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Biodiversity Impact Assessment (BIA) Guidelines

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1. Introduction

1. Introduction

1.1 What Is a BIA and How Is It Related to an EIA?

An Environmental Impact Assessment (EIA) is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse (Convention on Biological Diversity, n.d.). The EIA aims to predict environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts to reasonably practical levels, shape projects to suit the local environment and present the predictions and options to decision-makers (Convention on Biological Diversity, n.d.)

A Biodiversity Impact Assessment (BIA) is the biodiversity component of a full EIA. Development projects that are in or near to sensitive areas such as Nature Reserves, sensitive ecological areas, areas of biodiversity interest, and all coastal and marine development projects, will have their impacts on biodiversity be subject to greater scrutiny. The terms EIA and BIA are used for both the process and the resulting documentation (the report).

1.2 What Does a BIA report Contain?

A typical BIA report contains the following sections:

- Non-Technical Summary
- Project Description
- Literature Review and Baseline Survey Findings (raw data can be attached as appendices)
- Impact Assessment
- Mitigation Measures
- Environmental Monitoring and Management Plan

As the technical agency on biodiversity, NParks advises on the scope of the BIA. This includes but is not limited to: scoping the study area, the time frame or seasons for the study, highlighting particular impacts to be studied, the taxonomic groups to be surveyed, minimum Environmental Quality Objectives (EQOs), and other aspects that may be relevant. Once the scope of the BIA has been set out, consultants typically submit an inception report detailing proposed survey methods and report content to NParks for endorsement.

1.3 Objectives

The main objectives of these guidelines are to:

- Serve as a self-learning tool for developers, and environmental consultants new to conducting BIAs
- Provide suggested methods for conducting baseline surveys
- Explain the key components to a robust impact assessment related to biodiversity
- Share best practices on biodiversity impact assessments conducted around the world
- Offer guidance on assessment matrix and mitigation measures
- Provide information on developing the biodiversity component of an environmental management and monitoring plan (EMMP)

These guidelines are non-prescriptive and are meant to provide information on how biodiversity related impact assessments are carried out. For non-biodiversity related aspects of an EIA, please refer to the resource section at the back of the booklet.

1.4 How to Use this Booklet

Chapter 2 covers the **baseline physical and ecological studies** typically required for terrestrial sites, and provides commonly used survey methods to conduct baseline studies on both habitats and target species groups. This will also give developers a better understanding of the range of studies required, and help developers plan their project timeline to accommodate the studies.

Chapter 3 covers the **baseline physical and ecological studies** typically required for marine sites, and provides commonly used survey methods to conduct baseline studies on various parameters which are typically linked to habitat quality. This will also give developers a better understanding on the range of studies required, and help developers plan their project timeline to accommodate the studies.

Chapter 4 illustrates various methods to conduct a robust **impact assessment.**

Chapter 5 provides guidelines for developing appropriate **mitigation measures** to minimise impacts in terrestrial and marine developments respectively.

Chapter 6 outlines the considerations for the **Environmental Management and Monitoring Plan (EMMP)** which must be implemented by the developer's contractor. The EMMP provides a checklist of monitoring measures to ensure that the mitigation measures recommended in the BIA report are adhered to and are effective.

2. Conducting Baseline Studies for Terrestrial Sites

2. Conducting Baseline Studies for Terrestrial Sites

This chapter outlines the expectations of conducting and reporting the results of baseline studies. Baseline studies are typically split into two components – the habitat baseline study, and the target species group's baseline study. The former establishes the types and locations of habitats found on site including waterbodies, while the latter establishes the presence and behaviour of target species groups on site.

Various survey methods have been suggested in this chapter, however the developer/consultant should note that these methods are not prescriptive and are only suggestions for consideration. Consultants will have to take into account the nature of the development project, site constraints, and the specific physical and chemical attributes of the environment to select the most suitable methods, as well as the appropriate number of replicates. Nevertheless, the choice of standardised methods will facilitate comparisons before and after, as well as between projects and sites. Literature reviews should be conducted to inform the habitat and species group baseline studies. Further reading is listed under "Additional Reading" at the end of this booklet.

2.1 Study Area

This section of the BIA should include the following:

- Map of the study area, as defined by the agencies' scope
- Short description of the study area, highlighting relevant information such as the dominant vegetation type and species of conservation interest based on literature review and analysis of past land use based on historical reports (if available)

2.2 Habitat Baseline Study

2.2.1 Vegetation Mapping

This section typically includes an inventory and map of plant species within the study area. Depending on the study area and scope, minimally, trees of > 1 m girth are to be identified and mapped out. In Nature Reserves and sites with known sensitive habitats, quadrat sampling of all vascular plants may be requested by NParks. Plants with local conservation status according to the latest "Red Data Book List" (NParks, 2023) or relevant local published statuses such as in "Flora of Singapore: Checklist and bibliography" (Lindsay et al., 2022) should be mapped with location tagging to within 15 m at 95% confidence level and highlighted in the report. Inaccuracies arising from canopy cover should be accounted for. For plants identified for retention, subsequent measurements should be taken to obtain more accurate coordinates. Suggestions on plant survey methods can be found in Section 2.3.1.

2.2.2 Habitat Mapping

Based on the identified plant species and past land use of the site, the consultant should also produce a map showing the boundaries of various habitat types on site. The total area and observed health for each habitat type should also be included. Where available, stream locations should be reflected as part of the habitat maps. Table 2.1 contains a list of habitat types found in Singapore. Consultants should include all the site-specific observations that may not be captured by the habitat types listed in Table 2.1, including the understorey or successional flora composition, where they may differ from the main habitat type.

Table 2.1: Main Habitat Types in Singapore

Class	Habitat Type	Description Based on Vegetation and/or Physical Environment
Primary Forest	Lowland Mixed Dipterocarp Primary Forest	Contains an emergent layer that has dipterocarp trees such as *Shorea* and *Dipterocarpus*. Has a continuous layer of tall native trees, a sub-canopy consisting of smaller trees, and an understorey dominated by saplings of big tree species interspersed with other shrubs and treelets (Tan et al., 2007).
Native-dominated Secondary Forest	Native-dominated Young Secondary Forest	Developed on land cleared not long before the 1960s, or on degraded soils and not near other native-dominated forests. Dominated by native pioneer trees such as *Adinandra, Macaranga, Mallotus* and *Trema* (Yee et al., 2016).
	Native-dominated Old Secondary Forest	Developed on land cleared much earlier than the 1950s, often on less degraded soil and with higher species richness than early successional native dominated secondary forest. Common species found in the canopy layer include *Alstonia, Calophyllum, Campnosperma, Elaeocarpus, Garcinia, Litsea, Rhodamnia* and *Syzygium*. Common understorey plants include *Anisophyllea disticha* and *Agrostistachys borneensis* (Yee et al., 2019).
Exotic-Dominated Secondary Forest	Abandoned Land Forest	Developed from an abandoned kampung/plantation or orchard, usually dominated by fruit trees such as Durian (*Durio zibethinus*) or Rambutan (*Nephelium lappaceum*), or ornamental plants such as *Spathodea campanulata, Aglaonema commutatum*, *Dieffenbachia seguine* and *Heliconia* spp. (Yee et al., 2019). Abandoned plantations are usually dominated by Pará Rubber (*Hevea brasiliensis*) (Yee et al., 2019).
	Albizia/Acacia/ Leucaena/Cecropia Dominated Forest	Developed on land recently cleared, with plant communities dominated by exotic tree species such as *Acacia auriculiformis, Falcataria moluccana*, *Leucaena leucocephala* (Lam.) de Wit and *Cecropia pachystachya* (Yee et

Habitat Type	Description Based on Vegetation and/or Physical Environment
Scrubland / Grassland	Exposed areas with very little tree cover, typically dominated by grasses, shrubs and herbs (Lee Kong Chian Natural History Museum, 2017b). These can be further split into Grassland (dominated by members of the grass and sedge family), Scrubland dominated by ferns (e.g. *Dicranopteris linearis*), or by herbs and shrubs (e.g. *Mimosa pigra*, *Melastoma malabathricum*, *Piper aduncum*, *Pipterus argenteus*, *Ficus* spp etc), often with absent or scattered trees of *Acacia auriculiformis*, *Leucaena leucocephala*, *Mallotus paniculatus*, *Dillenia suffructicosa*, etc.). These subsequently develop into denser open woodland with patches of trees within the scrubland.
Freshwater Swamp Forest	Formed where slow-flowing streams drain into shallow valleys. The swamp is flooded periodically or semi-permanently, resulting in water-logged soils that are anaerobic and unstable. Dominated by plants with special adaptations such as stilt roots, plank-like buttresses and pneumatophores. Examples include *Xylopia fusca* and *Palaquium xanthochymum* (Tan, 2007).
Freshwater Marsh or Pond	A wetland which is covered by water and typically dominated by shrubs, grasses, sedges and other herbaceous plants or hydrophytes that are able to tolerate flooding (Lee Kong Chian Natural History Museum, 2017a).
Riparian Vegetation	Found along the banks of natural and naturalised streams. Common species on stream banks in secondary forest patches include *Angiopteris evecta*, *Alsophilia latebrosa* and *Dillenia suffruticosa*. Vegetation along native forest streams are more diverse and species such as *Cyrtosperma merkusii*, *Lasia spinosa* and *Hanguana* spp. can be present (Yee et al., 2019).

Natural Stream	A well-shaded stream which is shallow, cool, and typically has mildly acidic waters (pH 6–7). Typically flows along natural topographical gradients over sand, clay or mud substrate with accumulations of leaf litter and woody debris (Yeo et al., 2010).
Naturalised Stream	A stream which is warm and typically has less acidic water than natural streams (slightly less than pH 7). Typically modified from pre-existing natural streams and is often linear. Flows through natural earth or open grassy banks, lacking leaf litter and woody debris (Yeo et al., 2010).
Mangrove Forest	A tidal habitat consisting of flora that normally grows above mean sea level in the intertidal zone of marine environments and estuarine margins. Common species include *Rhizophora*, *Bruguiera, Avicennia* and *Sonneratia* trees which have roots that provide structural and respiratory support in the soft anaerobic sediments of the habitat (Ng et al., 2011).
Natural Coastal Vegetation	Found along un-reclaimed coasts where the forest is on sandy or rocky substrate. Dominated by hardy plants which can withstand higher temperatures, strong winds and salt sprays. Common species include *Casuarina equisetifolia, Cerbera* spp., and *Barringtonia* spp. (Tan et al., 2007).
Reclaimed land forest	Forest which develops on land that has been reclaimed. The community of unmanaged / spontaneous vegetation growing on reclaimed land depends on the fill material used.
Urban Vegetation	Consists of turf, shrubs or trees (often mostly non-native) which are planted by humans. This type of vegetation is typically managed for aesthetic purposes.

2.2.3 Hydrology

This section may be requested by technical agencies if either of the following conditions are met:

i) There are waterbodies (e.g. streams, drains, ponds, swamps, etc) on site; or

ii) If the development may impact important hydrological processes of adjacent aquatic habitats (e.g. freshwater stream, mangrove). For this type of development, hydrological baselines should include the status of groundwater across the study area. Hydrological modelling may be required to understand the relationship between surface water, groundwater and rainfall events, so that potential negative impacts could be properly assessed.

Depending on the scope of the study as defined by agencies and the sensitivity of the development, not all of the following subsections may be required.

2.2.3.1 Waterbody Mapping

This section should include a map minimally at a scale of 1:1000 of the locations and edges of all permanent waterbodies on site (e.g. streams, drains, ponds, swamps). The boundaries of the waterbodies and any significant bends of streams should be captured, with location tagging to within 15 m at 95% confidence level. Inaccuracies arising from canopy cover should be accounted for. For plants identified for retention, subsequent measurements should be taken to obtain more accurate coordinates.

Stream channel cross section capturing the character of the stream valley, types of riparian vegetation, canopy cover, composition of the alluvium (e.g. clay, sand) should be surveyed in intervals of 30–50m (depending on site sensitivity).

Where data is available, a map of the catchment area with contours and surveyed waterbodies, longitudinal profile of the stream should be presented.

2.2.3.2 Water Conditions

This section should include an assessment of the baseline water conditions of the waterbodies on site, including surface water and groundwater. The surface water measurements should be taken at 30–50 m intervals (depending on site sensitivity) along the stream or edge of the waterbody. Where groundwater sampling is required, at least four groundwater sampling points should be taken, covering headwater (source), upper, middle and lower reaches of the impacted stream course. The samplings should be conducted to cover the wet and dry period during different local seasons, if possible:

- Northeast Monsoon (December to early March)
- Southwest Monsoon (June to September)
- Inter-Monsoon (late March to May; October to November)

Note: Dry weather conditions are defined as after a continuous 48-hour period of no-rain, and wet weather conditions are defined as a rainfall event having more than 10 mm of rainfall, with samples to be collected within 3 hours after the rain stops.

2.2.3.2.1 Water Quantity

Cross-sections

The cross-section area of the stream should be estimated. This can be derived by calculating areas of trapeziums, which includes measuring the wetted width of the stream section with measuring tape, followed by the depth of the stream at regular intervals (5 points if width < 1 m; 7 points if width > 1 m). The bank height, bank full depth and bank slope should also be measured.

Stream Velocity and Flow Rate

For streams, the velocity and flow rate should be measured using a flow meter or best available methods (e.g., use of float and bucket method) and the following formula:

$$\textit{Average Velocity (m/s)} = \textit{Average x (Left – centre, Centre, Right – centre)}$$

$$\textit{Flow rate } (m^3/s) = \textit{Cross-section } (m^2) \textit{ x Average Velocity}$$

Groundwater Table

The groundwater levels within the study site should be provided for sites with groundwater concern. These can be measured by instruments such as piezometers.

2.2.3.2.2 Water Quality

Establish baseline water quality conditions in the identified waterbodies and compare with relevant water quality criteria to ecological uses.

The typical water quality parameters that should be measured for both surface water and groundwater should include but are not limited to the ones listed in Table 2.2. Water analysis should be carried out by SAC-SINGLAS accredited laboratories, specifically, on environmental testing. The standards and detection limits adopted for the water quality parameters are listed in Table 2.2. The necessary parameters for water quality monitoring are to be determined based on the specifics of each project.

Table 2.2. Standards and detection limits for typical parameters in water quality monitoring

Parameters	**Units**	**Standards**	**Detection limits**
Temperature	°C	-	-
pH	N/A	-	-
Conductivity	µS/cm	-	-
Dissolved Oxygen (DO)	mg/l	-	-
Biochemical Oxygen Demand (BOD)	mg/l	APHA 5210B	2
Chemical O_2 Demand (COD)	mg/l		2
Turbidity	NTU	APHA 2130B	-
Salinity	ppt		
Total Phosphorus (TP)	mg/l	APHA 4500-P (J)	0.01
Total Nitrogen (TN)	mg/l	APHA 4500-P (J)	0.01
Total Organic Carbon (TOC)	mg/l	APHA 5310B	1
Nitrate (NO_3-N)	mg/l	APHA 4500- NO_3 (I)	0.015
Ammonia (NH4-N)	mg/l	APHA 4500- NH_3 (H)	0.01
Orthophosphate (PO4-P)	mg/l	APHA 4500-P (G)	0.025
Total Dissolved Solids (TDS)	mg/l	APHA 2540C	10
Total Suspended Solids (TSS)	mg/l	APHA 2540D	10
Heavy metals (e.g. Lead)	µg/l	APHA3120B	5
Bacteria (Enterococcus, etc)	cfu/100ml	APHA 9230C	1

2.3 Target Species Groups' Baseline Study

The main objectives of conducting a baseline study for target species groups are to:

- Identify and map known locations of species of conservation interest, keystone species, and species that function as bioindicators
- Record and understand their interactions with the habitat

Species of conservation interest are species which have been identified to have high extinction risk and therefore have higher conservation priority. There are two levels at which species are of conservation interest – at the global and/or local level. Species with global status are listed by the International Union for Conservation of Nature (IUCN), while species with local status are listed in the "Red Data Book List" (NParks, 2023) or other relevant locally published statuses, such as "The Dragonflies of Singapore" (Ngiam & Loong, 2016) and "Flora of Singapore: Checklist and bibliography" (Lindsay et al., 2022). Each species recorded in the baseline study will need to have both its global and local conservation status listed in all BIAs.

A keystone species is a species that has disproportionately large effects on its environment relative to its abundance (Paine, 1995). Consultants should refer to available literature to identify local keystone species, or propose species which fit the keystone species criteria based on their understanding of the site.

Bioindicators are species which can be used to reveal the health or status of the particular ecosystem they are found in. Again, consultants should refer to available literature to identify local bioindicator species. Bioindicators can also be used to monitor development impacts to the environment.

This information will help to predict areas of high conservation priority and/or identify appropriate locations for refuge of target species groups within a development site. Should it be impractical to study all species within the development site, at least a few key species groups should be studied instead. Depending on the scope of the study as defined by agencies and the sensitivity of the development, fewer or more groups than what are listed below may need to be studied. The amount of time required for the baseline will also be dependent on the scope set out by agencies, though the final routes and appropriate number of replicates for each survey should be determined by the consultant. This can be justified using species accumulation curves (Ugland et al., 2003) to determine sampling adequacy. Note that sampling for both flora and fauna should be stratified across all representative habitat types within the study site.

It should be noted that the methods listed in this chapter are not exhaustive. Other methods can be proposed depending on the context of the site and the amount of information required for the baseline study. As mentioned in Chapter 1, NParks helps to scope the study and will review the methods proposed by the consultant during the inception report stage.

Typical species groups studied:

- Vascular plants
- Birds
- Reptiles and amphibians
- Mammals and/or bats
- Butterflies
- Odonates*
- Freshwater organisms (Fish & decapod crustaceans)*

Additional species groups, such as invertebrates (e.g. bees, wasps, flies, beetles, spiders, etc.) can be considered based on the survey site and in discussion with NParks during the study scoping stage.

*Add-on surveys for sites with freshwater elements

2.3.1 Vascular Plants

This section should establish the diversity of vascular plants (including pteridophytes, climbers and vascular epiphytes) at the site, and should include the global and local conservation status of the various species. It differs from the vegetation mapping for the habitat baseline study (refer to Section 2.2.1), which focuses on establishing the vegetation types within the site. The suggested methods are line transects, quadrat plots and/or modified gentry plots. The Herbarium of the Singapore Botanic Gardens should be consulted for identification of unknown plants based on samples (leaf cuttings, flowers) and photographs.

Table 2.3: Line Transects as a Survey Method

Suggested Method	**Line Transects**
Description	Surveyors should walk along the identified transect and record all flora species seen within the survey site boundaries. Species of conservation concern are to be location tagged where possible.
Frequency	Once per site.
Notes	Walking transects should not overlap with quadrat plots.

Table 2.4: Quadrat Plots as a Survey Method

Suggested Method	**Quadrat Plots**
Description	Standard quadrats of 20 m x 20 m are fully placed within identified habitat types randomly, away from the habitat edges. Each woody plant rooted within the quadrat area and with a diameter at breast height (DBH) of ≥ 2.5 cm should be identified or classified to the species level, if possible. When necessary, diameters will need to be measured 50 cm above buttresses and other stem irregularities. Surveyors should also inspect each tree for epiphytes and record them accordingly. Herbaceous plants and plants < 2.5 cm DBH can also be recorded in smaller subplots nested within the standard quadrat.
Spread	A minimum sampling density of one quadrat per 0.5 ha for every distinct habitat type is recommended.
Frequency	Once per site.
Notes	Quadrat plots should not overlap with walking transects.

Table 2.5: Modified Gentry Plots as a Survey Method (Conservation International, 2016)

Suggested Method	**Modified Gentry Plots**
Description	The layout of each plot can be adapted to the site. Figure 2.1 shows an example of a possible layout; each grid or subplot size can be adjusted accordingly. Each Modified Gentry Plot will cover about 0.1 ha within a 100 m × 200 m sampling grid. Ten 2 m × 50 m subplots should be established, with four to six 1 m × 1 m square plots to be set up adjacent to each of the 10 subplots (refer to Figure 2.1). Each woody plant rooted within the subplot area and with a diameter at breast height (DBH) of ≥ 2.5 cm should be identified or classified to the species level, if possible. When necessary, diameters will need to be measured 50 cm above buttresses and other stem irregularities. Surveyors should also inspect each tree for epiphytes and record them accordingly. Within each 1 m × 1 m subplot, each individual herbaceous plant should be identified or classified to the species level, if possible.
Spread	The number of Modified Gentry Plots should be randomly spread out such that 10–15% of each vegetation type is sampled.
Duration	N/A
Timing	N/A
Frequency	Once per site.
Notes	N/A

The following outcomes should be included in the report:

- Species list of vascular plants found on site, including their global and local conservation status, whether each species is native, exotic or invasive, and whether the species is likely from cultivation
- Plant girth sizes
- Information on whether the plants are flowering or fruiting
- Numbers of each tree species identified on site. Herbaceous plants can be estimated by number or percentage groundcover
- Map indicating plot location and locations of species of conservation interest
- Photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

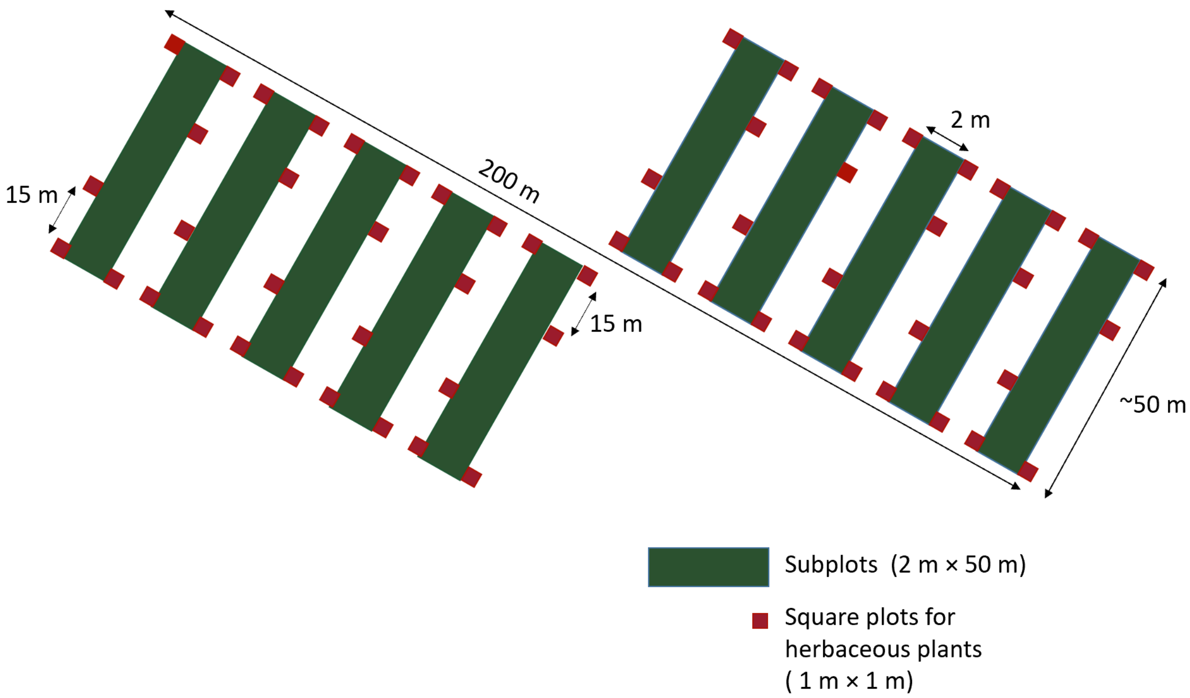


Figure 2.1: Modified Gentry Plot (adapted from Conservation International, 2016)

2.3.2 Birds

This section should establish the diversity of birds at the site, and include their global and local conservation status. The suggested methods are point counts and/or line transects.

Table 2.6: Point Counts as a Survey Method

Suggested Method	**Point Counts**
Description	Surveyor to stand at various points across the site and record all birds heard and seen within 50 m of each point. All birds should be identified to species level where possible. Sex (male or female) and age class (adult or juvenile) should also be noted if possible.
Spread	Spaced approximately 200 m apart.
Duration	10 mins at each point.
Timing	7 am to 10 am (diurnal), 7 pm to 10 pm (nocturnal).
Frequency	For diurnal surveys, each point should minimally be sampled once a month during the non-migratory season (April to August), and twice a month during the migratory season (September to March). For nocturnal surveys, each point should minimally be sampled once a month.
Notes	Selected points should be at least 200 m from line transects.

Table 2.7: Line Transects as a Survey Method

Suggested Method	**Line Transects**
Description	Surveyors should walk along the transect at a steady pace and record all birds heard and seen within 50 m of either side of the transect and 50 m ahead. All birds should be identified to species level where possible. Sex (male or female) and age class (adult or juvenile) should also be noted if possible, along with any behaviours (e.g. foraging, nesting).
Spread	200 m long transects, spaced approximately 200 m apart.
Timing	7 am to 10 am (diurnal), 7 pm to 10 pm (nocturnal).
Frequency	For diurnal surveys, each transect should minimally be sampled once a month during the non-migratory season (April to August), and twice a month during the migratory season (September to March). For nocturnal surveys, each transect should minimally be sampled once a month.
Notes	Transects should be at least 200 m from point count locations.

2.2.3.1 Shorebird Surveys

Line transects and/or point counts are appropriate methods for surveying shorebirds. However, if shorebirds are the target of the surveys, there are additional considerations on top of the information presented above:

- Appropriate tide timings should be considered. For instance, if surveying an area where shorebirds forage (e.g. Mandai Mudflats), the surveys should be conducted at low tide. On the other hand, if surveying an area where shorebirds roost (e.g. Sungei Buloh Wetland Reserve), the surveys should be conducted at high tide.
- The migratory period for shorebirds is between August to April. Therefore, surveys targeting migratory shorebirds need to commence one month earlier and end a month later compared to the landbirds. The methodology (points counts and/or transects) and frequency of these surveys (twice a month) are otherwise unchanged.

The following outcomes should be included in the report:

- Species list of birds found on site, including their global and local conservation status, whether each species is native or exotic, and whether it is resident, visitor or migratory
- Numbers of each species observed at each point count and/or transect location
- Noteworthy behaviour should be recorded and highlighted, especially for species of conservation interest (e.g. nesting behaviour such as adult birds with nesting material or feeding young birds should be noted)
- Map indicating point count and/or line transect locations and locations of species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

2.3.3 Reptiles and Amphibians

This section should establish the diversity of herpetofauna at the site, and include their global and local conservation status. The suggested methods are line transects.

Table 2.8: Line Transects as a Survey Method

Suggested Method	**Line Transects**
Description	Surveyors should walk along the transect at a steady pace and record each individual amphibian or reptile observed within 10 m on either side of the transect ahead. Surveyors should also turn logs and rocks, searching for potential refuges as they move along the transect, before returning the logs and rocks to their original position. Surveyors should also record the presence of calling frogs. The time of day that each animal is seen or heard should also be recorded. All amphibians and reptiles (seen or heard) should be identified to species level where possible. Sex (male or female) and age class (adult or juvenile) should also be noted if possible, along with any behaviours (e.g. foraging, nesting).
Spread	200 m long transects, spaced approximately 50 m apart.
Timing	7 am to 10 am (diurnal), 7 pm to 10 pm (nocturnal).
Frequency	Each transect should minimally be sampled for two cycles, with each cycle being one survey in the day and one at night, and with cycles spaced at

The following outcomes should be included in the report:

- Species list of reptiles and amphibians found on site, including their global and local conservation status, and whether each species is native, exotic or invasive
- Numbers of each species observed for each transect
- Time of day that each species was discovered
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

2.3.4 Mammals (Except Bats)

This section should establish the diversity of mammals at the site, and include their global and local conservation status. The suggested methods are camera traps and/or line transects.

Table 2.10: Camera Traps as a Survey Method

Suggested Method	**Camera Traps (Terrestrial and/or Arboreal)**
Description	Terrestrial camera traps should be mounted at a height of 30 to 50 cm off the ground. The angle of the camera should be such that there is a clear and direct field of view of a possible wildlife trail or of a relatively open area. Camera trap settings should be adjusted such that the trigger speed of cameras are 0.2 seconds or faster, and that colour photographs and/or videos are taken during the day and infrared photographs and/or videos are taken during the night. Arboreal camera traps should be mounted at a height of at least 3 m above the ground. The angle of the camera should be directed at a single branch in front of the camera with unblocked view. Camera trap settings should be adjusted such that the trigger speed of cameras are 0.2 seconds or faster, and that colour photographs and/or videos are taken during the day and infrared photographs and/or videos are taken during the night. When the camera trap data is retrieved and reviewed, information such as the time and behaviour of the animal (e.g. foraging) should also be recorded.
Spread	Approximately one every 3–5 ha, covering all representative habitats
Timing	Camera traps should be deployed for 24hr a day and for a minimum of 60 trap nights per camera per site.
Notes	Ensure understorey and canopy plants do not obscure the field of vision.

Table 2.10: Line Transects as a Survey Method

Suggested Method	Line Transect
Description	Surveyors should walk along the transect at a steady pace and record each individual mammal observed within 50 m on either side of the transect and 50 m ahead. At the same time, surveyors should also look out for indirect evidence of mammals, such as scats, tracks, and nests. Roadkill surveys should also be conducted where possible to identify animal crossing hotspots along roads. Sex (male or female) and age class (adult or juvenile) should also be noted if possible, along with any behaviours (e.g. foraging, nesting).
Spread	200 m long transects, spaced approximately 50 m apart. For roadkill surveys, transects should be along major roads adjacent to or within the study site.
Timing	7 am to 10 am (diurnal), 7 pm to 10 pm (nocturnal).
Frequency	Each transect should minimally be sampled for two cycles, with each cycle being one survey in the day and one at night, and with cycles spaced at least a month apart.
Notes	Number of transects should be proportional to the size of the study area, with more transects surveyed for a larger study area.

The following outcomes should be included in the report:

- Species list of mammals found on site, including their global and local conservation status and whether each species is native, exotic, or invasive
- Numbers of each species observed for each transect and camera trap
- Time of day that each species was discovered
- Any noteworthy behaviour (e.g. foraging)
- Locations of canopy linkages for arboreal mammals and culverts for terrestrial mammals, if any
- Map indicating locations of camera traps, transects and species of conservation interest
- Photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

2.3.5 Bats

This section should establish the diversity of bats at the site and include their global and local conservation status. The suggested methods are acoustic recording, mist nets and/or harp traps. Flyways and waterbodies are particularly good locations for bat surveys.

Table 2.11: Acoustic Recording

Suggested Method	**Acoustic Recording**
Description	Recording devices should be positioned to reduce the effect of multiple echoes bouncing off nearby hard or compacted surfaces. The devices should have flat (even) frequency response from the lowest (18 kHz) to highest (192 kHz) expected frequencies, and have a continuous minimum sampling rate of 384 kHz. The microphones on the devices should be oriented slightly less than horizontal so that moisture does not pool on the microphone membrane.
Spread	Spaced approximately 200 m apart (more closely in important forest habitats)
Timing	Between 7 pm to 7 am.
Frequency	Each location should minimally be sampled once.
Notes	When recording data is reviewed, the calls recorded should be measured and matched with known reference calls (refer to Pottie et al., 2005).

Table 2.12: Mist Nets

Suggested Method	**Mist nets (only to be used within forest habitats)**
Description	Mist nets should be set up in a forest opening, across a narrow stream, or near a water body. Unfurled nets should not be left unattended, and should be checked minimally every 30 minutes. All organisms obtained will be counted and identified to the best of the surveyors' abilities and released on the spot.
Spread	Spaced approximately 200 m apart along a fixed transect within a forested area.
Timing	Between 6 pm to 7 am.
Frequency	Each location should minimally be sampled once.
Notes	Mist nets set up near roosts should be checked every 10 minutes. If ants are seen anywhere near a mist net, it must be taken down. If it rains, the mist nets must be furled and animals released.

Table 2.13: Harp Traps

Suggested Method	Harp Traps (only to be used within forest habitats)
Description	Harp traps should be set up at locations with over-hanging and closed side vegetation. The sides of each trap should be filled with material to prevent bats from going around or under the trap. Traps should be checked hourly. All organisms obtained will be counted and identified to the best of the surveyors' abilities and released on the spot.
Spread	Spaced approximately 100 m apart along a fixed transect within the forested area of the site.
Timing	Between 6 pm to 7 am.
Frequency	Each location should minimally be sampled once.
Notes	Traps placed near roosts should be checked every hour. If ants are seen anywhere near a harp trap, the trap must be taken down. If it rains, the traps must also be taken down and animals released.

The following outcomes should be included in the report:

- Species list of bats found on site, including their global and local conservation status
- Estimates of relative abundance of each species observed for each recording device or harp trap
- Map indicating locations of transects and/or harp traps and species of conservation interest
- Where possible, photographs of all observed species should be taken and incorporated into the report for verification. This is especially important for rare species and/or species of conservation interest.

2.3.6 Butterflies

This section should establish the diversity of butterflies at the site, and include their global and local conservation status. The suggested method is line transects.

Table 2.14: Line Transects

Suggested Method	Line Transects
Description	Surveyors should walk along the transect at a steady pace and record each individual butterfly observed within 5 m on either side of the transect and 5 m ahead. Sweep netting can be used to collect species that are difficult to identify in flight, and all butterflies caught should be released on the spot. If a butterfly caterpillar is found to be feeding on the plant, the plant should be identified and recorded as well.
Spread	200 m long transects, spaced approximately 50 m apart.
Timing	10 am to 12 pm on sunny days.
Frequency	Each transect should minimally be sampled for two cycles, with each cycle being one survey in the day, and with cycles spaced at least a month apart.

The following outcomes should be included in the report:

- Species list of butterflies found on site, including their global and local conservation status
- Numbers of each species observed for each transect
- List of plants which the caterpillars were feeding on
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of all observed species should be taken and incorporated into the report for verification. This is especially important for rare species and/or species of conservation interest.

2.3.7 Odonates

This section should establish the diversity of odonates at the site, and include their global and local conservation status. The suggested method is line transects.

Table 2.15: Line Transects

Suggested Method	**Line Transects**
Description	Surveyors will slowly walk along or around the water body and record the adult odonates seen. Sweep netting can be used to collect species that are difficult to identify in flight, and all odonates caught should be released.
Spread	Full perimeter of pond/water body or full length of stream.
Timing	10 am to 12 pm on sunny days.
Frequency	Each transect should minimally be sampled for two cycles, with each cycle being one survey in the day, and with cycles spaced at least a month apart.

The following outcomes should be included in the report:

- Species list of odonates found on site, including their global and local conservation status
- Numbers of each species observed for each transect
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of all observed species should be taken and incorporated into the report for verification. This is especially important for rare species and/or species of conservation interest.

2.3.8 Freshwater Organisms

This section should establish the freshwater organism diversity (fish & decapod crustacean only) at the site, and include their global and local conservation status. The suggested methods are net transects and baited traps, but other methods (such as electrofishing) can also be employed.

Table 2.16: Net Transects as a Survey Method

Suggested Method	**Net Transects**
Description	During a fixed amount of time, surveyors will net as many freshwater organisms as possible. For streams, push netting and scoop netting are sufficient. For deeper water bodies such as ponds, cast netting may be deployed as well. All organisms obtained will be counted and identified to the best of the surveyors' abilities and released on the spot.
Spread	10 m long transects, spaced approximately 50 m (excluding the transect) apart along a stream or the perimeter of a water body.
Duration	Up to 30 mins per transect per surveyor (up to 20 minutes for two surveyors).
Timing	Daytime.
Frequency	Each location should minimally be sampled once.
Notes	Visual observations of organisms which may be too fast to catch can also be added to the survey results provided the surveyor is confident of the identification of the species.

Table 2.17: Baited Traps as a Survey Method

Suggested Method	**Baited Traps**
Description	Fish traps are baited with meat and checked after 24 hours. All organisms obtained will be counted and identified to the best of the surveyors' abilities and released on the spot.
Spread	To be placed within 10 m transect, spaced approximately 50 m (excluding the transect) apart along a stream or the perimeter of a
Duration	Overnight.
Timing	Each trap should be checked by noon the following day.
Frequency	Each stream or waterbody should minimally be sampled once.
Notes	Where possible, ensure that traps are not fully submerged as there are some local species of fish which breathe air and can drown if submerged for too long.

The following outcomes should be included in the report:

- Species list of freshwater organisms found on site, arranged by taxa, including their global and local conservation status, whether each species is native, exotic or invasive, and whether the species is a generalist or specialist
- Local abundance of each species discovered, expressed in terms of catch per unit effort
- Map indicating locations of transects and/or baited traps and species of conservation interest
- Photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

2.4 Identifying High Conservation Priority Areas

Upon completion of the baseline study, the consultant should overlay all the vegetation maps and maps indicating locations of species of conservation interest, keystone species, and bioindicator species. Areas with high conservation value such as critical or natural habitats should be highlighted as high conservation priority areas. Table 2.18 provides a guide to help determine what areas could be considered critical, natural, or modified habitats. Whether a habitat is classified as critical, natural, or modified depends on both its vegetation type and importance to species of conservation concern. However, much of this classification is dependent on site context, and what constitutes a high conservation priority area is typically further discussed among NParks and the consultant during the report refinement stage.

Table 2.18: Habitat Conservation Values (IFC, 2012)

Habitat Classification	Description
Critical Habitat*	Critical habitats are areas with high biodiversity value, including: i) habitat of significant importance to locally and globally Critically Endangered and/or Endangered species; ii) habitat of significant importance to endemic and/or restricted-range species; iii) habitat supporting globally significant concentrations of migratory species and/or congregatory species; iv) highly threatened and/or unique ecosystems in the national and global context; and/or v) areas associated with key evolutionary processes (i.e. ge-
Natural Habitat*	Natural habitats are areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological function and species composition.
Modified Habitat	Modified habitats are areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones and reclaimed wetlands.

*Habitats which are considered to have high conservation priority in Singapore

It is recommended that the consultants create a map indicating the location of habitats within the site (example in Figure 2.2). Where available, stream mapping should be overlaid on the habitat map. This should be in GIS format so that the information can be used by the developers or technical agencies, as they can help to guide decisions on where to site the development, which areas to retain for various purposes such as parks or nature corridors and what other mitigation measures are required (refer to Chapter 5).

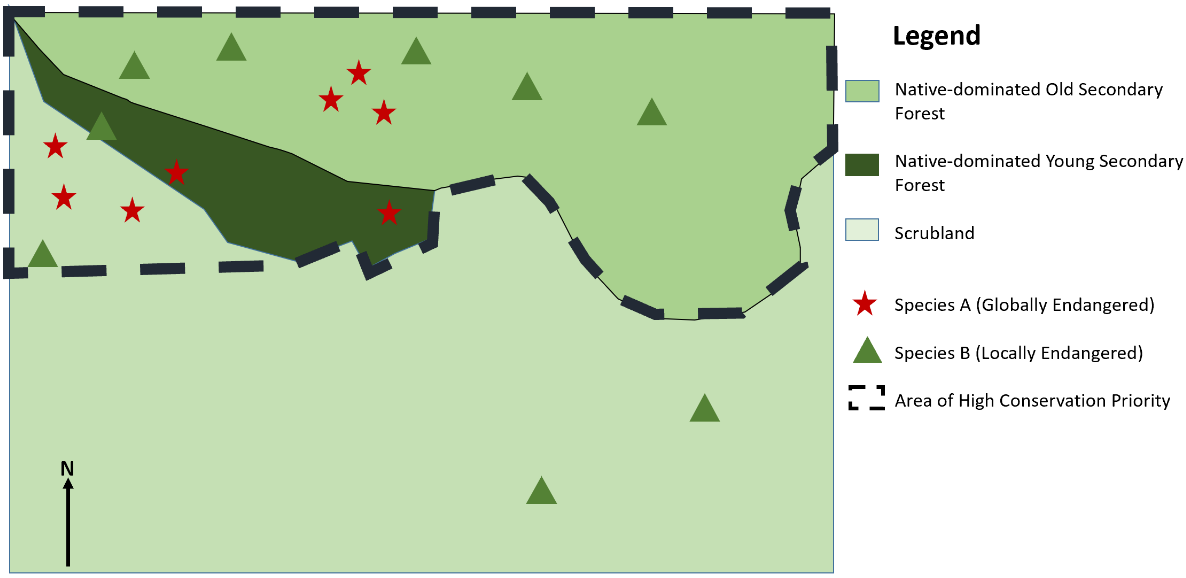


Figure 2.2: Example Map Indicating Habitat Types and Species of Conservation Interest

3. Conducting Baseline Studies for Marine Sites

3. Conducting Baseline Studies for Marine Sites

Any development at marine sites can have far-reaching impacts. As such, it is not sufficient to only consider the development footprint or even the development's immediate surroundings, but to also consider potential impacts to other connected areas, which may be adjacent to, or further afield from, the development.

Evaluating development impacts first requires robust baseline information. Baseline studies should consider the biodiversity in each habitat, water quality, hydrodynamics, the extent of the ecosystem, etc. being studied.

This chapter provides suggestions on how such baseline information can be collected.

3.1 Study Area

This section should include the following:

- Map of the study area as defined by agencies' scope. This typically includes the footprint of the development, all other areas linked to the development (such as staging areas), and the sites further afield that may be impacted by the development and its various activities
- Short description of the study area, highlighting relevant information such as justification for exclusion or inclusion of far-afield sites (i.e. sites outside the direct development footprint), the dominant biodiversity and species of conservation interest based on literature review (if available)

3.2 Habitat Baseline Study

3.2.1 Habitat Mapping

The habitats within the study area should be mapped through physical site surveys, and supplemented by the use of satellite imagery or aerial photos. The boundaries can also be supplemented by secondary sources like published papers.

The affected habitats should also be assessed in relation to the extent of such habitats within Singapore, as the proportion of the affected habitat to the extent of habitat may make a significant difference to the subsequent impact assessment.

The various types of marine environments in Singapore are described below:

Table 3.1 Marine Habitat Types in Singapore

Habitat Type	**Description of Habitat**
Mangrove Forests	A mangrove forest is a tidal habitat that comprises flora that normally grows above mean sea level in the intertidal zone of marine environments and estuarine margins. Common species include *Rhizophora*, *Bruguiera*, *Avicennia* and *Sonneratia* trees which have roots that provide support in the soft anaerobic sediments of the habitat (Ng et al., 2011). Mangrove forests also serve as roosting and nursery grounds for many bird species and invertebrates, protect shorelines from erosion, mitigate the effects of tsunamis and are important carbon sinks.
Mudflats / Soft-sediment Environments	Soft-sediment habitats, typically non-vegetated, are found between mean high-water and mean low-water spring tide datums. Located in estuaries and other low-energy marine environments (Dyer et al., 2000). Most of the biomass in mudflats is just below the surface, and the ”infaunal” community therein serves as an important food source for shore birds.
Sandy Shores	Sandy shores are loose deposits of sand, gravel and/or shells (Tope & Kotwicki, 2013).

Rocky Shores	Rocky shores are composed of hard material (Nybakken, 1997). In the local context, rocky shores also apply to intertidal areas with loose rock fragments or coral rubble. These habitats may serve as feeding grounds for some shorebirds, and nursery habitats for fish and crustaceans.
Seagrass Meadows	Seagrasses are flowering plants that live underwater (Nybakken, 1997). They are an important food source for dugongs and sea turtles and act as an important carbon sink, thus helping to mitigate climate change effects.
Coral Reefs	Coral reefs are diverse underwater ecosystems held together by calcium carbonate structures secreted by hard corals. While hard corals are animals, they live in symbiosis with an alga that provides them with the necessary energy to build up the coral reef structure (Nybakken, 1997). The coral reef systems of the world are an important source of food for coastal communities, and the carbon stored in the limestone structure acts as a carbon sink.
Lower Reef	In the local context, the lower reef typically occurs at depths of approximately 15 m. The lower reef is typically rich with other life forms or invertebrates, such as sea fans, sea whips, feather-stars and basket-stars, and houses a slightly different community of fishes.
Deep Sea Zone	In the local context, seabed of deeper than 20 m is considered deep and together with the pelagic habitat will collectively make up the deep sea zone. The communities on deep seabed are not well known, but recent studies indicate the presence of a diverse community of sessile and infaunal organisms not usually found in the shallow coral reef areas.
Artificial Coral Habitats	These includes seawalls and artificial reef structures which have been naturally/deliberately colonised with hard and soft corals.

3.2.2 Physical Parameters

The physical environment forms part of the habitat description. In the marine realm, water is the medium which connects sites, and is the medium by which pollutants can be spread. The common water-related processes and parameters that need to be studied are listed in Table 3.2. The list is by no means exhaustive nor prescriptive, and depends on the scope set out by technical agencies.

Table 3.2 Common Physical Parameters Descriptors

Physical Parameter	**Description**
Tidal Flooding and Inundation	Particularly important in mangroves, as this, together with sediment type will determine distribution of mangrove tree species (English et al., 1997).
Hydrodynamics	The flow of sea water within the area of interest. The hydrodynamic study will form the basis for much of the dispersion models that follow. Resolution of the models will depend on the issues to be studied; typically a layered approach is taken, with 75–250 m grids for coarse resolution, and 10–25 m grids for finer resolution. Examples of hydrodynamic models include MIKE 2D, MIKE 3D, Delft 2D or Delft 3D.
Sediment Plumes	Typically arising from reclamation or dredging activities. Plumes may also result from sediment run-off from land into the sea, or be dispersed by river outflow.
Sediment Loading	Refers to the amount of sediment suspended in the water column, thereby reducing light penetration. Light penetration is important for photosynthetic processes (especially in coral reefs and seagrass areas).
Sedimentation	Refers to the settling of sediments onto receptor sites, increasing the risk of organismal death by smothering. Especially important for coral reefs and seagrass beds. This parameter can be measured using sediment
Sediment Transport	Refers to erosion and accretion, usually as a result of changes in the hydrodynamics. The changes to the movement of mud and sand within the marine environment need to be assessed in relation to the development.
Re-suspension of Sediment-bound Material	Typically, in areas with soft-sediment bottoms, the material bound in or onto the sediment could be released during dredging or reclamation. The bound material could be in the form of nutrients, heavy metals, other compounds or chemicals.

Water Quality	This includes potential changes to temperature, pH, salinity, dissolved oxygen, Chl A, and other water quality parameters, including pollutants and heavy metals, based on the ASEAN Marine Water Quality Standards.
Nutrient Plumes	Nutrients are typically released into the marine environment as a result of discharges. This can happen during both the development and operational phases.
Nutrient Loading	This refers to the concentration of nutrients in the water column. May be acute or chronic, depending on the level and frequency of the discharge.
Freshwater Discharges	Some drains and canals discharge directly into the marine environment. Increases in freshwater discharge may result from expansion of the catchment area, or increased discharge from industrial or housing areas along the waterway. Such discharges may cause acute or chronic impacts, depending on the level and frequency of the freshwater discharge. The freshwater will cause changes in salinity and pH (among other things), and may also cause erosion and/or accretion to adjacent areas.
Other Forms of Discharges (not exhaustive)	Hypersaline wastewater (from desalination plants for example) will increase the salinity of the surrounding environment and disrupt osmoregulation of organisms. Heated wastewater discharge will impact the biological functions of organisms. For example, prolonged exposure of corals to heated water would cause bleaching, and ultimately, death. Conversely, prolonged exposure to cooled water would similarly cause disruption of biological functions of marine organisms.
Ship Wakes	Ship wakes have the potential to increase erosion and re-suspend sediment, increasing the sediment load of the water and leading to reduced light penetration, ultimately affecting the photosynthetic functions of light-dependent organisms.

3.3 Marine Biodiversity Community Surveys

Beyond identifying and mapping the habitat types, understanding the biodiversity community within each site is an important component of the baseline studies. Species of conservation interest should be identified as either at high risk of extinction on a local or global level, as indicated in the "Red Data Book List" or on the IUCN Red List, respectively.

The typical marine communities of interest would include:

- Mangrove flora
- Mangrove fauna (insects and shorebirds)
- Sandy shores
- Rocky shores
- Intertidal
- Mudflats and Soft Sediments (benthic and infauna)
- Seagrasses
- Coral reefs (benthic, mobile invertebrates and fishes)
- Seabed macrobenthic fauna
- Open water (including plankton, marine mammals, sea birds, etc.)

Brief descriptions of the methods to document these communities are provided in the subsequent sections, and references for detailed information on each method can be found on the resources page at the end of the booklet. Do note that these methods are not prescribed, but provided as examples. Technologies such as ROVs, drones, remote sensing, eDNA, spectral/infrared cameras can be leveraged and adapted to the methodology.

Singapore's climate is traditionally classified into 4 different local seasons according to average prevailing wind directions:

- Northeast Monsoon (December to early March)
- Southwest Monsoon (June to September)
- Inter-Monsoon (late March to May; October to November)

The local marine environment is subjected to seasonal and tidal influences for both biotic and abiotic receptors. Biodiversity /baseline surveys should cover the monsoon periods and the tidal regime to account for the variations.

3.3.1 Mangrove Flora Community

This section should establish the diversity of mangrove flora at the site, and include their global and local conservation status. The suggested method is the transect line plot method.

Table 3.3: Transect Line Plot Method as a Survey Method

Suggested Method	**Transect Line Plot Method**
Description	Transect Line Plots Method (English et al., 1997) is recommended. Permanent plots should be established along transects through each distinct forest type or zone in mangroves (see Figure 3.1). Transect lines should be perpendicular to the shoreline and plots should be set up within each vegetation zone. Surveys of these plots will provide quantitative descriptions of the species composition and community structure of the mangrove forest, and will enable tracking of changes in forest structure over the long term. If the mangrove forest is too narrow to show any zonation, a number of plots within this "fringe" zone will suffice. Each permanent plot should be no less than 10 m × 10 m, comprising up to 100 trees in each plot. Any tree larger than 4 cm in diameter at breast height (DBH) should be identified and recorded, and the girth documented. Species and the number of saplings (diameter < 4 cm) and seedlings (height < 1 m) should be recorded. All other vascular plants encountered during the survey should also be identified and counted.
Spread	Variable, depends on the size of mangrove forest.
Duration	N/A
Timing	Daytime
Frequency	The plots should be sampled for the baseline study, and can be re-sampled throughout the lifespan of the project. Minimally, the plots should be sampled at least once pre-development, at least once during development, and at least once every five years post-development.
Notes	Visual observations of other mobile organisms can also be added to the survey results provided the surveyor is confident of the identification of the species.

The following should be included in the report (in no particular order):

- Species list of mangrove plants, arranged by taxa, including their global and local conservation status
- Abundance of each species observed
- Map indicating locations of transects and plots and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report
- Number of seedlings of each species
- Number of saplings of each species
- Diameter at breast height of all trees larger than 4 cm in girth
- Qualitative observations can include:
    - ∗ estimated tree height
    - ∗ observations on flowering/fruiting
    - ∗ number of fruits/propagules
    - ∗ signs of health of mangrove plants

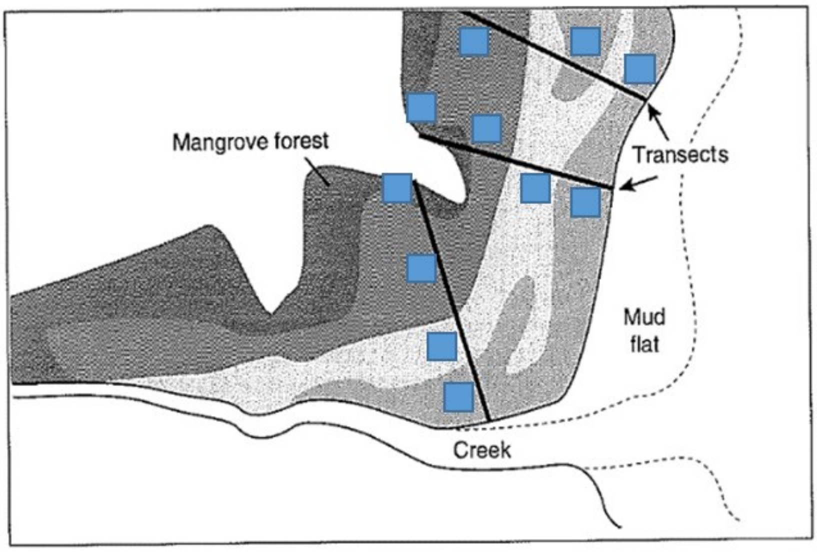


Figure 3.1: Transect Lines and Survey Plots in a Mangrove Forest (English et al., 1997). Habitat zones are indicated by the grey shaded areas and survey plots are indicated by the blue boxes.

3.3.2 Mangrove Faunal Community

This section should establish the diversity of mangrove fauna at the site, and include their global and local conservation status. There are various methods of surveys that are listed in Table 3.4.

Table 3.4: Suggested Survey Methods for the Mangrove Fauna

Suggested Methods	
Description*	Methodologies will vary with the taxa in question, and may include: • Visual surveys along transects (e.g. for crustaceans and mudskippers); transect locations should be pin-pointed using GPS • Insect trapping, using malaise nets • Tray netting • Seine netting • Cast netting • Benthic traps • Gill nets
Spread	Variable, depends on the size of mangrove forest and the extent of the water bodies therein.
Duration	N/A
Timing	Daytime; in the case of the insect traps, these can be left continuously in the field for up to a week.
Frequency	The fauna surveys should be carried out as part of the baseline study, and can be re-sampled throughout the lifespan of the project. Typically, this should include pre-development, during development, and post-development phases.
Notes	Visual observations of other mobile organisms can also be added to the survey results provided the surveyor is confident of the identification of the species.

*Birds are a major component of the mangrove forests and mudflats. See section 2.3.2 for suggested methods to document and monitor them

The following should be included in the report:

- Species list of mangrove fauna, arranged by taxa, including their global and local conservation status
- Age group of species of conservation status (to identify nursery areas that will be of higher conservation priority)
- Abundance of each species observed
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

3.3.3 Intertidal Community

This section should establish the diversity of the intertidal flora and fauna at the site, and provide a quantitative assessment of community composition. While intertidal surveys usually cover all flora and fauna communities, individual flora or fauna families can be surveyed for targeted qualitative assessment. A typical intertidal community will have seagrasses, algae, corals, fish, various invertebrates and cover a range of substrata from rocky, sandy, to mud/soft sediment. Some of these habitats may extend to the subtidal zone where dive-based transects or quadrat sampling may be employed, similar to coral reef surveys. A suggested quantitative method for intertidal community is quadrat sampling. For quantitative assessment of infauna in the substratum for intertidal or subtidal benthos, please see the next section on infauna community, 3.3.4.

Table 3.5: Quadrat Sampling as a Survey Method

Suggested Method	**Quadrat sampling**
Description	Quadrat sampling is the most common quantification method for ~~of~~ intertidal habitats such as mudflats and seagrass meadows (Loy et. al, 2024, McKenzie, 2003). Typically, three perpendicular-to-shore, 50 m-long transects are laid out in a 50 m × 50 m area. Standard quadrats of 50 cm × 50 cm are placed at an interval of every 5 m along the transect tape, and sediment composition, seagrass percent cover, species composition, canopy height and other variables are measured within the quadrats (see sample datasheet in Figure 3.2 on the following page).
Spread	Variable, depends on the size of seagrass meadow.
Duration	45 mins per transect.
Timing	Daytime, although access to seagrass meadows may be limited by tidal conditions.
Frequency	Transects should be sampled for the baseline study, and can be re-sampled throughout the lifespan of the project. Typically, this should include pre-development, during development, and post-development phases.
Notes	It is good practice to map the area of survey extent and/or transects with GPS.

SEAGRASS-WATCH MONITORING

ONE OF THESE SHEETS IS TO BE FILLED OUT FOR EACH TRANSECT YOU SURVEY

OBSERVER: ____________ DATE: ___/___/___
LOCATION: ____________
SITE code: ________ TRANSECT no.: ________
START TIME: ________ END TIME: ________

START of transect (GPS reading)
Latitude: ____°______'__ Longitude: ____°______'__

Quadrat (metres from transect origin)	Sediment (eg. mud/sand/shell)	Comments (eg 10x gastropods, 4x crab holes, dugong feeding trails, herbarium specimen taken)	📷 (√)	% Seagrass coverage	% Seagrass species composition					Canopy height (cm)	% Algae cover	% Epi-cover
1 (0m)												
2 (5m)												
3 (10m)												
4 (15m)												
5 (20m)												
6 (25m)												
7 (30m)												
8 (35m)												
9 (40m)												
10 (45m)												
11 (50m)												

END of transect (GPS reading)
Latitude: ____°______'__ Longitude: ____°______'__

Figure 3.2: Sample Seagrass Monitoring Datasheet (Seagrass-Watch, 2009)

The following should be included in the report:

- Species list of seagrasses, arranged by taxa, including their global and local conservation status
- Abundance of each species observed
- Map indicating locations of transects and quadrats and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

3.3.4 Infauna Community (Mudflats, Soft Sediments, Sand)

Benthic and infauna communities are important food sources for shore birds. Thus, abundance and biomass of organisms in soft-sediment areas such as mudflats are important parameters to measure impacts. The different various survey methods will be described in Table 3.6.

Table 3.6: Grabs, Sledges, Dredges and Nets as Survey Methods

Suggested Methods	**Grabs, Sledges, Dredges and Nets**
Description	Grabs, corers, sledges, dredges and nets are common tools to sample the benthic community in soft-sediment and loose substrates (see English et al., 1997). Grabs are typically used in soft-sediment environments to sample the top 15–25 cm of the substrate, providing quantitative results due to fixed volume sampled. Corers also provide quantitative results due to a fixed volume sampled, and allow for vertical sectioning of infaunal species. Sledges and dredges can be used in both soft-sediment and coarser sediment substrates, but give only semi-quantitative to qualitative results, as the area or volume of seabed sampled is more variable. They can be used to sample a wider area than corers or grabs. In some situations, video monitoring of benthic communities can be considered.
Spread	Variable, site-dependent.
Duration	N/A
Timing	Daytime; sampling may be limited by tides.
Frequency	The sites should be sampled for the baseline study, and can be re-sampled throughout the lifespan of the project. Typically, this should include pre-development, during development, and post-development phases.
Notes	Visual observations of other mobile organisms can also be added to the survey results provided the surveyor is confident of the identification of the species.

The following should be included in the report:

- Species list of benthic and infauna organisms*, arranged by taxa, including their global and local conservation status
- Abundance of each taxa observed
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

*In many cases, species identification may be impossible or very difficult, requiring very specialised expertise. In this case, identification to the lowest taxonomic level is permissible (e.g. to genus, family or order level).

3.3.5 Coral Reef Community

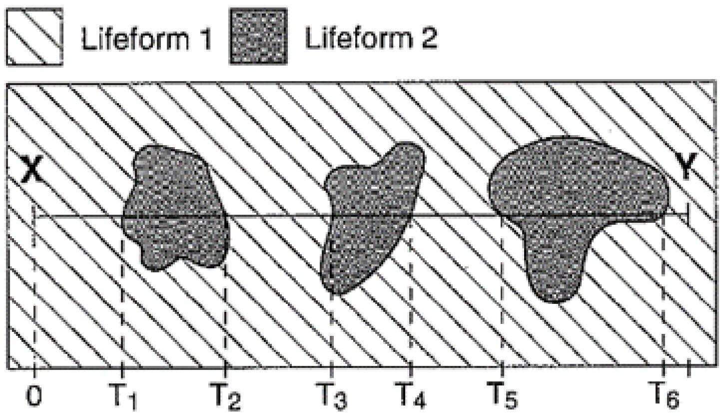
There are four sub-communities that are of interest: benthic, fish and mobile invertebrate communities, and the lower reef community.

3.3.5.1 Benthic Community

This part should establish the diversity of the benthic community at the site, and include their global and local conservation status. The suggested survey methods are Line-intercept or Point-intercept

Table 3.7: Line-intercept or Point-intercept as Survey Methods

Suggested Methods	**Line-intercept or Point-intercept**
Description	The coral reef benthic community is typically surveyed using the line-intercept (English et al.,1997) or point-intercept (Hodgson et al., 2006; Tun, 2012) method, to provide percent cover of hard corals and other sessile, benthic organisms. The survey comprises four to five 20 m transects laid out parallel to the reef, at the crest (or shallows) and 3 m below the crest (the deep). Variables such as growth form (English et al., 1997), genus and species intersected by the transect line (see Figure 3.3) are recorded. Additional information can also be collected to quantify bleaching and substrate consolidation (Tun, 2012).
Spread	Variable, in the local context, one island or patch reef can contain two to six sites, depending on the size of the reef.
Duration	45 mins per transect.
Timing	Daytime; sampling may be limited by tidal flows.
Frequency	The sites should be sampled for the baseline study, and can be re-sampled throughout the lifespan of the project. Typically, this should include pre-development, during development, and post-development phases.
Notes	Visual observations of other mobile organisms can also be added to the survey results provided the surveyor is confident of the identification of the species.



Intercept		Category
$T_1 - 0$	=	lifeform 1
$T_2 - T_1$	=	lifeform 2
$T_3 - T_2$	=	lifeform 1
$T_4 - T_3$	=	lifeform 2
$T_5 - T_4$	=	lifeform 1
$T_6 - T_5$	=	lifeform 2
$Y - T_6$	=	lifeform 1

Intercept		Category
$T_1 - 0$	I_1	lifeform 1
$T_2 - T_1$	I_2	lifeform 2
$T_3 - T_2$	I_3	lifeform 1
$T_4 - T_3$	I_4	lifeform 2
$T_5 - T_4$	I_5	lifeform 1
$T_6 - T_5$	I_6	lifeform 2
$Y - T_6$	I_7	lifeform 1

Figure 3.3: Schematic Diagram of a Transect Intersecting Lifeforms (English et al., 1997)

The following should be included in the report:

- Species list of benthic reef community (this includes the hard corals), arranged by taxa, including their global and local conservation status
- Abundance of each lifeform and/or taxa (expressed as percent cover), or species observed (as number of colonies)
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

3.3.5.2 Coral Reef Fish and Mobile Invertebrates

This part should establish the diversity of the coral reef fish and mobile invertebrates at the site, and include their global and local conservation status. The suggested survey method is using belt transects.

Table 3.8: Belt Transect as a Survey Method

Suggested Method	Belt Transect
Description	Coral reef fish species and their abundance within a belt 5 m wide and centered along the line are recorded (English et al., 1997; see Figure 3.4). Similarly, mobile invertebrates within the 5 m belt are documented (Hodgson et al., 2006).
Spread	Variable; in the local context, one island or reef patch can contain two to six sites, depending on the size of the reef.
Duration	30 mins per transect.
Timing	Daytime; sampling may be limited by tidal flows.
Frequency	The sites should be sampled for the baseline study, and can be re-sampled throughout the lifespan of the project. Typically, this should include pre-development, during development, and post-development phases.
Notes	Visual observations of other mobile organisms can also be added to the survey results provided the surveyor is confident of the identification of the species.

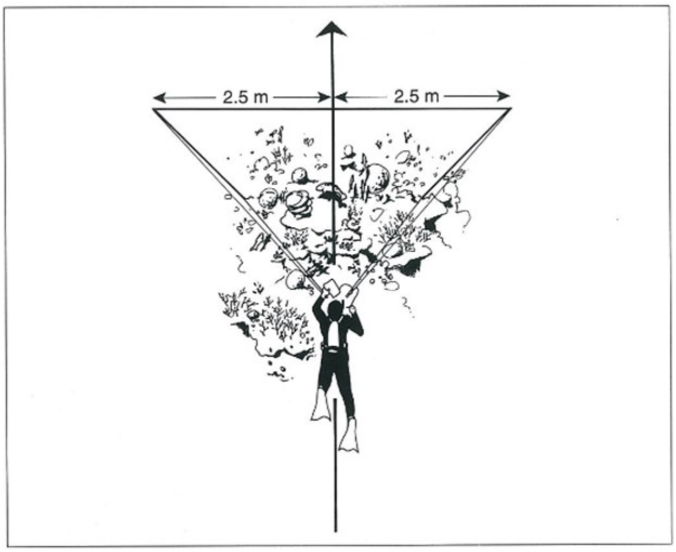


Figure 3.4: Diagrammatic Representation of a Belt Transect (adapted from English et al., 1997)

The following should be included in the report:

- Species list of reef fish and mobile invertebrates, arranged by taxa, including their global and local conservation status
- Abundance of each species observed
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of rare species and/or species of conservation interest should be taken and incorporated into the report

3.3.6 Plankton Community

This part should establish the diversity of the plankton at the site. The suggested survey methods are listed below.

Table 3.9: Plankton Survey

Suggested Methods	Microscopic or Genomic methods
Description	Samples may be collected via various methods including plankton nets (varying mesh sizes) and bottle samplers such as Niskin (based on desired depth of collection). Samples should be stored in an ice chest or under refrigeration for short term storage. Should long term storage be required, a fixative like formalin should be used. Lugol's Solution is a favorable preservative for plankton which are flagellated and ciliated (Verlecar & Desai, 2004). A trained technician should analyse the specimen under the microscope and identify the plankton. Various types of microscopy including Brightfield microscopy and Epiflourescence microscopy may be used (Kudela Lab Biological Oceanography, n.d.). A Sedgewick rafter may be used to contain the sample when observing under the microscope.
Duration	Approximately 15–30 mins per sample (microscopy). Duration for sampling may vary.
Timing	Sampling may be limited by tidal flows.
Frequency	The sites should be sampled for the baseline study, and can be re-sampled throughout the lifespan of the project. Typically, this should include pre-development, during development, and post-development phases.
Notes	Visual observations of other mobile organisms can also be added to the survey results provided the surveyor is confident of the identification of the species.

The following should be included in the report:

- Species list of plankton arranged by taxa, including their global and local distribution should be listed
- Abundance of each species observed
- Map indicating locations of transects and species of conservation interest
- Where possible, photographs of abundant and potentially harmful species (e.g. toxin producing species) should be incorporated into the report
- Additional methods such as genomics and flow cytometry may be used to analyse the diversity and to quantify the plankton population in as well.

4. Assessing Development Impacts

4. Assessing Development Impacts

The purpose of this section in the BIA report is to explain how impact assessments are conducted. Typically, a consultant will first identify potential impacts of the development. This should take into account the physical footprint of the development as well as the working space, access, outputs from the development such as discharge, and cumulative impacts from other developments in the vicinity. Following which, the consultant will proceed to evaluate and classify the significance of the impact on the environment, which could potentially be wider than the actual physical development footprint. When the impact is higher than the environmental quality objective set, mitigation measures are set to reduce identified impacts to be as minimal as feasibly possible.

After taking into account the proposed mitigation measures, the residual impact significance is assessed. The residual impact assessment forms the basis for subsequent decisions on whether the development should proceed, or if there should be conditions stipulated to further reduce impacts (e.g. reduction in development scale), as part of the planning approval process.

The process flow for the impact assessment studies is outlined below:

- Identifying types and sources of impacts
- Establishing environmental quality objectives
- Classifying levels of impacts
- Assessing impact significance
- Proposing mitigation measures (covered in Chapter 5)
- Assessing residual impacts
- Reporting the final impact assessment

4.1 Identifying Types and Sources of Impacts

The types of impact of a development is dependent on the proposed scope of development works, as well as the existing condition of the site (as per the findings of the baseline studies). The source of impact is the action which causes the impact, and the type of impact is the resulting effect of the impact; for example, the removal of half of a forested area results in loss of flora and fauna and forest edge effects. Development impacts can be broadly classified into 3 categories based on ecological organization (Miller, 2008; Rykiel, 1985): 1) environmental, 2) ecosystem, and 3) organismal. Table 4.1 lists some of the typical ecological impacts for terrestrial and marine developments. The list is non-exhaustive. While Environmental and Ecosystem impacts are considered on a site basis, Organism impacts should be considered individually for all flora and faunal species with conservation significance.

Table 4.1. Ecological impacts typical of terrestrial and/or marine developments.

Environmental Impact
• Water pollution or change in water quality
• Air pollution
• Light pollution
• Noise pollution
• Vibration
• Erosion
• Change in hydrology or hydrodynamics
• Increased sedimentation
• Increased seabed erosion
• Change in local climatic conditions
Ecosystem Impact
• Habitat loss
• Habitat degradation
• Habitat fragmentation
• Increased disturbance
• Loss of connectivity
• Edge effect
• Introduction of invasive species
• Loss of flora and fauna
• Loss of ecosystem function
Organismal Impact
• Mortality
• Displacement
• Loss of food and shelter
• Reduced local population size
• Reduced gene flow
• Increased environmental stressors
• Human-wildlife conflict
• Extinction of rare species

4.2 Establishing Environmental Quality Objectives

Environmental Quality Objectives (EQOs) are physical parameters (e.g. water quality) set to define acceptable impact levels in a given environmental receptor. Receptors can be biotic (e.g. species of conservation concern) or abiotic (e.g. water, soil, air). EQOs are often pegged to existing legislation, such as NEA's air, water, soil, and noise pollution regulations (refer to Annex A for a list of relevant Acts and Regulations), or existing baseline conditions (i.e. ambient noise level). The consultant is to determine a reasonable EQO for impacts to flora and fauna, taking reference from similar existing developments, standards and guidelines or legislated EQOs. Table 4.2 lists some examples of EQOs.

Table 4.2: Examples of EQOs

Ecological Impacts	EQO
Noise Pollution Affecting Animal Behaviour	Maximum noise level (project noise contribution) from 8 am to 6 pm: XXdB(A) Leq (5 min) Maximum noise level (project noise contribution) from 6 pm to 8 am: XXdB(A) Leq (5 min)
Light Pollution Affecting Animal Foraging and Behaviour	Maximum colour temperature level: XXX K
Discharge into the Sea Affecting Marine Ecosystems	Discharge must meet NEA's trade effluent water quality requirements for uncontrolled watercourses. See also Table 3.2.
Water Pollution Affecting Stream Ecosystems	Water quality parameters measured during development cannot differ more than 25% from baseline
Sediment Loading in Marine Environments	No impact to minor impacts, based on tolerance thresholds for specific habitat (see Table 4.4)
Sedimentation in Marine Environments	No impact to minor impacts, based on tolerance thresholds for specific habitat (see Table 4.4)
Temperature (for Marine Projects with Cooling Water Outfalls)	Heat to be dissipated within specified distance (dependent on site and environmental receptors)

4.3 Classifying Levels of Impacts

Before conducting the impact assessment, consultants should first define what the various levels of impacts correspond to. The impact classification scheme should ideally be quantitative, and customised for each of the major types of impacts. Existing standards and thresholds can also be used as a basis for impact classification. There are many variations for impact classifications, and consultants should choose the most useful classification scheme, taking into account the subsequent impact assessment methodology. A generalised classification scheme which considers impact intensity is shown in Table 4.3. The sensitivity of receptors to the impacts should also be considered.

Table 4.3: Example of an Impact Classification Scale

Classification	Description
Negligible	Changes are significantly below physical detection level, or with no to very minor loss to the quality and/or functionality of the receptor.
Minor	Short term, minor changes in quality and/or functionality of receptor.
Moderate	Loss of resource, moderate changes in quality and/or functionality of receptor.
Major	Large scale loss of resource, large changes in quality and/or functionality of receptor.

Common variations include the combination of “no impact” and “slight impact” to a classification of “negligible impact”, or an additional classification of “critical impact”. In some countries, impacts which are classified as critical require special attention.

In the marine environment, and especially for reclamation and dredging projects, sediment loading (suspended sediment) and sedimentation have been identified as key stressors, and are thus used as the main indicators of impacts. As different habitats have varying tolerances to stressors, the classification of impacts will need to be calibrated accordingly. For illustration, the suspended sediment and sedimentation thresholds for coral reefs and seagrasses are listed in Tables 4.4 and 4.5.

Table 4.4: Suspended Sediment Thresholds for Coral Reefs and Seagrasses in Singapore

Severity	Coral Reefs	Seagrasses
No Impact	Excess Suspended Sediment Concentration > 5 mg/L for less than 5% of the time	Excess Suspended Sediment Concentration > 5 mg/L for less than 20% of the time
Slight Impact	Excess Suspended Sediment Concentration > 5 mg/L for 5 to 20% of the time Excess Suspended Sediment Concentration > 10 mg/L for less than 5% of the time	Excess Suspended Sediment Concentration > 5 mg/L for more than 20% of the time Excess Suspended Sediment Concentration > 10 mg/L for less than 20% of the time
Minor Impact	Excess Suspended Sediment Concentration > 5 mg/L for more than 20% of the time Excess Suspended Sediment Concentration > 10 mg/L for less than 20% of the time	Excess Suspended Sediment Concentration > 25 mg/L for less than 5% of the time
Moderate Impact	Excess Suspended Sediment Concentration > 10 mg/L for more than 20% of the time Excess Suspended Sediment Concentration > 25 mg/L for more than 5% of the time	Excess Suspended Sediment Concentration > 25 mg/L for more than 20% of the time Excess Suspended Sediment Concentration > 75 mg/L for more than 1% of the time
Major Impact	Excess Suspended Sediment Concentration > 25 mg/L for more than 20% of the time Excess Suspended Sediment Concentration > 100 mg/L for more than 1% of the time	Excess Suspended Sediment Concentration > 75 mg/L for more than 20% of the time

Table 4.5 Sedimentation Thresholds for Coral Reefs and Seagrasses in Singapore (adapted from Doorn-Groen, 2007)

Severity	Coral Reefs	Seagrasses
No Impact	Sedimentation < 0.05 $kg/m^2/day$ (< 1.7 mm/14 days)	Sedimentation < 0.1 $kg/m^2/day$ (< 0.25 mm/day)
Slight Impact	Sedimentation < 0.1 $kg/m^2/day$ (< 3.5 mm/14 days)	Sedimentation < 0.25 $kg/m^2/day$ (< 0.63 mm/day)
Minor Impact	Sedimentation < 0.2 $kg/m^2/day$ (< 7.0 mm/14 days)	Sedimentation < 0.5 $kg/m^2/day$ (< 1.25 mm/day)
Moderate Impact	Sedimentation < 0.5 $kg/m^2/day$ (< 17.5 mm/14 days)	Sedimentation < 1.0 $kg/m^2/day$ (< 2.5 mm/day)
Major Impact	Sedimentation > 0.5 $kg/m^2/day$ (> 17.5 mm/14 days)	Sedimentation > 1.0 $kg/m^2/day$ (> 2.5 mm/day)

For development within marine environments, activities that have "slight to minor impact" are typically permitted in the area immediately adjacent to (within 500 m of) the work area, whilst "no impact to slight impact" is required for all environmental receptors remote from the work area.

4.4 Assessing Impact Significance

Quantitative methods are generally preferred to assess impact. Consultants should always try to utilise analytical tools first to assess changes in impact. However, where quantitative methods are not possible, qualitative methods can also be considered. There are various impact assessment matrices available to assist developers to conduct the impact assessment.

Three commonly used assessment methods are the Rapid Impact Assessment Matrix (RIAM), the Risk-based Impact Assessment Matrix and the Leopold Matrix. Each matrix has its merits:

- The **RIAM** is more comprehensive and is recommended for EIAs, i.e. environmental impact assessment of developments in a site.
- The **Risk-based Impact Assessment Matrix** is recommended for preliminary or desktop studies, and can be used for determining which site is the most suitable for development.
- The **Leopold Matrix** is also recommended for preliminary or desktop studies, and can be used for quickly identifying high impact activities which will require mitigation.

The three methods are elaborated in this chapter. Developers can use other methods not listed here as long as they are compatible with the development. More importantly, the method used to assess impacts has to be clearly defined and described in the report.

4.4.1 The RIAM method (modified from Pastakia & Jesen, 1998)

The RIAM method assigns an environmental score to each environmental impact and receptor(e.g. endangered or keystone species). The score is calculated as follows:

$$Environmental\ Score\ (ES) = \sum I_n * M_n * (P_n + R_n + C_n)$$

Scoring for each component is defined as follows:

Table 4.6: Score for Importance of Receptor

Importance (I)	Score
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 condition (within a large direct impact area)	2
Important only to the local condition (within a small direct impact area)	1

Table 4.7: Score for Magnitude of Impact

Magnitude (M)	Score
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

Table 4.8: Scores for Permanence, Recoverability and Cumulative Impact

Permanence (P)	Recoverability (R)	Cumulative Impact (C)	Score
Temporary	Recoverable or controllable through EMMP	Non-cumulative/single	2
Permanent	Irrecoverable	Cumulative/multiple	3

The resulting range of environmental scores based on the scoring system above, are shown in Table 4.9.

Table 4.9: Environmental scores for the impact of development

Range	Impact Indicators	Description of Range Band
116 to 180	D	Major positive change/impact
81 to 115	C	Moderate positive change/impact
37 to 80	B	Minor positive change/impact
7 to 36	A	Slight positive impact
-6 to +6	N	No Impact/Status quo/Not Applicable
-7 to -36	-A	Slight negative change/impact
-37 to -80	-B	Minor negative change/impact
-81 to -115	-C	Moderate negative change/impact
-116 to -180	-D	Major negative change/impact

4.4.2 The Risk-based Impact Assessment Matrix

This impact assessment matrix is based on methods that were originally used for risk assessments. The matrix is formed by comparing the magnitude of an impact with the likelihood of that impact occurring. Cells in the matrix then indicate the significance of the impact.

Magnitude of an impact describes the intensity of the change that is predicted to occur to the receptor of the impact type, e.g. how species of conservation interest (receptor) are affected by edge effects (impact type) as a result of the impact. There is currently no recommended function to establish the magnitude of impact, though the following impact characteristics are often taken into consideration: extent, duration, scale, and frequency.

Table 4.10: Likelihood and Magnitude of Impact

Likelihood	Magnitude of Impact			
	Large	Medium	Small	Negligible
Likely	Critical/Major*	Major	Moderate	Minor
Possible	Major	Moderate	Minor	Negligible
Unlikely	Moderate	Minor	Negligible	Negligible

*A common variation for the above matrix is the classification of likely large magnitude impacts into critical or major impact significance

Table 4.11: Characteristics of the Different Impacts

Impact Characteristic	Description
Spatial Extent	Whether the impact is confined to the development site or part of it, or spreads beyond the site (e.g. downstream, if there is drainage or a watercourse; widespread, if there is air movement bringing pollutants to distant areas), and over what distance (m, km) or area (ha, km^2).
Duration	Whether the impact is confined to the pre-construction, construction, operational or decommissioning phases, and whether these can be quantified in terms of days, months or years, and possibly particular seasons.
Scale	Whether the impact is large or small in terms of absolute numbers (e.g. number of individual animals lost) or in percentages (e.g. proportion of a population that is lost), or in terms of local, regional, national or international significance (e.g. number of IUCN Red List species affected), or in other, preferably quantitative terms.
Frequency	Whether the impact is a once-off event, recurrent, or continuous.

Quantifying the likelihood of the impact occurring is often not practical, and it is often necessary to assess likelihood qualitatively. Table 4.12 shows some examples of the likelihood of different types of impact.

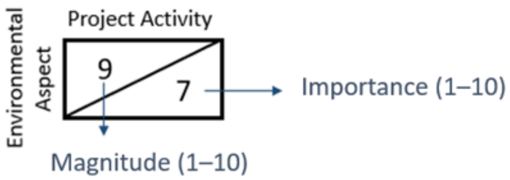
Table 4.12: Likelihoods of Different Types of Environmental Impacts

Likelihood	Examples of Types of Impacts
Likely	Vegetation clearance the size of the development footprint
Possible	Leakage of bentonite slurry into the ground
Unlikely	Pollution of untreated wastewater due to complete failure of water treatment system

The developer should have sound justifications for determining the magnitude, likelihood and significance of impacts as these are qualitative assessments. Assignment of magnitude can be made more reliable by consultation with agencies and the public during the BIA process.

4.4.3 The Leopold Matrix (Leopold et al., 1971)

The Leopold Matrix is a two-dimensional matrix which cross-references the activities linked to the project that are likely to have an environmental impact, and the existing environmental conditions that could possibly be affected by the project.



Environmental Aspect	Project Activity: Vegetation Clearance	Soil Investigation	Piling	Drain Construction	Building Operations
Plants	9 / 7	2 / 3			
Birds	7 / 7		5 / 7		5 / 3
Mammals	7 / 3		5 / 3	4 / 3	5 / 3
Reptiles	7 / 4		5 / 4	4 / 4	2 / 3
Spp. of Conservation Interest	7 / 7	2 / 3	5 / 3		5 / 3
Total	**37 / 28**	**4 / 6**	**20 / 17**	**8 / 7**	**17 / 12**

Figure 4.1: Example of the Leopold Matrix

The first step to the matrix is to draw a diagonal line for all interactions considered significant, i.e. activities which have magnitude and importance to the environmental aspect. The next step is to apply a number from 1 to 10 (1 being the minimum and 10 the maximum) to register the magnitude of the interaction. This number is then transferred to the upper left hand corner. The final step is to do the same for the lower right hand corner, but the number represents the real importance of the interaction.

The last row of the matrix sums up the total magnitude and importance for each project activity. Activities with high magnitudes and importance will need to be flagged out for further discussion on whether they are required, or if they can be mitigated.

4.5 Assessing Residual Impacts

After the impact assessment is completed, mitigation measures should be developed for all impacts classified, especially those classified as slight and above, or those which exceed set EQOs. The next chapter covers strategies in developing mitigation measures. Following the development of mitigation measures, a residual impact assessment will be conducted. This is done by repeating the same steps taken in the previous section, but with a revised impact magnitude depending on the expected effectiveness of the mitigation measures. The consultant should explain how mitigation leads to reductions to impact (if any). If prevention and mitigation cannot be done to reduce the level of significance from “critical” downwards, the viability of the entire project may need to be reconsidered.

4.6 Reporting the Final Impact Assessment

In the main BIA report, the impact assessment matrix need not be produced and printed separately for every impact. The impacts and their significance can be listed in tabular format and/or in plain text. The completed matrices for each impact can be attached to the main BIA report in the form of appendices.

5. Developing Mitigation Measures

5. Developing Mitigation Measures

5.1 What are Mitigation Measures

Mitigation measures are measures taken to avoid, reduce, or remedy adverse impacts arising from a development. They are directly linked to the impact assessment, and should be developed with the aim of reducing net impact. Mitigation measures should be tailored to address the different types and stages of construction work, as well as for the different habitats on site.

The approach to mitigation is hierarchical, with the first preference being to avoid the impacts. If this is not practicable, the next approach should be to reduce/minimise total impact. To reduce the residual impacts further, measures should be taken to remedy/restore the situation after the impact, and where possible, measures should be taken to compensate for the impacts in a different part of the development. The hierarchy of approaches is thus:

- Avoid
- Minimise
- Remedy/repair/restore
- Compensate/offset

The following example shows how the various approaches could be taken in a hypothetical situation where a building is planned to be constructed in a forested patch which is a habitat for rare birds and arboreal mammals:

Table 5.1: Example of Mitigation Measures Proposed According to the Mitigation Hierarchy

Mitigation Hierarchy	Example of Mitigation Measures
Avoid	The building is relocated/shifted away from the forested areas to avoid the need to clear the entire patch during the design and planning phase of the project.
Minimize	A wildlife shepherding plan is put in place to allow any animals trapped on the site to escape into the surrounding vegetation. During tree felling, any trees found with nests of rare birds are retained until the fledglings are mature and leave the nest. Spill budgets are set to minimise turbidity impacts from dredging.
Remedy/Repair/Restore	After construction, appropriate trees and shrubs are re-planted in appropriate locations on the impacted site to restore part of the habitat.
Compensate/Offset	Where site clearance is unavoidable, rare shrubs or trees that are important to the birds and mammals and are located within the impacted site are salvaged, to be planted elsewhere in consultation with NParks. Corals are relocated from direct impact zone to alternative sites within and/or outside of project area, in consultation with NParks.

Approval of an impact assessment report carries with it the implication that the mitigation measures will be implemented. Mitigation measures may be stipulated as requirements within land use and planning approvals, contracts and agreements.

If the mitigation measures described in the BIA are not put in place, potential difficulties could include rescinding of approvals, stopping of work orders and requiring resubmissions. As such, it is crucial that the developer only propose mitigation measures that are reasonable, implementable, economically feasible and sustainable. Including mitigation measures that are not realistic will result in delays to the project timeline and incur additional cost for developers.

5.2 When are Mitigation Measures Required

Mitigation measures should be developed for all stages of project implementation, namely:

- Design
- Pre-construction
- Construction (including site preparation works)
- Operation
- Decommissioning of infrastructure

Table 5.2: List of common activities where mitigation measures may need to be considered

Type of Activity	Pre-construction	Construction	Operation	Decommissioning
Placement of hoardings and barriers	√	√		√
Removal of trees and/or vegetation for site access, working space, storage, and rest areas	√	√		√
Removal of vegetation for site clearance		√		√
Night works /activities		√	√	√
Earthworks		√		√
Preparation of drainage		√		
Preparation of internal roads		√		
Laying on water, electricity or other facilities		√		
Waste disposal (solid, chemical, hazardous, toxic)		√	√	√
Delivery of materials to and from site		√	√	√
Installation of piles		√		

5.3 Developing Mitigation Measures

Before delving into specific mitigation measures for different impacts, the developer needs to consider if there are appropriate project alternatives or if it is possible to avoid development completely in conservation priority areas. Mitigation measures should only be considered if alternatives are not possible.

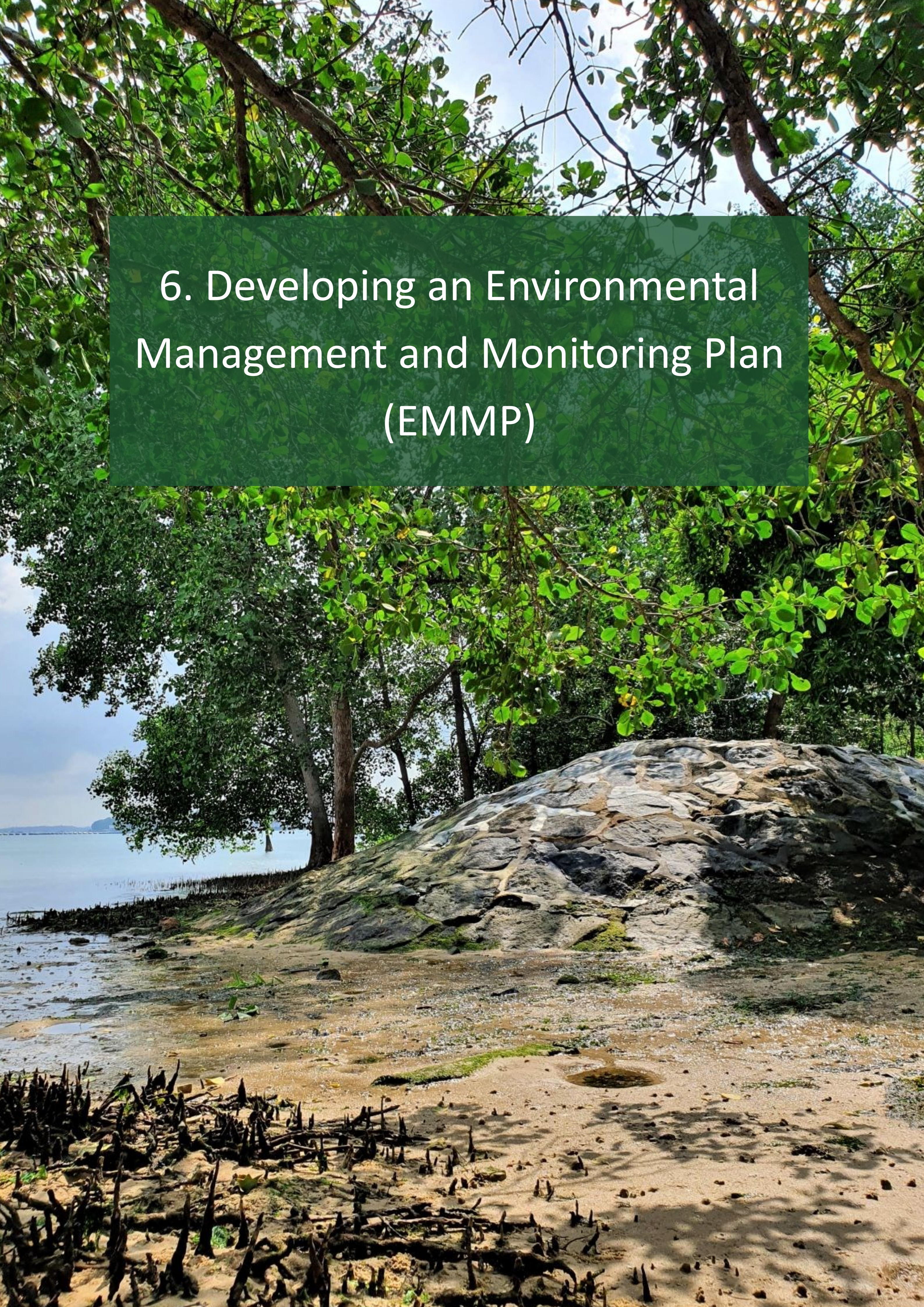
Mitigation measures can be written in a generalised fashion, or they can be written so that they are specific, measurable, achievable, realistic and time-bound (SMART). While generalised mitigation measures are acceptable for the BIA report, they will need to be converted into a SMART form for the Environmental Management and Monitoring Plan (EMMP; see next chapter).

As an example of the level of detail required for a SMART mitigation measure, a proposed mitigation measure to retain trees of conservation interest on a site should include geographical locations, cross-referenced to a map and descriptions of the trees of interest, including species information, tree health, size etc.

Below are other examples of SMART mitigation measures:

- Minimise vegetation clearance throughout project area, particularly in High Conservation Priority areas (see Section 2.4, where these zones are identified, described and mapped).
- Minimise slope cuts throughout project area, particularly in areas of biological importance (e.g. High Protection Zones). Reduce working space to avoid slope cuts (e.g. reduce working space such that the works are conducted completely on the base of the slope).
- Reduce working space to below 10 m to avoid removal of important habitats and flora (including trees).

6. Developing an Environmental Management and Monitoring Plan (EMMP)



6. Developing an Environmental Management and Monitoring Plan

6.1 What is an EMMP and How is it Related to a BIA?

The EMMP is the implementation tool of the overall Environmental Impact Assessment (EIA), which includes but is not exclusive to biodiversity. Until this point, the guidelines have focused only on the biodiversity related component of the EIA – the BIA. This chapter covers the EMMP more broadly, as the general approach to developing and implementing an EMMP is the same for biodiversity and non-biodiversity components of the EIA.

The EMMP is a tool to proactively manage and confirm that impacts of a development do not exceed the stipulated Environmental Quality Objectives (EQOs) for the project (Doorn-Groen, 2007). An EMMP describes how an action might impact the natural environment in which it occurs, and sets out clear commitments from the entity taking the action on how those impacts will be avoided, minimised, managed, remedied and compensated so that they are environmentally acceptable.

The EMMP should set out the indicators or criteria that will be used to:

1. Affirm that the mitigation and/or compensation measures from the impact assessment will be implemented;
2. Monitor whether the mitigation and/or compensation actions have been implemented, and that they are effective and sufficient;
3. Establish the response necessary to address impacts;
4. Confirm that appropriate tolerance limits have been adopted;
5. Detect any unexpected impacts at an early stage;
6. Specify the parties responsible for the actions, and the schedule for these tasks; and
7. Frame the environmental compliance reporting.

An EMMP is a continuous and adaptive management process which requires feedback mechanisms that link environmental objectives with the environmental management measures that are implemented. Effectiveness of the implemented measures must be monitored over time, and further adjustments to the mitigation measures or monitoring plans should be made as needed to achieve the environmental objective set.

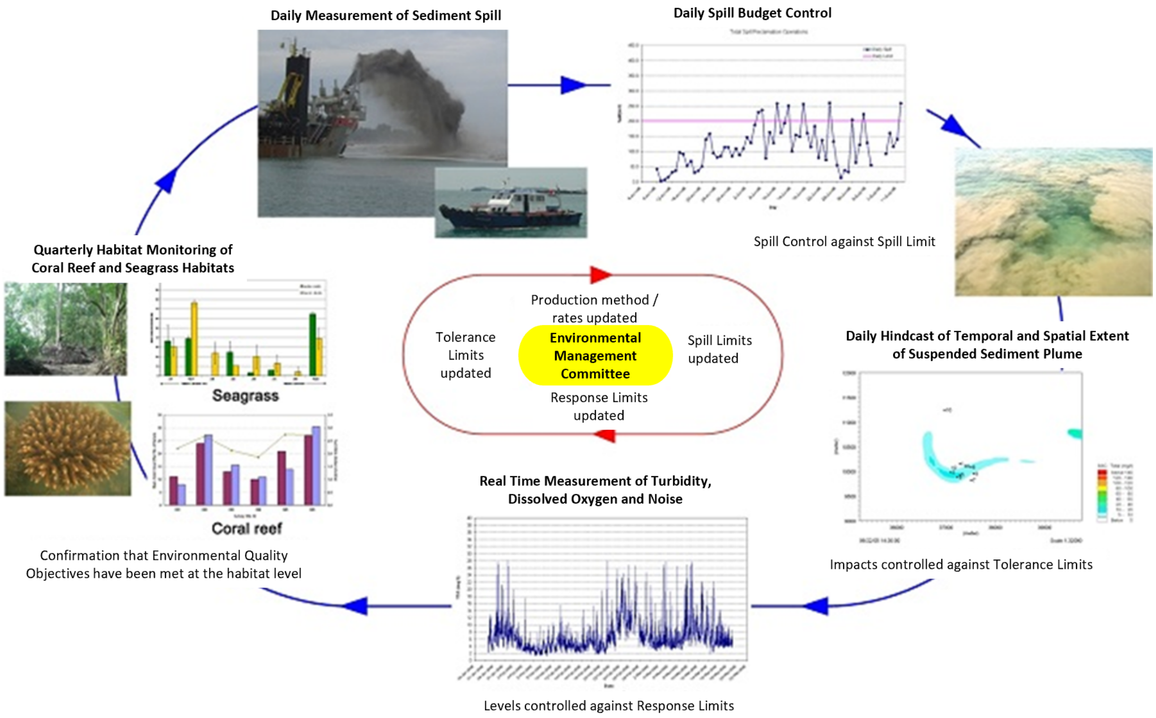


Figure 6.1: Example of Monitoring Required (adapted from Doorn-Groen, 2007)

In many instances, the same consultants who conducted the impact assessment follow through with implementing the EMMP. However, there have been cases where the contracts for the impact assessment and EMMP have been split (due to budget constraints or development timelines), resulting in several consultants or contractors becoming involved in the project. In these cases, it becomes imperative that the stakeholder agencies assess the competence of the subsequent consultants/contractors to carry out their tasks, so that the EQOs are met.

6.2 What to Include in an EMMP

An EMMP typically includes the following information:

- Executive summary or introduction
- Project description
- Environmental objectives
- Potential environmental impacts and risks
- Environmental management measures which will include:
    - Activities, controls and performance targets
    - Management maps and diagrams
    - Monitoring programmes and response plans
    - Corrective actions
- Environmental management roles and responsibilities
- Reporting procedures
- Environmental training for site workers
- Emergency contacts and procedures
- Audit and review procedures which include:
    - Environmental auditing
    - Environmental management plan review

The pertinent items are further elaborated in the subsequent sections.

6.2.1 Project Description

The project description should be similar to, and not conflict with, the description committed to in the EIA. It should include additional details and specifications that were not available earlier in the planning process. It should include:

- Relevant layout plans
- Tree felling and/or vegetation and site clearance plans
- Construction method statements
- Utilities and services (e.g. additional water and water supply structures needed for construction)
- Transportation and construction access and routes (e.g. additional paths needed to transport materials)

6.2.2 Environmental Objectives

The environmental outcomes of the plan should be refined in the EMMP. This should cover:

- The overall intent of the plan
- The specific purpose(s) of various monitoring measures in the EMMP
- The goals that the management plan wants to achieve

6.2.3 Potential Environmental Impacts and Risks

This section is relevant if the EMMP can only be submitted or refined after the EIA approval has been given. If the EMMP is drafted at this stage, the EMMP should minimally provide a quick summary of all the identified threats, as well as the identification, location and quantification of potential impacts, both direct and indirect, of the project. It should elaborate on the relevant impacts of the project, the nature and extent of the potential short-term and long-term effects, and highlight any uncertainties regarding the predicted impacts. This information is usually available as part of the EIA report and will allow the reader of the report to understand the environmental impacts without referring to the EIA report.

6.2.4 Environmental Management Measures

This section of the EMMP details the environmental management measures, i.e. the mitigation measures and monitoring programmes that need to be in place to achieve the environmental objectives outlined in the EMMP. This will form the bulk of the EMMP. It will state how the potential impacts of the proposed project will be managed. For each potential impact the plan should:

- Describe all environmental management activities;
- Detail the control measures that will be implemented to avoid or minimise environmental impacts;
- Specify the timeframes for implementation and the performance targets or outcomes to be achieved.

When defining the performance targets, the outcomes should be quantitative and auditable. These performance targets will then be used as triggers for corrective actions when they are not met.

Table 6.1 Example of Quantifiable and Auditable Performance Targets

Performance Target	
Noise will be kept to not more than 70dbA during the construction period of 8 am to 6 pm	√
Light will be kept to not more than 100 lux for night delivery of oversized equipment from 7 pm to 7 am.	√

The use of diagrams and maps is highly encouraged to illustrate:

- Specific designs of various environmental control practices
- Flowcharts of environmental management procedures
- Boundaries of environmentally sensitive areas on or near a project site
- Sources of impacts
- Vegetation that requires protection and other sensitive receptors
- Buffer zones or 'no-go zones'
- Monitoring locations

Monitoring programmes are required to establish the effectiveness of the environmental management measures in place. Monitoring also allows developers to detect any unanticipated impacts and make the necessary adjustments to the management plan to meet the environmental objectives of the project. In developing monitoring programmes, the consultants should include:

- Specific parameters that are being tracked
- Methodology
- Frequency and duration of monitoring activities
- Performance targets as triggers for corrective actions
- Details on the corrective actions to be taken
- Plans on how monitoring records will be maintained

6.2.5 Environmental Management Roles and Responsibilities

The EMMP should also define and document the roles and responsibilities of personnel in charge of the environmental management of the project. These include but are not limited to:

- Environmental Managers/Environmental Control Officers
- Contractors and subcontractors
- Arborist
- Flora and Fauna Specialists/Ecologists
- Emergency contacts

Table 6.2: Example of Roles and Responsibilities

Role	Responsibilities
Environmental Manager /Control Officer	• Coordinate and ensure the implementation of the EMMP • Report potential or actual instances of missed performance targets, including incidents and non-conformances
Arborist	• Implement tree protection, maintenance and care • Review method statement on tree felling and setting up of tree protection zones • Carry out tree inspection and reporting
Fauna specialist	• Carry out fauna monitoring surveys • Conduct pre-felling fauna inspections • Implement fauna inspections and reporting
External Auditor	• Spot-check construction works to verify contractor compliance to mitigation measures and management plans

6.2.6 Reporting

The EMMP should also provide a list of reporting requirements. This may include, but is not limited to:

- A list of required reports (e.g. training attendance records, environmental health and safety inspection reports, EMMP implementation audit reports, on-schedule monitoring reports, reports of environmental incidents, non-compliance, corrective actions and audits)
- A description of the standard report content
- Schedule or triggers for preparing a report
- Whom the report is provided to
- Document control procedures

6.2.7 Environmental Training

All people involved with the project should receive relevant environmental training to ensure they understand their responsibilities when implementing the environmental management plan. People to be trained include those involved in any of the project activities and operations, including contractors, subcontractors and visitors. The training should be tailored to the role of the individual in the project. The environmental management plan should describe the training to be implemented and could include, but is not limited to:

- Site inductions
- Identification of key points of environmental value and any relevant matters of environmental significance
- Understanding the requirements of the environmental management plan and the individual's role
- Environmental incident emergency response procedures
- On-site environmental controls
- An outline of the potential consequences of not meeting their environmental responsibilities
- Records of all training conducted should be maintained and include:
    - The name of the person receiving the training
    - The date the training was received
    - The name of the person conducting the training
    - A summary of the training

6.2.8 Emergency Contacts and Procedures

The EMMP should identify the key emergency contacts responsible for managing environmental emergencies associated with the project, and their contact details. These personnel should have the power to stop and direct works so that they can manage emergencies effectively. The EMMP should also establish procedures for managing environmental emergencies and ensuring that those procedures are implemented and maintained. These can include, but are not limited to situations such as encounters with wildlife on site, noise exceeding thresholds levels, and spillage of chemicals.

6.2.9 Review and Audit of EMMP

Monitoring results need to be reviewed on a regular basis to assess whether the plan is achieving its objectives and the requirements of any relevant approval conditions. Corrective action should be taken when performance targets are not met. The plan should also identify who will be responsible for undertaking the review, and the reporting structure within the organisation and to relevant government agencies. Environmental management measures may need to be adapted to more effectively address a potential impact during the review process, but the reasons for varying the environmental management plan should be clearly documented.

In addition to the regular review conducted by the contractors or consultants, independent third-party checks will ensure that the EMMP is fully implemented and achieving its environmental objectives. This is usually done on a regular interval or when pre-determined criteria are met (e.g. once a month, once a year, when a certain number of thresholds are not met). The audit should take into account environmental monitoring records, corrective actions and the results of any previous audits. A review of management and monitoring plans and subsequent changes may also be triggered during the independent audit as part of the corrective action, when environmental objectives are not met or when monitoring results reveal unanticipated impacts.

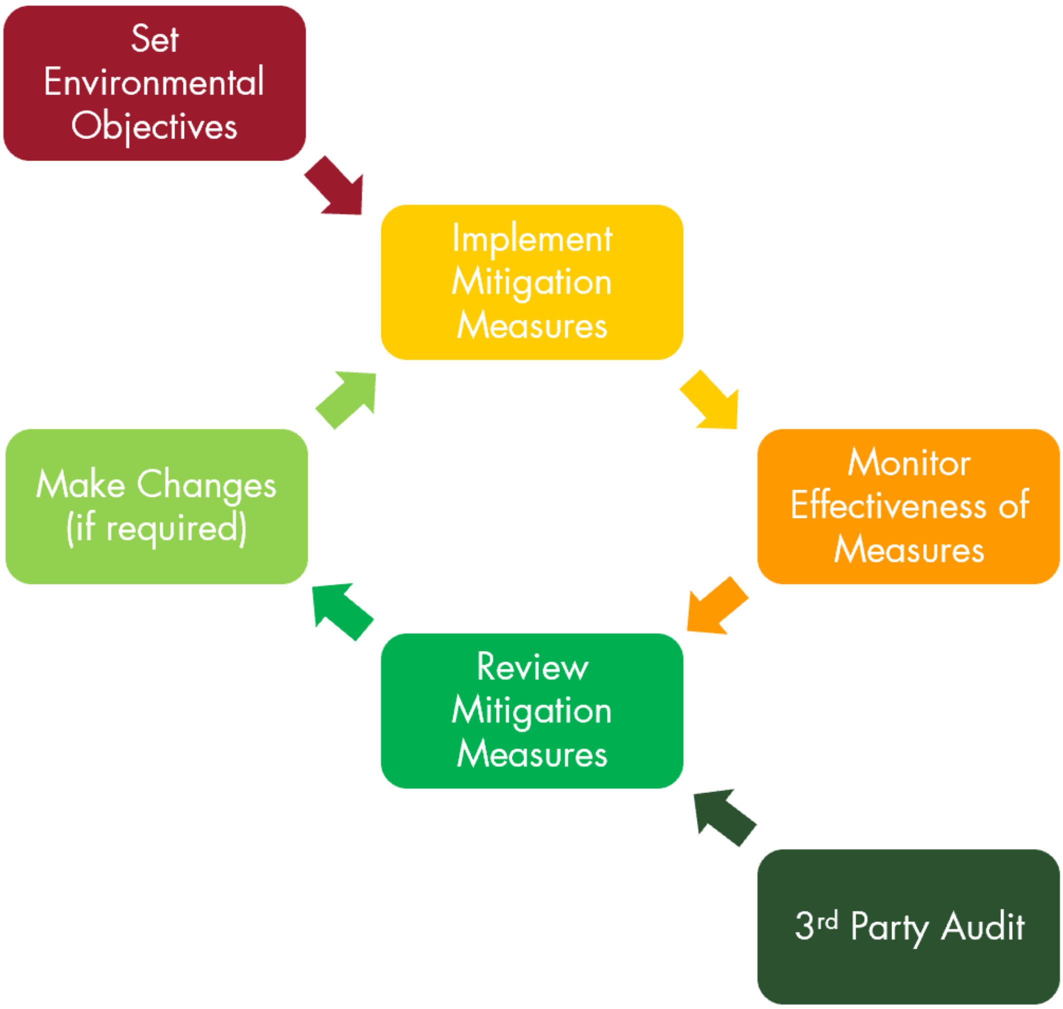


Figure 6.2: Summary of a Robust EMMP Framework

7. Conclusion

7. Conclusion

This booklet is a compilation of the collective knowledge and experience of conducting a BIA and developing a robust EMMP. The developer and consultant should be mindful of the following:

- These guidelines do not include other aspects of an EIA which may touch on social, cultural, historical or other non-biodiversity related components;
- While the guidelines provide suggestions on the methods to conduct baseline studies, these methods are non-prescriptive and non-exhaustive and we continue to welcome new technology and methods in conducting baseline studies that are suited to the location and type of development;
- The precautionary principle and worst-case scenarios should always be applied when there is any doubt in the evaluation of impacts and development of mitigation measures; and
- Monitoring programmes are crucial in ensuring environmental objectives of a project are met and are important components of a robust EIA.

In summary, each development is unique and there is no template for conducting an impact assessment. The developer and their consultant will need to tailor the assessment to the site conditions and the type of development. Where there is uncertainty about the scope and requirements of the EIA, the developer and consultant should err on the side of caution and consult technical agencies. We hope that the best practices provided in these guidelines will provide clarity on how to conduct a BIA and what is expected for a robust EMMP. Further resources are also available at the end of this booklet.

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Additional Reading

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Annex A: List of Relevant Acts and Regulations

Category	Relevant Acts and Regulations
Conservation of Trees and Protected Area	• Parks and Trees Act, 2006 • Parks and Trees Regulations, 2006 • Parks and Trees (Preservation of Trees) Order, revised 1998
Wildlife Protection	• Wildlife Act, 1965
Import of Animals and Plants	• Endangered Species (Import and Export) Act, 2008 • Animals and Birds Act, 2002 • Control of Plants Act, 2000
Surface Water Protection	• Public Utilities Act, 2002 • Public Utilities Act (Reservoirs, Catchment Areas and Waterways) Regulations, 2006 • Sewerage and Drainage Act, 2001 • Sewerage and Drainage Act (Surface Water Drainage) Regulations, 2008 • Environmental Protection and Management Act, 2002 • Environmental Protection and Management (Trade Effluent) Regulations, 2008 • Environmental Protection & Management Act (Part V – Water Pollution Control) 2008
Air Quality Protection	• Environmental Protection and Management Act, 2002 • Environmental Protection and Management (Vehicular Emissions) Regulations, 2008 • Environmental Protection and Management (Air Impurities) Regulations, 2008 • Environmental Protection and Management (Off-Road Diesel Engine Emissions) Regulations, 2012
Noise Protection	• Environmental Protection and Management Act, 2002 • Environmental Protection and Management (Control of Noise at Construction Sites) Regulations, 2008 • Environmental Protection and Management (Vehicular Emissions) Regulations, 2008
Waste Management	• Environmental Protection and Management (Hazardous Substances) Regulations, 2008 • Environmental Public Health Act, 2002 • Environmental Public Health (General Waste Collection) Regulations, 2000 • Environmental Public Health (Toxic Industrial Waste) Regulations, 2000 • Sewerage and Drainage Act, 2001 • Sewerage and Drainage (Trade Effluent) Regulations, 2008

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