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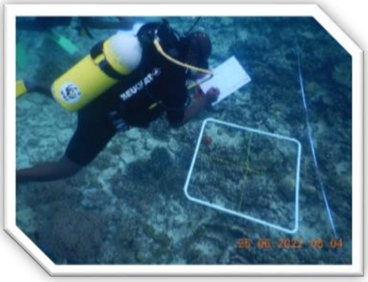



THE DAR ES SALAAM CORAL REEF STATUS REPORT JULY 2022

Pagu Julius, Humphrey Mahudi & Musa Ally

Disclaimer

The views expressed in this report are those of the authors and all scientific arguments are fully acknowledged. Correctness of the information presented herein is bound to the time of field data collection and compilation of this report.

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EXECUTIVE SUMMARY

This report is an output of the third phase of MPRU benthic monitoring. It comprised of **five chapters** addressing benthic cover, Invertebrates and Reef fish status eight monitored sites within Dar Es Salaam Marine Reserve systems (DMRs)

Benthic cover data was collected with a minimum of six transect of 10meter Line Intercept Transect (LIT) supplemented with video transect (Underwater camera Nikon COOLPIX W300 waterproof 30m/100ft 16.05 Megapixel was used). Corals were identified to genus level. Coral size distribution data was sampled on selected coral genera (23) in 25 x 1m belt transect with two transects minimum per dive. Coral recruit counts – A quadrat area of $1m^2$ was used and 12 quadrats per site was made, six (6) quadrats for each transect was placed every 5m along the transect at 0m, 5m, 10m, 15m, 20m, 25m resulting to a total of 12 quadrats at each site.
All recruits (corals less than 10cm in longest length) were counted by genus in 3 size-classes (0-2.5cm, 2.5-5cm, 5-10cm), using slates marked with respective class lengths to simplify coral size measurement where 0- 2.5cm and 2.5- 5cm are juvenile and 5cm- 10 cm are recruits. Slate was placed next to juvenile /recruits to estimate their sizes. Where there are no recruits in a quadrat, quadrat number was recorded and leaving the row blank.

Macro invertebrates were counted in a 10 x 2 m belt transect using the same benthic transect line for LIT, counting micro invertebrates 1m on either side of the transect line with six transect minimum per site. All macro invertebrates of economic importance were recorded.
Fish communities were counted along a 50 x 5 m belt transect while identifying fish to species level with four minimum transects per site. Fish surveys was undertaken in the opposite direction to benthic and coral surveys to avoid disturbance of fish by surveyors. Underwater visual census (UVC) techniques were used to assess fishes. Reef fish size, abundance and diversity in in belt transect. Fish size classes were estimated in centimetres (cm) with a 10cm class interval starting at 3-10 cm, 10-20 cm, 20-30 cm, etc and > 80 cm.

Chapter one, is an introductory part which provides an overview on Coral Reef Monitoring, key Monitoring objectives, Monitoring implementation mode and its management through MPRU as well as a background to coral reef monitoring in Tanzania.
Chapter two is literature review which reviews observation and various coral reef reports at local to global scale. It addresses issues related to Background to coral reefs, Threats, Mortality and Recovery of Reef Corals, Coral Reef Management and Coral reef monitoring aspects.
Chapter three covers method and underwater techniques applied in data collection for the various indicators, variables and respective data analysis. It covers surveyed sites indicating their appropriate geographic locations and management regime, and finally points-out the expected output as per terms of reference for this monitoring assignment.
Chapter four is the result and discussion, the results section is narrating major findings from this monitoring survey and establishing trend of indicator variables over the years. The chapter is divided into three components including benthic cover and hard corals in general, Macro-invertebrates, and Fish section for the eight (8) monitored sites.
(i) Benthic cover: presented in percentage (%) of benthic cover categories (hard coral, coralline algae, macro algae, soft corals, rubbles, sand, sponge, seagrass, rock, and dead coral). The average live hard corals was 53.86±4.3% of which the highest was at Mbudya Southwest reef with (69.9% ± 7.6) cover while the lowest was noted at Fungu yasini (30.4%± 8.6)
(ii) ***Coral community structure:*** estimated from benthic cover data and size class data. Coral genus diversity both overall and by-site were estimated from benthic cover data. The results demonstrated that the genera that have the highest average number of colonies in all site are *Montipora* (23%)

Porites branching (19%) Porites massive (14%) and Galaxea (14%) whereas in year 2018 the highest genera were *Porites* branching (15%) Fungia (13%) and Montipora (13%) . For site specific, at Bongoyo Northwest, Mbudya Northwest and Mbudya southwest, the highest genus with number of colonies was *Montipora* (>40%).

(iii) Coral population structure: Generally the coral cover at DMRS was dominated by mid coral size class 41-80, 81-160 and 161-362 (Fig 16). This reveals that the coral at DMRs is evenly distributed hence indicates that there is high recruitment. In terms of coral numbers, coral size class 11-20 and 41-80 demonstrated to have high numbers of colonies as compared to other size class.

(iv) Coral recruitment: Generally, the average recruitment for all sites in DMRS is 6 colonies in 1 m^2 the result which is similarly to the average of 6 colonies observed during the survey conducted in 2018. The highest recruitment was observed at Sinda southwest site with mean of 10.2 colonies per 1 m^2, followed by Mbudya northwest 6.9 colonies per m^2 and Bongoyo northwest 6.8 colonies per m^2.

Macro-invertebrates

Macro-invertebrates survey was particularly focused on density and distribution of sea urchins - as these have an implication on coral recruitment, growth and survival. A belt transect 10m x 2m was used for density estimation and results are presented as number of the individual sea urchins per $20m^2$. The average sea urchin for all site was found to be 5 individuals per $20m^2$. The highest density was recorded at Fungu yasini reef (35.8 individuals per 20 m^2). Sea urchin species *Tripneustes gratilla* was the dominant species recorded across all monitoring sites.

Fish population structure

This sub-section present ***fish community*** and ***fish population structures***. In general, 37 major fish families were recorded across all monitoring sites. And did include both the commercially important families (such as *Serranidae, Carangidae,* and *Scarridae)* and ecologically important reef fishes (such as *Acanthuridae* (Surgeons, and Unicorn fishes), *Pomacentridae* (Damsel fishes), *Labridae* (Parrot fishes), *Siganidae* (Rabbit fishes) and *Kyphosidae* (Rudder fishes). The commonest fish families in most of the sites surveyed include the functional *Pomacentridae, Scaridae* and *Labridae.*

Chapter five is the last it covers Conclusion and recommendations. The report concludes the former showing stability and/or steady recovery of corals from past decades of disturbances but cautiously noting the significant proliferation of sea urchin as a threat to coral reefs in some of the individual sites as presented.

ACKNOWLEDGEMENT

We acknowledge financial support of the Coastal Oceans Research and Development – East Africa (CORDIO) and Tanzanian Marine Parks and Reserves Unit (MPRU)

Team appreciate the MPRU Management for positive support to monitoring team for supporting the field work and facilitation to accomplishment of both the field work and writing of this report. Special thanks are due to the field work team from three MPRU field centres, skippers and other site-based local players for their participation, commitment and their self-motivations demonstrated at various stages are highly valuable.

Finally, all stakeholders from a wide range of Institute/University are all hereby highly acknowledged for review of and valuable comments in this report.

List of Abbreviations

AIMS	Australian Institute of Marine Sciences
ANOSIM	Analysis of Similarities
ASCLME	Agulhas - Somali Current Large Marine Ecosystem
CHICOP	Chumbe Island Coral Park
CORDIO	Coastal Oceans Research and Development – East Africa
COTS	Crown-of- thorns starfish
CRTR	Coral Reef Targeted Research
GCRMN	Global Coral Reef Monitoring Network
IMS	Institute of Marine Sciences
IOC	Indian Ocean Commission
IUCN	International Union for Conservation of Nature
LIT	Line Intercept Transect
MACEMP	Marine and Coastal Environmental Management Project
MDS	Multi-dimensional Scaling
MPA	Marine Protected Area
MPRU	Marine Park and Reserve Unit
NEMC	National Environmental Council
PRIMER	Plymouth Routines in Multivariate Ecological Research
RUMAKI	Rufiji-Mafia-Kilwa
SWIOFish	South West Indian Ocean Fisheries Governance and Shared growth
TACMP	Tanga Coelacanth Marine Park
TAFIRI	Tanzania Fisheries Research Institute
TzCRTF	Tanzania Coral Reef Task Force
WIO	Western Indian Ocean
WIOMSA	Western Indian Ocean Marine Sciences Association
WWF	World Wildlife Fund
ZEMA	Zanzibar Environmental Management Act

Belt-Transect Method	**DEFINITION OF TERMS** Belt transects are used in biology to estimate the distribution of organisms in relation to a certain area. The belt transect method is like the line transect method but gives information on abundance as well as presence, or absence of species. It may be considered as a widening of the line transect to form a continuous belt, or series of quadrats.
Coral bleaching	When corals are stressed by changes in conditions such as temperature, light, or nutrients, they expel the symbiotic algae (zooxanthellae) living in their tissues, causing them to look completely white. Bleached coral can recover if the stress is removed, otherwise dies when the stress is prolonged.
Coral reef resilience	The ability of coral reef ecosystems to absorb shocks, resist phase shifts and regenerate after natural or human-induced disturbances.
Coral reef resilience	The capacity of an individual colony, or a reef system (including all its inhabitants), to buffer impacts from the environment and maintain the potential for recovery and further development
Coral Resistance	The ability of individual corals to resist bleaching when exposed to high temperature and other mitigating factors, and if bleached to survive.
Corallimorpharia	Organisms in this order resemble the stony corals (Scleractinia), except for the absence of stony skeleton. Compete for reef space with hard corals.
Crown-of-thorns-starfish (COTS)	COTS or *Acanthaster planci* starfish occur naturally on coral reefs. At adult stage they eat only coral polyps. When in large numbers (outbreak) can cause mass mortality of corals.
Destructive fishing	Includes all fishing practices that disrupt or tilt the interactions between biological productivity, diversity, resilience and habitat suitability.
Functional groups	A collection of species that perform a similar function, irrespective of their taxonomic affinities
hard substrate	Is a Reef substrate that is rocky or composed of dead corals and or dead coral covered with algae - Is available or suitable substrate for coral recruits.
Line Intercept Transect (LIT) method	Line intercept transect (LIT) surveys are applied to estimate the percent cover of sessile reef benthos such as live hard corals, sponges, algae, Soft coral, etc. In addition to percent cover, the tape for LIT can be used to create a belt-transect into which the densities or number of individual colonies per unit area can be evaluated.
Live hard corals (HD)	Living and health corals that participate in deposition of calcium carbonate skeleton - Reef framework builders.
Macro algae (MA)	Weedy or fleshy (erect) brown, red algae, etc. Macro algae compete for reef space with corals.

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CHAPTER ONE

1.0 INTRODUCTION

Marine Parks and Reserves Unit (MPRU) is amongst the agencies under the Ministry of Livestock and Fisheries comprising four MPA Centers implementing daily activities including Coral Reef Monitoring. MPRU staff have been trained to conductresource monitoring for both benthic and other marine resources as the means to assess marine resource condition. The monitoring team are stationed in the four self-accounting centers that include:

- Mnazi Bay Ruvuma Estuary Marine Park (MBREMP) in Mtwara;
- Mafia Island Marine Park (MIMP) in Mafia District, Coast Region;
- Dar es Salaam Marine Reserves System (DMRS) in Dar es Salaam; and
- Tanga Coelacanth Marine Park (TACMP) in Tanga.

With the aim of understanding the status of marine resources in MPAs, It was recommended that MPRU should at least conduct biannual benthic monitoring at all centres in order to understand the condition of coral and coral reef ecosystems. SWIOfish supported implementation of biannual monitoring and programmed in three phases. The first phase of coral reef monitoring was done by MPRU staff in the 2016/2017 financial year backed with the expertise of a consultant who collaborated with MPRU's technical underwater survey staff.

This also involved training (capacity building) to MPRU staff to equip them with monitoring skills and internal capacity for MPRU in order to adequately carry out monitoring.. The training included lectures and field activities covering site selection, data sampling, data analysis as well as technical report writing.

Coral reef monitoring generates time-series information on the ecological condition of benthic and reef fish communities at selected monitoring sites. This information is an important tool in understanding the impact of both natural and anthropogenic disturbances on coral , for guiding management decisions for Marine Parks and Reserves.

Phase two benthic coral reef monitoring also was done by MPRU Staff in 2018/2019 financial year specifically in October 2018. Field work, data analysis and reporting were accomplished by MPRU Staff. This is due to the fact that the first phase was able to build capacity for MPRU staff. It is noted that, during the first phase MPRU Staff acquired high skills and experience for underwater ecological monitoring.

The second phase was accomplished by MPRU and/or improved during the previous training and field surveys where MPRU staff also participated in the Western Indian Ocean Regional Coral Reef Taxonomy skills and techniques conducted in Zanzibar/IMS in August 2018.

2.0 JUSTIFICATION FOR CORAL REEF MONITORING

2.1 Required Financial Support

Resource Monitoring in Marine Protected Areas is critical for making informed management interventions including appropriate allocations and prioritisation of limited resources to Managers. Marine Parks and Reserves Unit (MPRU) in Tanzania conducted the last Bi annual Coral Reef Monitoring to all MPAs (Mafia Island Marine Park (MIMP), Mnazi Bay Ruvuma Estuary Marine Park (MBREMP), Dar es Salaam Marine Reserves system (DMRs) and Tanga Coelacanth Marine Park (TaCMP)) in 2018 which was before the COVID 19 Pandemic impact. Subsequent Bi-annual monitoring was planned to be implemented in 2020, however, due to the financial crisis, it till March 2021 when only TACMP covered the status which remains the same to date.

The monitoring program was highly affected by COVID 19 pandemic impact due to the fact that MPRU daily activities are operated by revenues that are collected from tourists as entry fees. since March 11 2020 after the COVID 19 when the World Health Organization (WHO)globally flight burn, route cancellation, stop gathering, and associated prevention measures was instituted. It significantly affected MPRU activities including Coral Reef Monitoring.

Objectives:

Supporting MPRU Coral reef monitoring at Dar es Salaam marine Reserve's system (DMRs) were:

- Facilitate establishing current status and trends on coral reef, fish, and invertebrates in DMRs,
- Data will be used as a baseline for the current DMRs General Management Plan (GMP) which is under review
- Support the review of MPRU strategic plan to set accurate targets for resource conservation within DMRs.
- Monitoring established information to managers which acts and created self-assessment based on resource trends (coral health and fish) as an index for management effectiveness of the Protected Areas and institute appropriate interventions.
- Monitoring generated capacity building (skills) to the MPRU monitoring team, divers, and potential divers/staff through virtual training as part of memory refresh and methodology calibration based on GCRMN protocol. Monitoring provided accurate and reliable data to managers for supporting informed management interventions (decision making based on data)

- Monitoring updated information based on current coral reef status to DMRs & MPRU management, researchers, scientists, conservation partners, donors, and other interested parties.

2.2 Qualification and Experience of MPRU Staff

Generally, the capacity of MPRU staff to carry out benthic coral reef monitoring survey has been highly improved with majority of the monitoring team members now has high level skills. MPRU has more than ten Certified divers who frequently conduct monitoring under the Agency in their respective MPA centres. The entire team comprises research and monitoring staff from the four MPAs, whose general capacity has been improved through ecological monitoring training and field performance held in the first phase in 2016 at all MPAs, second phase 2018 at all MPAs, third phase 2021 in TACMP and Tanga Coral Reef Monitoring under CORDIO in February 2021. Both monitoring phases enhanced experience and knowledge sharing among members of the team. The first phase coral survey formed ground work in terms of the monitoring sites and data collected, at that time whereby participation of the same team members and the harmonized monitoring method was practically familiarized.

Table 1: MPRU Staff Participate in DMRs Coral Reef Monitoring

S/N	Name and Location	Qualification and Experience
1	Pagu Julius DMRs	MSc. holder, Certified diver, high expertise in benthic survey, coral identification. & reef fish identification.
2	Humphrey Mahudi TACMP	MSc. holder, Certified diver, high expertise in benthic survey & coral identification.
3	Magreth Mchome MPRU-HQ	MSc. holder, Certified diver, high expertise in benthic survey & coral identification.
4	Musa Ally MBREMP	MSc. holder, Certified diver, high expertise in benthic monitoring.
5	Amos Singo MBREMP	BSc. holder, Certified diver, high expertise in benthic monitoring.
6	Masanja Joram MIMP	BSc. holder, Certified diver, high expertise in benthic monitoring.

3.0. FIELD/TECHNICAL TEAM

The field technical team in Dar es salaam incorporated six (6) MPRU Staff (with qualification and experience outlined in Table (1) where the Lead personnel Mr. Pagu Julius with the assistance of

Mr.Humphrey Mahudi collaborated very closely to lead the field technical team in all activities of data collection, data manipulation, data analysis and technical report writing. Ms. Magreth Mchome and Mr. Musa Ally were the main players in field execution (data collection), detailed analysis and report drafting. The rest of the team members, Mr. Masanja Joram and Amos Singo, (who are mainly good at macro invertebrates counting in data collection and mobilization prior to detailed analysis and technical report writing.

Table 2: Monitoring sites in DMRs

s/n	Site	Lat (S)	Long (E)	MPA	Zone	Management
1	Mbudya North West	06°39.234'	039° 14.642'	DMRS	Sheltered	Core / no take
2	Mbudya South West	06°39.668'	039° 14.915'	DMRS	Sheltered	Core / no take
3	Bongoyo North West	06°41.413'	039° 15.479'	DMRS	Sheltered	Core / no take
4	Bongoyo South West	06° 42.060'	039° 15.879'	DMRS	Sheltered	Core / no take
5	Fungu Yasini	06° 35.511'	039° 13.647'	DMRS	exposed	Core / no take
6	Sinda	06° 49.223'	039° 23.575'	DMRS	Sheltered	Core / no take

Table 3: MPRU Technical Field Staff for DMRs Coral Reef Monitoring and their role

S/N	Participant	Competence	Recording role
1	Julius Pagu	Fish and Benthic cover assessment, Trainer (fish)	Fish count, Data analysis, Report writing
2	Masanja Joram	Scuba dive, LIT technique, Invertebrate counting	
3	Humphrey Mahudi	Benthic cover assessment Trainer (Coral reef, benthic cover)	Benthic, corals (cover and size-class) and invertebrates, Data analysis, Report writing
4	Magreth Machome	Benthic cover assessment	
5	Musa Hamisi	Benthic cover assessment	

6	Amos Singo	Scuba dive, LIT technique, Invertebrate counting	

One site was surveyed per day. Each site was surveyed in two dives, and dives was spaced by 500-1000m from each other (use the GPS to estimate distance between dives – mark waypoint of first dive and then navigated away from this point).

Exact GPS coordinates, depth estimates from dive computers and horizontal visibility measurements was taken in meters m) at each dive point.

Data was recorded in the field at replicate level (each quadrat/transect individually) and input the same day electronically.

Table 4 : Sites with surveyed dates

s/n	Site	Lat (S)	Long (E)	MPA	Zone	Dates
1	Mbudya North West	06°39.234'	039° 14.642'	DMRS	Sheltered	4/04/2022
2	Mbudya South West	06°39.668'	039° 14.915'	DMRS	Sheltered	4/04/2022
3	Bongoyo North West	06°41.413'	039° 15.479'	DMRS	Sheltered	5/04/2022
4	Bongoyo South West	06° 42.060'	039° 15.879'	DMRS	Sheltered	5/04/2022
5	FunguYasini North west	06° 35.511'	039° 13.647'	DMRS	exposed	6/04/2022
6	Funguyasin South west	06° 35.889'	039° 13.512'	DMRS	exposed	6/04/2022
7	Sinda _01	06° 49.223'	039° 23.575'	DMRS	Sheltered	7/04/2022
9	Bongoyo Wall (Outer reef)	06° 40.473'	039° 17.135'	exposed	Open access	8/04/2022

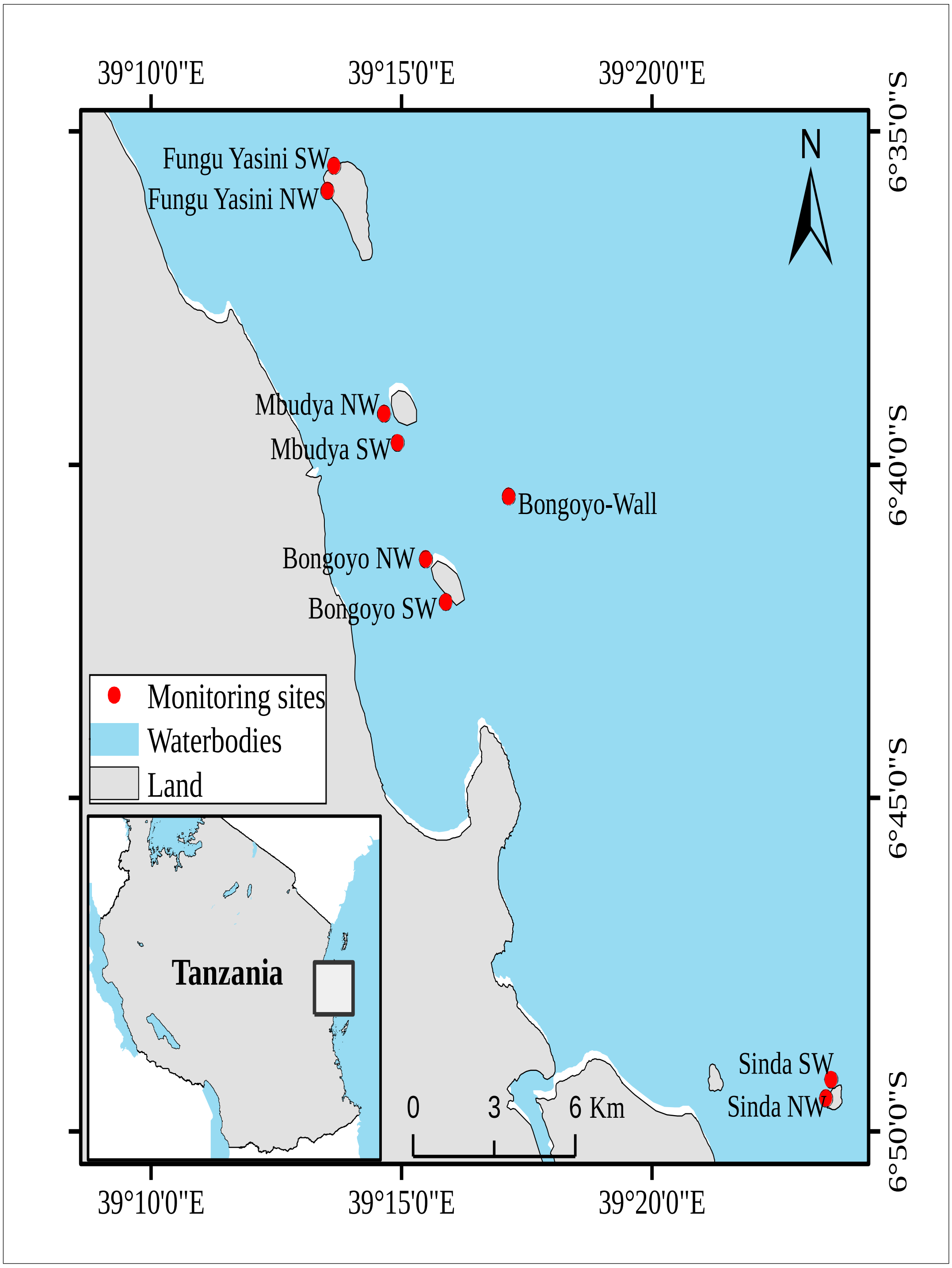


Figure 1: DMRs Coral Reef Monitoring sites

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1 Background to coral reefs

Corals are marine invertebrates within the class Anthozoa of the phylum Cnidaria. They typically form compact colonies of many identical individual polyps. Coral species include the important reef builders that inhabit tropical oceans and secrete calcium carbonate to form a hard skeleton. Symbiotic Dinoflagela algae (zooxanthellae) need enough sunlight for photosynthesis.

Corals can only live within a narrow temperature range from around 16°C to 30°C (IUCN,2008), mostly found in the tropical and sub-tropical region - Corals are adapted to live in ocean water, which contains very low levels of nutrients (coral reef alliance, 2003)

Coral reefs are shallow-water ecosystems that consist of reefs made of calcium carbonate which is mostly secreted by reef-building corals and encrusting macroalgae. They occupy less than 0.1% of the world ocean floor yet play important roles throughout the in marine lives, housing high levels of biological diversity as well as providing key ecosystem goods and services such as habitat for fisheries, coastal protection, and appealing environments for tourism (Wild *et al*., 2011). Coral reefs have high productivity and biodiversity and are regarded as keystone ecosystems (Hunter, 1996) in that they provide important ecological services that extend far beyond their area of coverage. Stemming from their ecological importance, coral reefs have great socio-economic importance in Tanzania. They are abundant with finfish, lobsters, prawns, crabs, octopuses, mollusks and sea cucumbers, thus supporting 70% of artisanal fish production in East Africa as well as being important for commercial fishing (Ngoile & Horrill, 1993; Jiddawi & Öhman, 2002).

Coral reefs have a very high level of biological diversity, with 93,000 species already identified by scientists. In fact, coral reefs contain 32 of the 34 recognized animal phyla. About 275 million people live within 30km of the coral reefs, all depending on the ecosystem services provided by the reefs (Burke *et al,* 2011 & hoegh-Guldberg, 2011). People have continued to benefit from, food, income through fisheries as well as tourism activities (Muhando, 2009)

Tanzania is endowed with a scenic, diverse and resource rich coastal area (coral reefs, beaches, estuaries, sea grass beds & extensive mangrove stands). Coral reefs support diverse marine ecosystems in Tanzania waters that include over 500 species of commercially important fish & invertebrates (Obura *et al*, 2017).

Coral reefs are among major productive coastal marine ecosystems; they prevent coastal erosion, flooding and regulate the pH. Coral reefs are the breeding and nursery sites for fishes and invertebrate organism like parrot fishes (Scaridae), surgeon fishes (Acanthuridae), rabbit fishes (Siganidae), damselfishes (Pomacentridae), wrasses fishes (Labridae), butterfly fishes (Chaetodontidae), snappers (Lutjanidae); and tiger fishes (Balistidae). Over 70% of coastal communities depend on coral reef resources as sources of livelihood (Wagner, 2004).

2.2 Threats, Mortality and Recovery of Reef Corals

Coral reefs are among the world's most fragile and endangered ecosystems. During the 1997-1998 global bleaching event eleven percent (11%) of the world's coral reefs was lost and another sixteen percent (16%) were severely damaged (Muhando, 2009. Scientists predict that another thirty-two percent may be lost over the next thirty years if human threats are not reduced (Coral reef alliance, 2003).

Coral reefs are threatened by two main causes, natural and anthropogenic. Natural threats like hurricanes, global warming resulting increase sea level and sea surface temperature are influenced by human activities resultant of climate change. Unsustainable fishing practices, urbanization, population growth, upstream development influence coral degradation (Wagner, 2011)

Climate-driven thermal stress events that cause coral bleaching events are accelerating in frequency, threatening the persistence of coral-dominated reefs across the tropics (Pandolfi et al. 2003; Heron et al. 2016). As global temperatures have risen from 1980 to 2016, coral bleaching recovery windows have shortened from 27 to 5.9 years (Hughes et al. 2018a), and are likely to become even shorter as severe bleaching events are expected to occur annually by 2050 (van Hooidonk et al. 2016). Although examples of resilient reefs that regenerate coral cover suggest that certain conditions, such as isolation from human stressors, facilitate recovery from bleaching (Sheppard et al. 2008; Gilmour et al. 2013).

Coral reefs in Tanzania are at risk from many threats including those enhanced by global climate change, e.g., coral bleaching, and Crown-of thorns-starfish, algal and corallimorpharia proliferation (Muhando *et al*., 2002; Muhando and Mohammed 2002; McClanahan *et al*. 2007a, 2007b).

The critical consequences of destructive fishing practices are that they reduce the total habitat space and decrease the variety of microhabitats by simplifying the topography. The most unsustainable destructive practice is dynamite fishing, which was common in Dar es Salaam from the 1960s until 1997 (Horrill *et al*., 2000) and which is still continuing at a lower level to the present day. Numerous blasts, each of which kills all life within a radius of 15-20 m (Guard & Masaiganah, 1997) and turns the reef structure into rubble within a radius of several metres (muhando, 2002), occurring every day over a period of about three decades has had severe impacts on the Dar es Salaam reefs.

Slow and patchy recovery after the 1998 bleaching have been reported for East Africa's coral reefs (Suleiman *et al*. 2005; Obura, 2005; Souter and Lindén, 2005). However, coral reef recovery from disturbances depends on the capacity of the remaining coral population to replenish it with new coral larvae or fragments of broken juvenile, or adult coral colonies (Birrell *et al*.2008). Coral recruitment therefore plays vital role in maintaining coral populations and enhance recovery of coral communities from storms, coral bleaching, or destructive fishing (Tamelander, 2002; Garcia and Aliño, 2008; Graham et al. 2011).On the other hand, recruitment is influenced by various factors which, among others, include spawning of the adults, fecundity and fertilization success of the gametes, larval dispersal and survivorship, settlement, and post-settlement survival (Ritson-Williams 2009; Sawall *et al*. 2013; Franziska, 2016).As per the Commonwealth of Australia (2009) and Graham *et al*. (2011), recovery of species or groups of species is generally a function of their biological patterns such as genetic constitution, complexity and suitability of habitat (environmental condition) and the absence of pressures on species (URT, 2018)

2.3 Coral Reef Management

Coral reefs are one of the most vulnerable marine ecosystems hence their management approach remains critical. More than half of the world's reefs are under medium or high risk of degradation (Burke *et al*., 2011). Most human-induced disturbances to coral reefs were local until the early 1980s (e.g., unsustainable coastal development, pollution, nutrient enrichment, and overfishing) when disturbances from ocean warming principally mass coral bleaching and mortality (Glynn, 1984)

Isolated reefs can recover from major disturbance, and the benefits of their isolation from chronic anthropogenic pressures can outweigh the costs of limited connectivity (Gilmour *et al*., 2013). Marine protected areas (MPAs) and fisheries management have the potential to increase ecosystem resilience and increase the recovery of coral reefs after climate change impacts such as mass coral bleaching and mortality (McLeod *et al*., 2009). Although they are key conservation and management tools, they are unable to protect corals directly from thermal stress (Selig *et al*., 2012), suggesting that they need to be complemented with additional and alternative strategies (Rau *et al*., 2012; Billé *et al*., 2013). While MPA networks are a critical management tool, they should be established considering other forms of resource management (e.g fish catch limits and gear restrictions) and integrated ocean and coastal management to control land-based threats such as pollution and sedimentation originating upstream..

Previous studies indicated the higher reef fish density, biomass, species diversity and live hard coral cover in the NDMRs compared to the SDMRs (Pagu ., *et al* 2021). It has been observed by Garpe and Öhman (2003) and Halford et al. (2004) that the loss of structural reef complexity often affects the health of fish communities. Sano et al. (1987)

Reefs of Mbudya, Bongoyo and Pangavini Islands, Inner and Outer Sinda and Inner and Outer Makatumbe islands are all managed by DMRs thus, there is need to Improve management of protected areas, fishery grounds and other use-areas to minimize and even eliminate impacts to critical habitats. Local, national and regional connectivity and integration of protected areas and management principles should be a priority. Strengthen the scope and coverage of area-based management tools, including monitoring, habitat maps and economic valuation for both use and non-use resources (Obura *et al*, 2017).

In DMRs reef survey in coral, mostly live or dead coral, bleached or partial bleached and rabble were observed. Reef fish were dominated by the families Chaeto-dontidae, Pomacentridae and Pomacanthidae in the NDMRs; probably because butterflyfishes (Chaeto-dontidae) have been observed globally to constitute almost half of the corallivorous fish families, followed by other families including the Pomacentridae (Cole et al., 2008). Invertebrates monitored includes; Octopus, Star fish, Sea urchin, Crown of thorn, Sea cucumber and Mollusks (melita, 2004

CHAPTER THREE

3.0 METHODOLOGY

3.1 Overall objective

The overall objective of this assignment was to conduct survey, analyse and report on assessment of the current status of reef benthic cover, invertebrates and fish community composition at selected sites within Dar es Salaam Marine Reserves

3.2 Specific objectives

i. Undertake literature review and data survey from previous and on-going coral reef monitoring programmes including previous monitoring phases.
ii. Conduct survey in previous monitored sites in 2016 and 2018 monitoring sites and refine selection ensuring strict inclusion of sites with long term monitoring data and consideration of the financial and technical capacities for a sustainable monitoring program.
iii. Survey monitoring/calibration to staff on coral genus, invertebrates and data entry and analysis
iv. Undertake field data collection using LIT, photos and video transect and standard AIMS/GCRMN protocols.
v. Assess status, establish and compare trend per site (s) of the monitoring indicators including genus identification both for corals and coral reef fishes.
vi. Undertake fish survey abundance #/ha, Biomass kg/ha and functional group at site specific
vii. Prepare and submit Technical Report on Coral Reef Monitoring after all necessary reviews at the MPRU and other key stakeholders.

3.3 Site Selection

Monitoring survey was repeated in sites surveyed in 2016 and 2018. Monitoring sites in table 4 are those surveyed during phase one and two for the year 2016 and 2018 respectively. Monitoring Protocol adopted is the Global Coral Reef Monitoring Network (GCRMN). Monitoring team involved a wide range of activities including.

3.4. Data collection / GCRMN Protocol

Data was collected following similar sampling protocol applied in the 2018 monitoring with minor modification of some techniques and addition of new dataset as follows:

i) Benthic cover data was collected using the 10meter LIT method and was supplemented with video transect. (Underwater camera Nikon COOLPIX W300 waterproof 30m/100ft 16.05 Megapixel was used).A minimum of six Line Intercept Transect (LIT) were executed per dive and Corals were identified to genus level.

ii) Coral size distribution data was sampled on selected coral genera (23) in 25 x 1m belt transect laid in coral-dominated spots within a sampling block with two transects minimum per dive. (Obura and Grimsditch (2009)

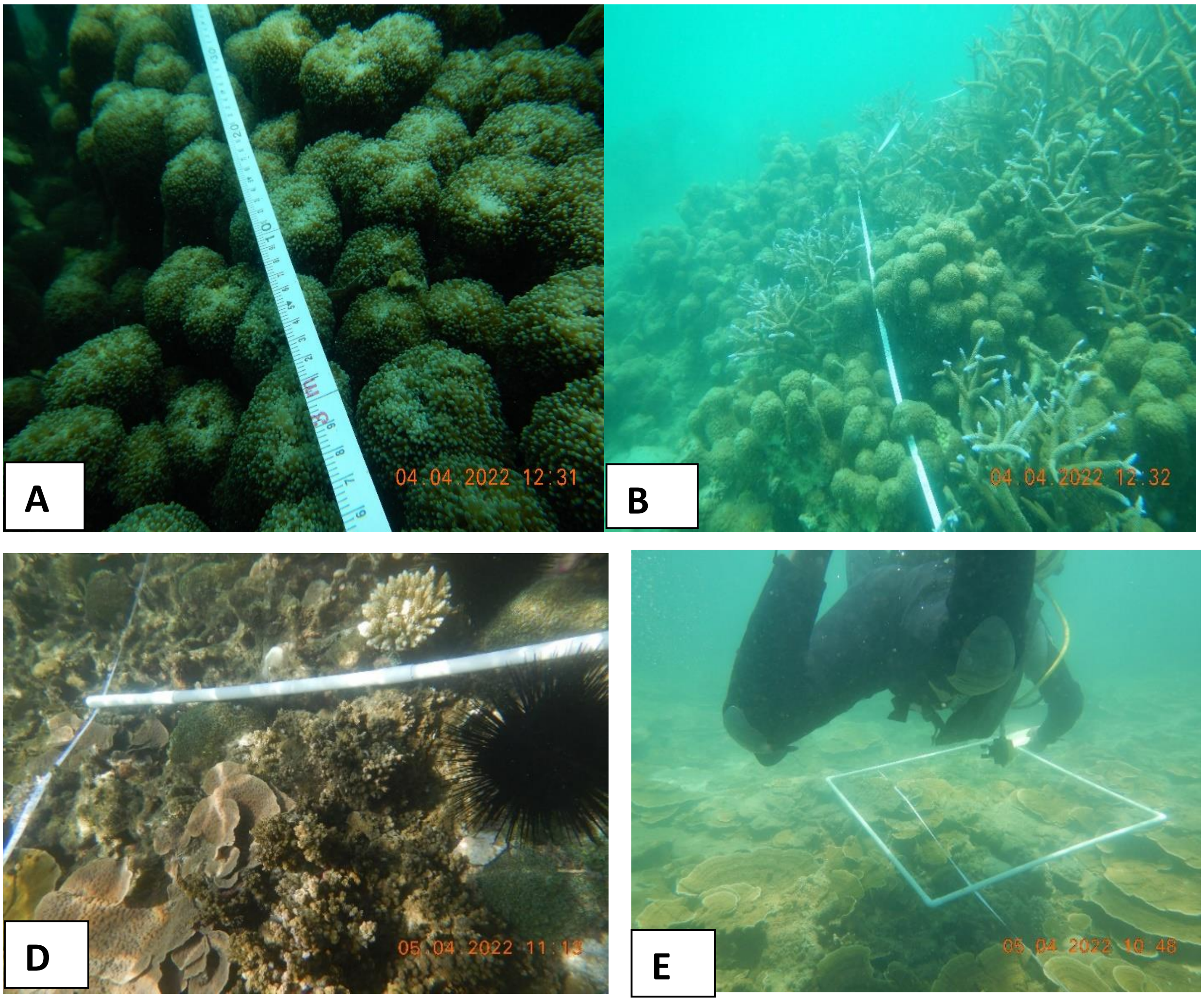
iii) Coral recruit counts – A Quadrat area of 1m^2. 12 quadrats per site was made, A total of six (6) quadrats per transect placed every 5m along the transect at 0m, 5m, 10m, 15m, 20m, 25m resulting to a total of 12 quadrats for the two transect at each site. All recruits (corals less than 10cm in longest length) were counted by genus in 3 size-classes (0-2.5cm, 2.5-5cm, 5-10cm), and prepared slates were marked with 0, 2.5cm, 5cm and 10 cm lengths to simplify coral size measurement. Slate was placed next to recruits to estimate which size class they are in. Where there are no recruits in a quadrat, quadrat number was recorded and leaving the row blank

iv) Macro invertebrates were counted in a 10 x 2 m belt transect preferably using the same benthic transect line for LIT, counting micro invertebrates 1m on either side of the transect line with six transect minimum per site. All macro invertebrates of economic importance were recorded.

v) Fish communities were counted along a 50 x 5 m belt transect while identifying fish preferably to species or genus level with four minimum transects per site Fish surveys was undertaken in the opposite direction to benthic and coral surveys to avoid disturbance of fish by surveyors and Fish was identified at species level

vi) Underwater visual census (UVC) techniques were used to assess fishes. Reef fish size, abundance and diversity in 50 m x 5 m belt transect. Fish size classes were estimated in centimetres (cm) with a 10cm class interval. Fish size class will include the lowest class 3-10 cm, 10-20 cm, 20-30 cm, etc and > 80 cm as described by McClanahan *et al*., 1999. Each individual fish feeding mode fish was used to determine its feeding functional group as described by Samoilys *et al*., (2019). Belt transects were deployed in such a way that they covered the reef slope and reef flat in all sampling sites. Fish counting and swimming speed was undertaken by swimming at low and constant speed along the belt transect covering 33m^2 min^{-1} and approximation of 3 - 4metre min^{-1} depending on fish abundance and complexity of the habitat or rugosity of coral reef as adopted from Samoilys and Carlos (2000). A period of 20 minutes after laying out a transect was given to allow fish to return to the area before census. During Underwater visual census process, fish observed were recorded on slate with its respective required details such as length and species name. For field species quantifications, a field guide as described by Bianch 1985; Lieske and Myers 2002; Allen and Steene 2007 were applied.

vii) Data validation after field work was done by using fish identification database (https://www.fishbase.in/identification/SpeciesList.php?genus=Quietula), later on processed and entered into predesigned excel sheets.



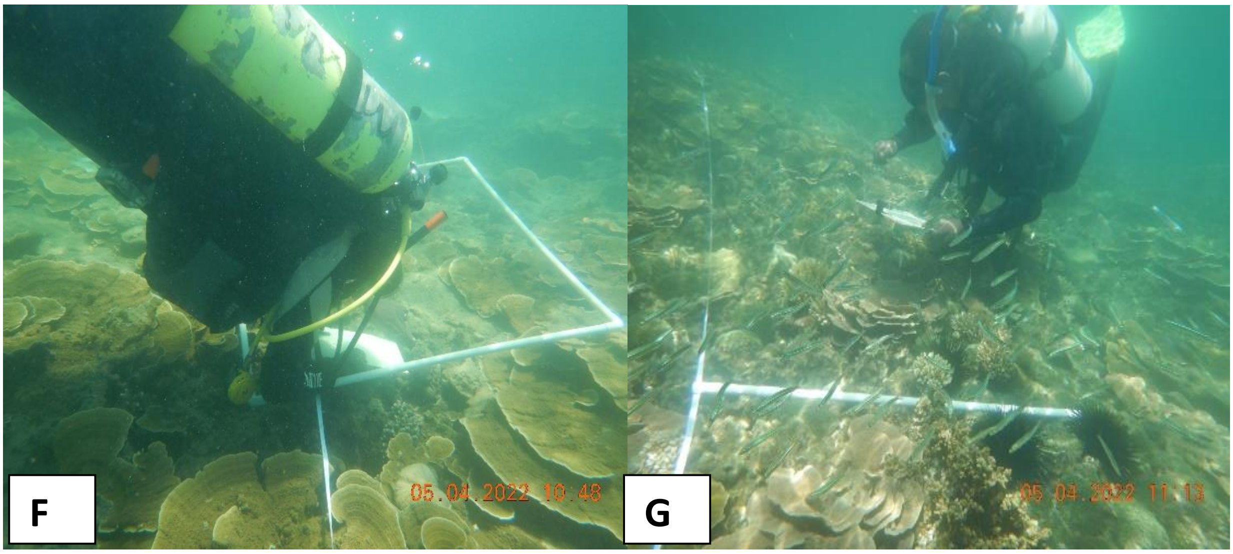


Plate A-G: Methodological approach

(Source: MPRU field work in April, 2022)

3.5. Data Analysis

Benthic cover data was analyzed using computer software GraphPad InStat vrn 3 and results generated in form of descriptive statistics. Data for coral sizes, macro invertebrates, and fish counts was organized using Microsoft Excel and analysed using GraphPad Instat vrn 3 producing descriptive statistical results. Multivariate data analysis software can also be applied to perform similarity analysis among sites and MPAs of the benthic cover, colony sizes, fish densities, biomass and coral genera, etc.

3.6. Outputs of the Assignment

i) Fieldwork report including photos and descriptions of reefs

ii) Raw data in an excel or CSV file at a replicate level

iii) A final *Coral Reef Monitoring Technical Report* including geographical coordinates of sampling stations

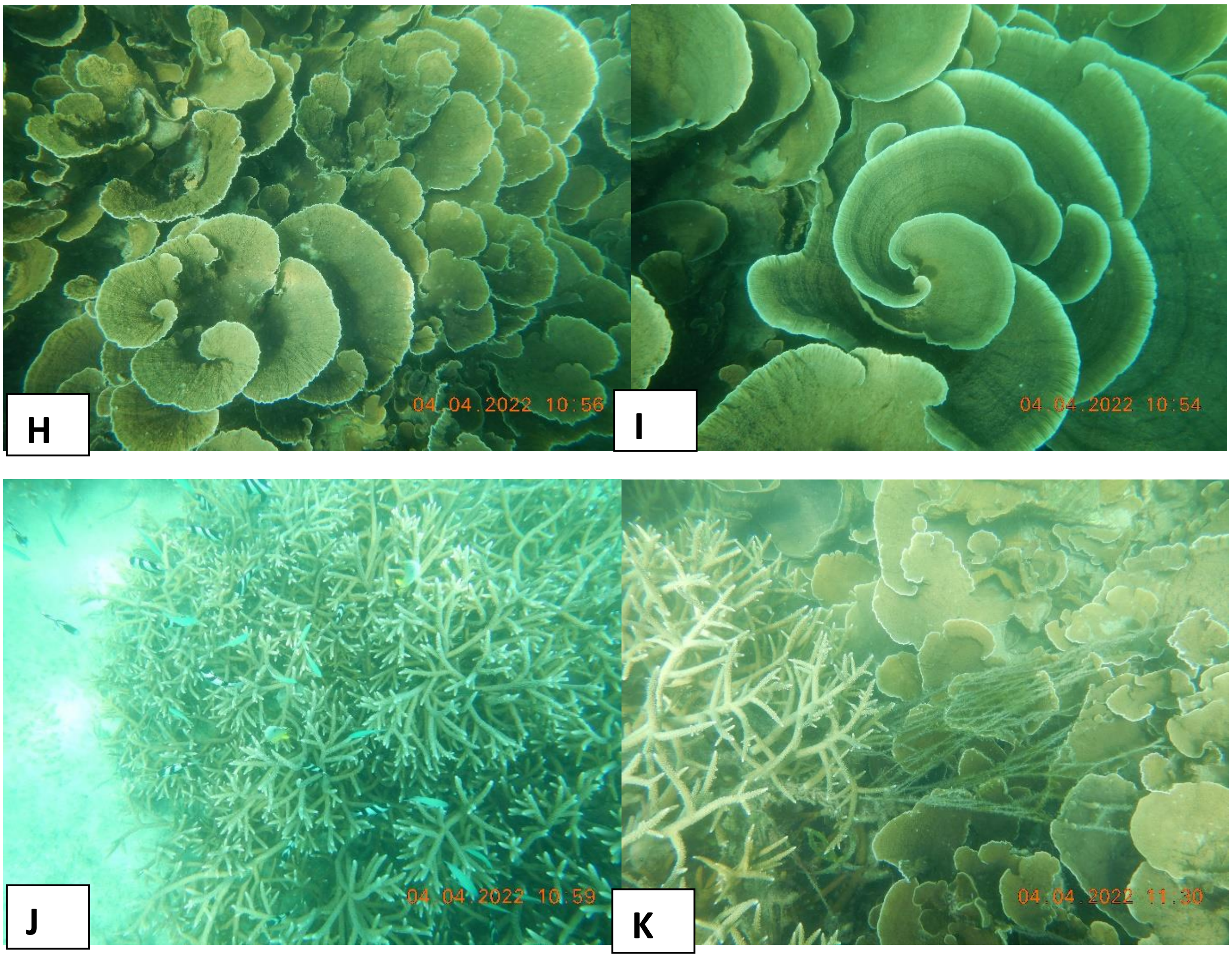
iv) Other collected information including videos from video surveys and/or transect videos

CHAPTER FOUR

4.0. RESULTS AND DISCUSSION

4.1. Health Status of eight Surveyed Reef Sites

The eight surveyed sites are located in areas of different oceanographic conditions with similar management regimes and therefore subjected to varying degrees of stresses and resilience (Figure. 2). Generally, all eight reefs have fairly diverse benthic substrates dominated by live hard coral cover. In all reefs, dead corals and rubbles were widespread especially in Funguyasini NW & SW and Bongoyo SW. Genus *Montipora* was the most dominant genus with noticeable dead form likely as a result of bleaching mortality and unsustainable fishing. Plates E-N below show representative benthic features of the different surveyed sites within DMRs.



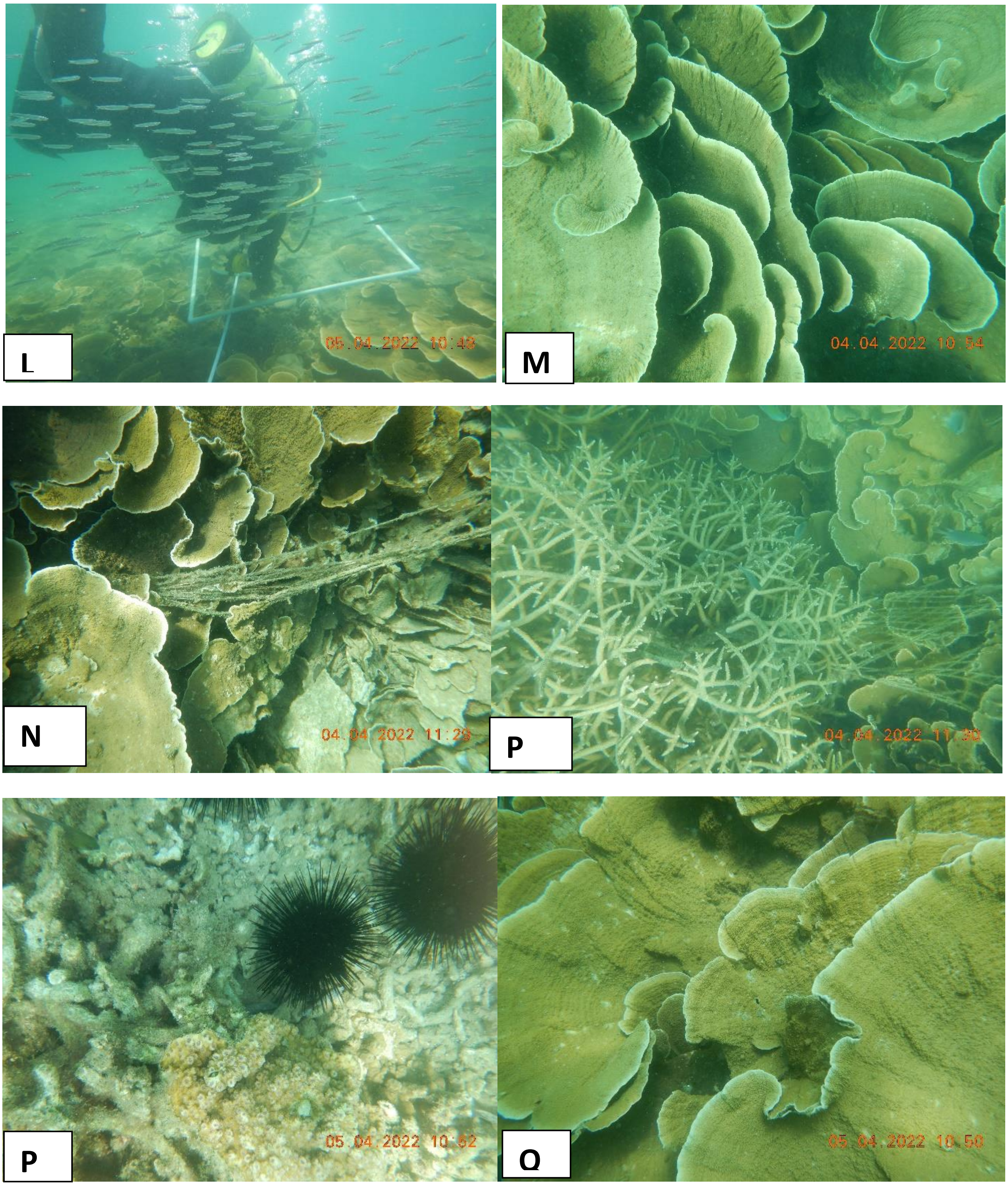


Plate H-Q: Representative bottom features of Surveyed reef within DMRs

(Source: MPRU field work in April, 2022)

4.2. Benthic cover

Benthic cover survey was conducted using Line Intercept Transect (LIT) method in which a minimum of six (6) transects at each site covering reef slope and reef flats were surveyed. About eleven benthic categories were surveyed namely coralline algae (CA), Dead Coral (DC), Hard coral (HC), Macro algae (MA), Rubble (R), Rock (RCK), Soft Coral (SC), Sponge (SP) and others (OT).

Statistics revealed significant difference on coral cover status among monitored sites. One-way Analysis of Variance (ANOVA); P = 0.0036, which was considered very significant with Mbudya SW has the highest percentage proportional (Mean +SE), 69.92 ± 7.6) and Funguyasini NW recording the lowest percent (Mean ± SE) 28.45+7.95

The results indicated the overall average Coral cover in DMRS was 53.86% in 2022 under the current survey. Comparing to previous survey conducted in 2018, the general trend for hard coral cover has slightly increased (Mean ± SE) from 42.90±5.83 to 53.86±4.3 % for 2018) and 2022 survey respectively Figure 2.

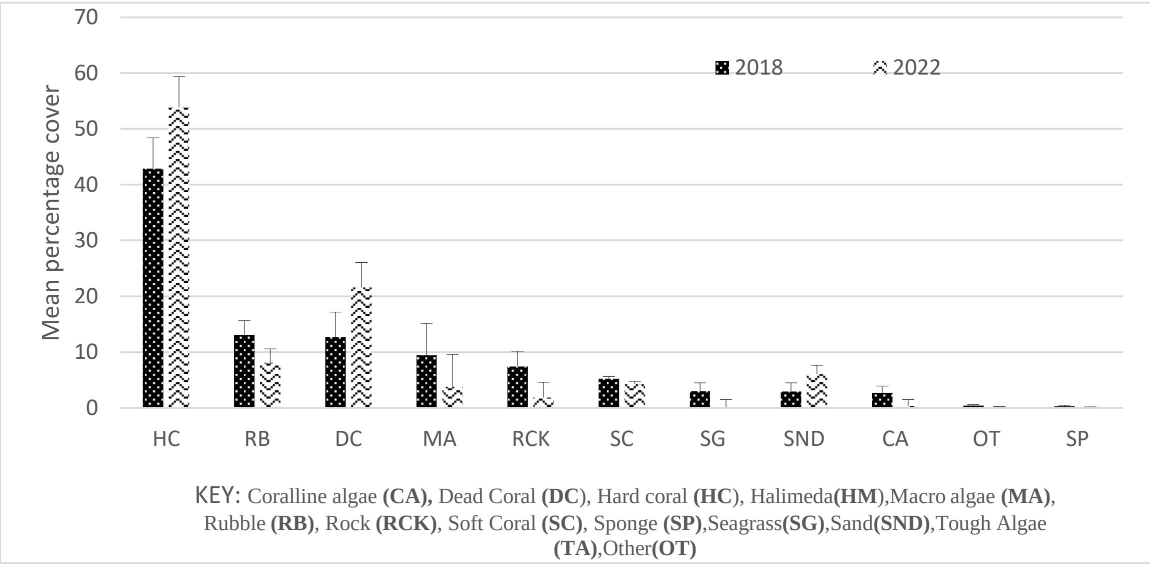


Figure 2: Comparison of Overall benthic cover for year 2018 and 2022 as recorded in all sites at DMRs

(Source: MPRU field work in April, 2022)

The slight increase of coral cover within DMRs was probably attributed by conservation efforts that have been intensified in MPAs including scaling down of dynamite fishing (Reuben, 2020), high resilience from coral bleaching (Obura 2005; Obura *et al*, 2017). Generally sites has indicated increase in coral cover except at Mbudya north west reefs which indicated a small decrease of coral percentage, Fungu yasini SW indicated a significant decrease of coral cover and increased number of dead coral (from **12.7%** in 2018 to **32.4%** in 2022.), this was due to high over growth of sea grass and algae (Figure 3 & 4)

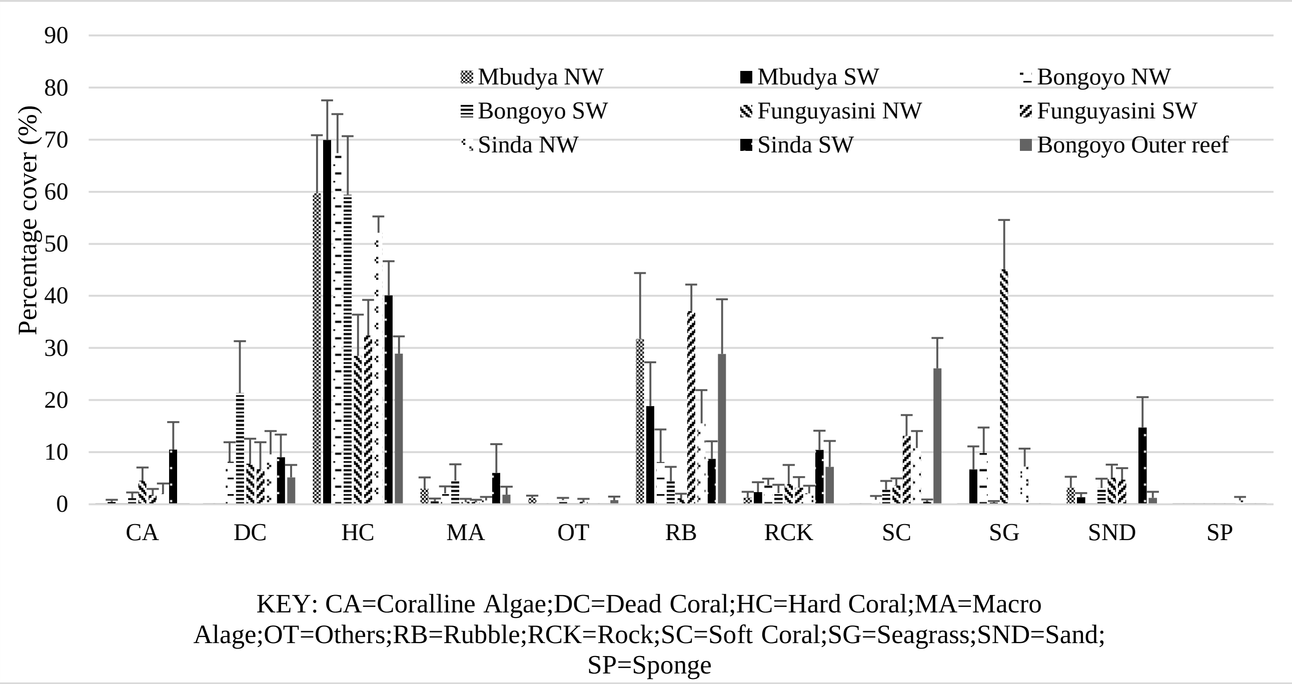


Figure 3: DRMs Benthic status in surveyed reef, 2022

4.3. Trend on benthic cover

Generally, most of sites recorded high hard coral benthic cover (HC) at ≥50 % except for Fungu yasini and Sinda reefs. On the other hand, Live hard corals had the highest cover at Mbudya SW reef with (69.9% ± 7.6) whereas Mbudya NW indicated a slight decrease of coral cover by 0.2% (59.1% ± 0.1) ,relatively Fungu yasini SW indicated a notable decrease by 17.2% (30.4% ± 8.6) for the current survey.

In addition, the trend of hard coral cover in most sites has increased as compared to 2018 survey results. The highest hard coral cover increase was noted at Bongoyo SW changing from 37.1% in 2018 to 59.4% in 2022. Despite the fact that Bongoyo SW is dominated by Galaxea, the increase in Galaxea cover is attributed by regeneration of other genera such as Acropora, echinopora, stylophora and Pocillopora. Fungu yasini reefs indicated a significant decrease of coral cover percentage from 47.6% in 2018 to 30.4% in 2022,(Figure 4).The decrease of coral percentage probably was triggered by increasing pressure from tourism activities, shipping and destructive fishing nearby Mbudya NW and Fungu yasini reefs.

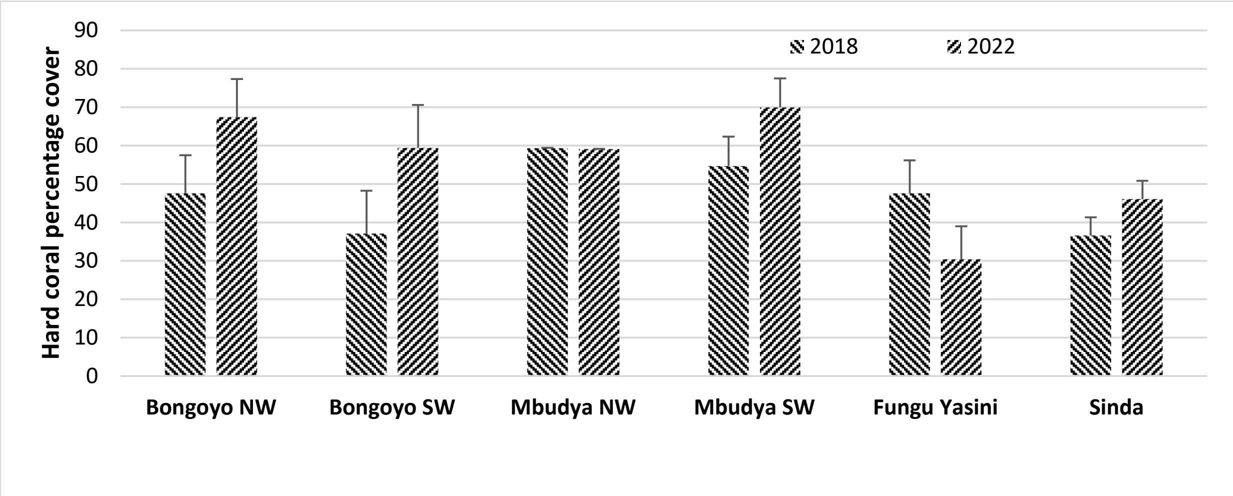


Figure 4: Comparison of hard coral cover percentages in all sites at DMRs (2018-2022)

Table 5: Trend of selected benthic cover categories for surveyed sites in DMRs

Cover category	Bongoyo NW			Bongoyo SW			Mbudya NW			Mbudya SW		
	2008	2018	2022	2008	2018	2022	2008	2018	2022	2008	2018	2022
Live coral (HC)	52.6	47.6	67.4	47.4	37.1	59.4	65.9	59.3	59.1	49.0	54.7	69.9
Coralline algae (CA)	0.1	1.0	0	0.1	0.7	1.13	2.0	1.9	0	0.1	1.6	0.42
Macro Algae (MA)	5.5	11.2	1.81	6.6	16.5	2.05	1.2	10.2	1.12	3.2	8.5	0
Dead coral (DC)	39.9	14.1	8.13	42.3	17.1	21.35	28.4	21.2	0	47.5	17.0	0

Cover category	Fungu yasini			Sinda		
	2008	2018	2022	2008	2018	2022
Live coral (HC)	-	47.6	30.4	-	36.6	46.12
Coralline algae (CA)	-	1.0	3.23	-	8.8	6.25
Macro Algae (MA)	-	11.2	0.25	-	3.0	2.00
Dead coral (DC)	-	14.1	7.24	-	10.1	9.27

4.1. CORAL COMMUNITY STRUCTURE

4.2.1. Community Structure from Benthic Cover data

This study recorded sixteen (16) coral genera through the LIT (Table 6), and 23 in the Belt intercept transects contrary to the 2018 survey at which about twenty five genera (25) were recorded (through Belt intercept transects), Some previous studies conducted in DMRs identified more than 50 coral genera (Hamilton et al 1975), However the monitoring sites and methodology employed during this survey does not match those of the previous studies, thus cannot be scientifically compared. Coral diversity in the 2018 survey result was extracted from photo quadrat result while current study diversity was obtained in LIT and Belt transect. The results further indicated diverse number of genera at Bongoyo NW and Sinda reefs (ie 12 genera), followed by Bongoyo SW (11 genera), Mbudya SW & Fungu yasini (9 genera) and the lowest was recorded at Mbudya NW (7 genera).Figure 5.

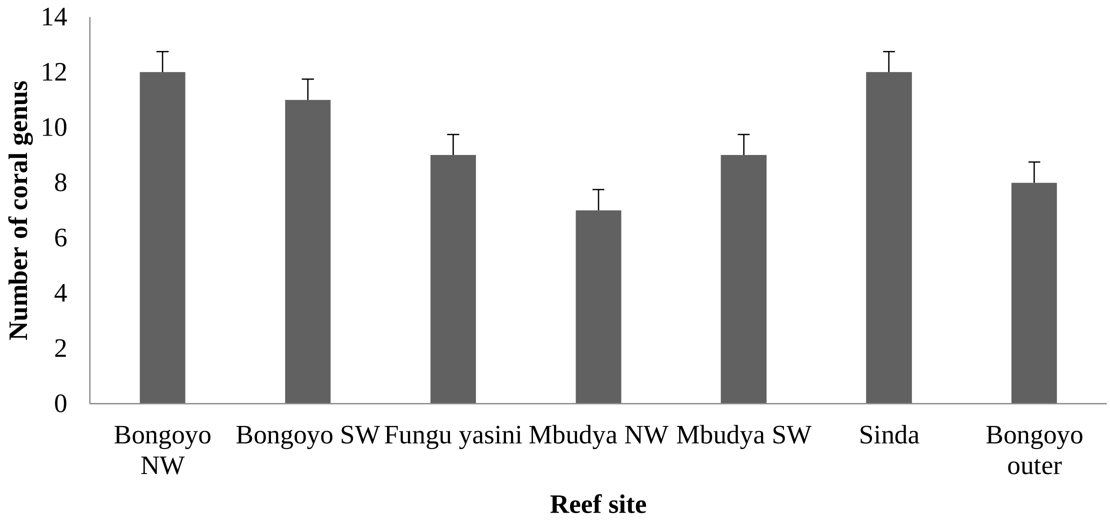


Figure 5: Number of coral genera in six surveyed sites at DMRs

(Source: MPRU field work in April, 2022)

Table 6: Comparison between years on relative abundance of various coral genera

	Genus abundance (mean) recorded from transects		
S/N	**Genus**	**2018**	**2022**
1	*Acanthastrea (ACA)*	0.2	
2	*Acropora (ACR)*	13.1	3.9
3	*Alveopora (ALV)*		
4	*Astreopora (AST)*		
5	*Coscinaraea (COS)*	1.3	
6	*Cyphastrea (CYP)*	15.2	
7	*Diploastrea (DIP)*		
8	*Echinophyllia (EPH)*		
9	*Echinopora (EPO)*	2.3	6.7
10	*Favia (FAV)*	1.6	0.1
11	*Favites (FTS)*		0.4
12	*Fungia (FUN)*	6.4	0.4
13	*Galaxea (GAL)*	15.9	25.2
14	*Gardinoseris (GAR)*		
15	*Goniastrea (GON)*	1.9	
16	*Goniopora (GOP)*	5.3	
17	*Halomitra (HAL)*		
18	*Herpolitha (HER)*	0.5	
19	*Hydnopohora (HYD)*	3.7	
20	*Leptastrea (LEP)*	0.9	
21	*Leptoria (LEO)*		
22	*Lobophyllia (LOB)*	0.2	
23	*Merulina (MER)*		
24	*Millepora (MIL)*	7.6	0.04
25	*Montastrea (MON)*		
26	*Montipora (MTP)*	28.3	1.0
27	*Mycedium (MYC)*	0.5	
28	*Oulophyllia (OUL)*		
29	*Oxypora (OXY)*	2.3	
30	*Pachyseris (PAC)*		
31	*Pavona (PAV)*	3.9	0.3
32	*Physogyra (PHY)*		
33	*Platygyra (PLA)*	5.9	0.0
34	*Plerogyra (PLG)*		
35	*Plesiastrea (PLS)*	1.2	
36	*Pocillopora (POC)*	0.4	1.3
37	*Podabacea (POD)*		

38	*Porites (POR)*	26.3	7.6
39	*Psammocora (PSA)*	4.3	
40	*Seriatopora (SER)*		0.02
41	*Stylophora (STY)*	0.3	3.4
42	*Symphillia (SYM)*		0.3
43	*Synarea*		0.6
44	*Tubipora (TUP)*		

Table 7 : Diversity and relative abundance of various coral genera among sites

		Coral Genus recorded in each site					
S/N	**Genus**	**Bongoyo NW**	**Bongoyo SW**	**Fungu yasini**	**Mbudya NW**	**Mbudya SW**	**Sinda**
1	Acanthastrea	0.0	0.0	0.0	0.0	0.0	0.0
2	Acropora	2.2	7.6	3.4	7.2	5.6	0.6
3	Alveopora	0.0	0.0	0.0	0.0	0.0	0.0
4	Asteriopora	0.0	0.0	0.0	0.0	0.0	0.0
5	Coscinaraea	0.0	0.0	0.0	0.0	0.0	0.0
6	Echinopora	4.4	8.5	5,4	23.9	5.9	0.0
7	Favia	0.2	0.1	0.0	0.0	0.0	0.025
8	Favites	0.9	0.9	0.3	0.3	0.8	0.0
9	Fungia	0.8	0.7	0.2	0.0	0.0	0.6
10	Galaxea	55.1	33.7	17.2	24.5	52.0	1.0
11	Gardinoseris	0.0	0.0	0.0	0.0	0.0	0.0
12	Goniastrea	0.0	0.0	0.0	0.0	0.0	0.0
13	Goniopora	0.0	0.0	0.0	0.0	0.0	0.0
14	Halomitra	0.0	0.0	1.0	0.0	0.0	0.0
15	Hydnophora	0.0	0.0	0.0	0.0	1.0	0.0
16	Leptastrea	0.0	0.0	0.0	0.0	0.0	0.0
17	Leptoria	0.0	0.0	0.0	0.0		0.0
18	Lobophyllia	0.0	0.0	0.0	0.0	0.0	0.0
19	Merulina	0.0	0.0	0.0	0.0	0.0	0.0
20	Millepora	0.0	0.0	0.0	0.0	0.0	0.2
21	Montastrea	0.0	0.0	0.0	0.0	0.0	0.0
22	Montipora	1.0	2.6	0.9	1.4	1.5	0.0
23	Mycedium	0.0	0.0	0.0	0.0	0.0	0.0
24	Oxypora	0.0	0.0	0.0	0.0	0.0	0.0
25	Pachycheris	0.0	0.0	0.0	0.0	0.0	0.0
26	Pavona	0.3	0.2	0.0	0.0	0.0	1.0
27	Physogyra	0.0	0.0	0.0	0.0	0.0	0.0
28	Platygyra	0.0	0.0	0.0	0.0	0.0	0.1

29	Plerogyra	0.0	0.0	0.0	0.0	0.0	0.0
30	Pocillopora	0.2	0.0	0.0	0.0	0.0	5.2
31	Podabacia	0.0	0.0	0.0	0.0	0.0	0.0
32	Porites (b)	1.8	1.7	0.0	3.3	3.0	22.4
33	Porites (m)	0.3	1.2	1.1	3.2	8.3	1.5
34	Seriatopora	0.0	0.0	0.0	0.0	0.0	0.1
35	Stylophora	1.0	1.3	0.6	0.5	0.9	11.0
36	Symphillia	0.0	0.0	0.3	0.0	0.0	0.0
37	Turbinaria	0.0	0.0	0.0	0.0	0.0	0.0

4.2.1.2. Relative abundance of coral genera overall and by site

4.2.2. Community Structure for Coral Size Class

4.2.2.0. Approach Overview

Genus abundance estimation from colony size data was based on 23 selected coral genera including *Acanthastrea, Acropora, Coscinarea Echinopora, Favia, Favites, Fungia, Galaxea, Goniastrea, Hydnophora, Leptastrea, Lobophyllia, Montipora, Oxypora, Pavona, Platygyra, Plerogyra, Pocillopora, Porites* massive - *Porites (*m)*, Porites* branching - *Porites (b), Seriatopora, Stylophora,* and *Turbinaria*. Selection of these genera was based on their abundance/common occurrence across reef systems within the western Indian Ocean (WIO) region, but also as representative categories in a range of susceptibility to disturbances such as coral bleaching (Obura & Grimsditch, 2009). Coral sizes were estimated by measuring colony diameter (cm) at the widest point of a naturally irregular shaped colony and identify the colonies to genus level. Size analys was based on seven size classes including 11-20cm, 21-40cm, 41-80cm, 81-160cm, 161-320cm and >320cm.

4.2.2.1. Coral Genus Abundance by Number and Area

The coral genus number was estimated by using belt method of 25m*2m (50m^2). The results demonstrated that Montipora (23 %) have the highest number of colonies, followed by Porites branching (19 %) and Porites massive (14%) (Figure 6). The results are relatively similarly to that of 2018 survey at which Montipora and Porites braching showed higher number of colonies.

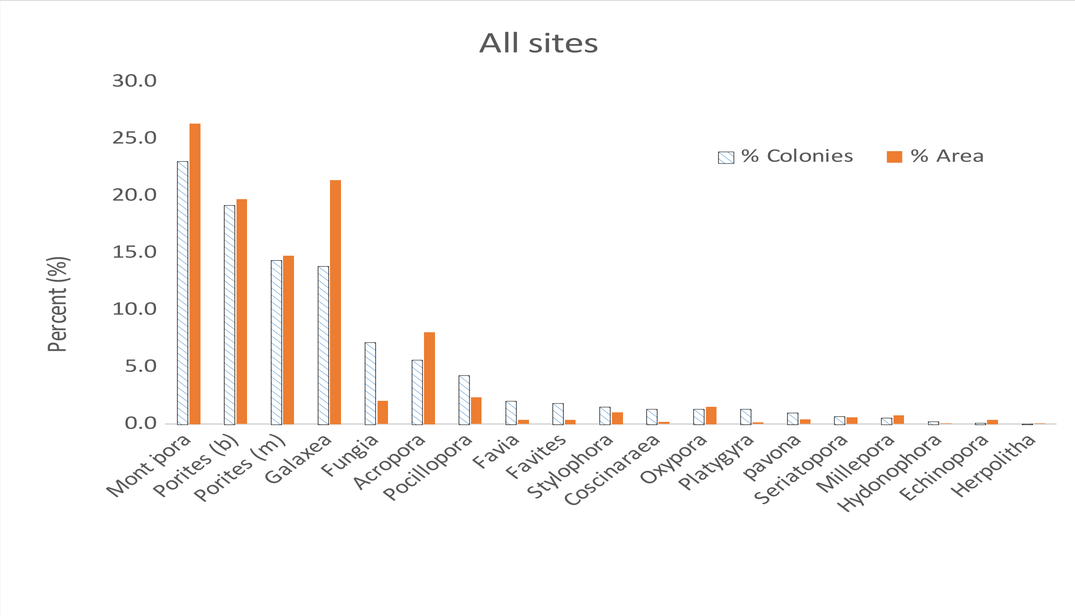
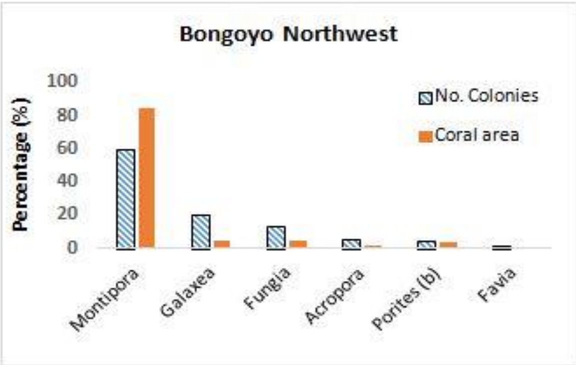


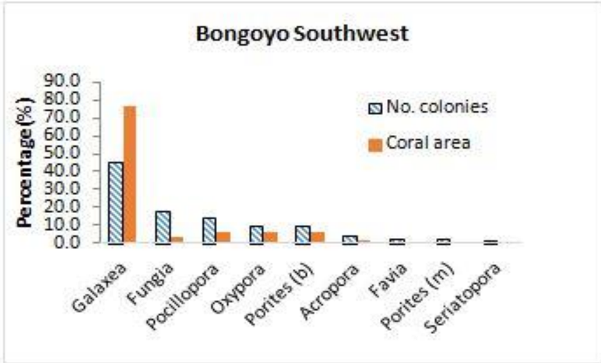
Figure 6: Coral genera distribution (%) by number of all colonies and area

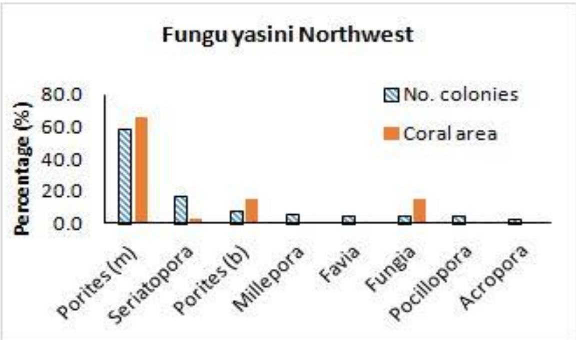
4.2.2.2. Coral Genus Abundance by sites

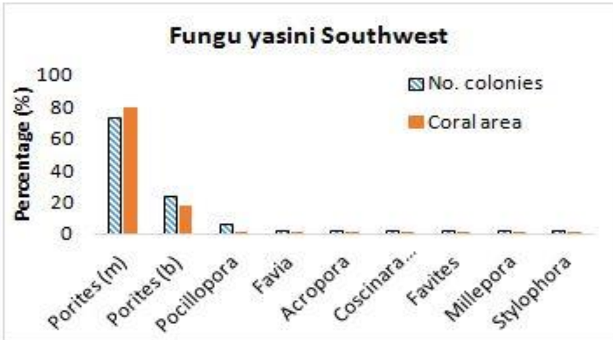
The coral genus number and area were estimated by using belt transect method. Two transects were laid of each 25m*2m (50m^2) coral genus and size class were recorded. The results demonstrated that the genera *Montipora* (23%) have the highest average number of colonies in all site followed by Porites branching (19%) Porites massive (14%) and Galaxea (13%) (Figure 5), whereas in year 2018 the coral genera with the highest number of colonies were *Porites* branching (15%) Fungia (13%) and Montipora (13%) (URT 2018).

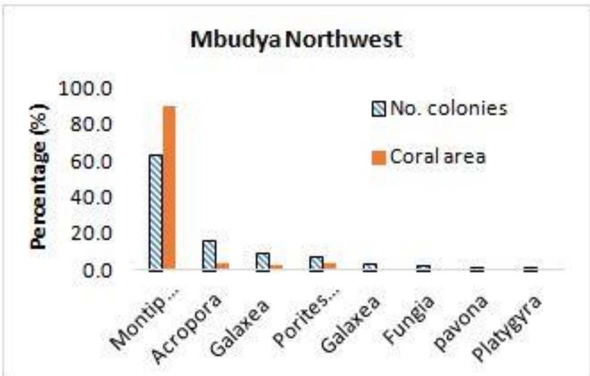
For site specific, Bongoyo Northwest, Mbudya Northwest and Mbudya southwest, was found to have the genus *Montipora* (>40%) with highest number colonies, while the Bongoyo Southwest is dominated by Galaxea (40%), Porites massive is observed at Fungu yasini Northwest, Fungu yasin Southwest (40%) . At Sinda North west and Sinda southwest, porites braching showed to have more number of colonies. Figure 7.

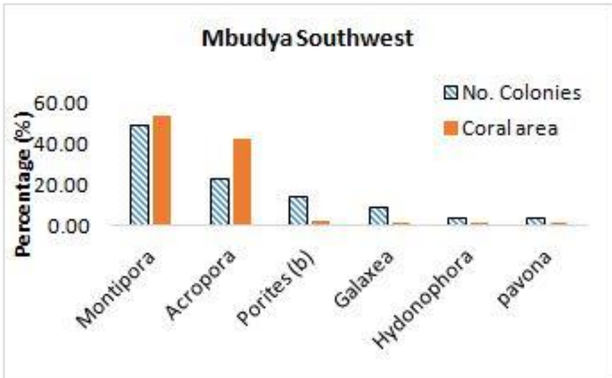

Bongoyo Northwest
Percentage (%)
100
80
60
40
20
0
No. Colonies
Coral area
Montipora
Galaxea
Fungia
Acropora
Porites (b)
Favia


Bongoyo Southwest
Percentage (%)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
No. colonies
Coral area
Galaxea
Fungia
Pocillopora
Oxypora
Porites (b)
Acropora
Favia
Porites (m)
Seriatopora


Fungu yasini Northwest
Percentage (%)
80.0
60.0
40.0
20.0
0.0
No. colonies
Coral area
Porites (m)
Seriatopora
Porites (b)
Millepora
Favia
Fungia
Pocillopora
Acropora


Fungu yasini Southwest
Percentage (%)
100
80
60
40
20
0
No. colonies
Coral area
Porites (m)
Porites (b)
Pocillopora
Favia
Acropora
Coscinara...
Favites
Millepora
Stylophora


Mbudya Northwest
Percentage (%)
100.0
80.0
60.0
40.0
20.0
0.0
No. colonies
Coral area
Montip...
Acropora
Galaxea
Porites...
Galaxea
Fungia
pavona
Platygyra


Mbudya Southwest
Percentage (%)
60.00
40.00
20.00
0.00
No. Colonies
Coral area
Montipora
Acropora
Porites (b)
Galaxea
Hydonophora
pavona

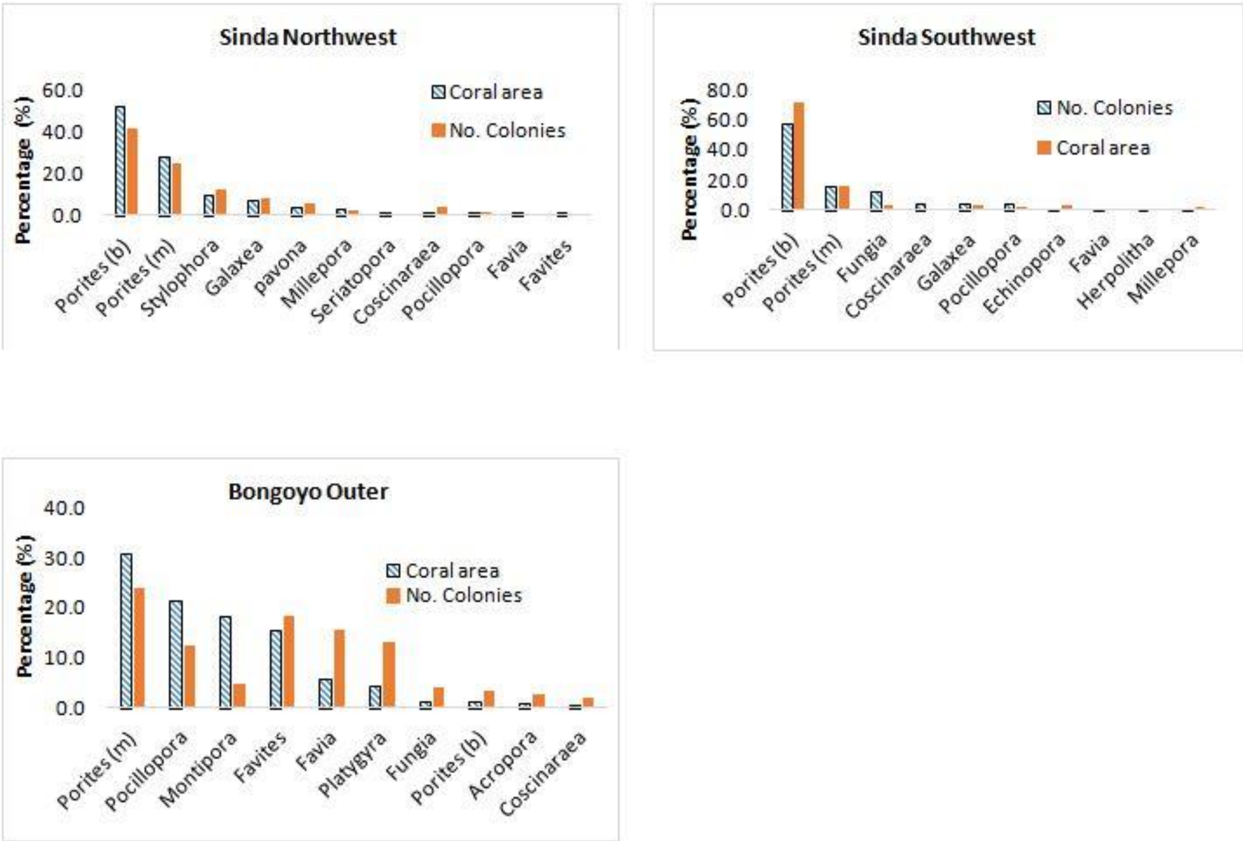


Figure 7: Consists of nine graphs showing Coral genera distribution per each surveyed site

(Source: MPRU field work in April, 2022)

4.3. CORAL POPULATION STRUCTURE

Coral Size Class Distribution by sites

Generally the coral cover at DMRS was dominated by mid coral size class 41-80, 81-160 and 161-362 (Figure 8). This reveals that the coral at DMRs is evenly distributed hence indicates that there is high recruitment. In terms of coral numbers, coral size class 11-20 and 41-80 demonstrated to have high numbers of colonies as compared to other size class (Figure 8). This result was similarly recorded in the 2018 (URT, 2018).

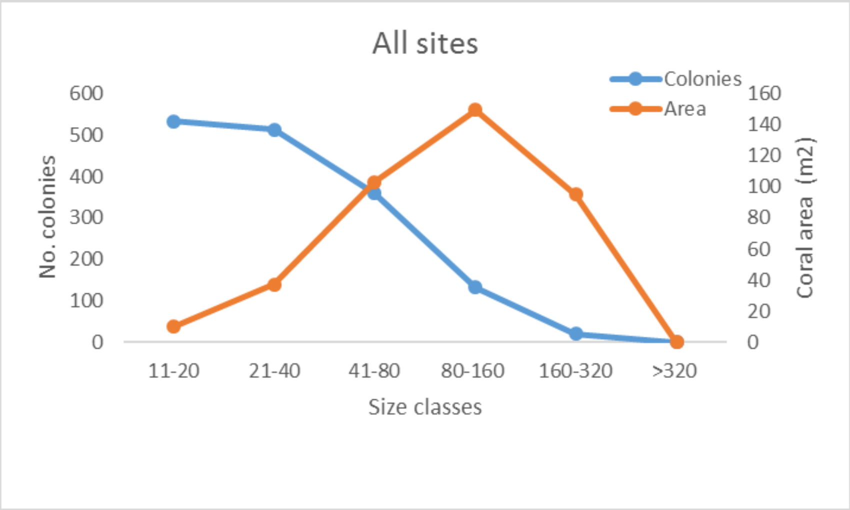
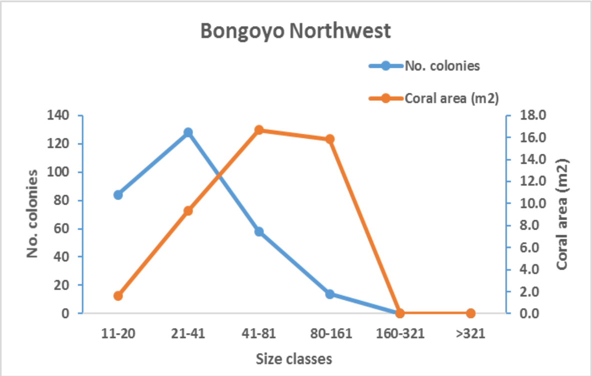
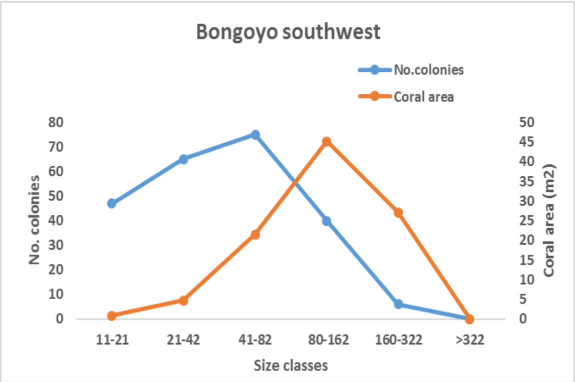


Figure 8: Size class distribution (number of colonies and area) of all corals

Monitoring was conducted at nine sites namely Bongoyo Northwest, Bongoyo southwest, Fungu yasini Northwest, Fungu yasini southwest, Mbudya southwest. Mbudya northwest, Sinda southwest, sinda northwest and Bongoyo outer reef, Mbudya reef site indicated an acute increase of coral cover for size class 160-320, this has amplified by dominance of Montipora and Acropora genera in the study site. This genus have a growth characteristic of covering large area.





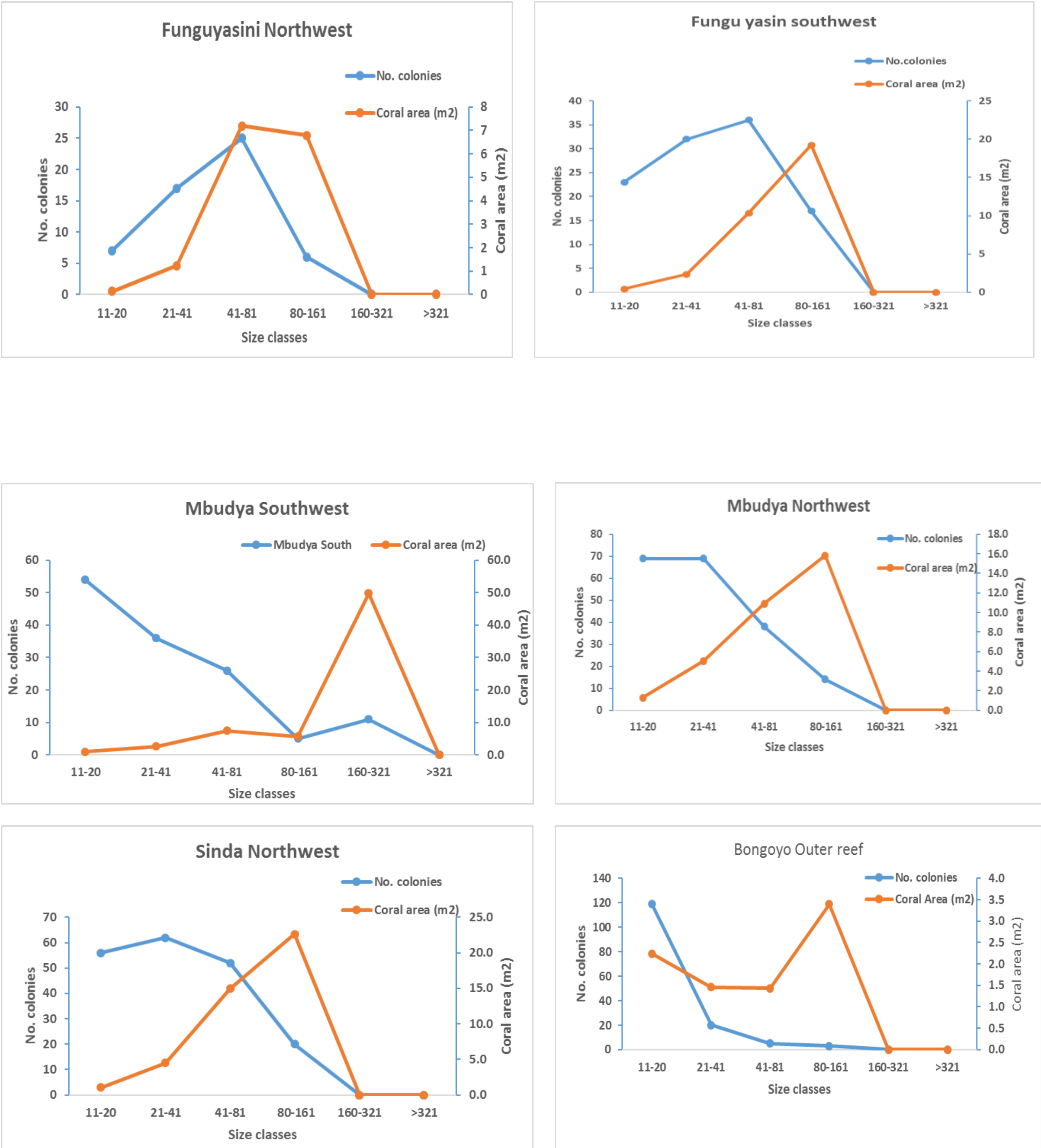
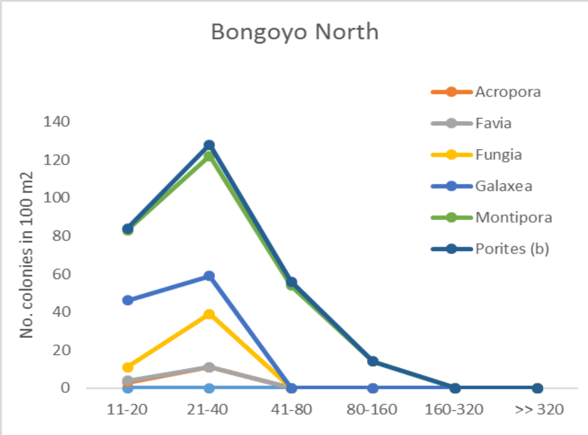
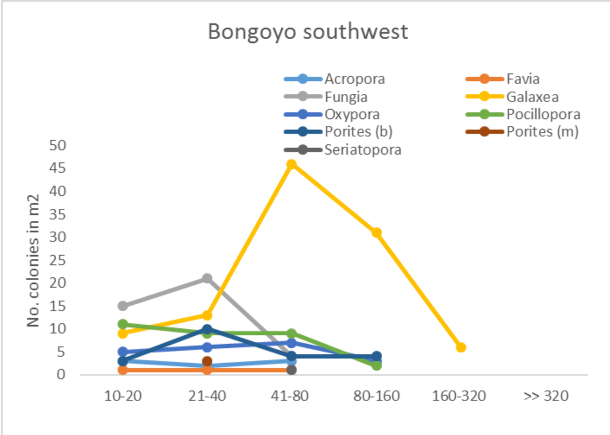
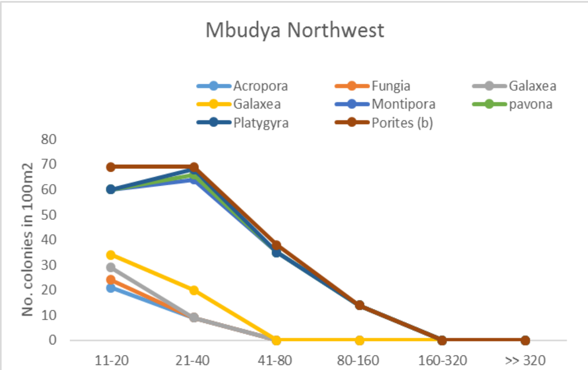
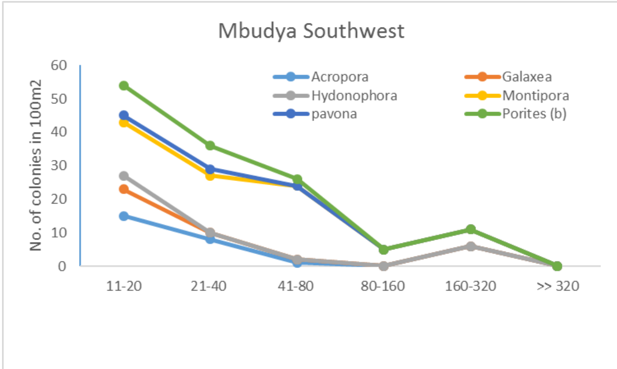


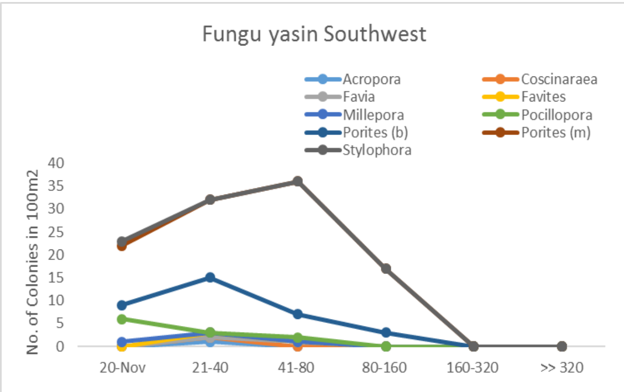
Figure 9: Consists of nine graphs indicating the Size class distributions (number of colonies and area) of all corals for every study sites.

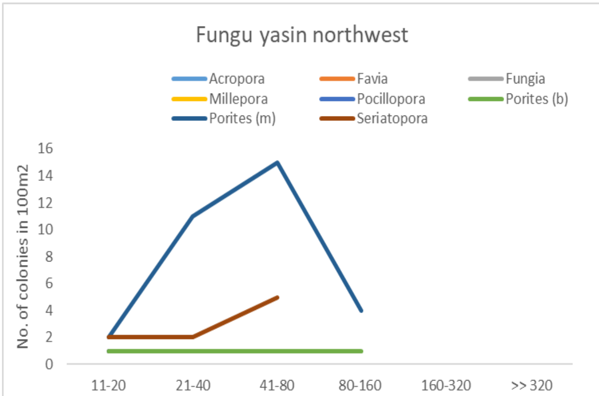

Bongoyo North
Acropora
Favia
Fungia
Galaxea
Montipora
Porites (b)
No. colonies in 100 m2
0
20
40
60
80
100
120
140
11-20
21-40
41-80
80-160
160-320
>> 320

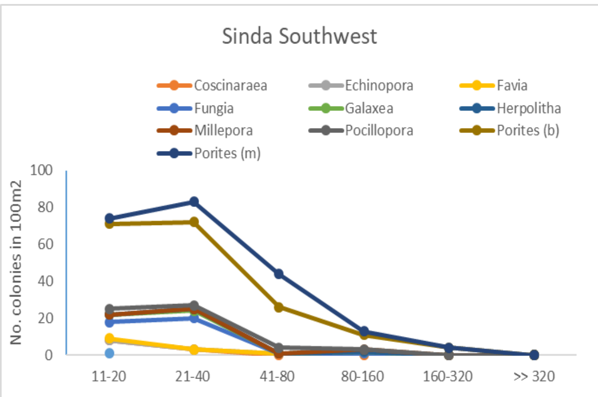

Bongoyo southwest
Acropora
Favia
Fungia
Galaxea
Oxypora
Pocillopora
Porites (b)
Porites (m)
Seriatopora
No. colonies in m2
0
5
10
15
20
25
30
35
40
45
50
10-20
21-40
41-80
80-160
160-320
>> 320

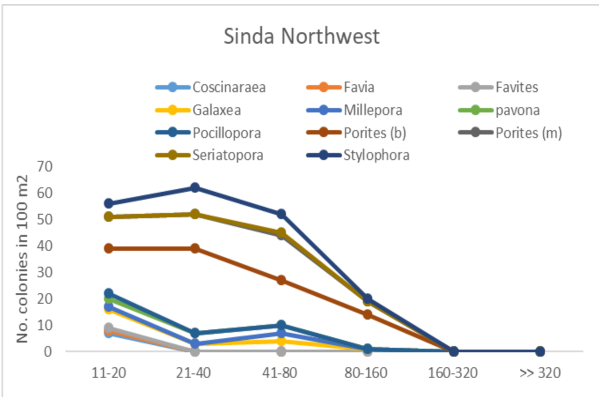

Mbudya Northwest
Acropora
Fungia
Galaxea
Galaxea
Montipora
pavona
Platygyra
Porites (b)
No. colonies in 100m2
0
10
20
30
40
50
60
70
80
11-20
21-40
41-80
80-160
160-320
>> 320


Mbudya Southwest
Acropora
Galaxea
Hydonophora
Montipora
pavona
Porites (b)
No. of colonies in 100m2
0
10
20
30
40
50
60
11-20
21-40
41-80
80-160
160-320
>> 320


Fungu yasin Southwest
Acropora
Coscinaraea
Favia
Favites
Millepora
Pocillopora
Porites (b)
Porites (m)
Stylophora
No. of Colonies in 100m2
0
5
10
15
20
25
30
35
40
20-Nov
21-40
41-80
80-160
160-320
>> 320


Fungu yasin northwest
Acropora
Favia
Fungia
Millepora
Pocillopora
Porites (b)
Porites (m)
Seriatopora
No. of colonies in 100m2
0
2
4
6
8
10
12
14
16
11-20
21-40
41-80
80-160
160-320
>> 320


Sinda Southwest
Coscinaraea
Echinopora
Favia
Fungia
Galaxea
Herpolitha
Millepora
Pocillopora
Porites (b)
Porites (m)
No. colonies in 100m2
0
20
40
60
80
100
11-20
21-40
41-80
80-160
160-320
>> 320


Sinda Northwest
Coscinaraea
Favia
Favites
Galaxea
Millepora
pavona
Pocillopora
Porites (b)
Porites (m)
Seriatopora
Stylophora
No. colonies in 100 m2
0
10
20
30
40
50
60
70
11-20
21-40
41-80
80-160
160-320
>> 320

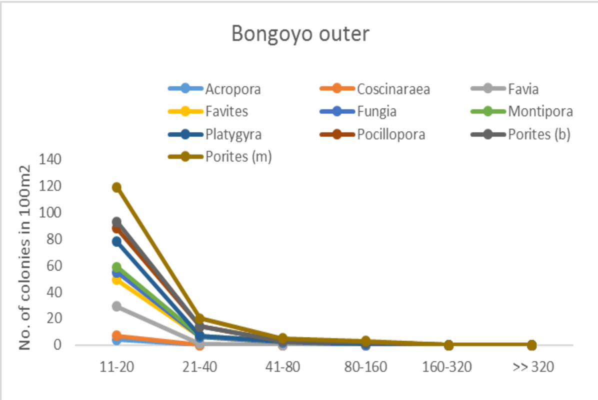


Figure 10: Size class distributions (number of colonies and area) of all corals recorded from Bongoyo northwest, Bongoyo southwest, Mbudya northwest, Mbudya southwest. Sinda northwest, Sinda southwest and Bongoyo outer reef sites.

1.2. Coral Recruitment

In this study, coral recruitment counted using 1 m^2 quadrat placed in 6 times in transect of 25 m long. The quadrats were placed every 5m along transect at 0m, 5m, 10m, 15m, 20m, 25m. The total number of transects were 2 per site hence make a total of 12 quadrats per site.

Generally, the average recruitment for all sites in DMRS is 6 colonies in 1 m^2 the result which is similary to the average of 6 colonies observed during the survey conducted in 2018 (URT 2081) The highest recruitment was observed at Sinda southwest site with mean of 10.2 colonies per 1 m^2, followed by Mbudya northwest 6.9 colonies per m^2 and Bongoyo northwest 6.8 colonies per m^2 The main contributor high recruits at Sinda southwest, Mbudya northwest and Bongoyo northwest is size class range at 2.5-5 cm. The least recruitment was at both Funguyasin northwest and Funguyasin southwest sites with mean of 2.1 colonies per m^2 .Figure 11.

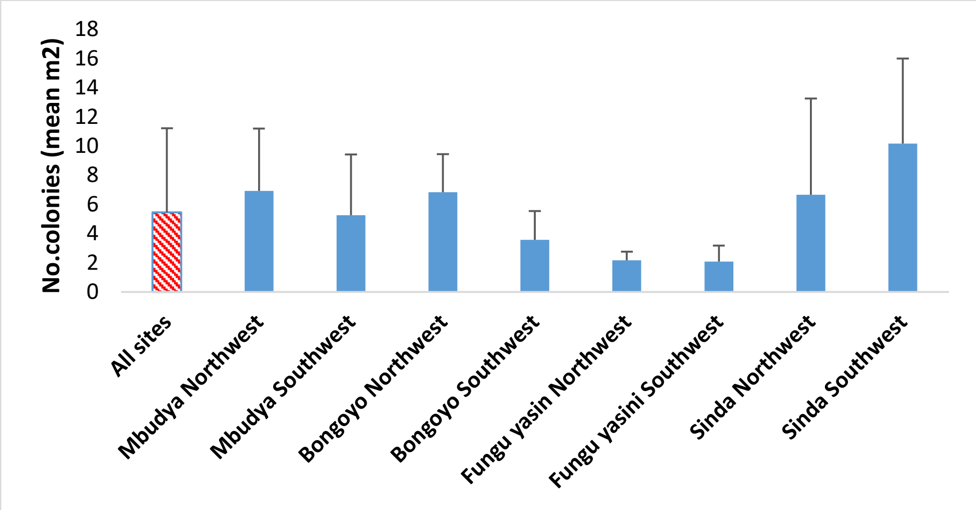


Figure 11: The average number of colonies for each site in each coral recruitment categories (0- 2.5 cm, 2.5-5 cm and 5-10 cm) in 1 m2

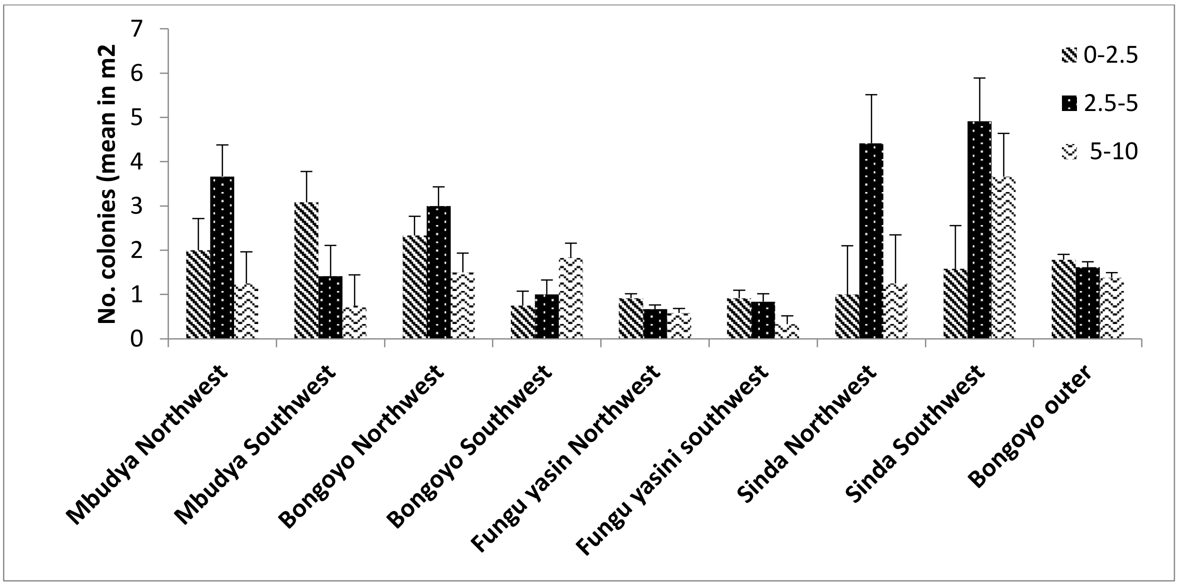


Figure 12: Comparison of number of colonies for each coral recruitment categories (0- 2.5 cm, 2.5-5 cm and 5-10 cm corals), for all sites presented as Mean (± SE) in 1m2

The coral recruitment as represented by corals in the size class 0-2.5 cm. 2.5-5cm, and 5-10 cm. Showed that the genus with highest recruitment was observed is Montipora with mean of 12.7 colonies per 1 m^2, followed by stylophora 6.3 and Porites branching. Figure 12

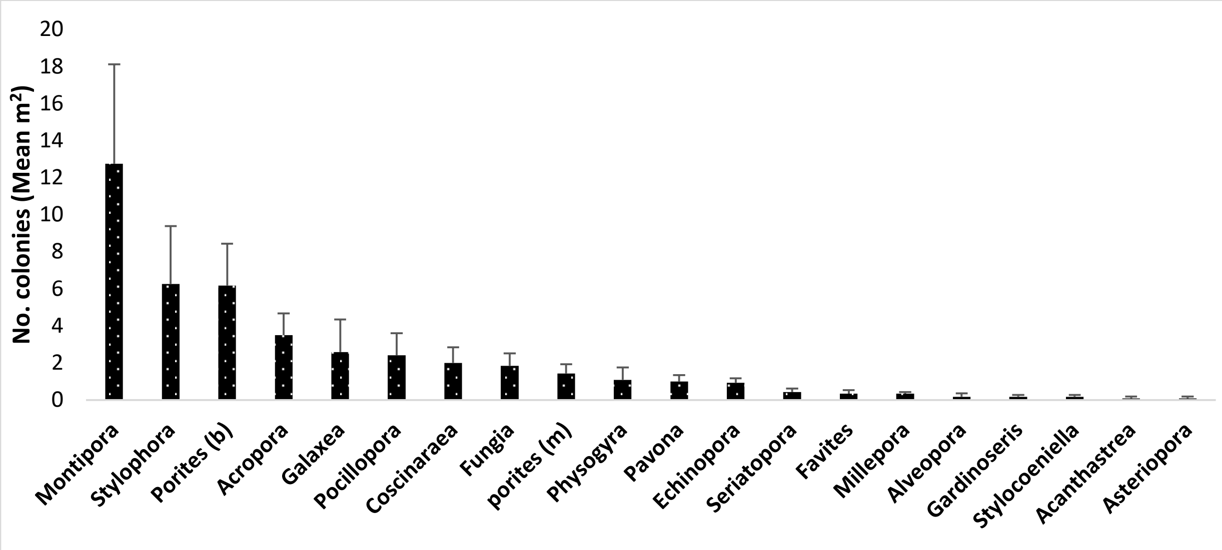


Figure 13: The average number of colonies for each genus in each coral recruitment categories (0-2.5 cm, 2.5-5 cm and 5-10 cm)

4.4. MACRO INVERTEBRATE DENSITY

The abundance of macro invertebrates "reef benthos" as recommended (English et al. (1994) and enumerated during the surveys have here been presented in terms of density per 20m^2 (± SE) which is a unit measure of a 10 x 2m belt transect. During this survey a number of Macro invertebrates were recorded including clams, gastropods, Crown-of-thorns starfish (COTS), sea urchins, starfish and sea cucumbers. However, discussion in this report preferably focused on sea urchin(key indicators) densities as such they have a significant implication to recruitment, growth and development of hard corals.

4.4.1. Density and Distribution of Macro Invertebrates among Sites

During this monitoring, Macro Invertebrates densities were surveyed at all six sites in DMRs. Generally analysis indicated the average number of macro-invertebrates to be 5 individuals per 20m^2 as compared to an average of 3 individuals per 20m^2 observed in 2018 (URT 2018). As an indicator species for ecological health, the density of sea urchin was 93.5% of all macro invertebrates counted. The highest average number of sea urchin was observed at Fungu yasini (35.8 individuals per 20 m^2), followed by Sinda (33.8 per 20 m^2) and Mbudya NW (14.7 per 20 m^2) while the lowest number was recorded at Bongoyo NW (3.8 individuals per 20 m^2) (Figure. 14).

Furthermore, a notable abundance of starfish with average density (1.25 individuals per 20 m^2) was recorded at Sinda. The higher abundance of sea urchin at Fungu yasini is an indication of ecologically unhealthy reef characterised by low numbers of reef fishes (triggerfish) which are the main consumers of sea urchins consequently causing the reef to become mainly dominated by dense stands of erect algae and seagrass bed as well as abundant seagrasses dwelling sea urchin species *Tripneustes gratilla.* Thus Fungu yasini sites has a relatively low coral diversity mainly a couple of massive *Porites* heads with generally many coral colonies partly of fully overgrown upon by macro algae. High fishing pressure and use of unsustainable gears at Fungu yasini fishing grounds probably have contributed to the deterioration of the entire reef systems.

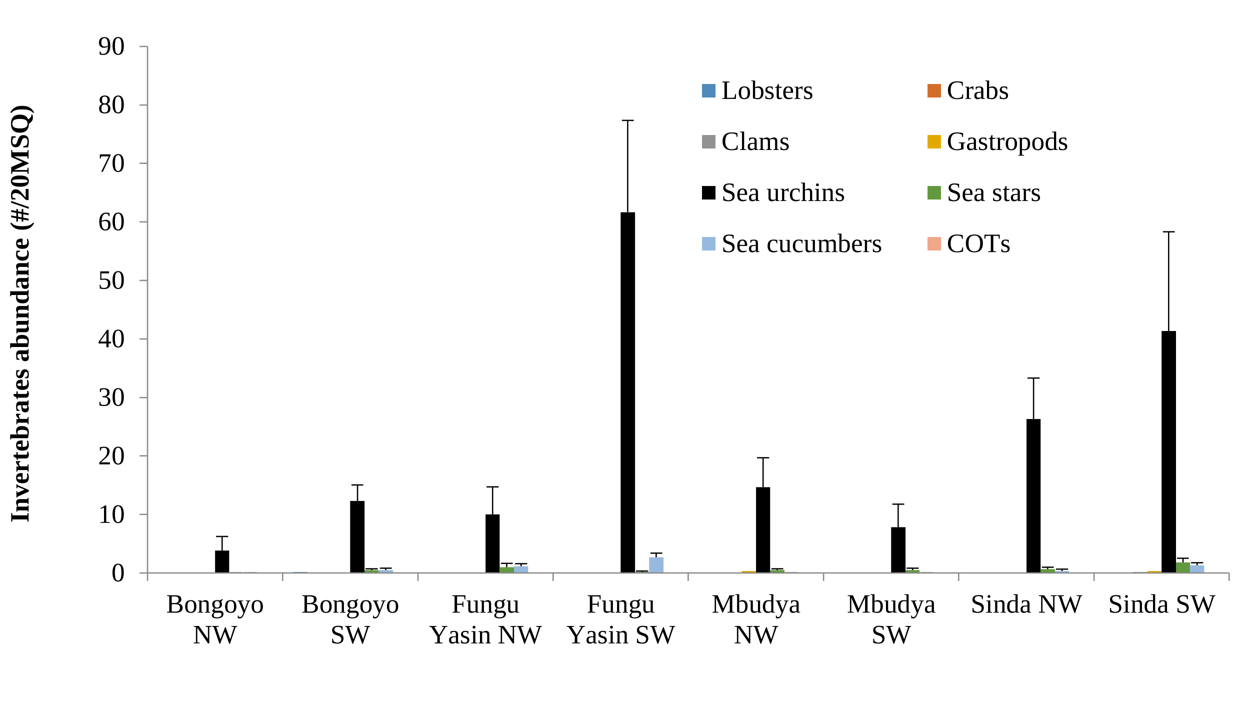


Figure 14: Invertebrates status and trend in DMRs

4.5. FISH COMMUNITY STRUCTURE

4.5.1. Major Fish Families Counted

This survey recorded 37 fish families overall including both the commercial and ecologically important reef fishes (Table 8). Populations of the highly targeted commercial species such as *Serranidae, Carangidae*, and *Scarridae,* and the ecologically important *Balistidae* (trigger fish) were generally low among study sites. It has been highlighted (Choat, 1991) that the most ecologically important reef fish families include *Acanthuridae* (Surgeons, and Unicorn Fishes), *Pomacentridae* (Damselfishes), *Labridae* (Parrotfishes), *Siganidae* (the Rabbit fishes) and *Kyphosidae* (the Rudder Fishes). The herbivorous group was more abundant with *Pomacentridae* being the most abundant family. Its highest abundance could be attributed to its not being targeted for fishing. Detailed results of the individual/key families have been explained in sub sections below.

Table 8: Fish families monitored

No.	Family	English name	No.	Family	English name
1	*Acanthuridae*	Surgeon fish	21	*Serranidae*	Grouper
2	*Aulostomidae*	Trumpet fish	22	*Siganidae*	Rabbit fish
3	*Balistidae*	Trigger fish	23	*Sphyraenidae*	Barracuda
4	*Carangidae*	Trevally	24	*Caesionidae*	Fusilier
5	*Chaetodontidae*	Butterfly fish	25	*Apogonidae*	Cardinal fish
6	*Diodontidae*		26	*Kyphosidae*	sea chub/Rudder fish
7	*Fistularidae*	Cornet fish	27	*Tetraodontiade*	Puffer fish
8	*Haemulidae*	Grunts / Sweet lip	28	*Zanclidae*	
9	*Holocentridae*	Soldiers & Squirrels	29	*Monacanthidae*	File fishes & Leatherjackets
10	*Labridae*	Wrasses	30	*Ephippidae*	Batfish
11	*Lethrinidae*	Emperors fish	31	*Monodactylidae*	
12	*Lutjanidae*	Snappers	32	*Ostraodontidae*	Box
13	*Mullidae*	Goat fish	33	*Bleniidae*	Blennies
14	*Muraenidae*	Eels	34	*Gobiidae*	Gobies
15	*Pempheridae*	Sweepers	35	*Nemipteridae*	Spine cheeks
16	*Penguipedidae*	Sandpeckers	36	*Pinguipedidae*	Sand perches
17	*Pomacanthidae*	Angel fish	37	*Cirrhitidae*	Hawk fishes
18	*Pomacentridae*	Damsel fish	38		
19	*Scaridae*	Parrot fish			
20	*Scorpaenidae*	Scorpaenidae/Lion fish			

4.5.3. Sites and Fish Community Composition

4.5.3.1. Fish composition by family

This part presents the abundance of fish families recorded in DMRs in terms of their percentage composition and distribution.The members of fish from families such as *Pomacentridae*, *Acanthuridae Scaridae*, *Pomacanthidae*, *chaetodontidae* and *Labridae* were the most dominant in most sites as also observed in the 2016 survey URT 2017 and 2018 survey (URT 2018) & MPRU 2021.

4.5.3.2. Fish composition by Site – all families combined

Abundance of fish families have been presented in terms of density per 250m^2 at site. The site surveyed includes Fungu yasini North West, Fungu yasini South West,Mbuya North West, Mbudya South West, Mbudya North West, Mbudya South West, Sinda North West, Sinda South West _(02) and Bongoyo Outer Reef.

Generally, the overall average fish density in DMRs noted during this study was 229 Individual per hectare which gives an average fish biomass of 106.7 kg per hectare, this biomass is below the recommended threshold level of at least 500-600 kg per hectare, which is a scientifically suggested biomass for a functional marine ecosystem (Mclanahan et al 2015). The highest fish density in DMRs was 382 individuals per hectare at Mbudya North West while the least record was noted at Fungu yasini South West with 108kg/ha and 175 kg per hectare at Sinda North west and the least record was revealed at Sinda South West with78.5kg/ha. To establish site history on trend in terms of abundance and Biomass for monitored sites, information still inadequate/limited to establish comparisons.

4.5.3.4. Fish abundance

Statistical tests revealed no significant difference in fish abundance among sites (Kruskal-Wallis test; **P = 0.7224).** Mbudya North West reef had the highest abundance when compared to other four reefs (Figure 15). *Pomacentridae (Damsel fishes)*, Wrasses, Parrot fish, Goatfish, Surgeonfish, Butterfly fish, Soldierfish, Squirrelfish, Sweetlips and Emperor, snappers were among the species that made significant contributions.

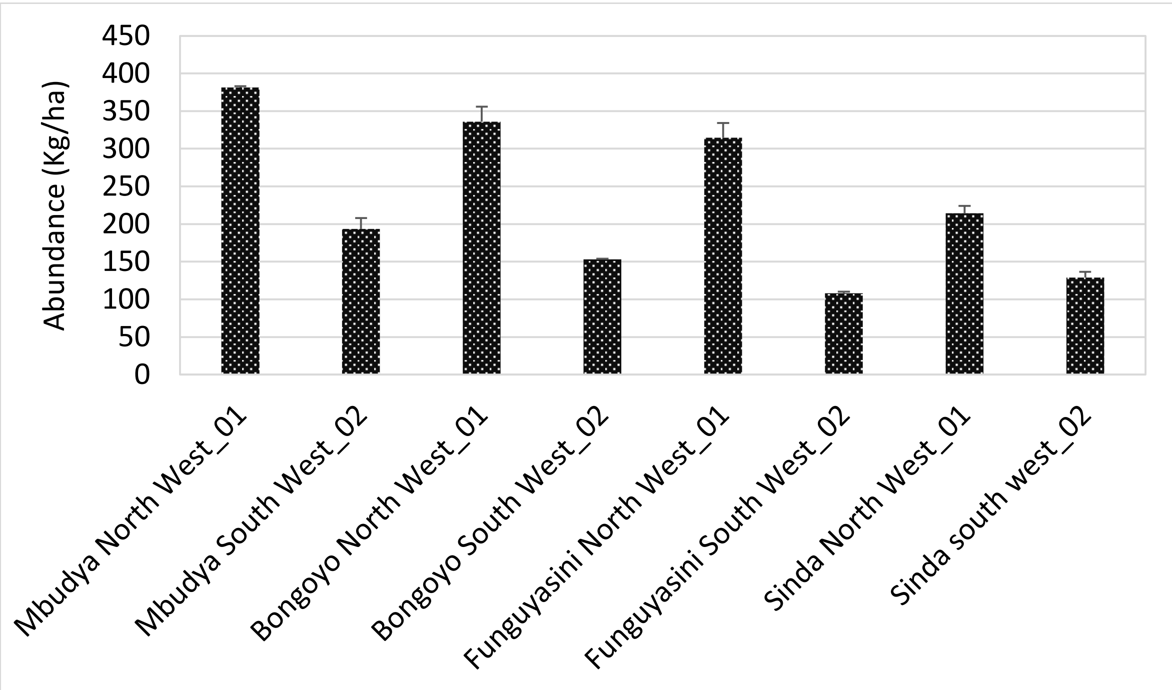


Figure 15: Fish abundance at the eight surveyed reef sites

(Source: MPRU field work in April, 2022)

4.5.3.5. Fish composition based on total biomass, fishable biomass, target biomass and non-target biomass

Target biomass (B_{TARG}) is the desired biomass of the stock, chosen to be the management target within a harvest strategy**.** The target biomass is also termed as Target Reference Points (TRP), TRP is a Biological Reference Point (BRP) also defined as the level of fishing mortality of the biomass which permits a long-term sustainable exploitation of the stock with the best possible catch. For this reason, these points are also designated as Reference Points for Management. It is characterised as the fishing level F_{target} or Biomass $B_{target.}$ The observed fishable population biomass (B) relative to the total biomass is expressed (Figure 16)

One-way Analysis of Variance (ANOVA); P = 0.0039, which is considered very significant fish biomass among sites.

Sinda North west has the highest fishable biomass due to the fact that it was dominated by large sized fishes attributing to Kg 174.47kg/ha and least at Bongoyo South west with 40.89kg/ha. The least biomass at Bongoyo South west is probably contributed by the poor water visibility encountered on the sampling date, it is among the affecting factor for visual census where it impact visibility particularly for the cryptic species and counting in crevices. Subsequently Sinda North West revealed the highest Fishable and target fish biomass contrary to Sinda South west which revealed less biomass (Figure 16)

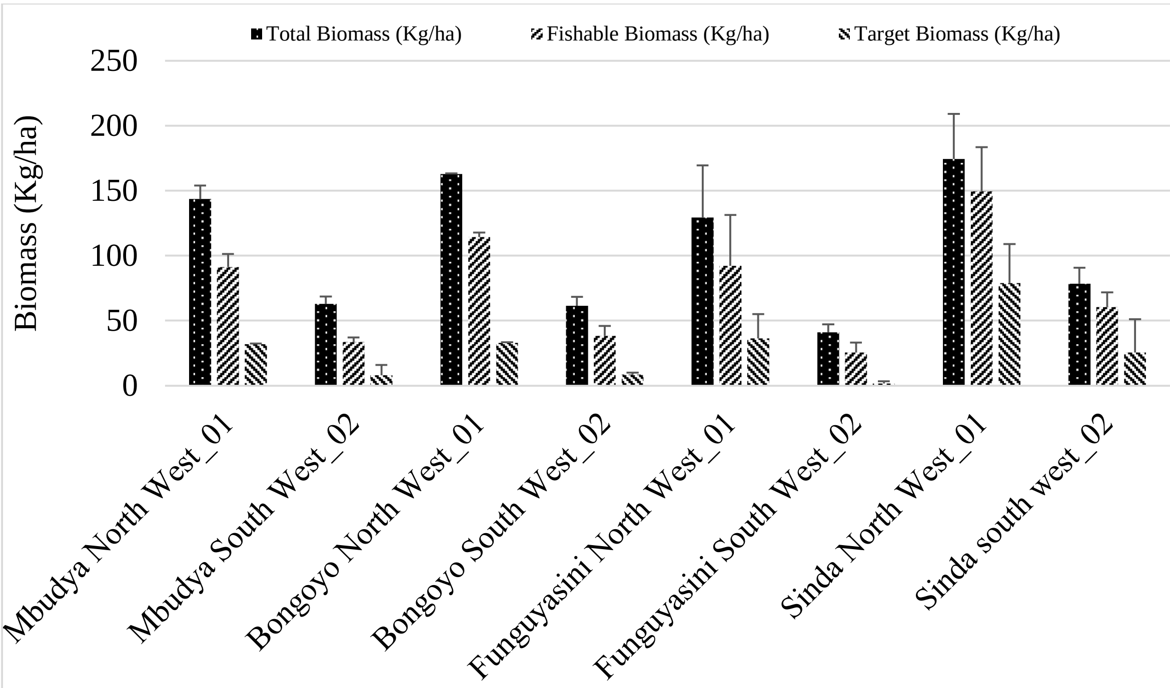


Figure 16: Average fishery exploited population biomass status expressed as total and fishable in each of the surveyed sites.

(Source: MPRU field work in April, 2022)

4.5.3.5 Fish Population and size Structure in Dar es Salaam Marine Reserves systems

The unprecedented worldwide coral reefs decline primarily is caused by a number of factors including climate change, exchange of biota, habitat degradation, and fishing activities (Hughes et al., 2003; Bell *et al*., 2006; Crabbe *et al*., 2008; Garrison and Ward, 2008). Fishing pressure and other local manipulations have significant impacts on the induced changes in abundance and spatial distribution of fish; hence other species interactions (Garrison and Link, 2000). Consequently, this has impacts on the trophic structure of an ecosystem in general.

Fish population structure was assessed in terms of abundance to various fish in size classes and families with individual fish's length overall estimated in centimetres (cm). There were 9 size classes applied for this matter including, the lowest class 3-10 cm, 10-20 cm, 20-30cm, 30-40cm, 40 – 50 cm, 50-60cm, 60-70cm, 70 - 80cm and > 80cm in size.

Fish recorded in all monitored sites in Dar es Salaam Marine Reserves their size classes was skewed to the left. The most abundant size ranging between 3-10cm and few in 10-20cm size class. This was Similar to results observed in 2016 and 2018 where more than 90% fish recorded were between size class of 3-10cm (URT 2018)

Data was tested for normality using GraphPad Insta vrt3 which automatically provided the appropriate statistical test. Kruskal-Wallis Test (Nonparametric ANOVA); The P value is < 0.0001, Population structure was considered extremely significant. Kruskal-Wallis Statistic KW = 20.569 (corrected for ties). Applying Dunn's Multiple Comparisons Test revealed the population was significant difference for 3-10 cm vs 20-30cm and not for 3-10 cm vs 10-20 cm and 10-20cm vs. 20-30cm size classes and the rest class were almost not observed.

Climatic pressure and anthropogenic activities such as unsustainable fishing is among of the cause on reduction of resources in protected areas (URT, 2021). Despite of some success, more management intervention on elimination of destructive fishing gears mainly pull nets (beach seine net) and other destructive practice which has been reported (McClanahan *et al.* 1999).

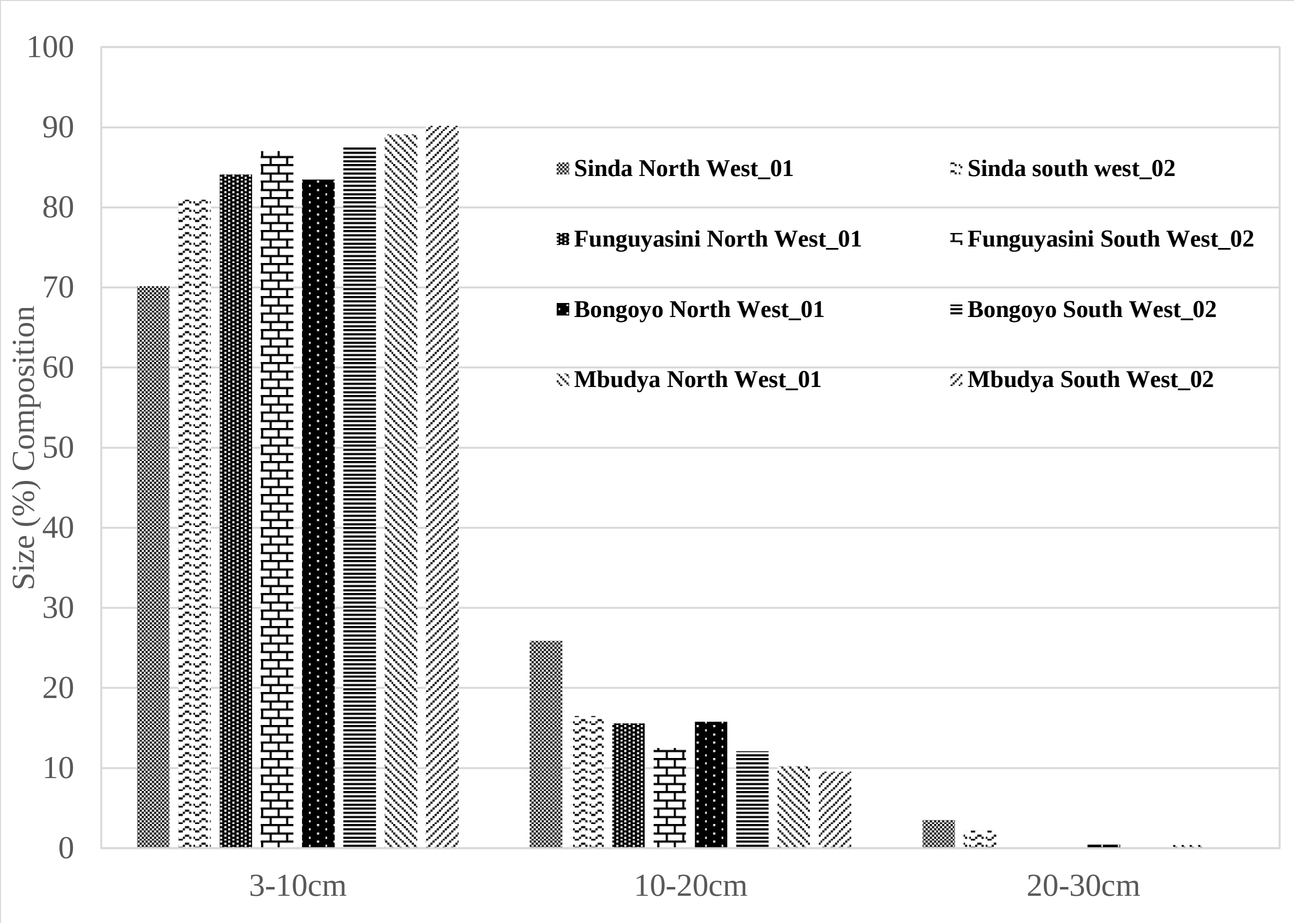


Figure 17: Fish size population structure in Dar es Salaam Marine Reserves

(Source: MPRU field work in April, 2022)

4.5.3.6. Fish abundance family percentage composition

Common reef fish families dominating in other studied areas at local and regional scale were noted. The most numerous were the damsel fish belonging to family *Pomacentridae* and juveniles of the families *Chaetodontidae*, *Labridae*, *Scaridae*, and *Acathuridae* were the most dominant by > 80% (Figure 18). Other families observed in the reefs in large numbers were *Scaridae*, *Haemulidae Holocentridae* and *Lutjanidae*. Generally, ecologically important species such as the *Balisistidae* and economic important familes such as *Carangidae*, *Scombridae* and *Serannidae* were highly depleted (See figure 18). The finding call for management interventions to effectively protect both ecological and economic importance species. The findings have an implication on high fishing pressure subjected to the resources under conservation. For the mobile resources such as reef fish, fishing pressure is high within the MPA which was revealed by remains of fishing nets and lines. Additionally due to high fishing pressure beyond the MPAs boundaries, the fish migrating outside the boundaries have a very limited chance to return to the MPA for reproduction

Statistical test revealed that, all sites surveyed are not significant different in terms of fish abundance which imply that in all sites the fisheries resources is depleted. Kruskal-Wallis Test (Nonparametric ANOVA); Kruskal-Wallis Statistic KW = 5.891 (corrected for ties); P =0.5526, which is considered as not significant.

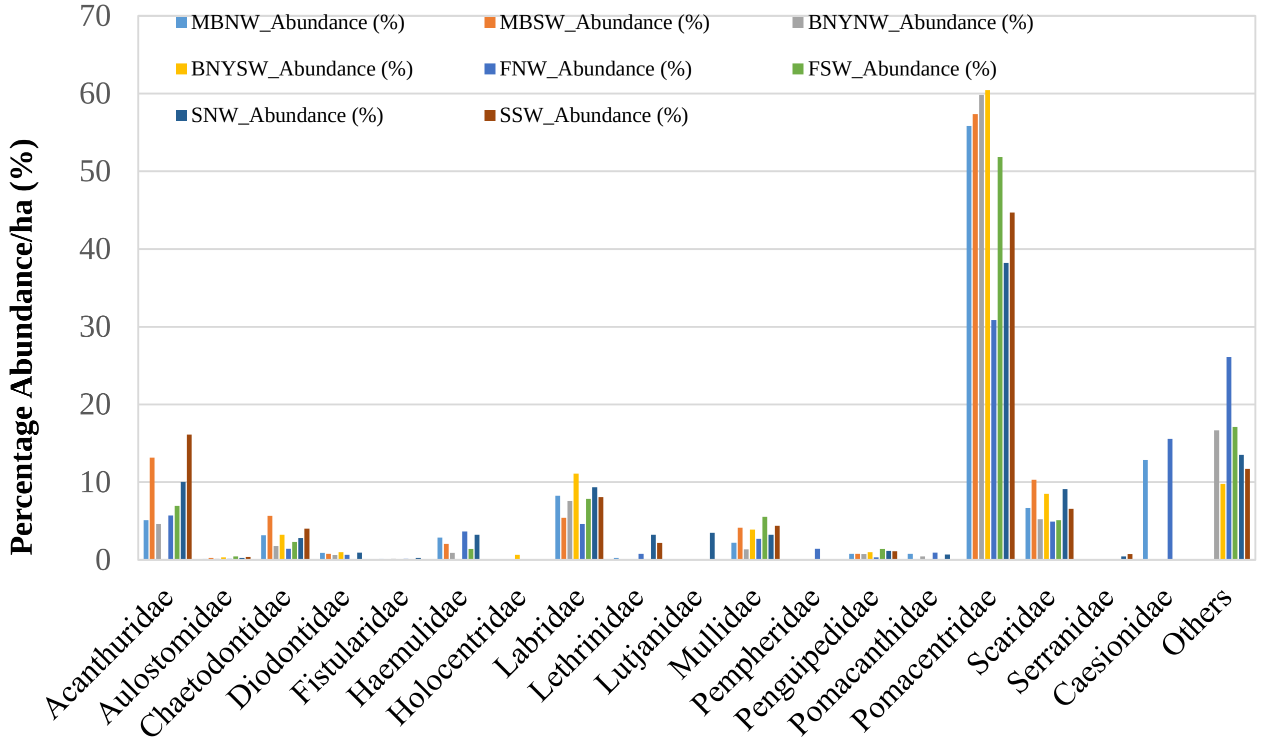


Figure 18: Fish abundance percentage proportions

(Source: MPRU field work in April, 2022)

4.5.3.7. Fish biomass family composition on studied reefs

A variety of common reef fish families found in Tanzania dominated the study sites). Fish biomass were proportional to the fish abundance where by family *Pomacentridae, Labridae and Scaridae* were the most leading biomass contributor. Juveniles of the families *Labridae*, and *Acathuridae* were the most dominant attribution to over 85% (Figure 19) fish biomass. Other families observed in the reefs in large numbers were *Haemulidae* and *Lutjanidae*. On the one hand, few individuals were recorded from predatory families of *Ballistidae, and Carangidae*. Fish biomass among sites were not significant different; Kruskal-Wallis Test (Nonparametric ANOVA); P=0.3132, considered not significant.

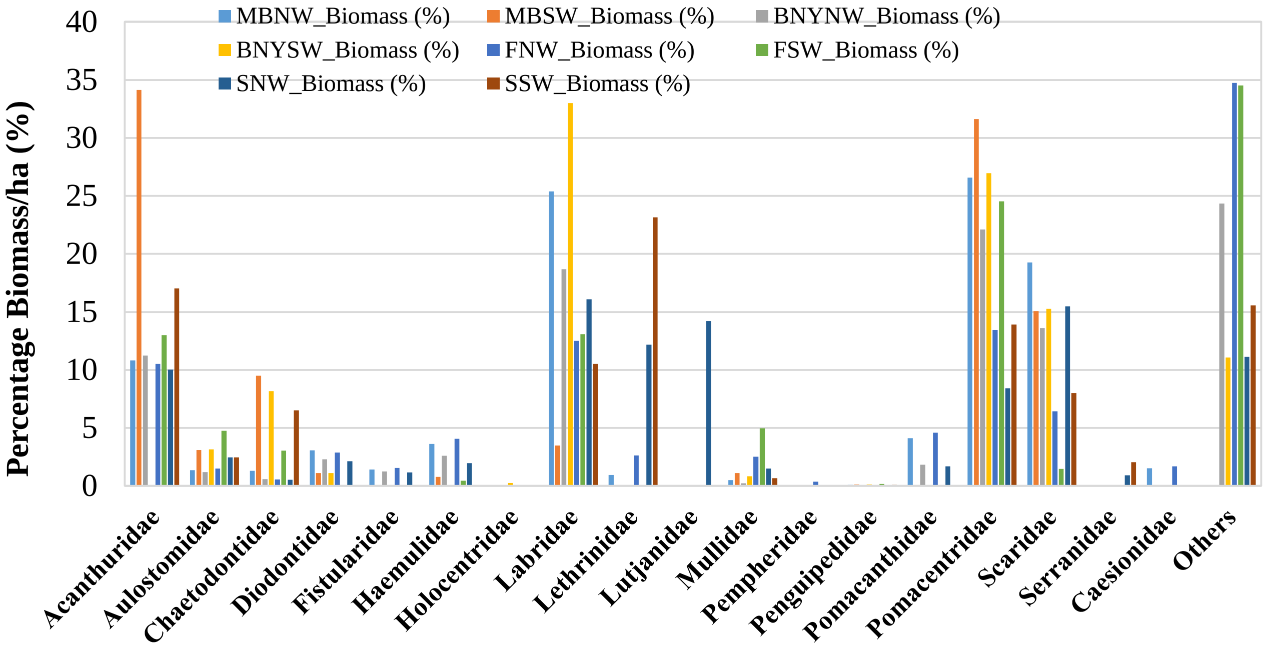


Figure 19: Fish biomass percentage proportions

(Source: MPRU field work in April, 2022)

CHAPTER FIVE

5.0. CONCLUSIONS AND RECOMMENDATIONS

5.1. Recommendations

The observed threats to the ecosystem within DMRs are those which were recommended in the previous monitoring which include the need for application of management techniques. With financial constraints some adjustment and range of monitoring is required. Monitoring team recommends the following;

i. The team recommend consistence monitoring in all MPAs to be instituted to detect changes timely as per monitoring plan

ii. Equip MPA centres with appropriate monitoring and research gears. These include compressors, diving sets, modern motorized boats and appropriate marine stationeries.

iii. To determine MPA performance establishment of effective monitoring programs in and outside MPAs to establish monitoring baseline within and beyond MPAs

iv. Recruit more staff to deal with increasing human pressure on reefs particularly strengthening MPA enforcement team to overcome fishing pressure within MPAs.

v. Establish and conduct regular training to staff to update on the current situation of their working environments. Effective law enforcement to regulate us sustainable fishing practices.

vi. Funguyasini Island Marine Reserves it coral reef cover is significantly declining, Management intervention is recommended to change the trend.

vii. Coral reef restoration programme is recommended to sites with the most low coral cover percentage to enhance the ecosystem functioning within MPAs.

REFERENCES

Bell, J.D., Ratner, Stobultzki, B.D., Oliver, J. (2006) Address the coral reef crisis in developing countries. *Ocean and Coast. Manag.* **49**: 976-985.

Bell, J.D., A. Ganachaud, P.C. Gehrke, S.P. Griffiths, A.J. Hobday, O. Hoegh-Guldberg, J.E. Johnson, R. Le Borgne, P. Lehodey, J.M. Lough, R.J. Matear, T.D. Pickering, M.S. Pratchett, A. Sen Gupta, I. Senina and M. Waycott, 2013: Mixed responses of tropical Pacific fisheries and aquaculture to climate change. *Nature Climate Change*, 3(6), 591-599.

Bianchi G (1985) Field guide to the commercial marine and brackish-water species of Tanzania, FAO Species identification sheets for fishery purposes. TCP /UR T / 4406 and FAO (FIRM) regular programme. Xiii+199

Birrell CL, McCook LJ, Willis BL, Diaz-Pulido GA (2008) Effects of benthic algae on the replenishment of corals and the implications for the resilience of coral reefs. *Oceanogr Mar Biol* Annu Rev 46:41

Brown, M. L., and C. S. Guy. 2007. Science and statistics in fisheries research. Pages 1–29 in C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland

Burke L, Reytar K, Spalding M, Perry A (2011) Reefs at Risk Revisited. World Resources Institute.

Clarke, K. R. & Gorley, R. N. (2009) Plymouth Routines in Multivariate Ecological Research - V6, PRIMER-E Ltd, United Kingdom

Crabbe, M.J., Martinez, E., Garcia C., Chub, J. Castro, L., Guy, J. (2008) Growth modelling indicates hurricane and severe storms are linked to low coral recruitment in the Caribbean. *Mar. Environ. Res.* **65**: 364-368.

Commonwealth of Australia (2009) Ecosystem resilience. Great Barrier Reef Outlook Report Great Barrier Reef Marine Park Authority.

Coral reef alliance, (2003), introduction to coral reef ecosystem, threats and solution report

Clarke, K. R. & Gorley, R. N. (2009) Plymouth Routines in Multivariate Ecological Research - V6, PRIMER-E Ltd, United Kingdom.

Franziska E. (2016) Factors affecting coral recruitment and calcium carbonate accretion rates on Central Pacific coral reefs

Garpe & Öhman (2003) Coral and fish distribution patterns in Mafia Island Marine Park, Tanzania: Fish-habitat interactions. *Hydrobiologia* **498:** 191–211, Garcia J.R. and Aliño P.M. (2008) Factors influencing coral recruitment patterns in the Sulu Sea marine corridors: Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008

Garrison, V. and Ward, G. (2008) Storm-generated coral fragments - A viable source of transplants for reef rehabilitation. *Biol. Conserv.* **141**: 3089-3100.

Gilmour JP, Smith LD, Heyward AJ, Baird AH, Pratchett MS (2013) Recovery of an isolated coral reef system following severe disturbance. Science 340:69–71

Graham NAJ, Nash KL, Kool JT (2011) Coral reef recovery dynamics in a changing world. Coral Reefs 30:283–294

Guard, M. and Masaiganah, M.. 1997. Dynamite fishing in southern Tanzania, geographical variation, intensity of use and possible solution. Mar. Pollut. Bull 34:758–762.

Heron SF, Maynard JA, van Hooidonk R, Eakin CM (2016) Warming Trends and Bleaching Stress of the World's Coral Reefs 1985–2012. Sci Rep 6:38402

Hoegh-Guldberg O. (1999). Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research 50, 839–866.

Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R., Folke, C., Hoegh-Guldberg, O., Jackson, J.B.C., Kleypas. J., Lough, J.M., Nystrom, P.M., Palumbi, S.R., Pandolfi, J.M., Rosen, J.M. and Roughgarden, J. (2003) Climate Change, Human Impacts, and the Resilience of Coral Reefs. *Science* **301**: 929-933.

Hughes TP, Anderson KD, Connolly SR, Heron SF, Kerry JT, Lough JM, Baird AH, Baum JK, Berumen ML, Bridge TC, Claar DC, Eakin CM, Gilmour JP, Graham NAJ, Harrison H, Hobbs J-PA, Hoey AS, Hoogenboom M, Lowe RJ, McCulloch MT, Pandolfi JM, Pratchett M, Schoepf V, Torda G, Wilson SK (2018a) Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. Science 359:80–83

Julius P, Ngoile M & Mfilinge, P (2016) Temporal and Spatial variability in Reef fish Density and Biomass within the Dar es Salaam Marine Reserve System, Tanzania. WIO Journal of Marine Science 15 (1) 69-78.

Lieske E & Myers R (2002) Pocket guide to Coral reef fishes, *Princeton University Press, New Jersey*. 400pp

Machano, H (2011) Status of Coral Reefs in Rufiji, Mafia and Kilwa,Tanzania WWF Rufiji Mafia Kilwa Seascape Programme.Coral Reef Vulnerability Monitoring Report20pp. WWF Dar es Saalam.

Obura D, (2004). Biodiversity surveys of the coral reefs of the Mnazi Bay Ruvuma Estuary Marine Park (IUCN EARO-Nairobi) vi+72pp

Obura, D. O. (2005) Resilience and climate change: lessons from coral reefs and bleaching in the Western Indian Ocean. Estuar Coast Shelf S 63:353-372.

Obura D (2007) Baseline Assessment of the coral reef ecosystems of Mafia and Songosongo-Kilwafor vulnerability to climate change. Part of the WWF US/GEF Coastal Resilience to Climate change project. Report submitted to WWF 30pp

Obura, D (2009) Resilience to climate change of coral reefs of Mafia and Songosongo, central Tanzania, Turbidity and fisheries as driving forces. Part of the WWF US/GEF Coastal Resilience to Climate Change Projectreport 45pp, WWF Dar es Saalam.

McClanahan TR, Muthiga NA, Kamukuru AT, Machano H, Kiambo RW (1999) The effects of marine parks and fishing on coral reefs of northern Tanzania. Biological Conservation 89: 161-182

Kamukuru, A.T. 1998. Assessment of the biological status of the Dar es Salaam Marine ReservesSystem off the Kunduchi coast, Tanzania. Western Indian Ocean Marine ScienceAssociation(WIOMSA), Zanzibar and IOC/UNESCO Paris, France. 31pp.

Mohammed, M.S, Muhando CA. and Machano H. 2000. Assessment of Coral Reef Degradation in Tanzania: Results of Coral Reef Monitoring in 1999. *In:* David Souter, David Obura and Olof Linden. (eds)

McClanahan, T. R. &Shafir, S. H. (1990) Causes and consequences of sea urchin abundance and diversity in Kenyan coral lagoons. *Ecological* 823: 362-370.

Radomski, PJ., and Goeman T J. 1996. Decision making and modeling in freshwater sport-fisheries management. Fisheries 21(12):14–21.

Kohler KE, Gill SM (2006) Coral Point Count with Excel extensions (CPCe: A visual Basic Program for the determination of coral and substrate coverage using random point count methodology. Computer and Geosciences, doi: 10.1016/j. Cageo. 2005.11.009.

URT (2016) Coral Reef Habitats in Marine Protected Areas InTanga, Dar Es Salaam, Mafia Islandand Mtwara,Tanzania, June - Dec 2016. Coral Reeef Monitoring report 72pp.

Julius P, Ngoile M & Mfilinge, P (2016) Temporal and Spatial variability in Reef fish Density and Biomass within the Dar es Salaam Marine Reserve System, Tanzania. WIO Journal of Marine Science 15 (1) 69-78.

Kamukuru, A.T. 1998. Assessment of the biological status of the Dar es Salaam Marine ReservesSystem off the Kunduchi coast, Tanzania. Western Indian Ocean Marine ScienceAssociation(WIOMSA), Zanzibar and IOC/UNESCO Paris, France. 31pp.

Machano, H (2011) Status of Coral Reefs in Rufiji, Mafia and Kilwa,Tanzania WWF Rufiji Mafia Kilwa Seascape Programme.Coral Reef Vulnerability Monitoring Report20pp. WWF Dar es Saalam.

Mohammed, M.S, Muhando CA. and Machano H (2000). Assessment of Coral Reef Degradation in Tanzania: Results of Coral Reef Monitoring in 1999. *In:* David Souter, David Obura and Olof Linden. (eds)

McClanahan, T. R. &Shafir, S. H. (1990) Causes and consequences of sea urchin abundance and diversity in Kenyan coral lagoons. *Ecological* 823: 362-370.

McClanahan TR, Muthiga NA, Kamukuru AT, Machano H, Kiambo RW (1999) The effects of marine parks and fishing on coral reefs of northern Tanzania. Biological Conservation 89: 161-182

ICRI 2th General Meeting (2014), Coral reef monitoring in Tanzania waters

IUCN, (2008), Coral reef: Sriyanie Miththapala, Coastal ecosystem series, vol.1

Julius P, Ngoile M & Mfilinge, P (2016) Temporal and Spatial variability in Reef fish Density and Biomass within the Dar es Salaam Marine Reserve System, Tanzania. WIO Journal of Marine Science 15 (1) 69-78.

Pagu Julius , Magnus Ngoile, Benaiah Benno, Milali Machumu, Nsajigwa Mbije (2021) Assessment of reef fish and benthic cover of the North and South Dar es Salaam Marine Reserves system before the 2016 El Niño. WIO Journal of Marine Science 20 (2) 2021 1-10

Kohler KE, Gill SM (2006) Coral Point Count with Excel extensions (CPCe: A visual Basic Program for the determination of coral and substrate coverage using random point count methodology. Computer and Geosciences, doi: 10.1016/j. Cageo. 2005.11.009.

Machano, H (2011) Status of Coral Reefs in Rufiji, Mafia and Kilwa,Tanzania WWF Rufiji Mafia Kilwa Seascape Programme. Coral Reef Vulnerability Monitoring Report 20pp. WWF Dar es Saalam.

McClanahan TR, Muthiga NA,Mamukuru AT, Machano H & Kiambo RW (1999) The effects of Marine Parks and Fishing on coral reefs of Northern Tanzania. *Biological Conservation 89: 161-182*

McClanahan, T. R. &Shafir, S. H. (1990) Causes and consequences of sea urchin abundance and diversity in Kenyan coral lagoons. *Ecological* 823: 362-370.

McClanahan, T., Ateweberhan, M., Muhando, C., Maina, J. and Mohamed, M.S. (2007a). Climate Change and Spatio temporal Variation in Seawater Temperature Effects on Coral Bleaching and Mortality in East Africa. Ecological Monographs

McClanahan TR (2015) Biogeography versus resource management: how do they compare when prioritizing the management of coral reef fish in the south-western Indian Ocean? Journal of Biogeography. **42**: 2414–2426.

McClanahan, T., Ateweberhan, M., Graham, N., Wilson, S.K., Ruiz-Sebastian, C., Guillaume, M.M. and Bruggenmann, J.H. (2007b). Western Indian Ocean coral communities: Bleaching responses and susceptibility to extinction. Marine Ecology Progress Series, 337:1-13

Melita S. (2004), Review of the village Monitoring Team's, Coral reef Monitoring programme in Tanga Region

Mohammed, M.S, Muhando CA. and Machano H. 2000. Assessment of Coral Reef Degradation in Tanzania: Results of Coral Reef Monitoring in 1999. *In:* David Souter, David Obura and Olof Linden. (eds)

Muhando, C.A. (2009), Coral reef Monitoring in Tanzania: an analysis of the last 20 years. Western Indian Ocean J. mar. Scl. Vol 8. 2:203-214.

Muhando, C.A., Kuguru, B.L., Wagner, G.M., Mbije, N.E. and Ohman, M.C. (2002). Environmental effects on the distribution of corallimorpharians in Tanzania. Ambio 31:558-561.

Muhando C.A. and Mohammed S.M. (2002). Coral reef benthos and fisheries in Tanzania before and after the 1998 coral bleaching and mortality event. Western Indian Ocean J. Mar. Sci., 1:43-52.

Muhando, C.A. 2011. Biophysical Features in the Northern Tanga Marine Reserves, Tanzania. Marine Parks and Reserves Unit, Dar es Salaam, Tanzania. vi +38 pp.

Obura D, (2004). Biodiversity surveys of the coral reefs of the Mnazi Bay Ruvuma Estuary Marine Park (IUCN EARO-Nairobi) vi+72pp

Obura D (2007) Baseline Assessment of the coral reef ecosystems of Mafia and Songosongo-Kilwa for vulnerability to climate change. Part of the WWF US/GEF Coastal Resilience to Climate change project. Report submitted to WWF 30pp

Obura, D (2009) Resilience to climate change of coral reefs of Mafia and Songosongo, central Tanzania, Turbidity and fisheries as driving forces. Part of the WWF US/GEF Coastal Resilience to Climate Change Project report 45pp, WWF Dar es Saalam.

Obura D, Gudka M, Rabi AF, Gian BS, Bijoux J,Freed S, Maharavo J, Mwaura J, Porter S, Sola E, Wickel J, Yahya S and Ahamada S (2017) Coral reef status report for the Western Indian Ocean.Global Coral Reef Monitoring Network (GCRMN)/International Coral Reef Initiative (ICRI).pp 144.

Pandolfi JM, Bradbury RH, Sala E, Hughes TP, Bjorndal KA, Cooke RG, McArdle D, McClenachan L, Newman MJH, Paredes G, Warner RR, Jackson JBC (2003) Global trajectories of the longterm decline of coral reef ecosystems. Science.vol.dddd

Radomski, PJ., and Goeman T J. 1996. Decision making and modeling in freshwater sport-fisheries management. Fisheries 21(12):14–21.

Radomski, PJ., and Goeman T J. (1996). Decision making and modeling in freshwater sport-fisheries management. Fisheries 21(12):14–21.

Samoilys MA, Halford Aand Osuka K (2019) Disentangling drivers of the abundance of coral reef fishes in the Western Indian Ocean. *Journal of Ecology and Evolution.***9:**4149–4167. DOI: 10.1002/ece3.5044

Samoilys M and Carlos G (2000). Determining methods of underwater visual census for estimating the abundance of coral reef fishes. *Environmental Biology of Fishes* **57**: 289–304.

Samoilys M., Horrill C., Kalombo H, Kabamba J, and S. Wells. (2007b). Coral reefs and mangroves: maintaining ecosystem health. In: Wells, S, Makoloweka, S, and Samoilys M.(eds.) Putting Adaptive Management Into Practice: Collaborative Coastal Management in Tanga, northern Tanzania. IUCN Eastern Africa Regional Office. pp: 77-102.

Sheppard CRC, Harris A, Sheppard ALS (2008) Archipelago-wide coral recovery patterns since 1998 in the Chagos Archipelago, central Indian Ocean. Mar Ecol Prog Ser 362:109–117

Souter, D. and Lindén, O (2005) (eds.) Coral Reef Degradation in the Indian Ocean. Status Report

Suleiman, M., Muhando, C., Machano, H., Daniels, C., Tyler, E., Jiddawi, N. and Yahya, S. (2005) Status of Coral Reefs in Tanzania: In Souter, D. and Lindén, O. (2005) Coral Reef Degradation in the Indian Ocean. Status Report.

Tanga Coelacanth Marine Park, General management plan (2011) United republic of Tanzania

United republic of Tanzania (2018), Coral reef status report for Tanzanian Marine Protected Area. 85pp

URT (2016) Coral Reef Habitats in Marine Protected Areas InTanga, Dar Es Salaam, Mafia Island and Mtwara,Tanzania, June - Dec 2016. Coral Reef Monitoring report 72pp.

URT (2021) Annual progress report for Tanga Coelacanth Marine Park.

van Hooidonk, R., Maynard, J., Tamelander, J., Gove, J., Ahmadia, G., Raymundo, L., Williams, G., Heron, S.F., Planes, S. (2016) Local-scale projections of coral reef futures and implications of the Paris Agreement. Sci Rep-Uk 6.

Wagner, G M. (2004). Coral Reefs and Their Management in Tanzania. Western Indian Ocean J. Mar. Sci. Vol. 3, No. 2, pp. 227–243, 2004.

Wild, C., Hoegh-Guldberg, O., Naumann, M.S., Colombo-Pallotta, M.F., Ateweberhan, M., Fitt, W.K., Iglesias-Prieto, R., Palmer, C., Bythell, J.C., Ortiz, J.C., Loya, Y., van Woesik, R. (2011) Climate change impedes scleractinian corals as primary reef ecosystem engineers. Mar Freshwater Res 62, 205- 215.