Environmental and Social Impact Assessment for the Regional Solid Waste Management Facility (RSWMF) Thilafushi

Marine Survey Report

Thilhafushi house reef. Photo by: Water Solutions

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1 Introduction

The marine environment survey of Thilafushi covered the shallow lagoon, deep lagoon, reef-flat, and reef slope of the house reef of areas of Thilafushi Island. Thilafushi consists of deep, shallow lagoon, reef flat and reef slope areas. More than half of the shallow lagoon or reef flat area is now reclaimed. The south wing of Thilafushi is wider compared to north wing. The widest reef flat area is on the south wing on the west side of the reef. The enclosed deep lagoon area towards east is well protected with very restricted water movement. This area is used by vessels as a mooring basin. The stagnant water coupled with waste dumping in this area has degraded the lagoon environment on the east side. The deep lagoon of this area has very low visibility, the bottom substrate of the deep lagoon consists mainly of sand. Towards the east of deep lagoon, the bottom substrate is mainly mud and garbage debris.

2 Scope of work

The marine survey at Thilafushi has been conducted to cover the marine component of the TOR for the EIA for the Establishment of the Regional Waste Management Center for Zone III issued by EPA. Hence the TOR requested to assemble, evaluate and present baseline data on the relevant environmental characteristics of the study area, focused on the marine environment. Aspects of the environment shall be described to the extent necessary for assessment of the environmental impacts of the proposed development. The extent and quality of the available data shall be characterized indicating significant information deficiencies and any uncertainties associated with the prediction of impacts.

All available data from previous studies, if available shall be presented. Information required includes the following:

Assessment of the marine environment should be undertaken from all locations from which data was taken in 2011 EIA report. This assessment should cover coral cover and fish census information. Plankton Assessment from 05 different locations around Thilafushi. Areas of special sensitivity including coral reefs and marine protected areas near Thilafushi shall be marked on a map and described. This shall include environmentally sensitive areas, protected areas and significant dive sites.

3 Methodology

A coral reef survey of Thilafushi reef was carried out to establish a baseline of the existing coral reef environment. The baseline assessment assessed the diversity and abundance of coral reef, fish, and significant invertebrates that are commonly associated with the reef environment of Maldives. The method involved determining percentage of various benthic substrate (categories) using standard benthic categories for coral reef benthic substrate sampling as described by Hodgson et.al (2006) in Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring.

Site selection for the marine survey was based on the location of the WTE, existing dumpsite, and proposed hotwater outfall and seawater intake and as well as control sites for future monitoring purposes. At survey sites M1 to M7 benthic composition and fish abundance was surveyed at depths of 5 meters and 10 meters and at survey sites M8 to M10, surveys were done to a depth of 30 metres along the reef profile. A Manta Tow survey was conducted along 500 metres from M9 to M10 along the reef edge on the southern side of Thilafushi at both 5 and 10 metres. The inner lagoon was not surveyed as the area is not of ecological importance.

The marine benthic and fish surveys at Thilafushi Island was focused on 10 sites. Plankton tows and water samples were done at 7 sites on 23rd – 24th April 2018. Marine surveys were done at marine sites M1 to M7 on 23rd – 24th April 2018 2018. Three sites, M8 to M10 were surveyed on 1st September 2019 as more detail marine survey was requested to locate the hot water discharge location on southern side of Thilafushi. These three sites were chosen within a 500 m zone on the southern side of Thilafushi as shown in Figure 3. M8 was one of the potential site to locate the hot water discharge outfall.

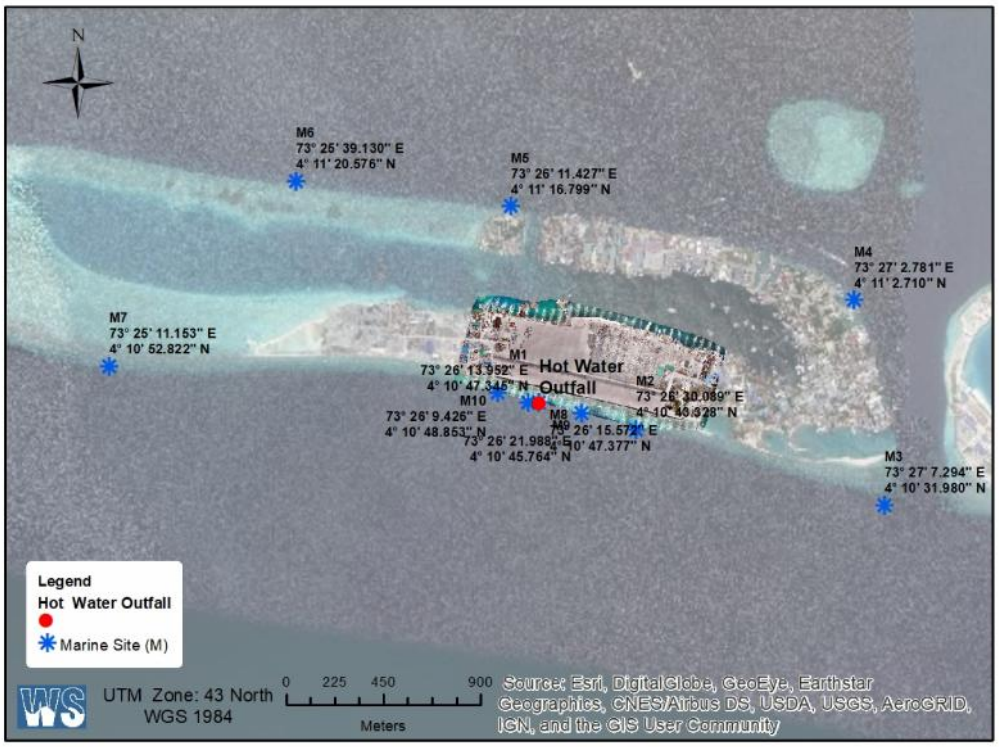

Figure 1: Marine surveyed locations with coordinates in 23rd – 24th April 2018 and 1st September 2019

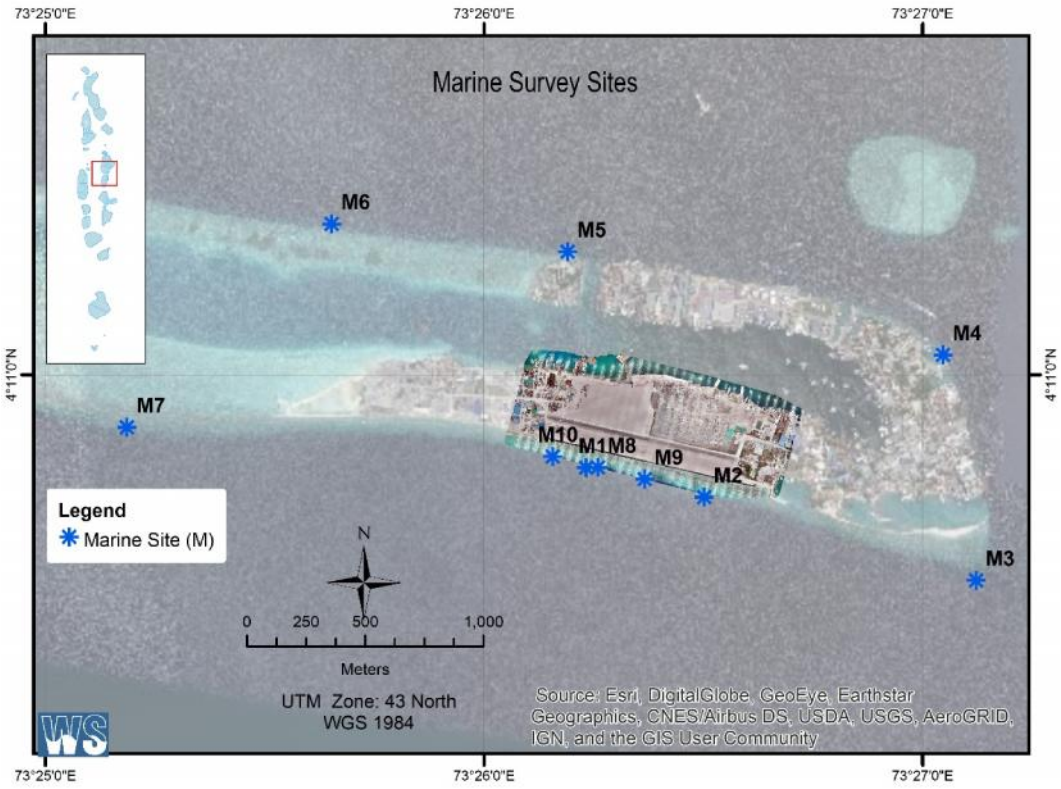

Figure 2: Marine surveyed locations with coordinates in 23rd – 24th April 2018 and 1st September 2019

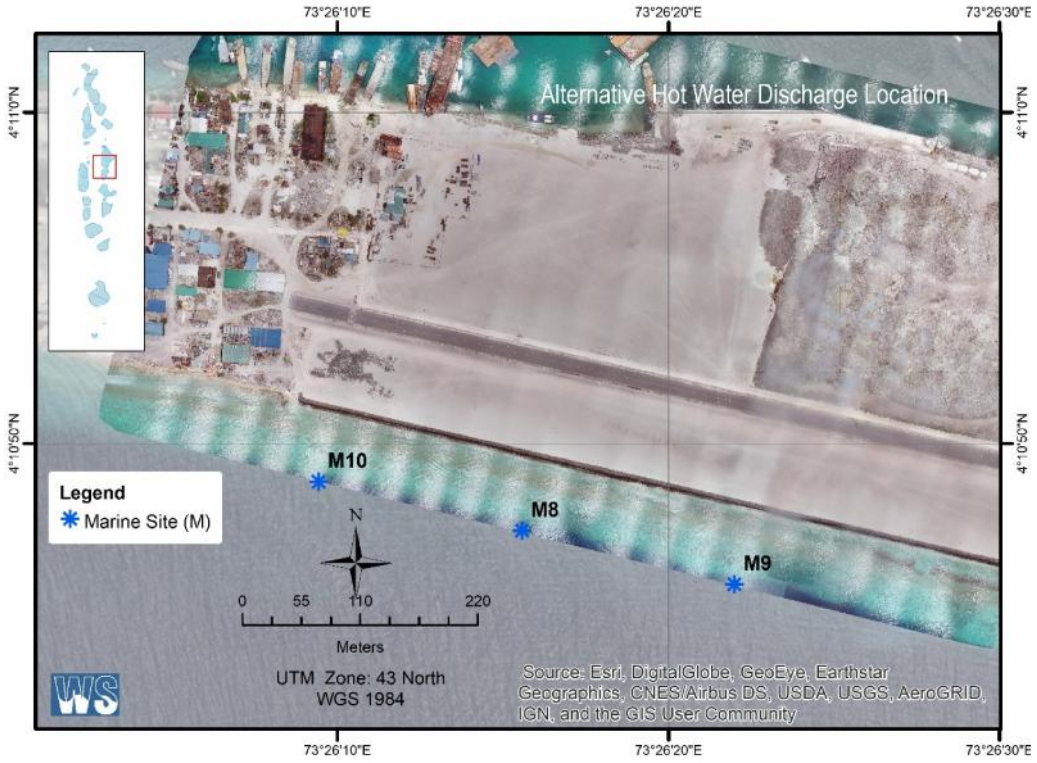

Figure 3: Marine surveyed locations on 1st September 2019

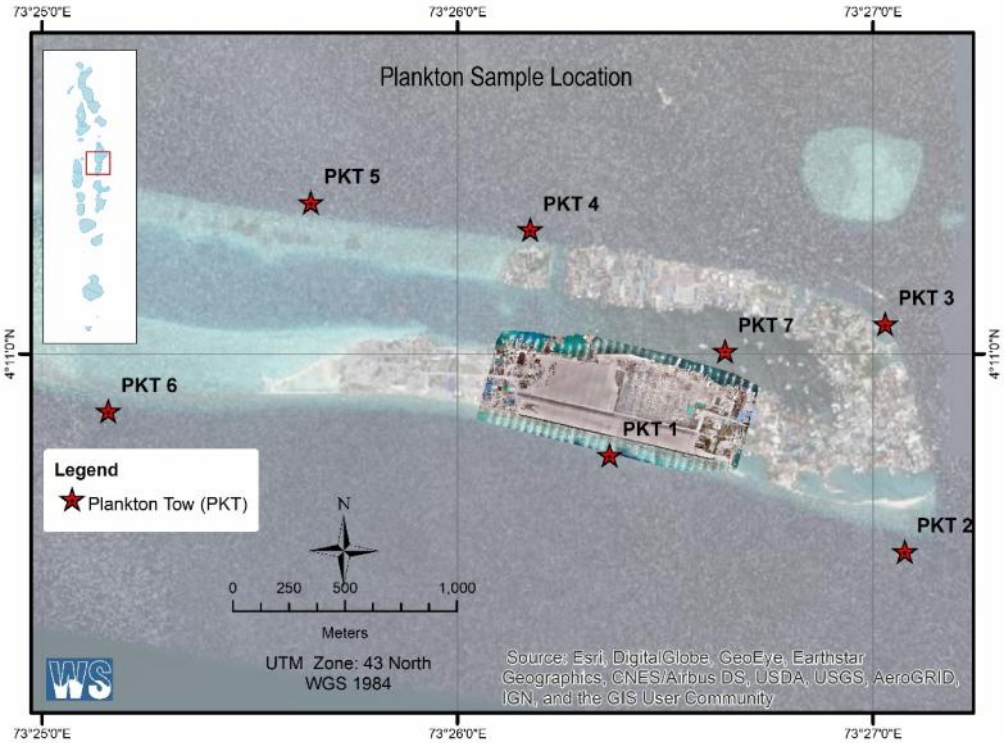

Figure 4: Plankton tows and water sampled location on 23rd – 24th April 2018

3.1 Benthic Survey

All surveys were carried out by underwater SCUBA diving. The marine surveys were carried out by surveyors who had been trained to undertake Reef Check surveys as outlined in the Reef Check Instruction Manual: A Guide to Reef Check Coral Reef Monitoring (2006). Based on the Guide to Reef Check Coral Reef Monitoring (2006) photo quadrat surveys were done in order to measure the benthic composition 10 sites (M1-M10) located on areas on the outer reef around Thilafushi island. At the survey sites M1 to M7 benthic composition and fish abundance was surveyed at depths of 5 meters and 10 meters. At survey sites M8 to M10, marine surveys were done to a depth of 30 metres along the reef profile.

3.1.1 Surveys in April 2018

The photo quadrat surveys were undertaken at marine site M1 to M7. A transect line of 20 metres at each site is set out, the surveyor then places a half a metre quadrat made from PVC along the transect line and takes a photo directly from vertically above. The second photo is then taken along in the same manner after approximately 1 m away from the first photo. In this manner, photos are taken along the transect line and in total, 10 photos on each transect line are taken. In each of the sites 4 transects were place in two depths (5 & 10m). The surveys were undertaken on 23-24 April 2018.

3.1.2 Reef profile Survey in September 2019

Marine survey sites M8 to M10, were three additional sites surveyed using photo quadrat methods. Unlike the conventional reef transect surveys, the three sites were assessed for benthic composition by undertaking photo quadrates from the top reef up to 30 metres, along the reef profile.

Before start of the survey, the starting points were marked using a plastic bottle tied with a rope and weight at its end. The weight rested at the top reef, approximately 5 metres from the reef slope. This allowed the divers to descent from the exact required location up to 30 metres.

Photos were taken using the half metre quadrat made from PVC along the transect line (vertical) and takes a photo directly from above. The second photo is then taken along in the same manner after approximately 1 below the first photo. In this manner, photos are taken along the transect line.

3.1.3 Manta Tow survey in September 2019

A Manta Tow survey was conducted along 500 metres from M9 to M10 along the reef edge on the southern side of Thilafushi at both 5 and 10 metres. Manta towed was conducted by swimming along the stretch and recording the observations on an underwater slate. The tow at 5 metres was undertaken with the help of a boat which towed the swimmer along the survey stretch using a rope.

The parameters observed include percentage cover of live coral, other benthic organisms, substrate diversity of the reef in terms of benthic and pelagic life. Overall status of the reef along this stretch was determined based on this survey and the results are outlined below.

4 Data Processing methodology

Analysis of the photos was done using a computer program called, CPCe (Coral Point Count with Excel extensions). This is an internationally recognized software used all over the word to assess the benthic composition of the reefs. In this programme, photographs are analyzed using pre-defined benthic categories. Depending on the type of survey, these categories can be user defined at any given level. Users can have very complex levels ranging from individual coral families or have broader assessment categories. As the objective of this survey was to assess the impact of dredging and reclamation, it made sense to use a broader categories. Hence, benthic categories adopted by the Reef Check protocol were utilized. A text file containing these categories was created and imported to CPCe. The Reef Check protocol allows categorizing life forms followed under the Reef Check protocol, which emphasizes on benthic composition categorizing such as hard corals, sand, rock and others. The emphasis is not on recording corals to their species levels, but rather the general coral and other life forms such as hard and soft corals. This method is more accurate as the percentage of healthy coral cover and other life forms can be more accurately recorded even by a non-experienced surveyor.

The following are definition of benthic categories used in this survey.

- **HC:** All living coral including bleached coral; includes fire, blue and organ pipe corals
- **SC**: Include zoanthids but not anemones (OT)
- **DC**: Coral that has died within the past year; appears fresh and white or with corallite structures still recognizable
- **ALG**: All macro-algae except coralline, calcareous and turf (record the substrate beneath for these); Halimeda is recorded as OT; turf is shorter than 3cm.
- **SP**: All erect and encrusting sponges (but no tunicates).
- **RC**: Any hard substrate; includes dead coral more than 1 year old and may be covered by turf or encrusting coralline algae, barnacles, etc.
- **RB**: Reef rocks between 0.5 and 15cm in diameter
- **SD**: Sediment composed of particles of less than 0.5cm in diameter; in water, falls quickly to the bottom when dropped.
- **SI**: Sediment that remains in suspension if disturbed; recorded if color of the underlying surface is obscured by silt.
- **OT**: Any other sessile organism including sea anemones, tunicates, gorgonians or non-living substrate.
- **SG**: All types of sea grass observed categorized in the field SG.

Each of the 10 photos from transect are imported, cropped and prepared for analysis. The CPCe program then generates a matrix of random points overlaid on the image for each point to be visually identified. Users can then input the defined categories for each photo and once all the photos are analysed, the results are displayed on a table.

5 Results of the marine survey

5.1 Status of site 1 (M1)

Site 1 was selected from the Southern rim of the island reef. The site was chosen as the site was adjacent to the proposed waste rehabilitation centre. The substrate at the site is dominated by rock at depths of 5 (58 ± 14.2%) and 10 (64.5 ± 2.78) meters respectively. Hard coral cover was observed to be moderate at the site at depths of 5 (19.5 ± 5.91) and 10 (21 ± 2.68) meters. Massive porites were the dominating the group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, damselfishes and butterfly fishes. Fishes observed to be abundant at a depth of 10 meters were anthias, damselfishes and triggerfishes. The following graph outlines the status of site 1(M1) at depths of 5 and 10 meters.

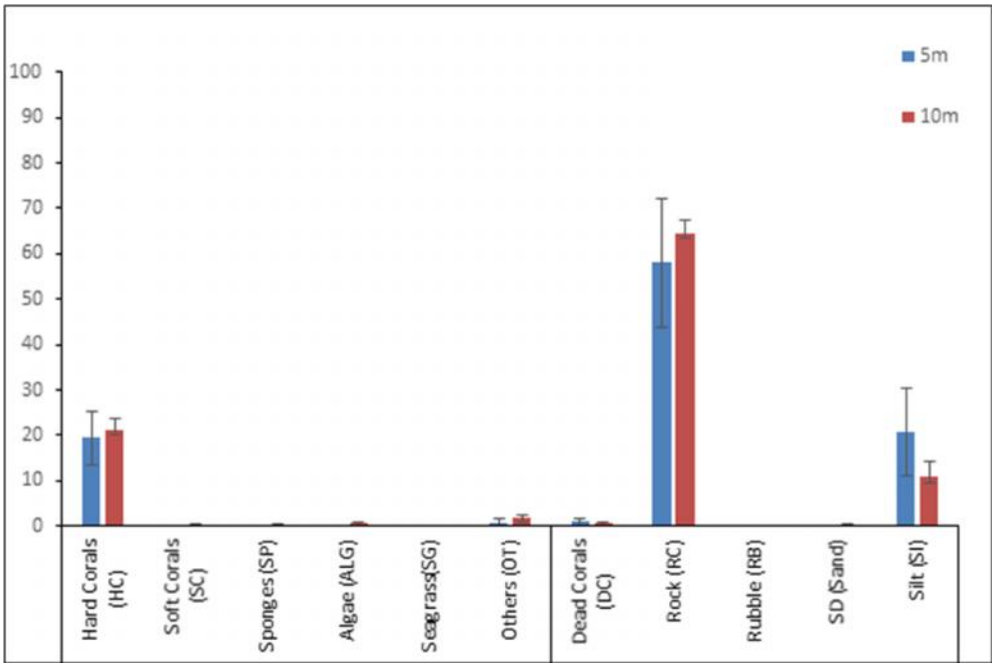

Figure 5: Percentage benthic composition at site 1(M1) at depths of 5 and 10 meters ± Standard Error (SE) (23rd April 2018).

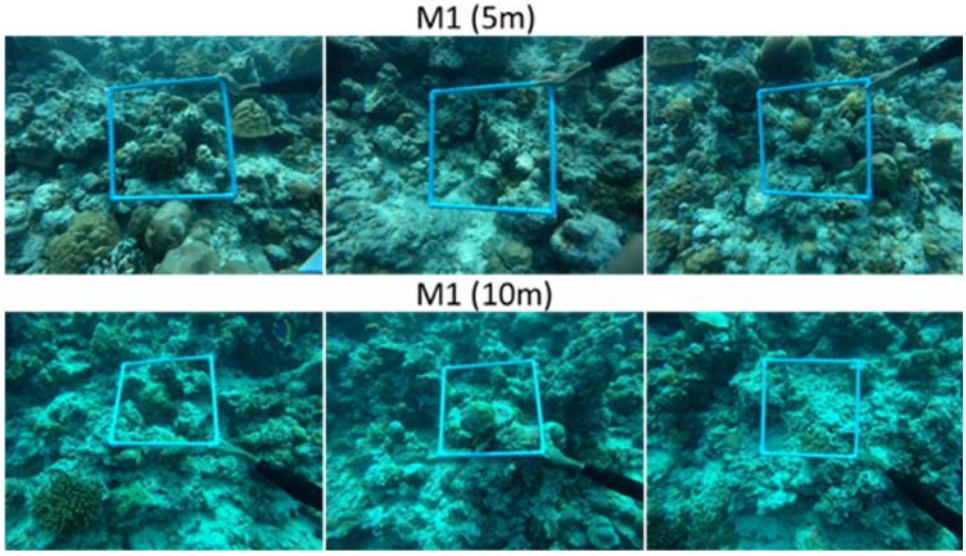

Figure 6: Photos taken from site 1 at depths of 5 and 10 meters (M1) (23rd April 2018).

5.2 Status of site 2 (M2)

Site 2 was selected from the Southern rim of the island reef east of site 1. The site was chosen as the site was adjacent to the proposed waste rehabilitation centre. The substrate at the site is dominated by rock at depths of 5 (71.25 ± 3.86%) and 10 (63 ± 6.14) meters respectively. Hard coral cover was observed to be moderate at the site at depths of 5 (22.25 ± 2.95) and 10 (23.25 ± 5.17) meters. Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at depth of 5 meters were anthias, surgeon fishes, damselfishes, parrotfishes, triggerfishes and butterfly fishes. Fishes observed to be abundant at depth of 10 meters were anthias, damselfishes, butterfly fishes and triggerfishes. The following graph outlines the status of site 2(M2) at depths of 5 and 10 meters.

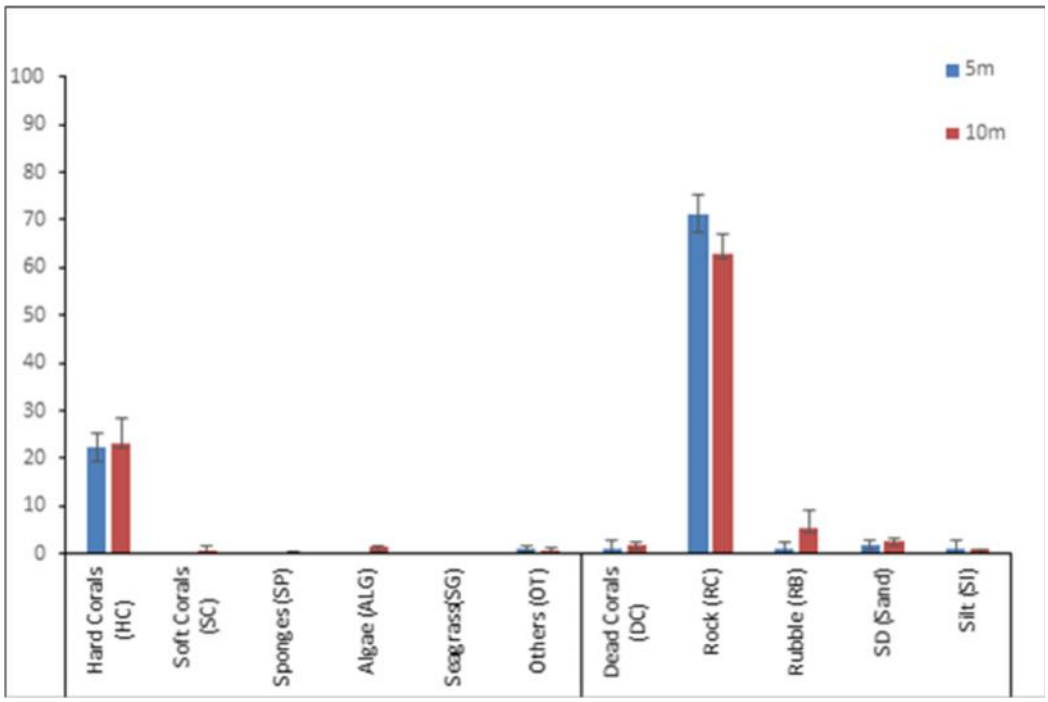

Figure 7: Percentage benthic composition at site 2 (M2) ± SE (24th April 2018).

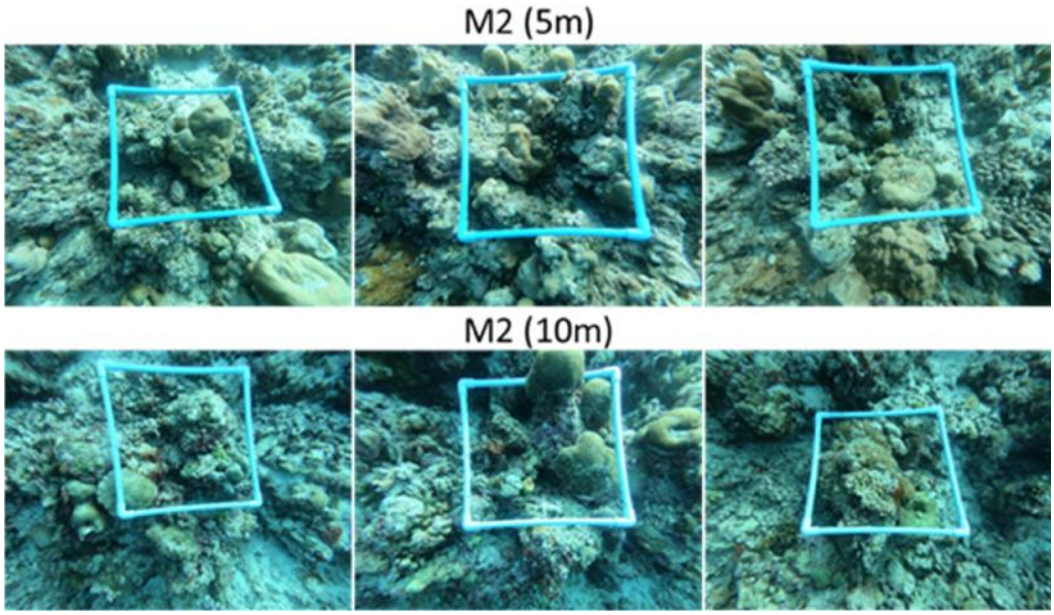

Figure 8: Photos taken from site 2 (M2) (24th April 2018).

5.3 Status of site 3 (M3)

Site 3 was selected from the Southern eastern corner of the island reef. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 (76.25 ± 2.10%) and 10 (65.75 ± 2.46) meters respectively. Hard coral cover was observed to be moderate at the site at depths of 5 (17 ± 2.48) and 10 (16.5 ± 0.65) meters. Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes and jacks and trevallies. Fishes observed to be abundant at a depth of 10 meters were anthias, damselfishes and triggerfishes. The following graph outlines the status of site 3(M3) at depths of 5 and 10 meters.

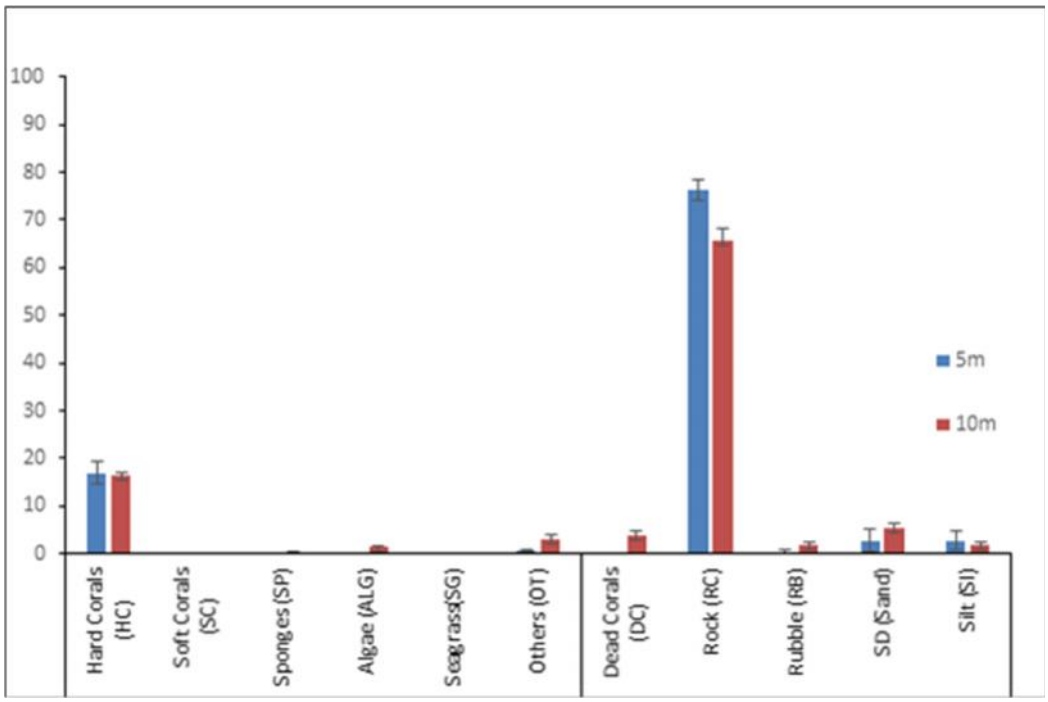

Figure 9: Percentage benthic composition at site 3 (M3) ± SE (23rd April 2018).

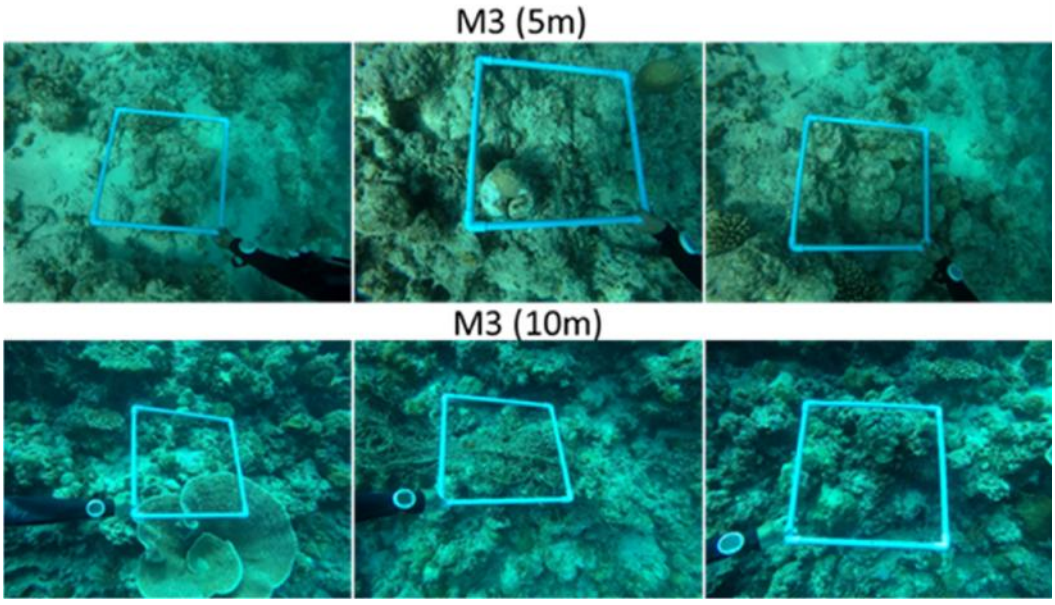

Figure 10: Photos taken from site 3 (M3) (23rd April 2018).

5.4 Status of site 4 (M4)

Site 4 was selected from the North-eastern rim of the island reef. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rubble at depths of 5 (67 ± 4.49%) and 10 (60 ± 6.42) meters respectively. Hard coral cover was not observed at the site at depths of 5 and 10 meters. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, butterfly fishes and fusiliers. Fishes observed to be abundant at a depth of 10 meters were only fusiliers. The following graph outlines the status of site 4(M4) at depths of 5 and 10 meters.

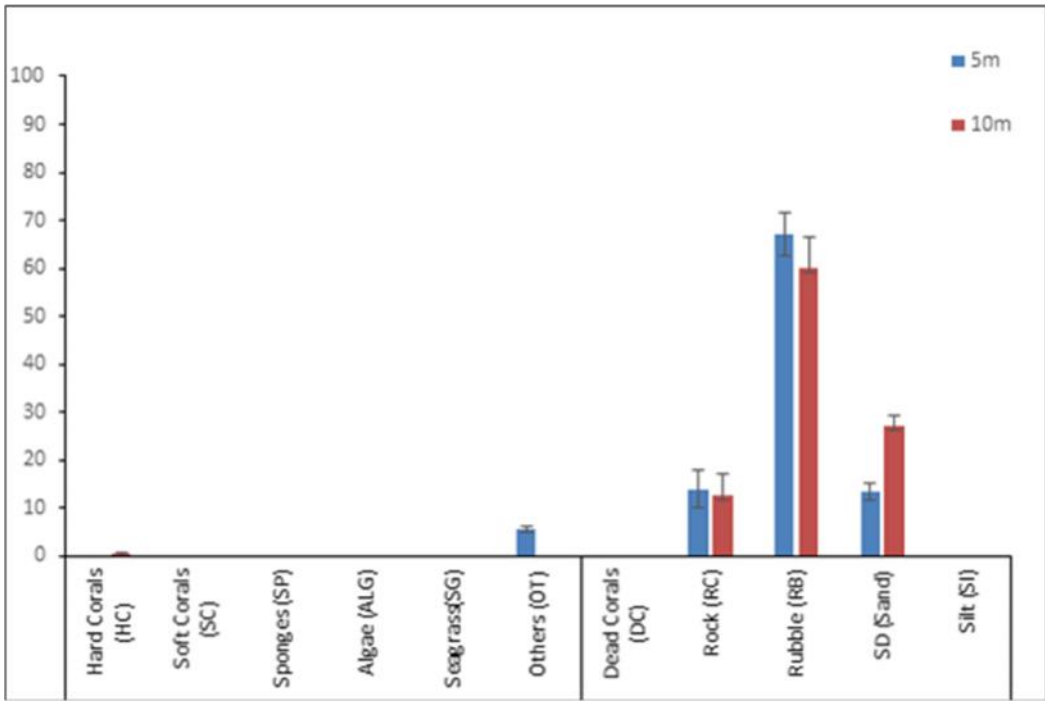

Figure 11: Percentage benthic composition at site 4 (M4) ± SE (24th April 2018).

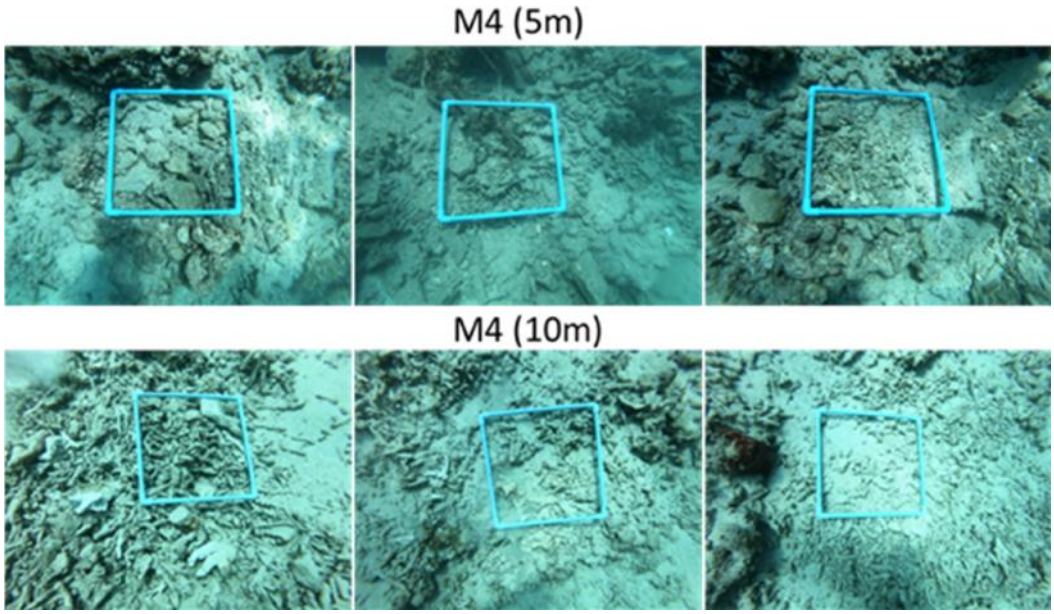

Figure 12: Photos taken from site 4 (M4) (24th April 2018).

5.5 Status of site 5 (M5)

Site 5 was selected from the Northern rim of the island reef close proximity to the entrance channel. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 (46.75 ± 6.28%) and 10 (51.5 ± 5.81) meters respectively. Hard coral cover was observed to be low at the site at depths of 5 (5 ± 1.58) and 10 (4.25 ± 0.75) meters. Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes and parrotfishes. Fishes observed to be abundant at a depth of 10 meters were surgeon fishes, damselfishes and triggerfishes. The following graph outlines the status of site 5(M5) at depths of 5 and 10 meters.

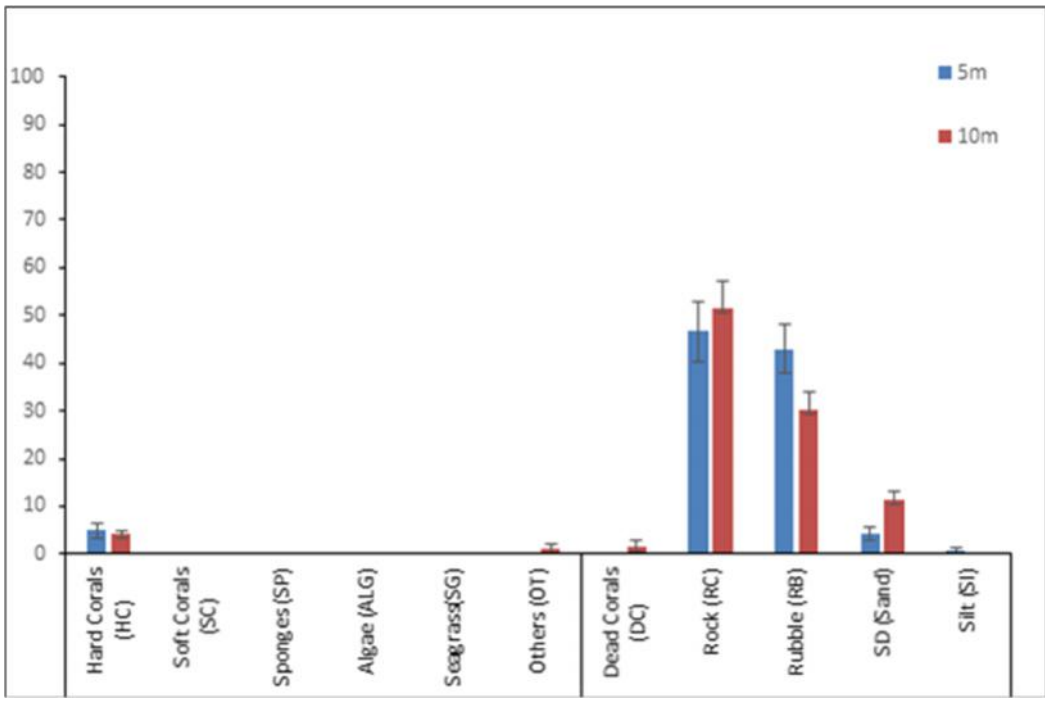

Figure 13: Percentage benthic composition at site 5 (M5) ± SE (24th April 2018).

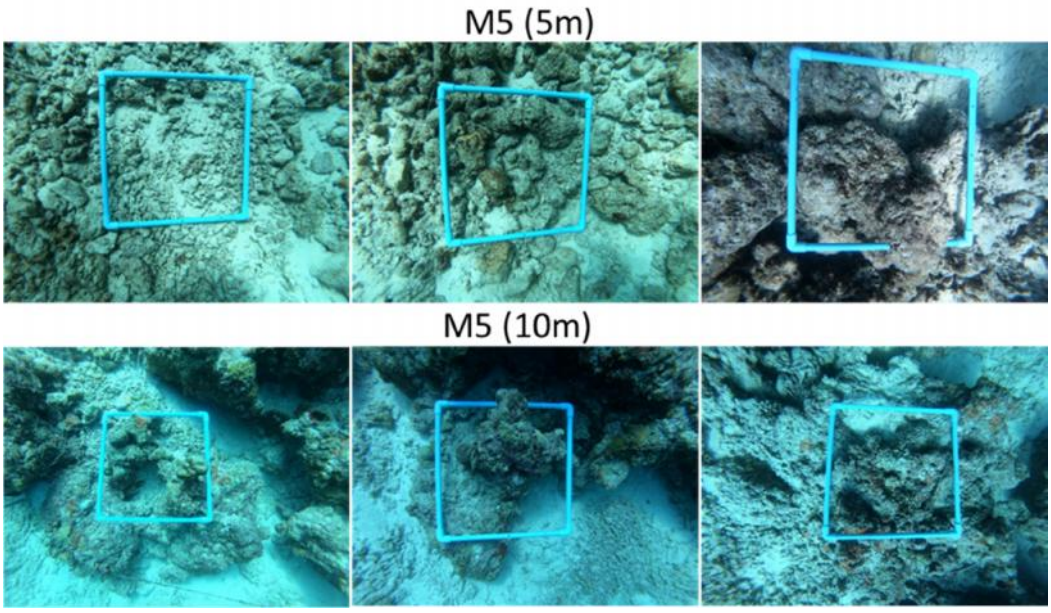

Figure 14: Photos taken from site 5 (M5) (24th April 2018).

5.6 Status of site 6 (M6)

Site 6 was selected from the Northern rim of the island reef west of site 5. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 (80.5 ± 4.19%) and 10 (36.5 ± 5.85) meters respectively. Hard coral cover was observed to be low at the site at depths of 5 (8.75 ± 2.53) and 10 (14 ± 2.58) meters. Particular group of hard corals were not observed to dominate the substratum. A diverse group of corals from groups such as Acropora, Pocillopora and Porites were observed at the site. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, wrasses, triggerfishes, damselfishes and butterfly fishes. Fishes observed to be abundant at a depth of 10 meters were surgeon fishes, damselfishes, triggerfishes and butterfly fishes. The following graph outlines the status of site 6(M6) at depths of 5 and 10 meters.

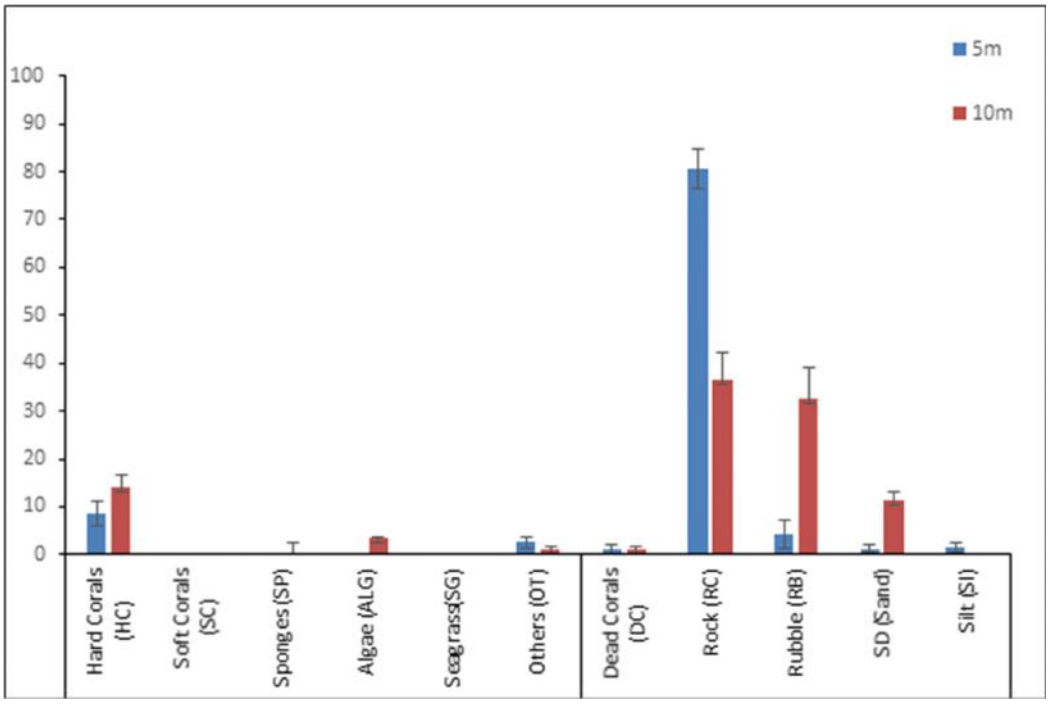

Figure 15: Percentage benthic composition at site 6 (M6) ± SE (24th April 2018).

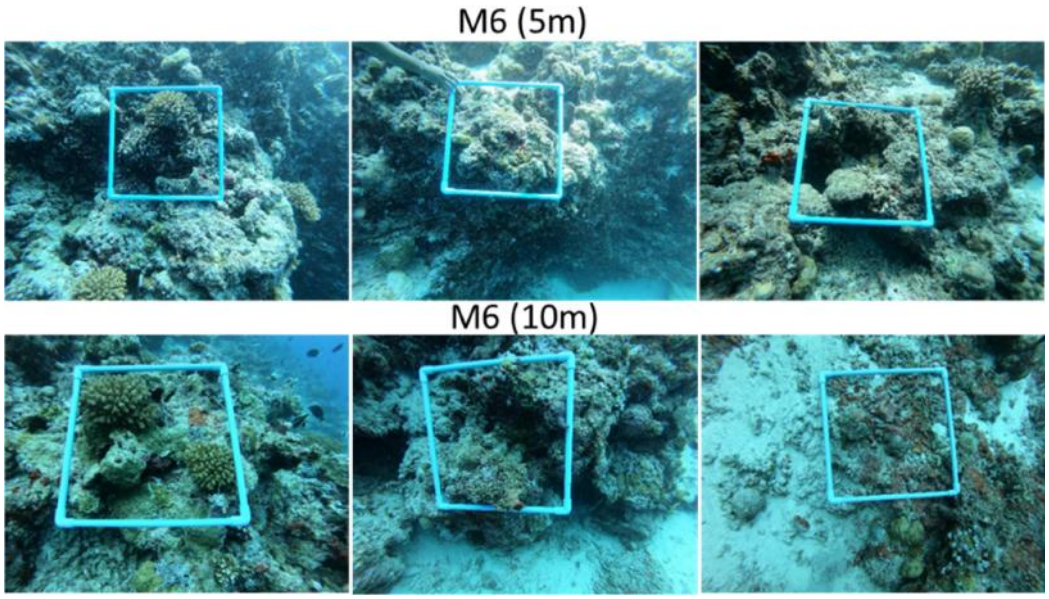

Figure 16: Photos taken from site 6 (M6) (24th April 2018).

5.7 Status of site 7 (M7)

Site 7 was selected from the Southern rim of the island reef west of site 1. The site was chosen as a control site as well as to get a broader understanding of the ecological baseline around the reef. The substrate at the site is dominated by rock at depths of 5 (76 ± 5.87%) and 10 (77.75 ± 3.33) meters respectively. Hard coral cover was observed to be low at 5 meters (5 ± 1%) and moderate in 10 meters (17.5 ± 3.2). Massive porites were the dominating group of hard coral observed at the site at both the depths. Fishes observed to be abundant at a depth of 5 meters were surgeon fishes, damselfishes and butterfly fishes. Fishes observed to be common at a depth of 10 meters were surgeon fishes. The following graph outlines the status of site 7(M7) at depths of 5 and 10 meters.

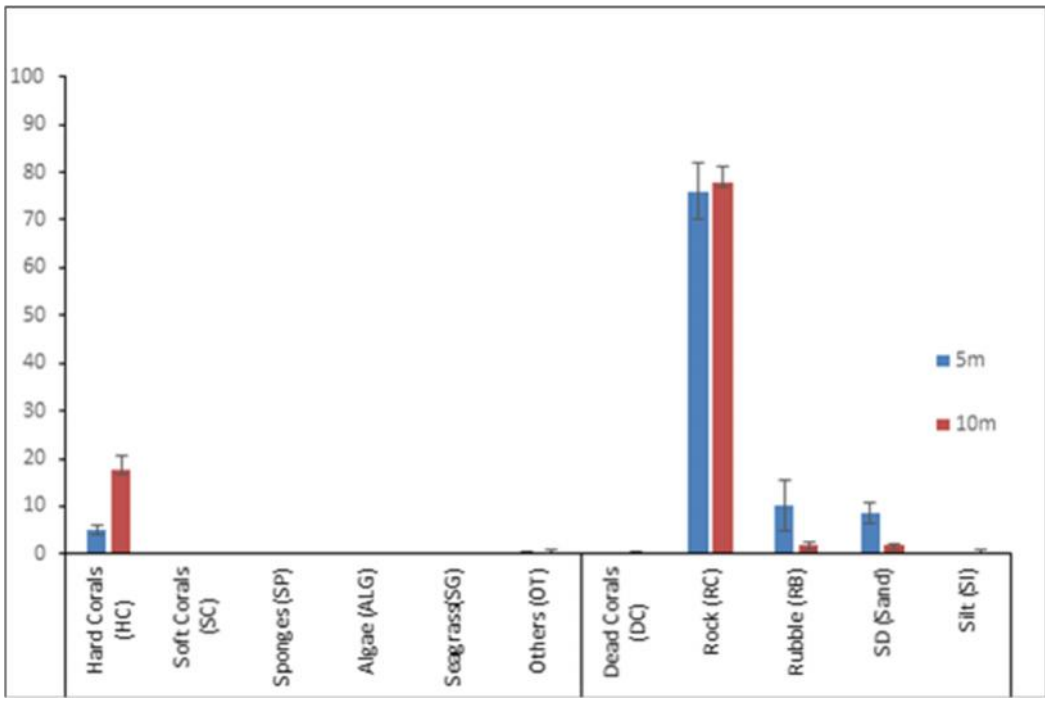

Figure 17: Percentage benthic composition at site 7 (M7) ± SE (23rd April 2018).

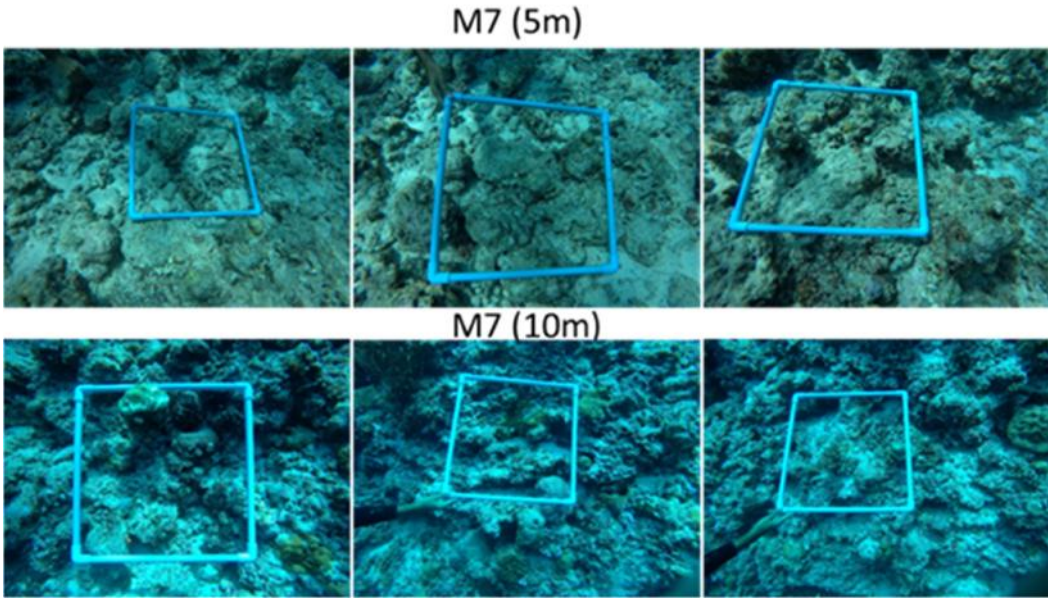

Figure 18: Photos taken from site 7 (M7) (23rd April 2018)

5.8 Observation during the marine survey in 2019

The highest coral cover was observed at the depth of 10 meters in site M2 adjacent to the current waste dumping area. The results are highlighted in the figure below. Therefor there is the possibility the leachate from land fill are not having negative impacts on the reef at site M2.

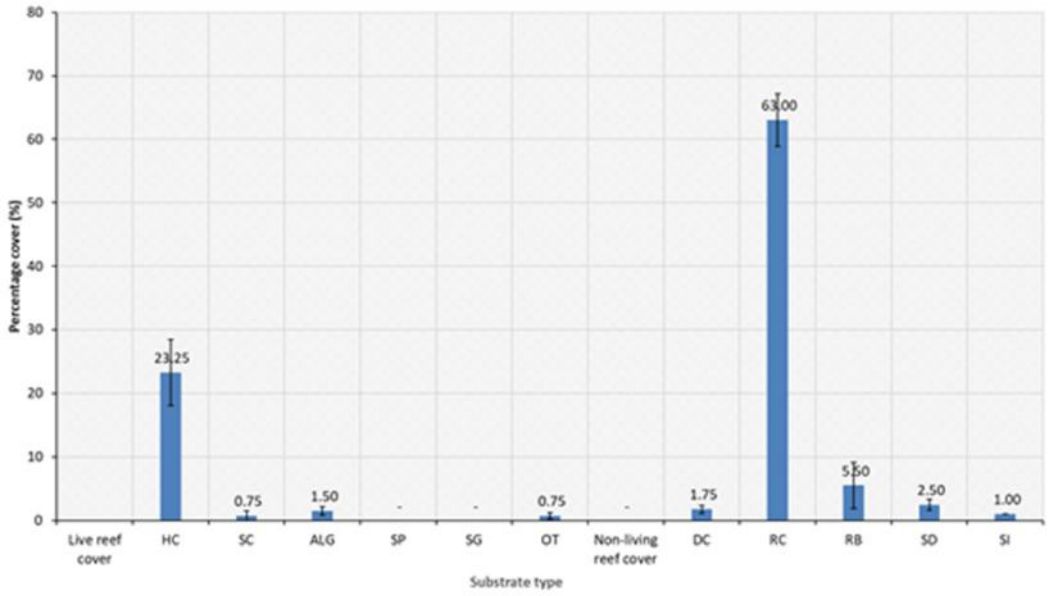

Figure 19: Percentage benthic composition at site 2(M2) at a depth of 10 meter ± standard error (SE).

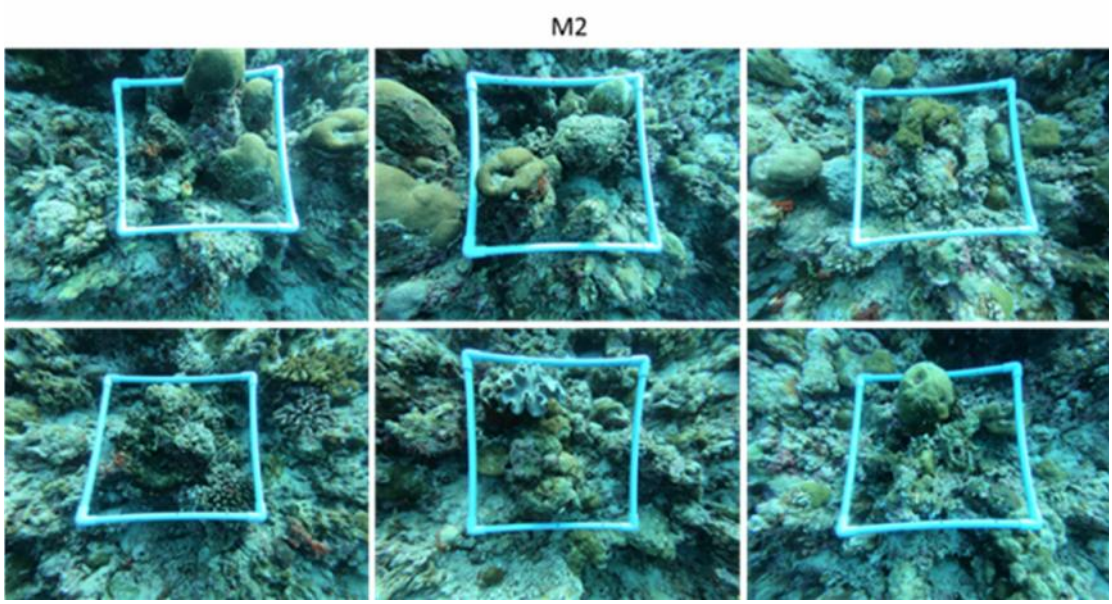

Figure 20: Photos compiled from site 2 (M2) at a depth of 10 meters.

5.9 Status of site M8

Site M8 was selected from the Southern rim of the island reef. The site was chosen as this is the proposed location for the hot water discharge outfall. The substrate at the site is dominated by silt along the entire transect line (43 ± 11.69%). Hard coral cover was observed to be low (8 ± 2.71). Massive porites were the dominating the group of hard coral observed at the site. Fishes observed to be very rare. It is to be noted that just a week prior to the survey, due to the severe weather, this entire stretch of reef has been hit by strong waves causing the sediments on the western side of the Thilafuhi to be spread along most part of the southern side. This has resulted in large areas of the reef being covered with silt. The following image illustrates the reef slope characteristics at site M10.

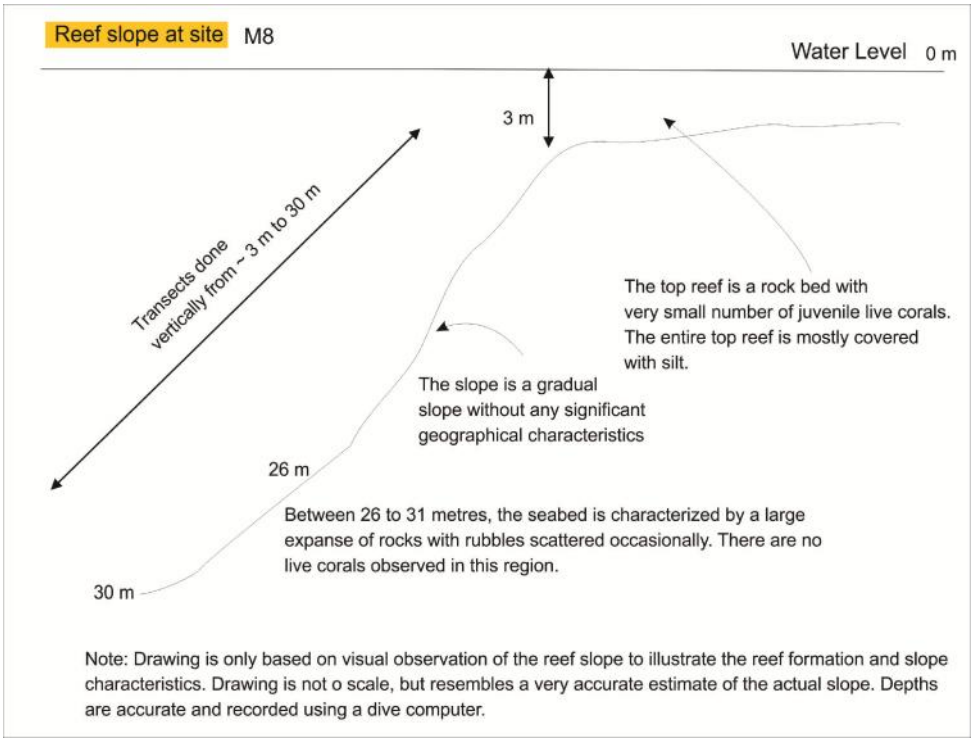

Figure 21: Reef slope characteristics at M8 (1st September 2019).

The following graph outlines the status of site M8.

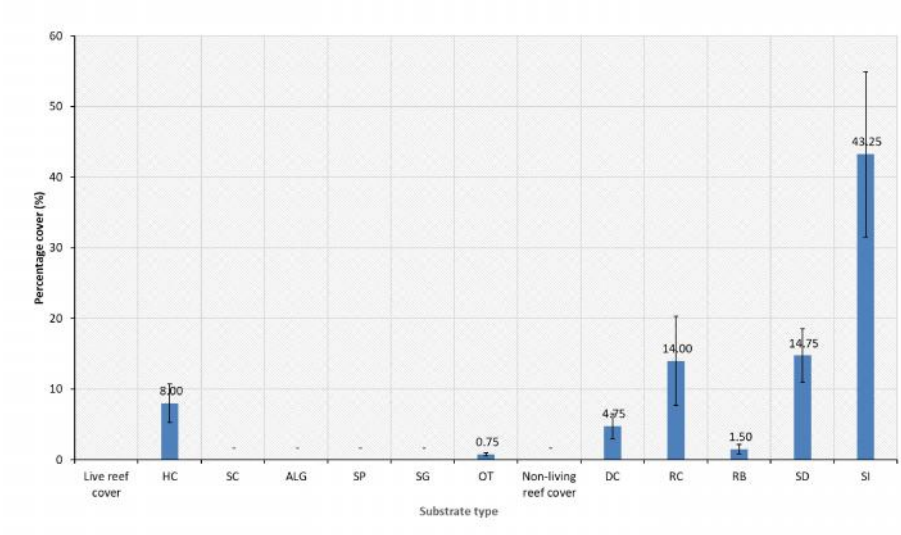

Figure 22: Percentage benthic composition at site M8 at depths from ~ 3 to 30 meters ± Standard Error (SE) (1st September 2019).

5.10 Status of site M9

Site M9 was also selected from the Southern rim of the island reef east of site 1. The substrate at the site is dominated by silt (64.5 ± 3.77%). Hard coral cover was observed to be low along the surveyed depths from approximately 3 to 30 metres (10.75 ± 3.22). Massive porites were the dominating group of hard coral observed at the site. Fishes observed were very low and includes anthias and surgeon fishes (refer to the fish census table for details). The following graph outlines the status of site M9.

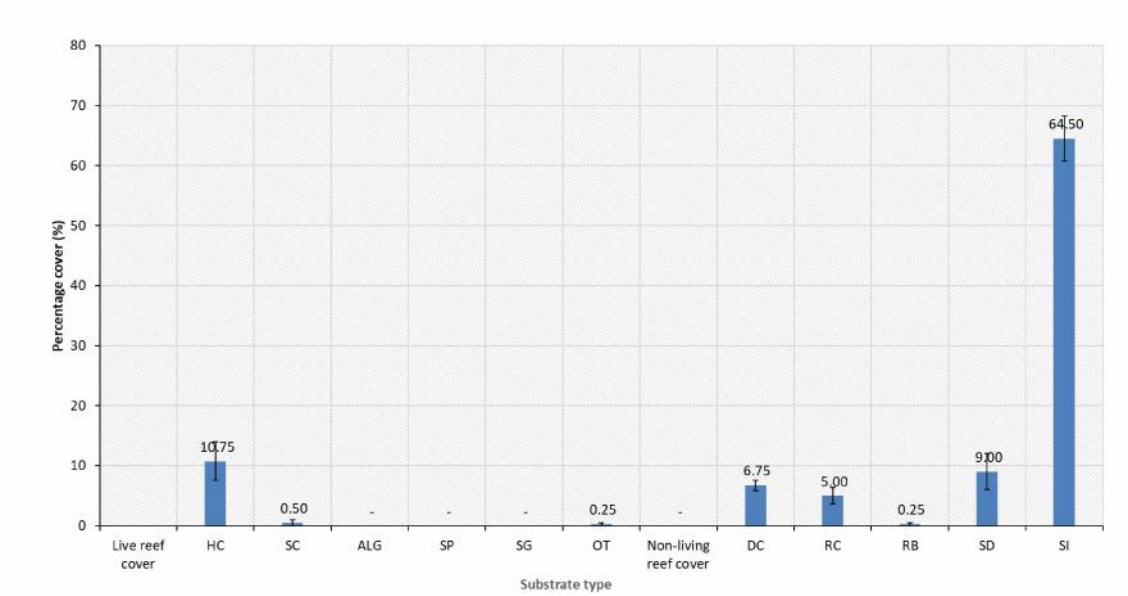

Figure 23: Percentage benthic composition at site M9 at depths from ~ 3 to 30 meters ± SE (1 September 2019).

The following image illustrates the reef slope characteristics at site M9.

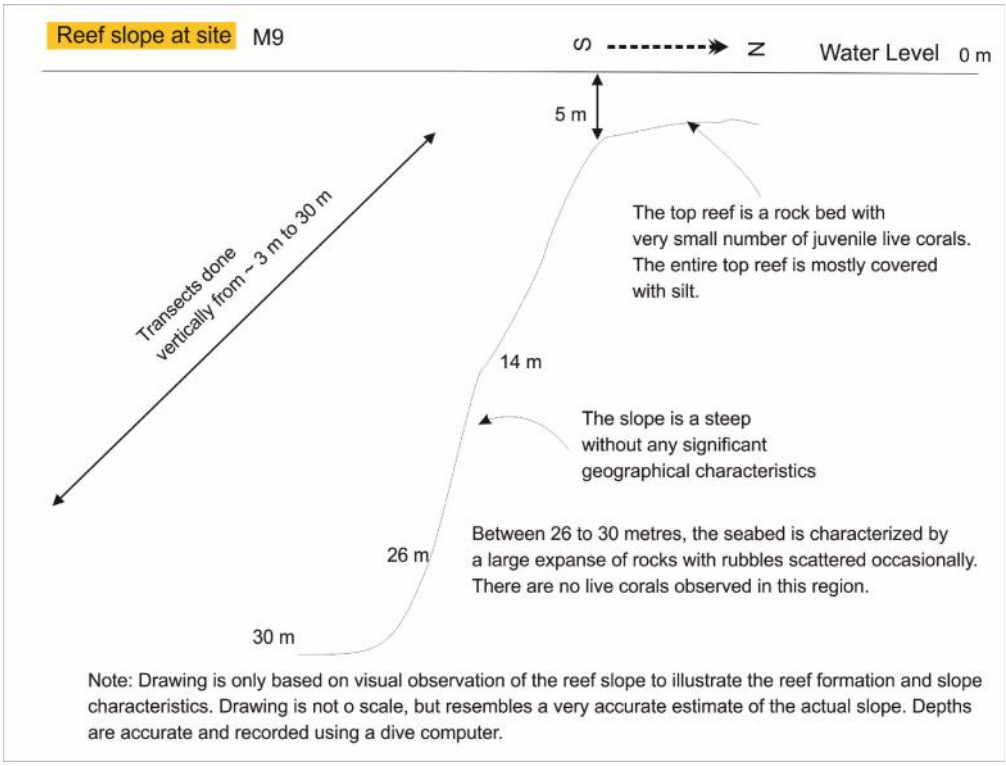

Figure 24: Reef slope characteristics at M9 (1 September 2019).

5.11 Status of site M10

Site M10 was also selected from the Southern side of the island reef. The following image illustrates the reef slope characteristics at site M10.

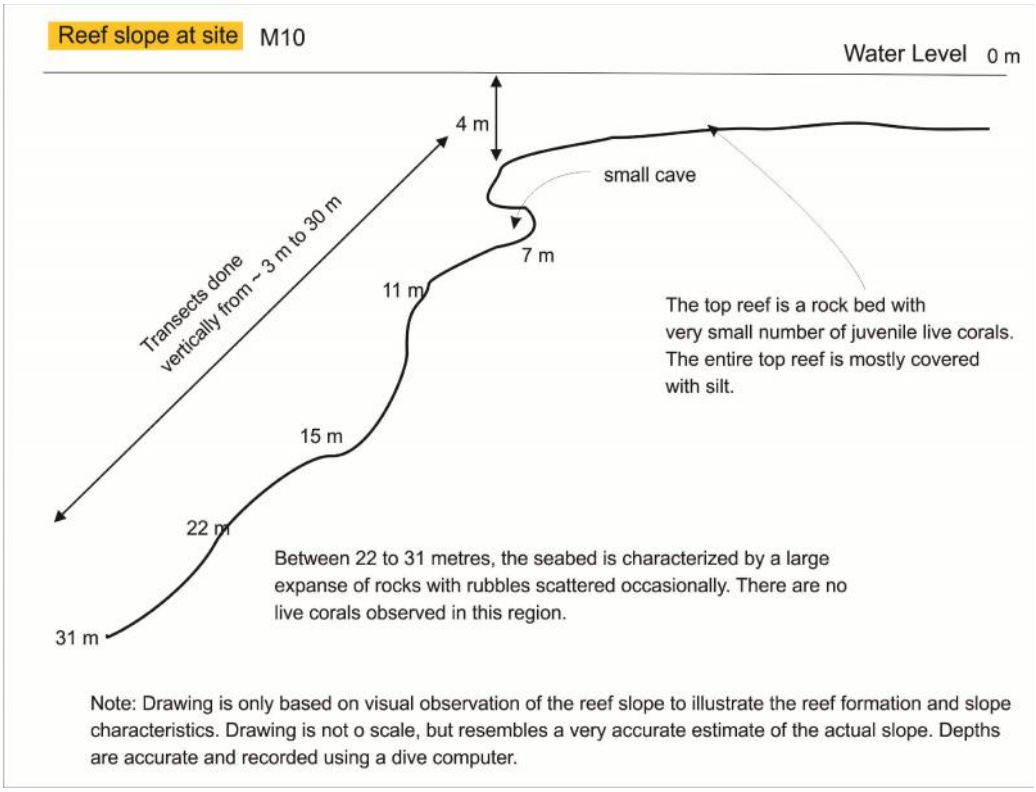

Figure 25: Reef slope characteristics at M10 (1 Sept 2019).

The substrate at the site is dominated by silt (58.50 ± 4.57 %). Hard coral cover was observed to be moderate (23.75 ± 7.43). Massive Porites were the dominating group of hard coral observed at the site. Fishes observed to be very low. The following graph outlines the status of site M10.

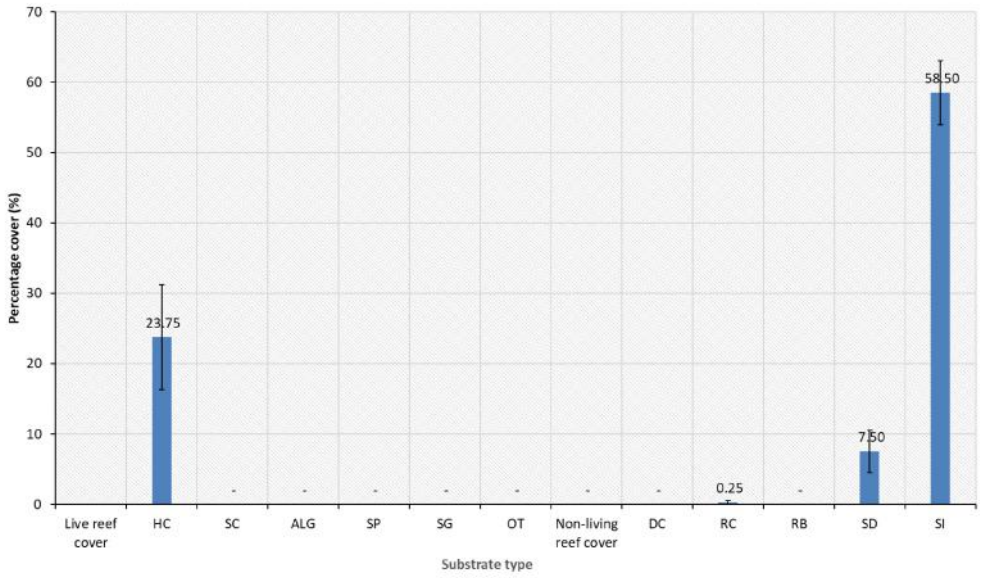

Figure 26: Percentage benthic composition at site M10 ± SE (1 Sept 2019).

5.12 Manta Tow between M9 and M10

The following table outlines the results of the Manta Tow survey that was carried out on 1st September from M9 to M10

Table 1: Manta Tow survey results of approximate substrate cover around the reef edge

	Love Coral cover%	Dead coral cover%	Soft corals cover%	Rock cover %	Rubble cover %	Silt cover %	Benthic diversity	Fish diversity
5 metres								
	5	8	-	15	2	70	low	low
10 metres								
	10	6	-	27	7	50	Low	low

The Manta Tow survey showed that coral reef system along the surveyed stretch is not in very good conditions in term of percentage live coral cover, diversity of corals, benthic and pelagic life. The overall live coral cover of the reef system appeared to be approximately 5% at 5 metres and approximately 10% at 10 metres. The reef substrate at both these depths were dominated by silt. Abundance and diversity of fish was also lower along the stretch. The live coral cover was highest at 10 metres. The corals inmost abundance were massive type coral head belonging to the genus Porites.

5.12.1 Protected marine species

During the Manta tow survey, no protected marine species such as sharks or were observed and recorded.

5.12.2 Reef Aesthetics

This attribute was assessed by visual observations based on the observer's judgment and experience of the relative merits of a reefs in the Maldives. This value judgment incorporated coral cover, diversity of life forms, fish life, reef structure and general appeal. The following categories were used to determine aesthetics of the reef system:

a. Very poor (mostly dead corals, pelagic life not abundant and diversity very low, structure uniform).
b. b. Poor (Lot of dead corals, pelagic life not abundant and diversity low, some differences in structure).
c. c. Average (Live corals about 10%, pelagic life abundant, diversity low, some structural variations exists).
d. d. Good (Live corals about 20% pelagic life abundant, diverse, structural variations exists).
e. e. Very good (Live corals about 30%, pelagic life abundant, diverse, overhangs, and other structures).
f. f. Excellent (Live corals over 40%, pelagic life very abundant, very diverse, lots of different structures, overhangs, caves, gullies, and different habitat types exists.

Reef aesthetics of Thilafushi's coral reef system (along the 500 metres) is regarded as very poor, given that substantial level of the reef is covered in sill and poor diversity of life forms. Fish life and abundance are very poor at the time of surveying and generally this stretch of reef can be considered to be very poor.

5.13 Fish Diversity and Abundance (April 2018)

The amount and type of fish present at a given site can be a good indicator of the marine environment. For example, increased grazers are generally a sign of increased nutrients in the area, thus decreased coral cover and increased algal cover. 15-minute fish counts were done in sites M1-M7 in depths of 5 and 10m. The counts include Mega fauna in addition to fishes. The fishes were identified to family level, however some protected species such as the napoleon wrasse, were identified to species level. The following table outlines the fish count survey at all the sites.

Table 2: Fish abundances observed at sites 1 to 7 at a depth of 5 and 10 meters.

Family/Subfamily	**Site M1**		**Site M2**		**Site M3**		**Site M4**		**Site M5**		**Site M6**		**Site M7**	
Depth	**5m**	**10m**	**5m**	**10m**	**5m**	**10m**	**5m**	**10m**	**5m**	**10m**	**5m**	**10m**	**5m**	**10m**
Anthias (Anthiadinae)	R	A	A	A	R	A	C	-	R	C	C	C	R	-
Surgeonfishes (Acanthuridae)	A	C	A	C	A	C	A	C	A	A	A	A	A	C
Wrasses (Labridae)	C	C	-	C	-	-	C	C	C	C	A	-	C	-
Parrotfishes (Scaridae)	C	C	A	C	R	R	C	R	A	-	C	C	C	-
Triggerfishes (Balistidae)	C	A	A	A	-	A	R	-	C	A	A	A	C	-
Boxfishes (Ostraciidae)	-	-	R	-	-	-	-	-	-	-	-	-		-
Damselfishes (Pomacentridae)	A	A	A	A	-	A	C	-	R	A	A	A	A	-
Groupers (Serranidae)	R	-	R	R	R	-	R	-	R	R	R	R	R	-
Moorish idol (Zanclidae)	R	R	R	R	R	R	R	R	C	R	R	R	R	R
Butterflyfishes (Chaetodontidae)	A	C	A	A	C	C	A	C	R	C	A	A	A	-
Goatfishes (Mullidae)	-	-	R	R	-	-	C	C	R	-	R	-	R	-
Hawkfishes(Cirrhitidae)	-	-	R	R	R	-	-	-	R	-	R	-	-	-
Threadfin and Whiptail breams (Scolopsis)	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Octopus (Octopodidae)	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Fusiliers (Caesionidae)	-	-	-	-	-	-	A	A	-	-	-	-	-	-
Rabbitfishes (Siganidae)	-	-	-	-	-	-	R	-	-	-	R	-	-	-
Gobies (Gobiidae)	-	-	-	-	R	-	-	R	R	-	-	-	-	-
Pipefishes and seahorses (Syngnathinae)	-	-	-	-	-	-	R	-	R	R	-	-	-	-
Puffers (Tetraodontidae)	-	-	-	-	R	-	R	-	C	-	R	-	-	-
Emperors or scavengers (Lethrinidae)	-	-	-	-	-	-	-	-	C	-	R	-	-	-
Jacks and Trevalleys (Carangidae)	-	-	-	-	A	-	-	-	R	-	-	-	-	-

Family/Subfamily	Site M1		Site M2		Site M3		Site M4		Site M5		Site M6		Site M7	
Depth	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m
Angelfishes (Pomacanthidae)	-	-	-	-	-	-	-	-	R	-	R	R	-	-
Lizardfishes (Synodontidae)	-	-	-	-	-	-	-	-	R	-	-	-	-	-
Squirrelfishes, soldierfishes (Holocentridae)	-	-	-	-	-	-	-	-	-	-	R	-	-	-
Grunts and Sweetlips (Haemulidae)	-	-	-	-	-	-	-	-	-	R	R	-	-	-
Eels and Morays (Anguilliformes)	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Napoleon Wrasse (Cheilinus undulatus)	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Sharks & Rays (Elasmobranchii)	-	-	-	-	-	R	-	-	-	-	-	-	-	-
Sea Turtles (Chelonioidea)	-	-	-	-	-	R	-	-	-	-	-	-	-	-

A= Abundant (Meaning that during the 15-minute time swim survey, species counts were recorded more than 50, hence it is difficult to count their numbers). C=Common (Meaning that during the 15-minute time swim survey, they were spotted occasionally and throughout the survey, but their numbers were less than 50). R=Rare (Meaning that during the survey, only few of these species were observed, often 1 or 2

5.14 Fish Diversity and Abundance (September 2019)

The following table outlines the results of the fish counts along the survey points which was conducted from approximately 3 meters up to 30 meters at each site.

Table 3: Fish abundances observed at sites M8, M9 & M10 on 1st September 2019.

Family/Subfamily	Site M8	Site M9	Site M10
Anthias (Anthiadinae)	-	C	R
Surgeonfishes (Acanthuridae)	R	C	R
Wrasses (Labridae)	-	-	-
Parrotfishes (Scaridae)	R	-	R
Triggerfishes (Balistidae)	-	-	-
Boxfishes (Ostraciidae)	-	-	-
Damselfishes (Pomacentridae)	-	-	-
Groupers (Serranidae)	-	-	-
Moorish idol (Zanclidae)	-	-	-
Butterflyfishes (Chaetodontidae)	-	-	-
Goatfishes (Mullidae)	-	-	-
Hawkfishes(Cirrhitidae)	-	-	-
Threadfin and Whiptail breams (Scolopsis)	-	-	-
Octopus (Octopodidae)	-	-	-
Fusiliers (Caesionidae)	R	-	R
Rabbitfishes (Siganidae)	-	-	-
Gobies (Gobiidae)	R	-	R
Pipefishes and seahorses (Syngnathinae)	-	-	-
Puffers (Tetraodontidae)	-	-	-
Emperors or scavengers (Lethrinidae)	-	-	-
Jacks and Trevalleys (Carangidae)	-	-	-

A= Abundant (Meaning that during the 15-minute time swim survey, species counts were recorded more than 50, hence it is difficult to count their numbers). C=Common (Meaning that during the 15-minute time swim survey, they were spotted occasionally and throughout the survey, but their numbers were less than 50). R=Rare (Meaning that during the survey, only few of these species were observed, often 1 or 2.

5.14.1 Plankton tows

Plankton are the base of the marine food chain. The phytoplankton and zoo plankton abundances in the area could possibly be affected by the presence of heavy metals. If the plankton community is thriving in these areas the heavy metals maybe bio accumulating in the food chain. Therefore plankton counts were done around Thilafushi Island in order to establish a baseline. A plankton net of 50µm mesh was built to carry out the survey. The plankton tows were carried out at sites where the marine water samples were collected.

5.14.1.1 Data Collection methodology

A plankton net of opening 0.48 x 0.48 m was tied to a 20m rope and released from a vessel. The net was allowed to drift for 20 meters and then towed towards the boat. Any organisms or particles larger than 50µm gets caught up in the net and collected in the cod end.

5.14.1.2 Data processing methodology

5.14.1.2.1 Zooplankton

Analyses of the samples were done using a microscope using a Sedgewick rafter counting chamber. The chamber has a volume of approximately 1ml. The samples collected from the net were approximately 150 – 250ml in volume. For the zooplankton count, the samples were transferred to a beaker diluted to approximately 500 – 900 ml and the volume recorded. The purpose of dilution is to reduce the number of plankton in the optical view of the microscope for ease of counting. Two sub-samples were counted from each sample. To calculate Total count in the sample, the counts in the subsamples were averaged. Thereafter the average value in the sub samples were multiplied with the total Volume in the diluted sample to obtain the Total count in the Sample. From the Total count in the sample and from the opening area of the net and the distance towed, the abundance of zooplankton per meter cube was calculated using the formula, Abundance = Total Count in the Sample/(Distance towed x Opening area). During the survey the zoo plankton were classified into Rotifera, Protozoa, Chordata, Mollusca, Annelida, Cnidaria, Crustacea and Chaetognatha. Additionally, Copepods were classified into three groups, Calanoida, Cyclopoida and Harpacticoida.

5.14.1.2.2 Phytoplankton

Analyses of the samples were done using a microscope using a Sedgewick rafter counting chamber. The chamber has a volume of approximately 1ml. The samples collected from the net were approximately 150 – 250ml in volume. For the phytoplankton count, the samples were transferred filtered through a 200µm sieve to remove large zooplankton for ease of counting. Thereafter the sample was transferred to a beaker, and diluted to approximately 500 – 900 ml and the volume recorded. The purpose of dilution is to reduce the number of plankton in the optical view of the microscope for ease of counting. Two sub-samples were counted from each sample. To calculate Total count in the sample the counts in the subsamples were averaged. Thereafter the average value in the sub samples was multiplied with the total Volume in the diluted sample to obtain the Total count in the Sample. From the Total count in the sample and from the opening area of the net and the distance towed, abundance of zooplankton per meter cube was calculated using the formula, Abundance = Total Count in the Sample/(Distance towed x Opening area).

5.14.1.3 Limitations of the methodology

The above method gives approximate estimates of abundances for each group/genera of plankton. Using a Sedgewick rafter to count zooplankton limits the subsample volume to 1ml thus, rare groups in plankton would likely not be observed in the counts. The method is reliable to estimate the total abundance of common groups of Zooplankton which are greater than 50µm in size and phytoplankton greater than 50 µm and less than 200µm.

5.14.1.4 Plankton abundance

5.14.1.4.1 Zooplankton

5.14.1.4.1.1 Common Phyla

Crustaceans were observed to be of the highest abundance amongst the zooplankton from all 7 sites. Additionally, the highest abundance of zoo plankton was observed from site 7 (PKT 7). The lowest abundance of zooplankton was observed from site 5. The table and figures below outline the variation in zooplankton abundance between the sites.

Table 4: Abundance of common phyla of zooplankton from sites PKT 1 to PKT 7.

Phyla	Abundance at sites (Individuals/m^3)						
	PKT 1	**PKT 2**	**PKT 3**	**PKT 4**	**PKT 5**	**PKT 6**	**PKT 7**
Rotifera	174	760	1,270	293	195	814	1,519
Protozoa	260	2,170	1,563	1,172	781	1,628	868
Chordata	347	705	1465	977	391	746	217
Mollusca	87	163	391	NA	98	339	217
Annelida	174	54	98	NA	98	68	NA
Cnidaria	217	380	98	488	NA	NA	NA
Crustacea	3,212	7,378	16,113	9,277	1,465	6,782	21,267
Chaetognatha	43	109	488	98	NA	NA	217
Total Zooplankton	7,769	19,151	37,598	21,582	4,492	17,158	45,573

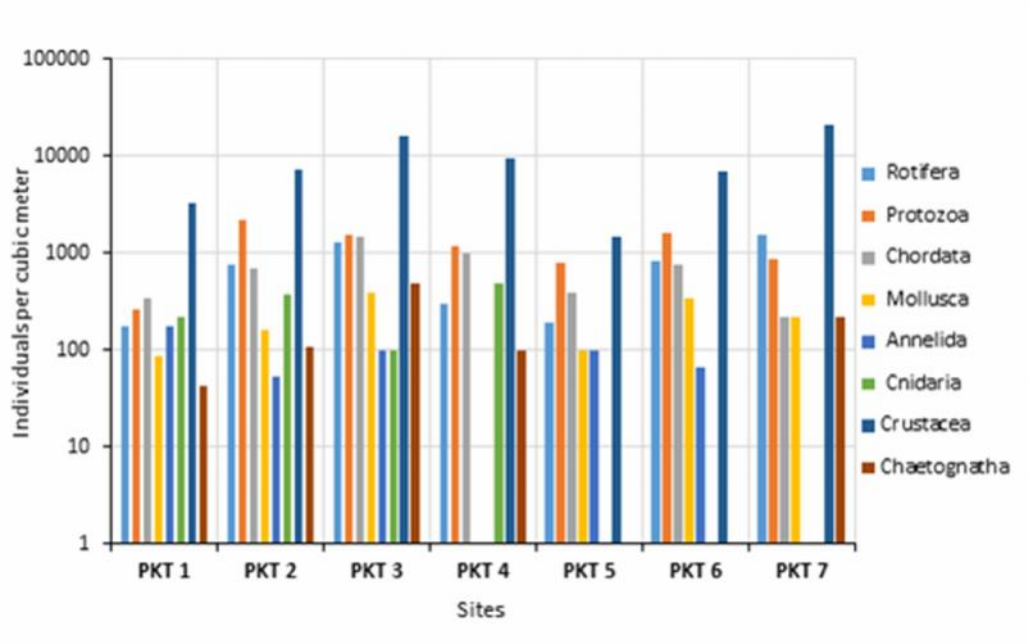

Figure 27: Abundance of common phylum of zooplankton from sites PKT 1 to PKT 7.

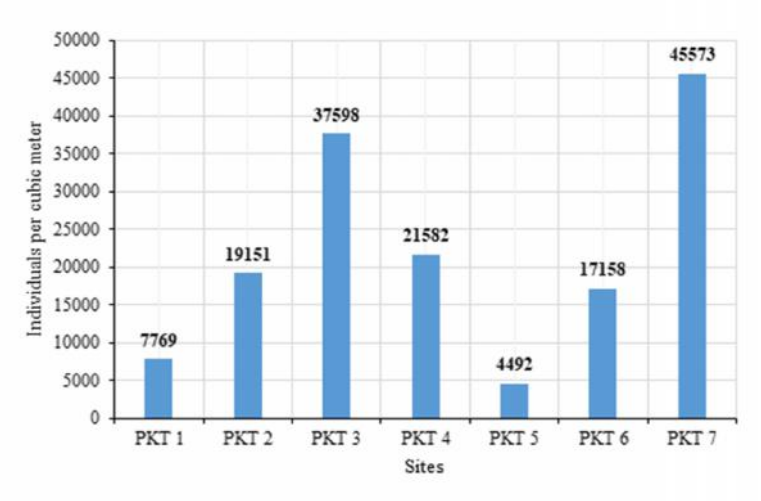

Figure 28: Total abundance of zooplankton from sites PKT 1 to PKT 7.

5.14.1.4.1.2 Copepods

The dominating group of copepods observed in the sites were calanoids. The highest abundance of copepods were observed at site 7 and the lowest abundance of copepods at site 5. The table and figure below outlines the variation in copepod abundance between the sites.

Table 5: Abundance of copepods from sites PKT 1 to PKT 7.

Order	Abundance at Sites (Individuals/m^3)						
	PKT 1	PKT 2	PKT 3	PKT 4	PKT 5	PKT 6	PKT 7
Calanoida	1693	2767	6543	3516	684	2509	11502
Cyclopoida	260	434	1367	391	195	543	1085
Harpacticoida	391	163	195	684	195	407	651

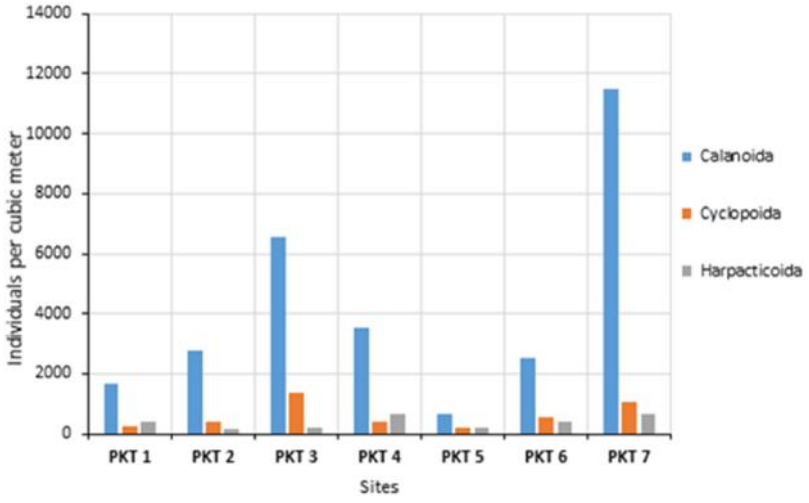

Figure 29: Abundance of copepods from sites PKT 1 to PKT 7.

5.14.1.4.2 Phytoplankton

Diatoms were observed to be of the highest abundance, amongst the phytoplankton from all 7 sites. Additionally, the highest abundance of phytoplankton was observed from site 7 (PKT 7). Additionally,

the lowest abundance of phytoplankton were observed from site 5. The Figures below show the variation in phytoplankton abundance between the sites.

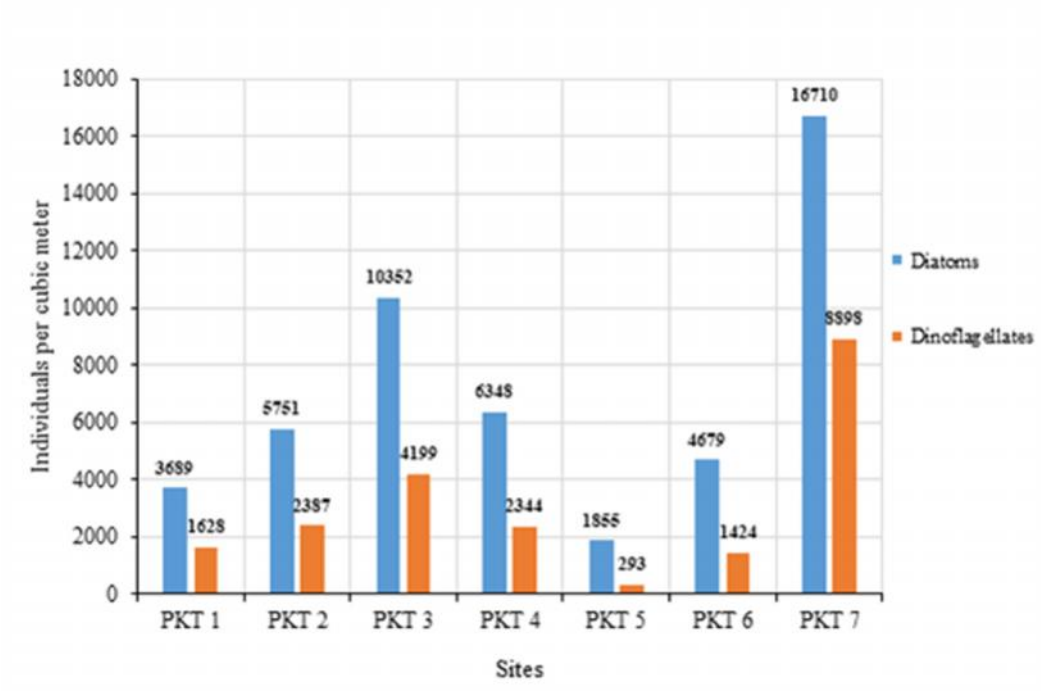

Figure 30: Abundance of diatoms and dinoflagellates from sites PKT 1 to PKT 7.

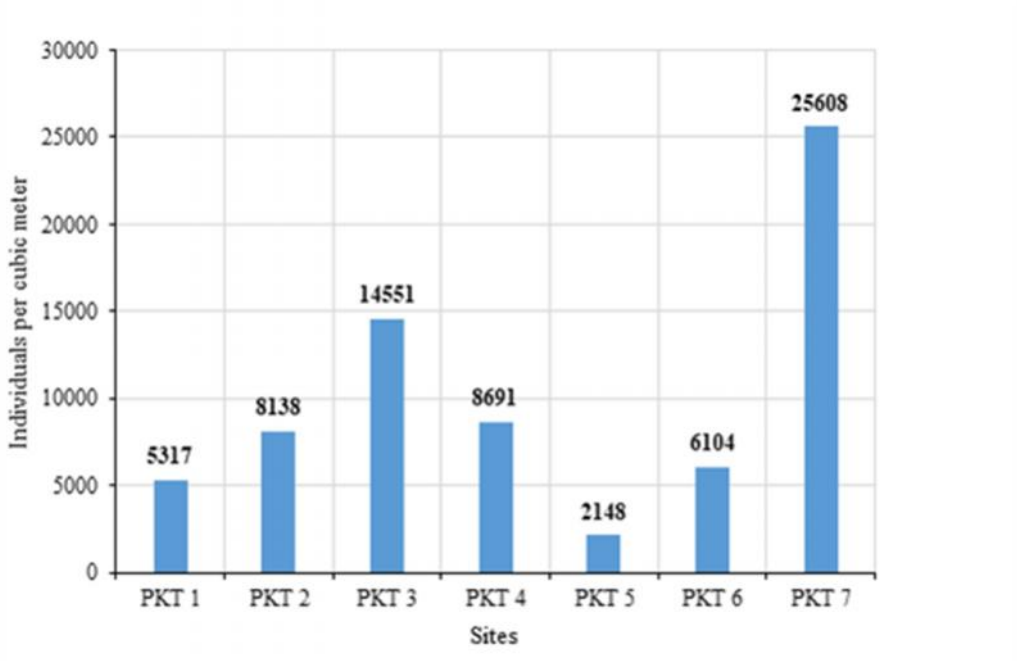

Figure 31: Total abundance of phytoplankton from sites PKT 1 to PKT 7.

6 Conclusion

The coral reef of Thilafushi has been under a lot of stress over the past two decades from the various industrial activities and developments that have occurred on this once barren reef. Over the years, the coral reef has undergone significant direct and indirect impacts resulting from the evolution of this artificial island that has been reclaimed initially from waste and later expanded in a more ecologically sound manner.

Surveys were undertaken in April 2018 and September 2019 to assess the coral reef and its health. The initial surveys were carried out in April 2018 which indicates that the highest coral cover was prevalent at a depth of 10 meters in site M2. This site is adjacent to the current waste dumping area. Therefor based on this results, there is the possibility that one can conclude that the leachate from land fill is not having a significant negative impacts on the reef at site M2 in terms of coral cover. On the overall, the reef around Thilafushi does not indicate a very healthy reef with average coral cover below 20% in most of the surveyed sites (based on the surveys done in April 2018).

A new set of surveys were conducted in three sites, M8, M9, M10, on 1st September 2019. This detail marine survey was carried out along a 500 m coastal stretch of house reef on southern site of Thilafushi between M9 and M10. The results indicate that very few (or none at all) marine species are found at a depth of less than 10 m along this stretch. The survey also revealed further that no significant marine life such as live corals, fishes or other pelagic organisms was found at greater depths from 10 m to 30 m along this stretch of house reef. The marine survey carried out in September 2019 found that the reef profiles at M8, M9 and M10 are very identical and at any of these sites, an outfall could be laid. Geographically, these three sites does not pose major challenges when it comes to laying an outfall pipe. There were no sensitive corals nor benthic cover recorded in any of these sites nor are any odd slope formations there.

The reef slope at surveyed sites M8, M9 and M10 is characterized by a wall with the majority of the benthic composition being mainly rubble and silt. Along these sites, from a depth of approximately 20 meters and below, there is no live coral cover and the fish life is virtually none existent at the time of the survey on 1st September 2019. The southern side of Thilafushi is also exposed to a lot of sedimentation during south-west monsoon, which causes dispersion of sediments along a large area of the reef. This is the reason why the percentage of silt along M8, M9 and M10 were so high during the surveys undertaken in September 2019.

During the surveys in April 2018, one sea turtle was recorded. Sea turtles are very commonly observed throughout the Maldives due to their protected state. Their numbers have grown significantly since they were declared as a protected species in the 1980's. Since then, turtles are observed in a lot of reefs throughout the Maldives. Thilafushi being an artificial island does not possess the right coastal ecology for turtles to lay their eggs and no reports of turtle nests nor eggs have been reported to have been spotted from Thilafushi beaches. Hence, this single observation of a turtle can be confidently declared as an occasional occurrence.