.2).

Baseline Phase: An initial baseline reading should be established at Barge Mooring and Desalination Discharge water quality monitoring points before the start of works. This should be done over two (2) surveys during Spring and Neap tides, covering both flood and ebb tides.

Construction Phase: The Construction phase applies specifically to the period where barging works are active. Water quality readings should be taken from the Barge Mooring water quality monitoring point in the vicinity of the island (Figure 9.1). Fortnightly and Daily monitoring is required during this period. This allows for detection of construction-related changes in water quality. The recommended monitoring parameters are detailed in Table 9.1.

Testing Phase: The Testing phase reflects the first two months of the broader Operational Phase, applied specifically to the Desalination Discharge monitoring point after the desalination unit has been installed. Readings are to be taken fortnightly. During this phase, monitoring should be done at the Desalination Discharge water quality monitoring station as shown in Figure 9.2, to monitor the impact of the saline outfall on the nearby habitat receptors and to prevent the exceeding of acceptable parameters laid out in Section 8.2.1.2. The recommended monitoring parameters are detailed in Table 9.2.

Audit Phase: The Audit phase reflects the period one month after the completion of the Construction phase. Readings should be taken from the Barge Mooring water quality monitoring point over two (2) surveys during Spring and Neap tides, covering both flood and ebb tides to effectively compare with the readings taken during the Baseline phase.

Table 9.1 Water quality parameters required for the Barge Mooring monitoring point.

Parameter	Phase	Frequency	Monitoring period	Depth	Reporting Personnel
In Situ Measurements – Only during active barge operations					
Turbidity (NTU)	Baseline	Twice Fortnightly	1 month	Profile at 1m intervals	EMMP consultant
	Construction	Fortnightly	6-8 months		
	Audit	Twice Fortnightly	1 month		
Light (PAR)	Baseline	Twice Fortnightly	1 month	Profile at 1m intervals	EMMP consultant
	Construction	Fortnightly	6-8 months		
	Audit	Twice Fortnightly	1 month		
Secchi Disc Depth	Baseline	Twice Fortnightly	1 month	N/A	EMMP consultant

Parameter	Phase	Frequency	Monitoring period	Depth	Reporting Personnel
	Construction	Daily	6-8 months		Contractor, to survey and report results to EMMP consultant
	Audit	Twice Fortnightly	1 month		EMMP consultant

Table 9.2 Water quality parameters required for Desalination Discharge monitoring point.

Parameter	Phase	Frequency	Monitoring period	Depth	Reporting Personnel
In Situ Measurements					
Salinity	Baseline	Twice Fortnightly	1 month	Profile at 1m intervals	EMMP consultant
	Testing	Fortnightly	2 months		
pH	Baseline	Twice Fortnightly	1 month	Profile at 1m intervals	EMMP consultant
	Testing	Fortnightly	2 months		
Conductivity	Baseline	Twice Fortnightly	1 month	Profile at 1m intervals	EMMP consultant
	Testing	Fortnightly	2 months		
Dissolved Oxygen (DO)	Baseline	Twice Fortnightly	1 month	Profile at 1m intervals	EMMP consultant
	Testing	Fortnightly	2 months		

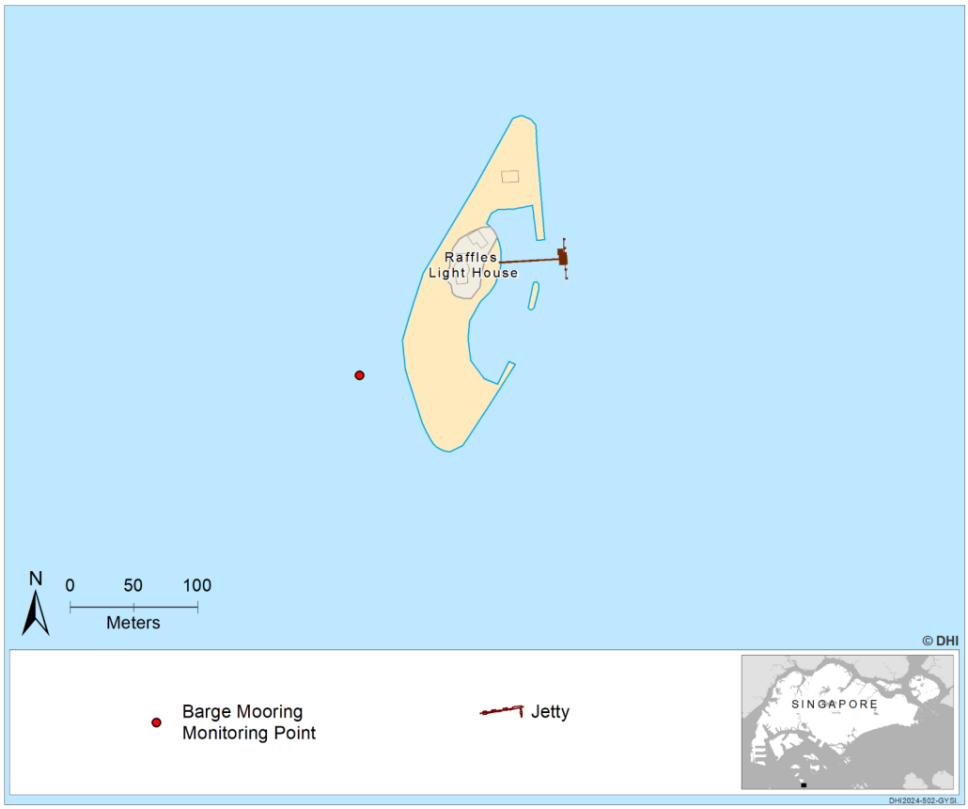


Figure 9.1 Barge Mooring water quality monitoring point

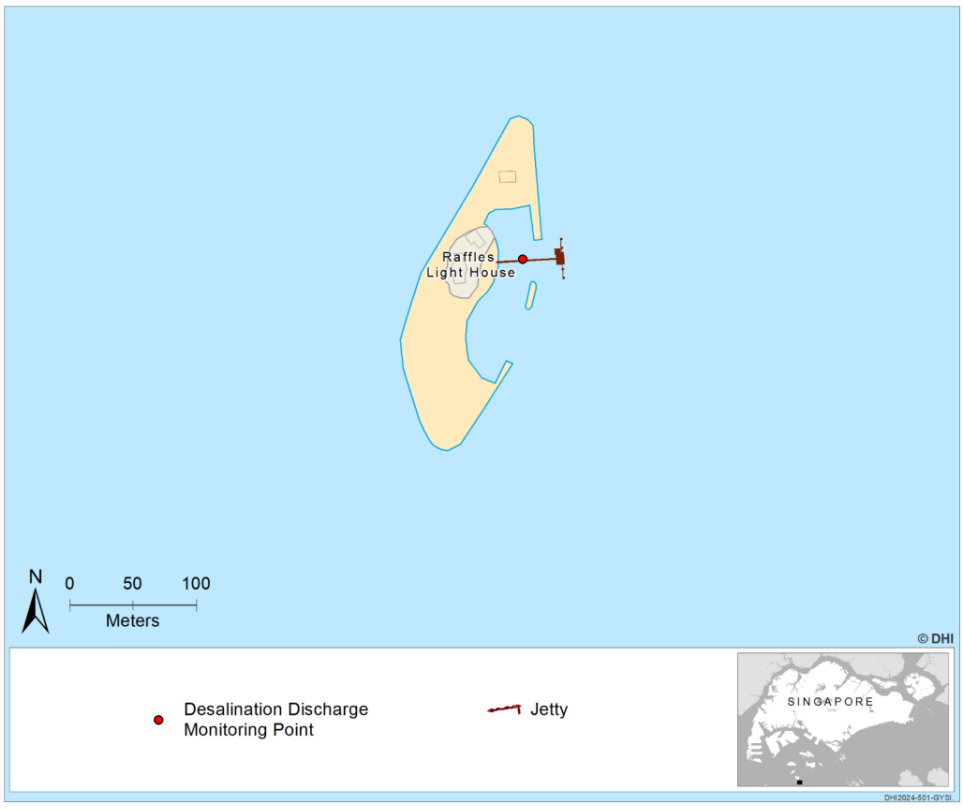


Figure 9.2 Desalination Discharge water quality monitoring point

Intertidal Biodiversity Monitoring

Intertidal Biodiversity will need to be monitored during the Baseline (pre-construction), Construction and Audit (post-construction) phases. Survey points should be located along the shoreline immediately adjacent to the barge mooring (Figure 9.3).

Figure 9.3 Intertidal Biodiversity monitoring points

9.3 EMMP Reporting

A EMMP report will be prepared on a fortnightly basis. Firstly, the report should provide an overview of technical specifications of the project, including but not limited to details concerning the number, area occupied and installation of PV panels, alongside intake, outfall and discharge rates of the desalination plant as well as the installation progress. Secondly, relevant details pertaining to the construction process, including but not limited to, the times and durations in which barges were moored at the designated point, involved in the transportation of equipment and supplies and other relevant activities should be included. Finally, the fortnightly report should catalogue the data obtained in the monitoring process. By comparing the monitoring data with that of pre-established EQOs, the report should qualitatively and/or quantitatively assess the effectiveness of mitigation measures and presence of anomalies to evaluate EQO compliance.

9.4 Feedback Management

The Contractor will establish a feedback management process to ensure that any complaints or feedback received from stakeholders are appropriately recorded, investigated, and resolved where required throughout the Project. The main components of the feedback process will include:

- Prompt acknowledgement and response to stakeholder complaints, keeping them informed of the progress and outcomes
- Accurate records of complaints, investigations and outcomes are maintained
- Resolution within a specified timeframe (proposed four weeks)
- An escalation mechanism in the event that complaint cannot be resolved by the Developing Agency within the specified timeframe
- Government Agencies to be kept informed of complaints, where required.

9.5 Management of Change

Deviations from the scope of work might occur during execution of the Project. Change is an inevitable part of the Project, so managing and reviewing change during the execution phase is an important factor in success of the Project. The overall aim of the EMMP is to ensure that environmental management is implemented, and its performance monitored. This means there must be scope for corrective action to be taken if required. It may be necessary to make modifications to the EMMP over the course of the Project when:

- Unanticipated environmental impacts are identified that require additional mitigation
- When mitigation proposed proves ineffective or unable to be implemented
- When the Project changes in a way that is different to that described in the Biodiversity Study (e.g. internal changes initiated by the project team, external changes initiated by the Employer; or external changes that are a result of third-party stakeholders)

The overall responsibility for the management of change to the EMMP during construction and operation phase rests with the Employer in consultation with the relevant specialists and/or technical agencies where required. The steps for managing change to the EMMP are as follows:

- Identify and describe unanticipated impacts, ineffective mitigation or changes in the Project construction or operation that require updates to the EMMP
- Suggest mitigation to manage the identified issues
- Concerns/issues could, for example, be highlighted in site inspection reports or progress calls with the Employer on an ongoing basis
- Review and update the EMMP in consultation with the relevant specialists and/or technical agencies
- Record recommended corrective action in a Minutes of Meeting.

9.6 Non-Compliance and Remedial Action

In the event of non-compliance of the Contractor with the requirements of the EMMP, the following process is recommended:

- The Employer to issue a notice of non-compliance to the Contractor, stating the nature and magnitude of the contravention.

- The Contractor to provide the Employer with a written statement describing remedial actions to be taken to rectify the non-compliance and expected results of the actions.
- The Contractor to correct the non-compliance within a period that is stipulated by the Employer, to provide the Employer with documented evidence of the completed remedial actions and obtain the Employer's approval for closure of the non-compliance notice.

If the Contractor fails to remedy the non-compliance within the predetermined timeframe or if the non-compliance gives rise to physical environmental damage, the Employer may take action (e.g. impose a penalty, require specific remedial action to be undertaken or stop work) based on the conditions of contract.

9.7 Environmental Impact Register

The objective of environmental monitoring will be to check for compliance with the EMMP by monitoring the construction activities of the Project. This includes monitoring of actual impact of activities on selected sensitive receptors so that impacts not anticipated in the Biodiversity Study or impacts which exceed EQOs can be identified and managed. This shall be maintained by Contractor. The Environmental Impact register shall be made available for inspection on demand by the Employer.

Construction Phase

Table 9.3 Environmental Impact Register for the construction phase of the Project.

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
Ecology and Biodiversity	Terrestrial flora	Moderate	Loss of terrestrial flora	Slight Negative	• Avoid working in coastal vegetation areas with *C. pendenculatus* • Perform transplantation of *C. pendenculatus* specimens if direct impacts cannot be avoided	• Contractor • EMMP consultant • Arborist	Slight Negative	N/A	Monthly EMMP report Final Audit Report Pre-felling/clearance inspection report
	Avifauna	Moderate	Loss of terrestrial fauna	Minor Negative	• Perform pre-felling and pre-clearance fauna inspections in vegetation and targeted trees • Replacement/offset planting of shrubbery after the cessation of construction activities, to restore lost habitat. • Chopped wood originating from felled trees can be reused to designate planter beds, or other aesthetic purposes to reduce the		Slight Negative		
	Herpetofauna	Low		Slight Negative			Slight Negative		
	Butterflies	Low		Slight Negative			Slight Negative		
	Odonates	Low		Slight Negative			Slight Negative		

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
					amount of waste material.				
	Sea turtles	Very important	Disturbance to sea turtles	Minor Negative	• Minimise working during the sea turtle nesting season. • Should works during the sea turtle nesting season be necessary, construction activities should be restricted to daylight hours to prevent the disruptive influence of lighting on sea turtle activity. • Any access to the sandy beach should be avoided during the sea turtle nesting season.	• Contractor • EMMP consultant • Wildlife Rescue & Management specialist	Slight Negative		Monthly EMMP report Final Audit Report
	Yellow-lipped sea krait	Moderate	Loss of nesting sites	Minor Negative	• Replacement/offset planting of shrubbery to act as substitute habitat for displaced fauna • Chopped wood originating from felled trees can be reused to form natural refuges for Yellow-lipped sea kraits.	• Contractor • EMMP consultant	Slight Negative	N/A	Monthly EMMP report Final Audit Report Pre-felling/clearance inspection report
	Corals	Very Important	Loss of habitat during	Minor Negative	• Avoid using a barge mooring area with	• Contractor • EMMP	Slight Negative	Daily and Fortnightly In-	Daily EMMP report

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
			equipment transportation		higher coral cover, instead, choose the barge mooring area with lowest subtidal and intertidal coral cover. Barge to be moored at a sufficient distance from shore to avoid coral areas during anchoring and spudding. • Minimise barge works during the coral spawning season. The conduct of excessive barge activities during the season may result in a disruption to the spawning process. • Major vessel movement around the barge mooring point will be limited to hightide and/or areas where sufficient water depth is present. • Minimise working during the sea turtle nesting season.	consultant		situ water quality monitoring • Turbidity • Light • Secchi disc depth Baseline, Construction and Audit phase Intertidal monitoring	Fortnightly EMMP report Final Audit Report
			Suspension of marine sediment	Slight Negative			Slight Negative		
			Chemical spills and leaks	Minor Negative			Slight Negative		
	Rocky Shore and sandy beach	Moderate	Loss of habitat during equipment transportation	Slight Negative			Slight Negative		
	Macrobenthos	Low	Loss of habitat during equipment transportation	Slight Negative			Slight Negative		
	Marine Megafauna	Very Important	Boat Strikes	Slight Negative			Slight Negative		
			Underwater noise disturbance from construction vessels	Minor Negative			Slight Negative		
			Chemical spills and leaks	Minor Negative			Slight Negative		

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
	Marine Fauna	Moderate	Underwater noise disturbance from construction vessels	Slight Negative	• Should works during the sea turtle nesting season be necessary, construction activities should be restricted to daylight hours to prevent the disruptive influence of lighting on sea turtle activity. • Any access to the sandy beach should be avoided during the sea turtle nesting season. • The discharge points of hypersaline water enriched via the desalination process should be placed in an area with high current flow and substantive flushing. Additionally, the presence of coral species around potential discharge points should be considered; hypersaline discharge should be directed away from species sensitive to changes in salinity. • A relocation plan for		Slight Negative		
			Suspension of marine sediment	Slight Negative			Slight Negative		
			Chemical spills and leaks	Slight Negative			Slight Negative		

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
					errant hatchlings or stray adults should be in place, and may involve the Sister's Island Sea turtle hatchery. • Consider using smaller vessel/s and barge/s with shorter keels and smaller engines, and explore options for muffling the engine where feasible to reduce underwater noise. Additionally, utilise spuds with a smaller diameter. • Transfer of equipment and supplies from the barge to the island should be carried out from the indicated optimal vessel mooring area. • Aim to complete equipment unloading to the temporary staging area in as few tidal cycles as practically possible, this minimises the potential of				

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
					damaging intertidal and shallow subtidal coral habitats and minimise the occurrence of spudding and anchoring during barge mooring. • Construction crew to assign staff to keep active lookout of marine megafauna during marine operations • Vessels to slow down when marine mammals or marine reptiles are observed within 100 m and when approaching the island. Additionally, vessels are to actively avoid marine megafauna until the animal(s) have left the immediate observation zone. • An emergency spill response plan and related equipment for the project site to be developed to ensure a maximum response time of 60 minutes after				

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
					detection of leak or spill while the slick is mostly localised to the release site.				

Operational Phase

Table 9.4 Environmental Impact Register for the operation phase of the Project.

Environmental Aspect	Description of Receiver		Description of Potential Impact		Proposed Mitigation Measures	Implementation Agent	Residual Impact Significance	Proposed Monitoring Requirement	Reporting Requirements
	Receiver	Importance	Impact	Impact Significance					
Ecology and Biodiversity	Corals	Very Important	Salinity increases from desalination effluent discharge	Slight Negative	• The discharge points of hypersaline water enriched via the desalination process should be directed away from areas in which the presence of corals has been recorded, particularly where species sensitive to changes in salinity persist. • Discharge of desalination effluents could be done during periods of high flushing to promote rapid dispersal of highly saline brine, if the water quality monitoring conducted during the Testing Phase indicate a significant increase in salinity during operations of the desalination unit(s).	MPA	Slight Negative	Fortnightly In-situ water quality monitoring • Salinity • pH • DO	Fortnightly EMMP report for 2 months
	Marine Fauna	Moderate		Slight Negative			Slight Negative		

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APPENDICES

APPENDIX A

Baseline Survey Species List

A Baseline Survey Species List

A.1 Intertidal Survey Fauna Checklist

Table A.1 Checklist of intertidal fauna recorded during the baseline at Pulau Satumu

Scientific name	Common name	RDB3	Occurrence	
			VQP	Walk-by Survey
Family Sabellidae	White fan worm	NA	x	x
Thalamita danae	Blue swimming crab	NA		x
Atergatis floridus	Floral egg crab	**VU**	x	x
Atergatis integerrimus	Red egg crab	NT	x	
Ligia sp.	Sea slaters	NA	x	x
Heliopora coerulea	Hard coral	LC	x	x
Acropora sp.	Hard coral	NA	x	x
Montipora sp.	Hard coral	NA	x	x
Turbinaria sp.	Hard coral	NA	x	x
Galaxea sp.	Hard coral	NA	x	x
Dipsastraea sp.	Hard coral	NA	x	x
Favites sp.	Hard coral	NA	x	x
Oulastrea crispata	Zebra coral	NA	x	x
Platygyra sp.	Hard coral	NA	x	x
Fungia sp.	Hard coral	NA	x	x
Pavona sp.	Hard coral	NA	x	x
Pocillopora sp.	Hard coral	NA	x	x
Porites sp.	Hard coral	NA	x	x
Palythoa tuberculosa	Sea mat zoanthid	NA	x	x
Zoanthus sp.	Button zoanthid	NA	x	x
Holothuria leucospilota	Black long sea cucumber	**EN**	x	x
Tridacna crocea	Burrowing giant clam	**EN**	x	x
Spondylus sp.	Thorny oyster	NA	x	
Nerita chamaeleon	Chameleon nerite	LC	x	x
Nerita undata	Waved nerite	NA	x	x
Pictocolumbella ocellata	Lightning dove snail	LC	x	x
Thais sp.	Chunky drill	NA	x	
Family Onchidiidae	Ornate onch slug	NA	x	
Rochia sp.	Giant top shell snail	NA	x	
Trochus maculatus	Spotted top shell	LC	x	
Acanthozoon sp.	Spangled flatworm	NA		x
Drombus triangularis	Brown shore goby	LC		x
Istigobius goldmanni	Black-spotted lagoon-goby	LC	x	x
Dischistodus fasciatus	Yellow-Banded damsel	NT		x
Selatium brockii	Mangrove tree-dwelling crab	NA	x	
Metopograpsus sp.	Purple Climber Crab	NA	x	x
Eriphia ferox	Red-eyed Reef Crab	**VU**	x	x
Diadema setosum	Black Long-spined Sea Urchin	NA	x	
Perisesarma indiarum	Face-banded Sesarmine Crab	NA	x	
Episesarma chentongense	Pink-fingered Tree Climbing Crab	NA	x	

Cerithium zonatus	Zonated horn snail	NA		**x**
Ambassis kopsii	Kops' glass perchlet	LC		**x**
Terapon jarbua	Cresent Perch	LC		**x**
Strongylura leiura	Banded Needlefish	NT	**x**	
Carcharhinus melanopterus	Blacktip reef shark	**EN**	**x**	
Mugil cephalus	Flathead grey mullet	DD		**x**

A.2 Terrestrial Survey Fauna Checklist

Table A.2 Checklist of terrestrial fauna recorded during the baseline at Pulau Satumu

Group	Species		Conservation Status	
	Scientific name	Common name	IUCN	RDB3
Bird	*Actitis hypoleucos*	Common Sandpiper	LC	**VU**
Bird	*Anthus rufulus*	Paddyfield Pipit	LC	LC
Bird	*Cinnyris jugularis*	Olive-backed Sunbird	LC	LC
Bird	*Ichthyophaga leucogaster*	White-bellied Sea Eagle	LC	LC
Bird	*Haliastur indus*	Brahminy Kite	LC	LC
Bird	*Hirundo tahitica*	Pacific Swallow	LC	LC
Bird	*Numenius phaeopus*	Eurasian Whimbrel	LC	NT
Bird	*Passer montanus*	Eurasian Tree Sparrow	LC	LC
Bird	*Pycnonotus goiavier*	Yellow-vented Bulbul	LC	LC
Bird	*Spilopelia chinensis*	Spotted Dove	LC	LC
Bird	*Thalasseus bengalensis*	Lesser Crested Tern	LC	**EN**
Bird	*Thalasseus bergii*	Greater Crested Tern	LC	**EN**
Reptile	*Gehyra mutilata*	Four-clawed Gecko	LC	LC
Reptile	*Hemidactylus frenatus*	Spiny-tailed Gecko	LC	LC
Reptile	*Lepidodactylus lugubris*	Maritime Gecko	LC	LC
Butterfly	*Acraea terpsicore*	Tawny Coster	NL	LC
Butterfly	*Eurema hecabe contubernalis*	Common Grass Yellow	NL	LC
Butterfly	*Junonia orithya wallacei*	Blue Pansy	NL	LC
Butterfly	*Zizina otis lampa*	Lesser Grass Blue	NL	LC
Odonate	*Crocothemis servilia*	Scarlet Skimmer	LC	LC
Odonate	*Ischnura senegalensis*	Common Bluetail	LC	LC
Odonate	*Macrodiplax cora*	Coastal Glider	LC	LC
Odonate	*Pseudagrion microcephalum*	Blue Sprite	LC	LC
Odonate	*Rhyothemis phyllis*	Yellow-barred Flutterer	LC	LC

A.3 Terrestrial Survey Flora Checklist

Table A.3 Checklist of terrestrial flora recorded during the baseline at Pulau Satumu

Species	Native Status	National Conservation Status	Origin of Individuals on site	Family	Form
Barringtonia asiatica	Native	CR	Planted	Lecythidaceae	Tree
Cyperus pedunculatus	Native	VU	Spontaneous	Cyperaceae	Herbaceous Plant
Alysicarpus vaginalis	Native	LC	Spontaneous	Fabaceae	Herbaceous Plant
Chrysopogon aciculatus	Native	LC	Spontaneous	Poaceae	Herbaceous Plant
Emilia sonchifolia	Native	LC	Spontaneous	Asteraceae	Herbaceous Plant
Fimbristylis dichotoma	Native	LC	Spontaneous	Cyperaceae	Herbaceous Plant
Grona triflora	Native	LC	Spontaneous	Fabaceae	Herbaceous Plant
Ipomoea pes-caprae	Native	LC	Spontaneous	Convolvulaceae	Creeper
Ischaemum muticum	Native	LC	Spontaneous	Poaceae	Herbaceous Plant
Scaevola taccada	Native	LC	Spontaneous	Goodeniaceae	Shrub
Wollastonia biflora	Native	LC	Spontaneous	Asteraceae	Herbaceous Plant
Zoysia matrella	Native	LC	Spontaneous	Poaceae	Herbaceous Plant
Axonopus compressus	Non-Native	Naturalised	Planted	Poaceae	Herbaceous Plant
Cocos nucifera	Non-Native	Naturalised	Planted	Arecaceae	Palm
Mimosa pudica	Non-Native	Naturalised	Spontaneous	Fabaceae	Herbaceous Plant
Tridax procumbens	Non-Native	Naturalised	Spontaneous	Asteraceae	Herbaceous Plant
Youngia japonica	Non-Native	Naturalised	Spontaneous	Asteraceae	Herbaceous Plant
Garcinia mangostana var. *mangostana*	Non-Native	Casual	Planted	Clusiaceae	Tree
Hibiscus sabdariffa	Non-Native	Cultivated Only	Planted	Malvaceae	Shrub
Moringa oleifera	Non-Native	Cultivated Only	Planted	Moringaceae	Tree
Musa sp.	Non-Native	Cultivated Only	Planted	Musaceae	Herbaceous Plant
Barringtonia asiatica	Native	CR	Planted	Lecythidaceae	Tree
Cyperus pedunculatus	Native	VU	Spontaneous	Cyperaceae	Herbaceous Plant
Alysicarpus vaginalis	Native	LC	Spontaneous	Fabaceae	Herbaceous Plant

APPENDIX B

Locations of Flora of Interest

B Locations of Flora of Interest

B.1 Locations of Trees or Palms with 1m girth or more and Conservation Significant Plants

Table B.1 Locations of Trees or Palms with 1m girth or more and Conservation Significant Plants on Pulau Satumu

No.	Common Name	Botanical Name	Girth (m)	Height (m)	Easting	Northing	Status	Origin
T1	Coconut	*Cocos nucifera*	1.2	6	359879.9	128261.5	Non-Native, naturalised	Planted
T2	Coconut	*Cocos nucifera*	1.1	6	359880.9	128255	Non-Native, naturalised	Planted
T3	Coconut	*Cocos nucifera*	1.4	8	359871.9	128243.7	Non-Native, naturalised	Planted
T4	Coconut	*Cocos nucifera*	1.3	8	359890.6	128230.5	Non-Native, naturalised	Planted
T5	Coconut	*Cocos nucifera*	1.3	7	359891.4	128228.8	Non-Native, naturalised	Planted
T6	Coconut	*Cocos nucifera*	1.3	7	359870.6	128235.3	Non-Native, naturalised	Planted
T7	Coconut	*Cocos nucifera*	1.2	7	359871.1	128231	Non-Native, naturalised	Planted
T8	Coconut	*Cocos nucifera*	1.3	7	359879.7	128225.3	Non-Native, naturalised	Planted
T9	Coconut	*Cocos nucifera*	1.2	8	359872.1	128223.4	Non-Native, naturalised	Planted
T10	Coconut	*Cocos nucifera*	1.3	7	359877.9	128220.4	Non-Native, naturalised	Planted
T11	Coconut	*Cocos nucifera*	1.3	8	359880.5	128215	Non-Native, naturalised	Planted
T12	Coconut	*Cocos nucifera*	1.1	7	359883.5	128214.4	Non-Native, naturalised	Planted
T13	Coconut	*Cocos nucifera*	1.2	6	359864	128213.5	Non-Native, naturalised	Planted
T14	Coconut	*Cocos nucifera*	1.2	7	359866.9	128211.9	Non-Native, naturalised	Planted
T15	Coconut	*Cocos nucifera*	1	7	359865.6	128208.5	Non-Native, naturalised	Planted
T16	Coconut	*Cocos nucifera*	1.1	8	359868.3	128208	Non-Native, naturalised	Planted
T17	Coconut	*Cocos nucifera*	1.3	9	359881.8	128206.5	Non-Native, naturalised	Planted
T18	Coconut	*Cocos nucifera*	1.2	5	359886	128207.1	Non-Native, naturalised	Planted
T19	Coconut	*Cocos nucifera*	1	4	359861	128204.1	Non-Native, naturalised	Planted
T20	Coconut	*Cocos nucifera*	1	7	359869.1	128202.5	Non-Native, naturalised	Planted
T21	Coconut	*Cocos nucifera*	1.2	9	359873.1	128201.4	Non-Native, naturalised	Planted
T22	Coconut	*Cocos nucifera*	1.1	8	359884.6	128202.1	Non-Native, naturalised	Planted
T23	Coconut	*Cocos nucifera*	1.1	7	359887.7	128201.7	Non-Native, naturalised	Planted
T24	Coconut	*Cocos nucifera*	1.1	4	359860.2	128198.1	Non-Native, naturalised	Planted

T25	Coconut	*Cocos nucifera*	1	7	359866.1	128192.9	Non-Native, naturalised	Planted
T26	Coconut	*Cocos nucifera*	1	8	359876.9	128195.2	Non-Native, naturalised	Planted
T27	Coconut	*Cocos nucifera*	1.3	9	359880.6	128194.8	Non-Native, naturalised	Planted
T28	Coconut	*Cocos nucifera*	1.2	8	359888.3	128195	Non-Native, naturalised	Planted
T29	Coconut	*Cocos nucifera*	1.2	6	359866.1	128190.5	Non-Native, naturalised	Planted
T30	Coconut	*Cocos nucifera*	1.1	5	359874.2	128188.4	Non-Native, naturalised	Planted
T31	Coconut	*Cocos nucifera*	1.3	7	359872.6	128181.4	Non-Native, naturalised	Planted
T32	Coconut	*Cocos nucifera*	1.1	7	359878	128178	Non-Native, naturalised	Planted
T33	Coconut	*Cocos nucifera*	1	7	359873.2	128175.5	Non-Native, naturalised	Planted
T34	Coconut	*Cocos nucifera*	1.3	8	359875.8	128173.4	Non-Native, naturalised	Planted
T35	Coconut	*Cocos nucifera*	1.4	6	359865.1	128171.3	Non-Native, naturalised	Planted
T36	Coconut	*Cocos nucifera*	1.1	6	359867.2	128165	Non-Native, naturalised	Planted
T37	Coconut	*Cocos nucifera*	1.2	7	359868.7	128160.8	Non-Native, naturalised	Planted
T38	Coconut	*Cocos nucifera*	1.1	7	359886.5	128160.7	Non-Native, naturalised	Planted
T39	Coconut	*Cocos nucifera*	1.2	7	359888.8	128163.4	Non-Native, naturalised	Planted
T40	Coconut	*Cocos nucifera*	1.3	7	359892.5	128162.2	Non-Native, naturalised	Planted
T41	Coconut	*Cocos nucifera*	1.1	6	359869.8	128155.7	Non-Native, naturalised	Planted
T42	Coconut	*Cocos nucifera*	1.2	9	359872.4	128153.9	Non-Native, naturalised	Planted
T43	Coconut	*Cocos nucifera*	1.1	70	359885.5	128149.5	Non-Native, naturalised	Planted
T44	Coconut	*Cocos nucifera*	1	5	359871.8	128147	Non-Native, naturalised	Planted
T45	Coconut	*Cocos nucifera*	1.2	6	359872.5	128139.6	Non-Native, naturalised	Planted
T46	Coconut	*Cocos nucifera*	1.2	8	359880.7	128125.1	Non-Native, naturalised	Planted
T47	Coconut	*Cocos nucifera*	1.2	8	359885.3	128121.6	Non-Native, naturalised	Planted
T48	Fish Killer Tree	*Barringtonia asiatica*	0.6	4	359897.2	128164.3	Native, CR	Planted
T49	Fish Killer Tree	*Barringtonia asiatica*	0.7	5	359897.4	128170.6	Native, CR	Planted
T50	Fish Killer Tree	*Barringtonia asiatica*	0.3	3.5	359890	128172.1	Native, CR	Planted
T51	Fish Killer Tree	*Barringtonia asiatica*	0.3	1	359892.5	128177.7	Native, CR	Planted
T52	Fish Killer Tree	*Barringtonia asiatica*	0.3	5	359884.2	128175.4	Native, CR	Planted
-	Beachstar	*Cyperus pedunculatus*	-	-	359888.6	128203.8	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359888.2	128200.2	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359888.5	128197.8	Native, VU	Spontaneous

-	Beachstar	*Cyperus pedunculatus*	-	-	359889.4	128194.9	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359892.2	128194.9	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359891.9	128199	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359892.5	128204.6	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359890	128204.7	Native, VU	Spontaneous
-	Beachstar	*Cyperus pedunculatus*	-	-	359888.6	128203.8	Native, VU	Spontaneous