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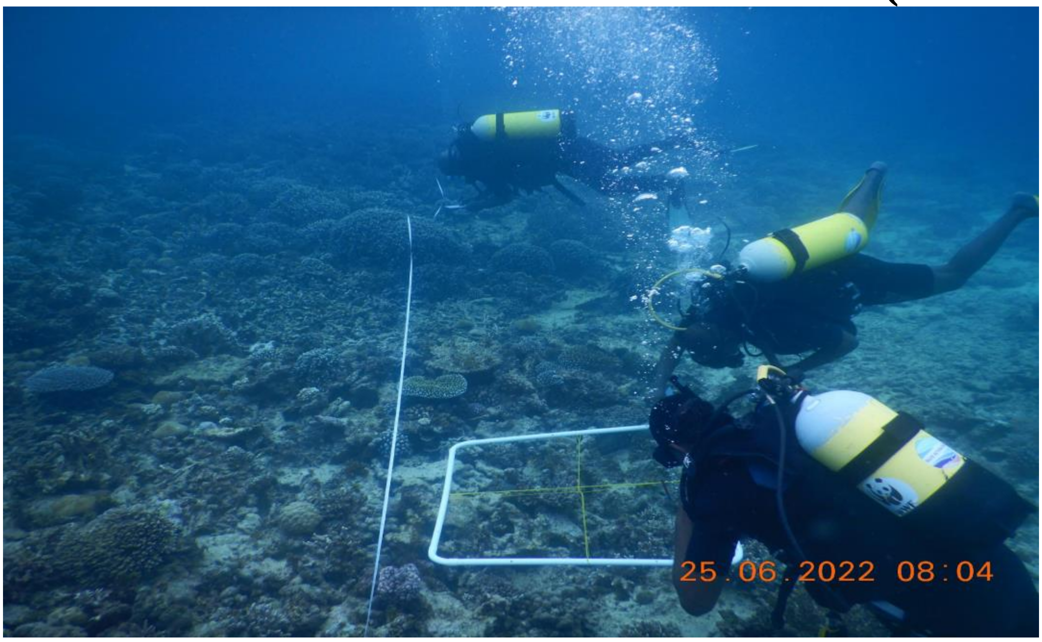


# CORAL REEF AND GROUPERS STATUS REPORT IN MAFIA ISLAND MARINE PARK

## NOVEMBER 2022

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BLUE ACTION FUND

MARINE PARKS AND RESERVES TANZANIA

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# EXECUTIVE SUMMARY

World Wide Fund for Nature Tanzania Country Office (WWF TCO) through Marine Programme is implementing a five-year project titled "*Strengthening Marine Protected Areas Management in Rufiji, Mafia and Kilwa Districts in Tanzania*" with funding from the Blue Action Fund (BAF), commonly abbreviated as RUMAKI-BAF project. This project effectively started its activities implementation in August, 2019. The coral reefs monitoring activity is linked to the project Output zero - monitoring of coral reef and groupers within Mafia Island Marine Park (MIMP) and also supports work package number one which is described as Improved management effectiveness of Mafia Island Marine Park (MIMP), with activities to be implemented outlined under Sub – outputs (Table 1). The project has so far implemented one activity related to coral reef whereby a consultancy assignment commissioned to two Marine Scientists enabled to conduct a study and produces a report titled *"Establishment of baseline scientific information on reef fish biomass, abundance and population structure in selected sites of Mafia Island Marine Park, Tanzania"* in May 2021. The current monitoring repeated the same site and methodology to assess coral reef status and trend in the ten coral reef sites monitored in a 2018 survey and to establish a grouper baseline in the given sites.

Methodology applied was per the Global Coral Reef Monitoring Network (GCRMN). Standard benthic cover data was assessed using the 10 metre Line intercept Transect (LIT) method supplemented with video /photo transect using an underwater camera (Nikon COOLPIX W300). A minimum of six transects were done per site. Corals were identified to genus level with respective data collected and imported onto computers on the same day.

Coral size-class distribution was sampled on selected coral genera (23) -along 25 x 1m belt transects, laid in coral-dominated spots within a sampling block with two minimum transects per site. A total of 12 quadrats with 1 x 1 $m^2$ size were sampled at each site for coral recruit and juvenile, with six quadrats placed per transect, distributed every 5m starting at 0m, 5m, 10m, 15m, 20m, 25m. Coral recruit counts were made using 1m sq quadrat. All recruits (corals less than 10cm in longest length) were counted by genus in three (3) size-classes (0-2.5cm, 2.5-5cm, 5-10cm). Slates were marked with the three (3) size classifications and used to estimate which size classes they were in.

Macro invertebrates were counted in a 10m x 2m belt transect using the same transect line (LIT) used for benthic cover sampling. A minimum of six transects per site were sampled.

Underwater visual census (UVC) technique was used for estimating grouper abundance, population structure and for biomass calculations. Fish were sampled in a 100m x 5m belt transects, and fish

were attributed to one of eight (8) size classes: 3-10cm, 10-20cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm and > 80cm.

Training sessions for capacity building to new MPRU certified divers on monitoring protocols and both coral and fish identification skills were implemented. These sessions were facilitated by Mr. Pagu Julius, the Team Leader and an experienced Coral and Fish expert. Training sessions included Coral and Fish identification techniques and monitoring protocols particularly following the Global Coral Reef Monitoring Network (GCRMN) standards.

The current status of overall coral reef cover (average of the percentage cover) revealed an increase in cover from 40.42% in 2018 to 42.19% in 2022 with an average of a 1.77% coral cover increase across the ten monitored sites, over the past 4 years The reefs with their respective percentage coral cover changes are shown in details in chapter four: For other benthic categories, an increase of coralline algae of 1.02 % was observed, as compared to the study in 2018 which implies on the increase of substrate for coral larvae settlement and recruitment while there is decline on macro algae across all ten monitoring sites by 12.3% when compared to the last coral reef monitoring in 2018.

The results of adult coral size class indicate that most of the reefs have numerous colonies within the size class of 21-40 cm. Four reefs (Nyamalile North, Nyamalile South, Kitutia and Msumbiji) have many corals with a smaller size class of 11-20cm above 200 colonies per 50msq (1meter *25meter belt transect * 2 transect). Msumbiji and Chawe have acute cover at size class 160-320 cm but few number of colonies which indicates that the main contributor on coral cover were the genus *Galaxea* and *Echinopora*. The coral genus has a growth characteristic of covering large areas. Moreover, the reefs of Chawe, Msumbiji, and Utumbi were dominated by larger 160-320cm colonies, and at Kisiwa kikubwa and Kitutia by 80-160cm colonies. Nyamalile South and Nyamalile North recorded coral areas largely dominated by corals in the early adult stage (21-40cm) in size. The coral class size indicates that Sites dominated by smaller size classes can easily be affected by bleaching events and other associated stressors such as pull net fishing practices compared to larger size classes while being relatively stable and their management efforts should be different accounting on their sensitivity and stability in the ecosystem.

The average recruits and juveniles across all sampling sites in MIMP recruits was 6.8 colonies / $m^{2}$. The result revealed an increase of 51% compared to the average of 4.5 colonies observed during the survey conducted in 2018. Currently, the highest recruitment was observed at Nyamalile North site with a mean of 13.3 colonies / $m^{2}$, followed by Msumbiji 11.3 colonies / $m^2$ and Chawe 9.8 colonies /

$m^2$ and the lowest density of 2.6 observed at Kisiwa kikubwa**.** The genera of *Fungia, Seriatopora* and *Acropora* colonies are the most that contribute the overall and across the recruit – juveniles size ranges. Current findings suggest high coral reef recruitment potential as compared to 2018 coral recruitment status.

Invertebrates of commercial and ecological importance were monitored at the ten monitoring sites. Results for sea urchin abundance, which is used as an indicator of a stressed reef, Nyamalile north had the highest abundance with 11individuals per $20m^2$, followed by Nyamalile south with 8 individuals per $20m^2$ and Mange reef with 4 individuals per $20m^2$. Sites such as Chawe and Utumbi where sea urchin were not observed, their respective predator reef fish including *Labridae* was very high which imply sea urchin was reduced in the ecosystem by predation. Overall the sea urchin abundance recorded in this survey was low (Mean $\pm$ SE) 5.2 $\pm$ 1.3 average per transect compared to 5.8 $\pm$ 2 recorded in the 2018 survey. However in both survey invertebrate abundance was dominated by sea urchin. This may indicate monitored sites are more disturbed which resulted in decline in coral cover status.

Grouper fish abundance and biomass was established in all monitored sites, Yuyuni reef revealed the highest abundance with a total of 20 individuals and all were juvenile, Kitutia reef ranked second the highest population with 11 individuals of which all were juvenile eight with 3cm-10cm size range, two individuals with 10-20cm size range and one with 20-30cm size ranges. Third was Mange reef with eight individuals in 3-10cm, 10-20cm and 20-30cm size classes with 2, 2 and 4 individuals respectively. Utumbi reef was the fouth in terms of grouper abundance with seven individuals recorded in 10-20cm, 20-30cm and 30-40cm size classes containing 2, 3 and 2 individuals respectively. Two groupers were recorded at Chawe reef falling in 3-10cm size class revealing both were juveniles likewise at Kifinge reef. One individual was recorded at Msumbiji in a 20-30cm size class. At Nyamalile north one grouper was recorded in 10-20size class and no grouper were recorded at Kisiwa kikubwa  and Nyamalile south reef. Overall it appears all groupers were in the 4 smallest size categories, no fish were recorded in the top 50% of size classes (greater than 40cm). This may be concerning that only small groupers were found.

For biomass status, Utumbi reef recorded the highest grouper biomass with 65.3kg per ha but ranked third on grouper abundance. The highest biomass record was attributed by the largest size class of 30-40cm which were not recorded in any of the sites, additionally the lowest size class of 3-10cm were not recorded at the reef which reflect all groupers recorded at the site were relatively larger. Yuyuni reef which recorded the highest abundance with 20 individuals total observations as it ranked fouth on biomass after Utumbi, Mange and Kitutia reef. Similarly Kitutia reef which ranked second for grouper abundance ranked third on biomass 11.6kg/ha after Mange reef 32.9kg/ha and Utumbi reef 65.3kg/ha. Msumbiji ranked fifth with 7.4kg/ha, Sixth Chawe 0.27kg/ha and last Nyamalile north with 0.13kg/ha while no biomass recorded at Kisiwa kikubwa and Nyamalile South similar reflecting similar record as for abundance. The current status on groupers at these sites shows a general trend on increase of grouper abundance particularly on the juvenile size class in comparison to previous surveys which reflect similar trend on biomass. The results suggest that, there is high potential for abundance and biomass improvement of the commercial important fish species if effective management interventions are instituted.

The overall trend of the coral reef survey suggests that there is an overall increase in the coral cover, the coral reef class indicates most dominant size colonies are within the size class of 21-40 cm across all sites. The results of coral recruits revealed an increase of 16% in the current survey compared to 2018 survey, an observation which indicates good coral recruitment potential. The invertebrate's trend, particularly the overall sea urchin abundance recorded in this survey, was less than that recorded in the 2018 survey as given in figures above. General fish population structure revealed a declining trend with an increase in grouper juvenile abundance, which implies overfishing of commercially important fish species in the Park and further details are discussed in chapter four.

The current study concludes the followings:

i. Coral cover is highest with over fifty percent at Kitutia, Utumbi, Msumbiji and Chawe reefs with below average on hard coral cover at Nyamalile North, Nyamalile South and Kisiwa kikubwa reefs with an overall increase of 1.77% when compared to previous monitoring surveys in 2018.

ii. The overall hard coral cover in MIMP increased slightly by 1.8% compared to the previous 2018 survey. The average percentage cover was approximately 42.19% ± 6.5 in 2022 whereas that of 2018 was 40.42%.

iii. There is an overall increase for the substrate "rubble" of 2.6% across all monitored sites, However, except Msumbiji, Chawe and Nyamalile north there was a decrease in rubble

iv. There was a decline on macro algae across all ten monitoring sites by 12.3% when compared to the last coral reef monitoring in 2018. This could be attributed by the increase of fishes particularly herbivores as observed in this study.

v. It was observed an increase of coralline algae by 1.02% as compared to the study in 2018 which implies on the increase of substrate for coral larvae settlement category at across all ten monitoring sites.

vi. There is increase of overall recruits and juveniles for all sites (6.8$\pm$ SE) per $m^2$ the result revealed an increase by 51 % to the average of (4.5$\pm$SE) colonies observed during the survey conducted in 2018 (URT 2081). This has been contributed by many factors including the increase in coralline algae, which is the conducive for coral larvae settlement.

*vii.* Grouper fish populations are dominated by juvenile *Cephalopholis argus* (Peacock Groupers) in most of the monitored sites except at Yuyuni which was dominated by *Cephalopholis nigripinnis.*

Some management recommendations from this study (further explained in the report narrative) are:

- Unsustainable fishing which was also observed operational compliance and law enforcement section is recommended to be strengthened
- Climate change induced impact to MIMP resources Climate adaptation and mitigation such as sustainable coral reef restoration initiatives are recommended to minimize the consequences.
- Sites with positive trends on coral cover has revealed their resilience to both threats encountered and the management intervention is recommended to sites which are most sensitive to both threats which revealed decline on coral cover under current survey.
- Coral reef restoration is recommended as a human intervention to restore the ecosystem as intended. Coral reef restoration with emphasis on genus which are resistant to bleaching are recommended to enhance the ecosystem under conservation.
- Legal management tools require strengthening to support law enforcement efforts. Currently the Marine Parks and Reserves Unit No 29 of 1994 and the respective Mafia Island Marine Parks regulations of 2006 are too weak for the deterrence on unsustainable fishing within the MPA. The present circumstances (weak Act & Regulations), both legal management tools require substantial reviews, amendments and updates to enable effective enforcement.
- Strengthening law enforcement and compliance for deterrence and elimination of unsustainable fishing within the MPA.
- Strengthen Stakeholders engagement on conservation of MPAs resources to supplement MPA staff shortage and create a sense of community ownership to MIMP as well as strengthening co-management.

- Conservation awareness creation remains the best option on resources management with MIMP where involvement of all resources users i.e. fishers, tour operators, hoteliers is critical to reveal the resource value and appreciate its sustainability.
- Coral reef in MIMP has indicated the highest potential on resilience for both anthropogenic and natural threat hence full protection should be implemented to enhance natural ecosystem recovery.
- Fish communities are depleted throughout the system. Fisheries controls will be essential for long term sustainability and productivity of the fisheries in MIMP.
- Strengthening the efforts and needs of increasing surface area of well-managed MPAs envisaged in SDG 14 Target 2 and Aichi Target 11 by 2020, with a clear long term goal that the areas should increase to the broadly accepted 30% surface area under MPAs target by 2030.

**TABLE OF CONTENTS**

**LIST OF FIGURES**

**LIST OF TABLES**

**LIST OF PLATES**

**List of Acronyms and Abbreviations**

| | |
|---|---|
| AIMS | Australian Institute of Marine Sciences |
| ANOSIM | Analysis of Similarities |
| ASCLME | Agulhas - Somali Current Large Marine Ecosystem |
| BAF | Blue Action Fund |
| BRP | Biological Reference Point |
| BTLS | Biomass trophic level spectra |
| CFMA | Collaborative Fisheries Management Area |
| CHICOP | Chumbe Island Coral Park |
| CORDIO | Coastal Oceans Research and Development – East Africa |
| COTS | Crown-of- thorns starfish |
| CRTR | Coral Reef Targeted Research |
| DMRs | Dar es Salaam Marine Reserve systems |
| GMP | General Management Plan |
| 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 |
| MIMP | Mafia Island Marine Park |
| MDS | Multi-dimensional Scaling |
| MPA | Marine Protected Area |
| MPAs | Marine Protected Areas |
| MBREMP | Mnazi Bay Ruvuma Estuaries Marine Parks |
| MPRU | Marine Park and Reserve Unit |
| NEMC | National Environmental Council |
| PRIMER | Plymouth Routines in Multivariate Ecological Research |
| PADI | Professional Association of Diving Instructors |
| RUMAKI | Rufiji-Mafia-Kilwa |
| SCUBA | Self-Contained Underwater Breathing Apparatus |
| SSI | SCUBA School International |
| SWIOFish | South West Indian Ocean Fisheries Governance and Shared growth |
| TACMP | Tanga Coelacanth Marine Park |
| TAFIRI | Tanzania Fisheries Research Institute |
| TCO | Tanzania Country Office for WWF |
| TzCRTF | Tanzania Coral Reef Task Force |
| URT | United Republic of Tanzania |
| UVC | Underwater Visual Census |
| VLC | Village Liaison Committee |
| WIO | Western Indian Ocean |
| WIOMSA | Western Indian Ocean Marine Sciences Association |
| WWF | World Wildlife Fund |

| | **Definition of Terms** |
|---|---|
| Belt-Transect Method | 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 the 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. |

**CHAPTER ONE**

## 1.0 INTRODUCTION

Marine Parks and Reserves Unit (MPRU) is one government agency under the Ministry of Livestock and Fisheries and is responsible for management of the fifteen marine reserves and three Marine Parks which are distributed in the four Marine Protected Areas (MPAs) stations. MPRU staff involved in marine resources monitoring are stationed in the four MPAs centres that include:

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

The capacity of MPRU staff to carry out benthic coral reef fisheries resources monitoring surveys has been improving overtime with the majority of the monitoring staff members participating regularly in field work monitoring and also involved in other programmes outside MPRU. This has been improving their level of monitoring skills. MPRU now has more than ten Certified Open Water Divers who routinely conduct coral reef monitoring in their respective MPAs. However, due to staff shortage, the major benthic coral reef surveys are organized by including all diving team staff in the respective survey. The entire team comprises staff from the department of research and monitoring, licensing and law enforcement alongside staff from the four MPAs. MPRU was among the implementing institutions in the SWIOFish project in which benthic coral reef monitoring was among the project components. This allowed MPRU to conduct bi-annual benthic coral reef monitoring in all four MPAs from 2016 to 2018. Therefore the MPRU has a baseline from this period that can be used to identify trends.

Coral reef and fish 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 reefs, and for guiding management decisions and strategic adaptive management.

There is also additional coral reef survey data that was conducted by two Marine Scientists under a consultancy through WWF Tanzania, Marine Programme under RUMAKI-BAF project. This assignment produced a report titled *"Establishment of baseline scientific information on reef fish biomass, abundance and population structure in selected sites of Mafia Island Marine Park, Tanzania"* submitted in May 2021. The results indicated that the benthic form in the surveyed reef sites was highly diversified ranging from live coral cover, algae, sea grasses, dead corals, rubbles and others conforming to two monitoring studies done in the previous recent years. Fish abundance was observed to be a non-significant difference among sampled sites as detailed under chapter. It was dominated by members of small sized non-target fish in all sites that included the families *Labridae* (Wrasses) *Pomacentridae* (Damsel fishes) and *Holocentridae* (Soldier fish), where 85% of them had a total length less than 20cm.

The coral reef and groupers monitoring activity, planned under RUMAKI-BAF is an important assignment to be undertaken in MIMP this year 2022 as it will help in following trends by comparing the result of 2018 and previous years (as baseline) for the project indicators on the percentage cover hard coral for all species in the five sites (Table 2). The current status needs to be compared with the baseline and situation at the end of the project will be assessed using the same methodology on those sites in 2024.

### 1.1 Project Description

WWF TCO through Marine Programme is implementing a five-year project titled 'Strengthening Marine Protected Areas Management in Rufiji, Mafia and Kilwa Districts in Tanzania' with funding from the Blue Action Fund (BAF) which is abbreviately known as RUMAKI-BAF project. This project effectively started its activities implementation in August, 2019. One of the main work packages is 'Improved management effectiveness of Mafia Island Marine Park – MIMP'. The project has so far implemented one activity related to coral reef where a consultancy assignment commissioned to two Marine Scientists (who were also involved in this current survey) enabled to conduct a study an produces a report titled *"Establishment of baseline scientific information on reef fish biomass, abundance and population structure in selected sites of Mafia Island Marine Park, Tanzania"* in May 2021.

**Table 1:** RUMAKI - BAF PROJECT activities within Mafia Island Marine Park

| **Sub-output 1.1: General management plan (GMP) for Mafia Island Marine Park revised** | |
|---|---|
| **Activities** | **Activity Description** |
| Activity 1.1.1 | Consultancy to facilitate consultations and draft revised plan |
| Activity 1.1.2 | Two rounds of consultation: 14 communities; tourism & fisheries sectors; district authorities; MIMP advisory committee etc. |
| Activity 1.1.3 | 3x meetings of technical team [MPRU/MIMP/Mafia District etc.] |
| Activity 1.1.3 | Translation to Kiswahili, printing & dissemination of revised GMP |
| **Sub-output 2.1: Training & capacity-building: Mafia Island Marine Park** | |
| Activity 2.1.1 | Train 6 MIMP staff on fisheries co-management |
| Activity 2.1.1 | Train 5 MIMP staff on monitoring control & surveillance [Fisheries Education & Training Agency, TZ] |

| | |
|---|---|
| Activity 2.1.1 | Train 8 MIMP staff on maritime skills [Dar es Salaam Maritime Institute] |
| **Sub-output 2.2: Cost effective monitoring, control & surveillance in MIMP including demarcation** | |
| Activity 2.2.1 | Construct (1) and refurbish (1) MIMP ranger posts |
| Activity 2.2.2 | Construct house for ranger accommodation |
| Activity 2.2.2 | In-water demarcation: procure and install buoys to demarcate two no-take zones in MIMP |
| Activity 2.2.3 | Construction and installation of 2 signboards at road/ beach intersections in MIMP |
| Activity 2.2.3 | Refurbish 13 existing village liaison committees (VLC) offices in MIMP |
| Activity 2.2.3 | Procure equipment to strengthen MIMP sea patrol capacity |
| Activity 2.2.7 | Procure and operationalize drones for remote surveillance of no-take zones |
| **Sub-output 2.6: Monitoring & evaluation MIMP and CFMAs** | |
| Activity 2.6.2 | Introduce mobile app for fisheries catch data collection within MIMP |
| Activity 2.6.4 | Data feedback to fisher assemblies in MIMP: |
| Activity 2.6.5 | Procure SCUBA equipment for reef monitoring |
| Activity 2.6.6 | Conducting study visit for Octopus FIP management for Jibondo and Bwejuu communities |
| **Sub-output 3.1: Increased income from complementary livelihoods** | |
| Activity 3.1.1 | Establish village savings & loans (VSL) groups in 14 villages within MIMP |
| Activity 3.1.2 | Introduce mobile app technology to village savings & loans (VSL) groups 37 communities |
| Activity 3.1.3 | Demand-led entrepreneurship and skills training to members of village savings & loans (VSL) groups in 13 communities within MIMP (consultancy) |
| **Output 0.1: Monitoring & Evaluation Impact and Outcomes (BAF Indicators)** | |
| Activity 0.1.3 | Coral reef & grouper monitoring |

## 1.2 Justification for Resource Monitoring in Marine Protected Areas

### 1.3 Resource Monitoring in MPAs

Resource Monitoring in Marine Protected Areas (MPAs) is critical for making informed management interventions including appropriate resource allocations and prioritisation of limited resources. Coral reef cover and fish resources (biomass and abundance) are critical indicators for assessing the management effectiveness of the MPAs. The group of fish termed "Groupers" are a highly targeted fish by fisherman, both artisanal and commercial, whereby the degree of their abundance can be used to indicate effective MPA management. The RUMAKI-BAF project has an activity numbered 0.1.3 described as *"Coral reef and grouper monitoring"* which was among the activities planned in the June

2022 work plan. The indicator to be observed in this activity is as described (Table 1) below where the project baseline data is based on the survey conducted in MIMP by MPRU staff in 2018.

**Table 2**: **Indicator for coral reef monitoring within Mafia Island Marine Park**

| RESULTS | Indicator | Baseline (2018) | Current status (2022) | Target | Comments |
|---|---|---|---|---|---|
| 1.1.6. Hard corals [*Scleractinia* - approx. 285 species] | Percentage cover hard coral [all species] at 5 sampling sites within MIMP | • Yuyuni 23.4%<br>• Kisiwa kikubwa 26.6%<br>• Kitutia 58.3%,<br>• Mange 30.0%,<br>• Nyamalile south 30.7%<br>• Kifinge 37.2%<br>• Msumbiji 41.19%<br>• Nyamalile North 48.4%,<br>• Utumbi 54.0%,<br>• Chawe 54.4%<br>• (Source: MPRU 2018, Coral Reef Monitoring Status Report) | • Yuyuni 30.5%<br>• Kisiwa kikubwa 18.9%<br>• Kitutia 56.18%<br>• Mange 19.72%<br>• Nyamalile south 32.18%,<br>• Kifinge 54.8<br>• Msumbiji 52.19%,<br>• Nyamalile North 47.72%<br>• Utumbi 55.72%<br>• Chawe 54.0%,<br>• (Source: MPRU 2022, Coral Reef Monitoring Status Report) | Yuyuni **Gain**<br>• Kisiwa kikubwa **Loss**<br>• Kitutia **Loss**<br>• Mange **Loss**<br>• Nyamalile South **Gain**<br>• Kifinge **Gain**<br>• Msumbiji **Gain**<br>• Nyamalile North **Loss**<br>• Utumbi **Gain**<br>• Chawe **Stable** | The next coral monitoring is planned to be done before the project phase out by July 2024). The activity will be repeated with the same methodology in the same transects. |

## 1.4 Objectives

### 1.4.1 The Overall Objective of the Coral Reef and Grouper Monitoring Survey

The overall objective of this survey is to establish the scientific data on Coral reef and fish biomass (groupers) per hectare, abundance and population structure of selected sites in MIMP, Tanzania.

### 1.4.2 Specific Objectives

The specific objectives of the survey fall within the following areas of interest:

(i) Review and documentation of coral reef and fish biomass trend and status of MIMP;

(ii) Establish scientific data on the grouper's abundance (Number/ha), biomass (Kg/ha) and population structure at different selected sites in MIMP

(iii) Establish scientific data on hard coral cover (*Scleractinia*) (%) in MIMP at selected Monitoring sites. In addition, further added objectives include:

(iv) Document coral size structure distribution in MIMP monitoring sites

(v) Document coral recruitments per $m^2$ in MIMP Monitoring sites

(vi) Documents invertebrates' status per $20m^2$ in MIMP monitoring sites

(vii) Training capacity building to new MPRU certified divers on monitoring protocol and both coral and fish identification skills

## 1.6 Deliverables

i) A draft fieldwork technical report on *Coral Reef and Groupers Status* in Mafia Island Marine Park.

ii) Raw data in an excel file for the hard coral cover (%) and grouper abundance (Number/ha) and biomass in kg/ha.

iii) A final comprehensive *Coral Reef and Groupers Monitoring Status Technical Report*

iv) High quality photos including description of reefs and other collected information in video clips from the surveys and/or transect videos.

# 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. Reefs are formed of colonies of coral polyps held together by calcium carbonate. Coral species include the important reef builders that inhabit tropical oceans and secrete calcium carbonate to form a hard skeleton. Symbiotic Dinoflagellate algae (zooxanthellae) need enough sunlight for photosynthesis. Coral reef is therefore an underwater ecosystem characterised by reef-building corals. Most coral reefs are built from stony corals, whose polyps cluster in groups.

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 and can only live within a narrow temperature range from around 16°C to 30°C (IUCN, 2008). 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). They 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 a variety of finfish, lobsters, prawns, crabs, octopuses, molluscs 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; Wagner, 2004).

Coral reefs have a very high level of biological diversity, and this small area is home to about 30% of the marine species described to date i.e. 93,000 species described in the reefs out of a total of 274,000 known marine species (Porter and Tougas, 2001), including 25% of marine fishes (Allsopp et al., , 2009): coral reefs are nearly 400 times richer in species diversity than other ocean areas, which is comparable per square kilometre to large rainforests (Reaka-Kudla, 1997).

Previously in Mafia Island Marine Park (MIMP) a nominal list of 273 species in 63 genera and 15 families were identified using a timed search method and species diversity is predicted to exceed 300 species with sufficient sampling (Obura, 2004). The Faviidae and Acroporidae were the most species-rich families with 66 and 60 species, respectively (Obura, 2004).

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 benefit from food, income through fisheries as well as tourism activities (Muhando, 2009). Coral reefs support diverse marine ecosystems in Tanzania waters that include over 500 species of commercially important fish & invertebrates (Obura *et al*, 2017).

There are five administrative regions situated along the mainland coast: Tanga, Coast, Dar es Salaam, Lindi and Mtwara. These regions are further subdivided into districts. The islands of Unguja and Pemba makeup Zanzibar, the other part of the Union of Tanzania. The five coastal regions cover about 15 percent of the country's total land area and are home to approximately 25 percent of the country's population. 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

Overall, historical coral coverage was estimated to range from 58% to 70% in coral reef systems worldwide. There has been approximately a 50% decline in coral reef cover globally from 1957–2007. Coral reefs occur in more than 100 countries and territories and whilst they cover only 0.2% of the seafloor, they support at least 25% of marine species.

Coral reefs worldwide are facing impacts from climate change, overfishing, habitat destruction, and pollution. The cumulative effect of these impacts on global capacity of coral reefs to provide ecosystem services is unknown. Global coverage of living coral has declined by half since the 1950s. Catches of coral-reef-associated fishes peaked in 2002 and are in decline despite increasing fishing effort, and catch-per-unit effort has decreased by 60% since 1950. At least 63% of coral-reef-associated biodiversity has declined with loss of coral extent. It is projected continued degradation of coral reefs and associated loss of biodiversity and fisheries catches, the well-being and sustainable coastal development of human communities that depend on coral reef ecosystem services are threatened (Eddy et al, 2021)

The Western Indian Ocean (WIO) region comprises almost 6% (about 15,180 $km^2$) of the total global area of coral reefs, and the region is a globally important hotspot for coral reef biodiversity. The WIO coral reef average ranged 26.2% to 28.8% for the year between 1985 to 1997 respectively (GCRMN 2020).

The unprecedented coral bleaching and mass mortality, which occurred between March and June 1998, resulted in substantial degradation of many coral reefs in Tanzania (Wilkinson *et al,* 1999; Muhando 1999a 1999b). The extent of bleaching and mortality differed between species and sites (e.g. between Chole Bay and Kitutia reef in MIMP). *Acropora, Pocillopora*, *Seriatopora*and *Stylophora* were among the most affected genera.

After the 1998 bleaching event, the live coral cover at Kitutia and Mange reefs decreased from 80% in 1991 to 15.1% in 1999 and *Acropora*species were badly affected while on Msumbiji and Utumbi reefs about 4km apart (in Chole Bay) the live coral cover was relatively high (30%) (Mohammed *et al.*, 2000). The fleshy algae increased substantially on Tutia reef from 1% in 1996 to 15% in 1999. The most abundant algal species at Kitutia reef were *Stypopodiumzonale*, *Turbinaria*, *Dictyota* and *Sargassum*. Despite higher mortality of corals, Ohman *et al.*, (1999) reported an increase in reef fish abundance and change in species composition in favour of herbivores. Despite the mass coral reef mortality in MIMP, coral recovery and resilience has been very high, attributed to a favourable environment of intact coral skeleton, clear water, availability of recruits revealing a high coral recruitment and progressive increase in coral cover over time (Muhando & Francis, 2000). Generally, coral reefs in the Tanzania MPAs have demonstrated high resilience when subjected to coral bleaching.

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 have predicted that 32% of corals may be lost over the next three decades if human threats are not reduced (Eddy *et al.,* 2021).

Coral reefs are threatened by two main causes, i.e. natural and anthropogenic. Natural threats include hurricanes, global warming resulting in an increase in sea level and sea surface temperature are influenced by human activities resultant of climate change. Unsustainable fishing practices, urbanisation, population growth, upstream development also 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 coral reef topography. The most unsustainable destructive practice remaining to date in MIMP is the application of pull net fishing which was observed operational by the survey team on the way to Mange Reef during the survey on 17$^{th}$ June 2022.

Other destructive fishing practices were reported in the past (Horrill *et al.*, 2000) and were significantly reduced in the last two years in coastal waters in Tanzania. Blast fishing impacts, 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), However this was successfully eliminated in MIMP (GMP 2011).

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 fertilisation 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 were recorded due to 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.

Subsequently, has been reported (e.g. Garpe and Öhman 2003; Halford et al, 2004; Julius et al., 2016 & Julius et al., 2021) that the loss of structural reef complexity often affects the population structure of fish communities where groupers are inclusive (Sano *et al.,* 1987).

Comprehensive study on groupers population at local and regional scale is inadequate, however abundance on selected species has been reported

Fish biomass is a primary driver of coral reef ecosystem services and has high sensitivity to human disturbances especially fishing (McClanahan *et al.,* 2016). Estimating fish biomass, their spatial distribution, and abundance are important for evaluating reef status and crucial for setting management priorities and targets.

Fish biomass estimates across all reefs of the western Indian Ocean using key variables and showed high variability ranging from ~15 to 2900 kg/ha (McClanahan *et al'*., 2016).

General information on reef fish abundance and biomass in the WIO and beyond is fairly exist and some on selected species, however compressive monitoring on gropers is missing

## CHAPTER THREE

## 3.0 METHODOLOGY

### 3.1 Study Areas

The Mafia Island Marine Park (MIMP) with a total area of 822 km$^2$ of which 75% is sea water and 25% is land mass was gazetted in April 1995 as the first multiple use Marine Protected Area (MPA) in Tanzania. MIMP is situated 60 km south of Dar es Salaam and 21 km east of the Rufiji delta and its boundary incorporates varied coral reef, mangrove, seagrass and soft bottom habitats, islands of raised Pleistocene reef, bays, and coastal forest (URT 2011). The Park covers the Southern part of Mafia Island and includes the inhabited islands of Chole, Juani, Jibondo and Bwejuu and several uninhabited islets and the associated waters (Garpe and Ohman 2003; URT 2011). The Mafia Island Marine Park (MIMP) is located in southern Tanzania, in the centre of the East Africa Marine Ecoregion. Coral reefs in the MIMP are restricted to a relatively narrow band fringing the island and reef slopes (Obura, 2004). The Park has three different marine management zones including core zone 5%, specified use zone 25% and the general use zone 70%.

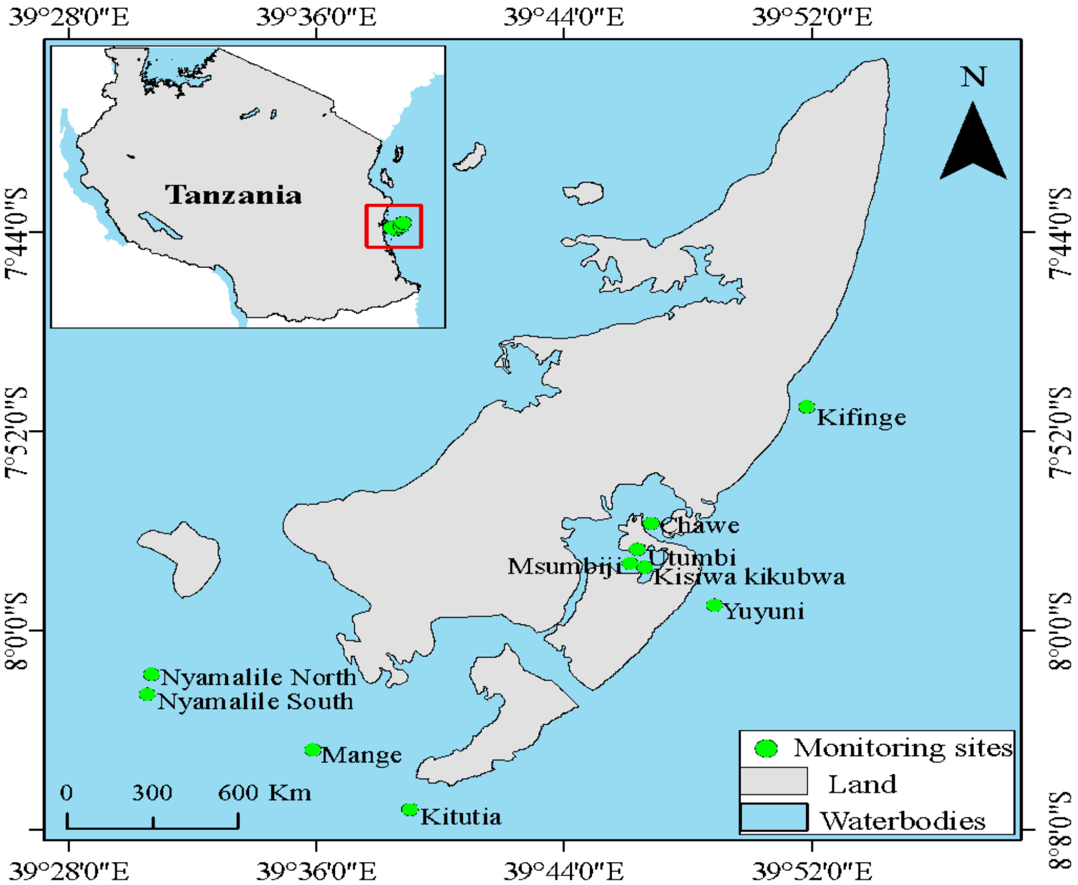



**Figure 1: Map showing Mafia Island Marine Parks Monitoring sites**

### 3.2 Field Approaches and Methods

Image Method approach

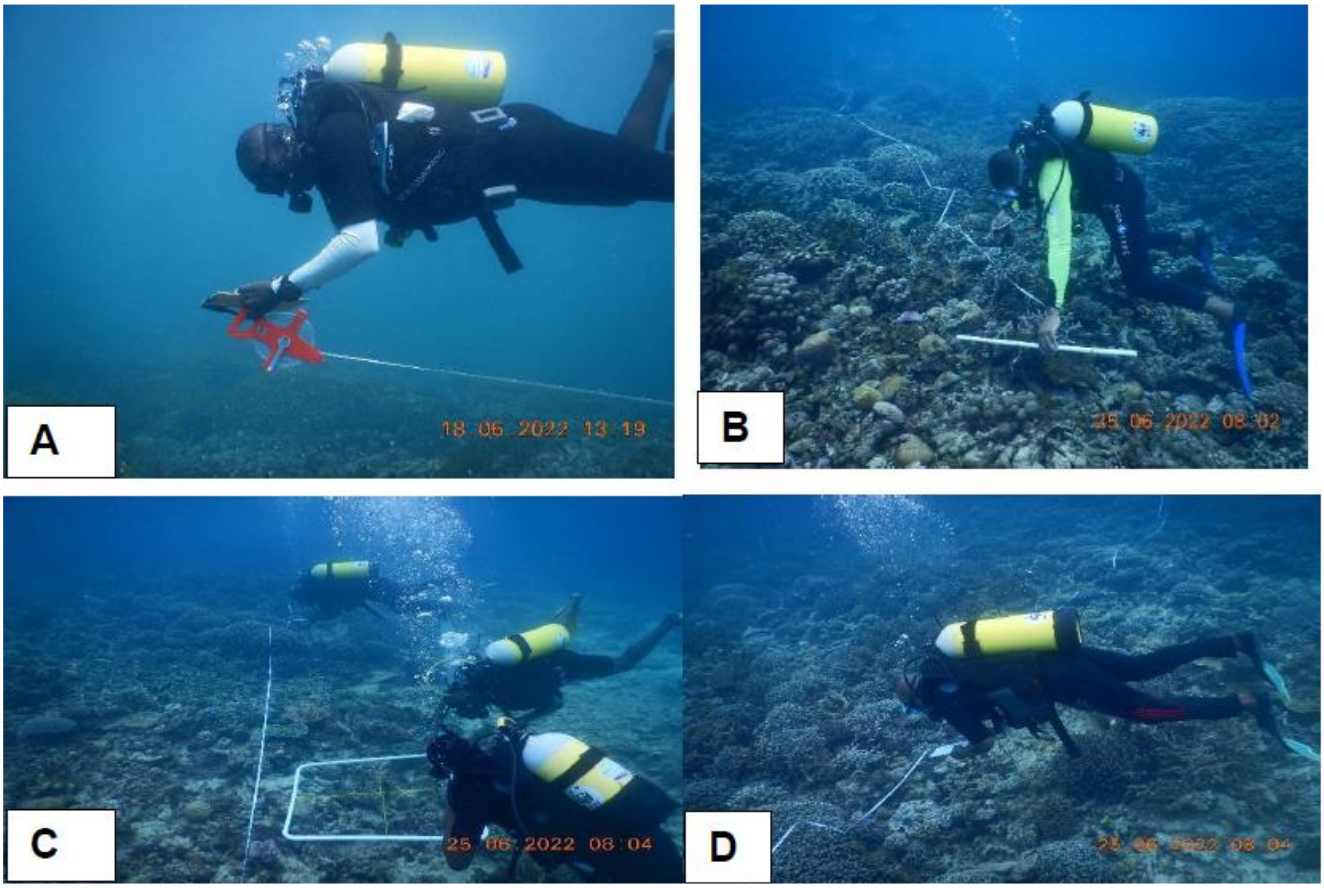



**Plate 1 A-D: Methodology applied (A-For fish transect; B-For coral size class, D-For quadrat for coral recruit & Juvenile and D-For Line Intercept transect)**

Monitoring applied the regional and global Monitoring techniques (Obura, 2014) in order to make comparison with the previous survey implemented in 2018 where a similar method was applied and data were used as baseline for the RUMAKI-BAF project. MPRU Staff were responsible for the field data collection, data entry, analysis, interpretation and report writing with support from WWF. Monitoring sites were accessed using GPS coordinates points established in 2018 and detailed at MPRU Coral reef monitoring in MIMP at all ten monitoring sites (Table 4). Added objective to the assignment on establishing the grouper status as per the parameters or indicator under the WWF Blue Action Fund (BAF) Project. The first pair of divers descended first and lay the transect for the fish/grouper counting followed by the diving team responsible for coral reef data collection who laid their transect in the opposite direction of the fish team in order to avoid disturbing the fish during counting.

In addition, three trainees participate in the coral reef monitoring following theory and practical training classes. They also participated in the invertebrate data collection methods under supervision of experienced staff. .

Methodologies to address multiple objectives were made, namely:

(i) Available publications, Monitoring reports, research and other sources including open sources will be used to document the coral reef and fish biomass trend and status of MIMP where intensive literature review was applied.

(ii) Underwater visual census (UVC) technique was used to assess grouper fish biomass, abundance and population structure as well as other reef fishes observed in the belt transect. A 100m x 5m belt transect (Fig. 3) was used to assess fish biomass, abundance, population structure, and fish size classes. Size class was estimated in centimetres (cm), categorised into 3-10cm, 10-20cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm and > 80cm as described by McClanahan *et al.,* 1999.

During the UVC process, fish observed were recorded using pencil and slates including details such as length and species name. For species identification, a field guide as described by Bianch 1985; Lieske and Myers 2002; Allen and Steene 2007 was applied. A minimum of six (6) transects were made per site.

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

A total of ten (10) sites were planned for monitoring by eight experienced MPRU Staff participated and three currently certified divers / staff were trained on monitoring protocols for coral as well as fish identification skills.

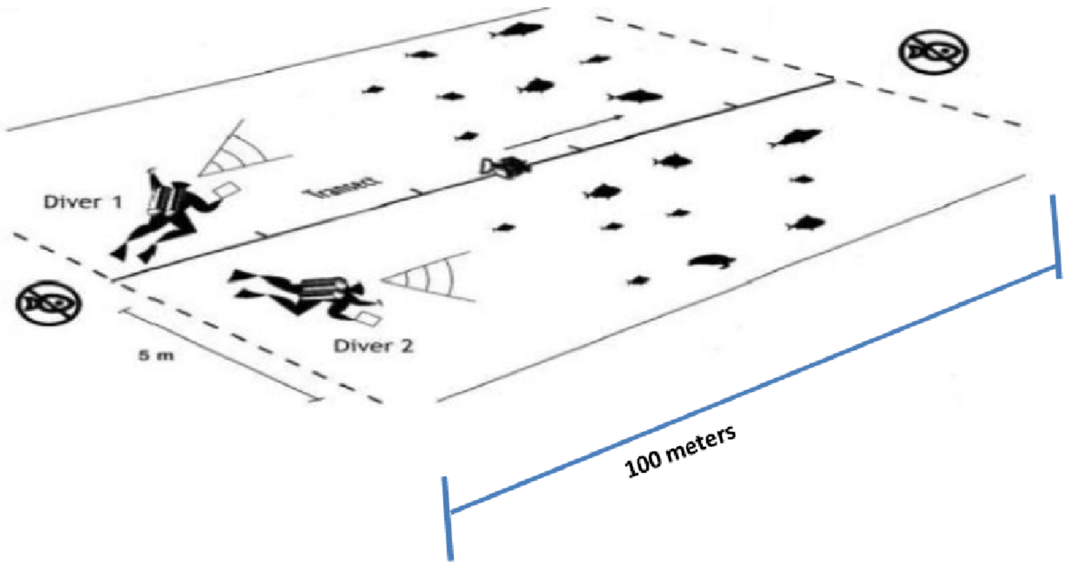



**Figure 2: Illustration of belt transect layout for Fish survey**

(iii)Benthic cover data was collected using the 10 meter Line Intercept Transect (LIT) method and was supplemented with video transect/photo. (Underwater camera Nikon COOLPIX W300 was used). A minimum of six LIT transects were done per site and coral was identified to genus level.

The GPS coordinates, depth estimates from dive computers and horizontal visibility measurements were taken (m) at each dive point and recorded for metadata section

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

(iv)Coral size distribution data was sampled on 23 pre- selected coral genera in 25 x 1m belt transect laid in coral-dominated spots within a sampling block with two transects per dive. (Obura and Grimsditch, 2009). Size classes were based on seven classes including 11-20cm, 21-40cm, 41-80cm, 81-160cm, 161-320cm and >320cm.

(v) Coral recruit counts were made using 1m$^2$ quadrats. A total of 12 quadrats per site was laid, six (6) quadrats per transect placed every 5m along the transect at 0m, 5m, 10m, 15m, 20m, 25m resulting in 12 quadrats in total 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). Slates were marked with 0, 2.5cm, 5cm and 10 cm lengths. Slate was placed next to recruits to estimate which size class they were in. If there were no recruits in a quadrat, quadrat number was recorded and leaving the row blank.

(vi) Macro invertebrates were counted in a 10 x 2 m belt transect preferably using the same benthic transect line counting micro invertebrates 1m on either side of the transect line with six transect minimum per site. (See figure 2 below for clarity).

(vii) Training sessions for capacity building to new MPRU certified divers on monitoring protocols for both coral and fish identification skills were also done. These sessions were facilitated by Mr. Pagu Julius, the Team Leader and a Coral and Fish expert specifically focusing on Coral skill and identification techniques, Fish identification techniques and monitoring protocol particularly on Global Coral Reef Monitoring Network (GCRMN).

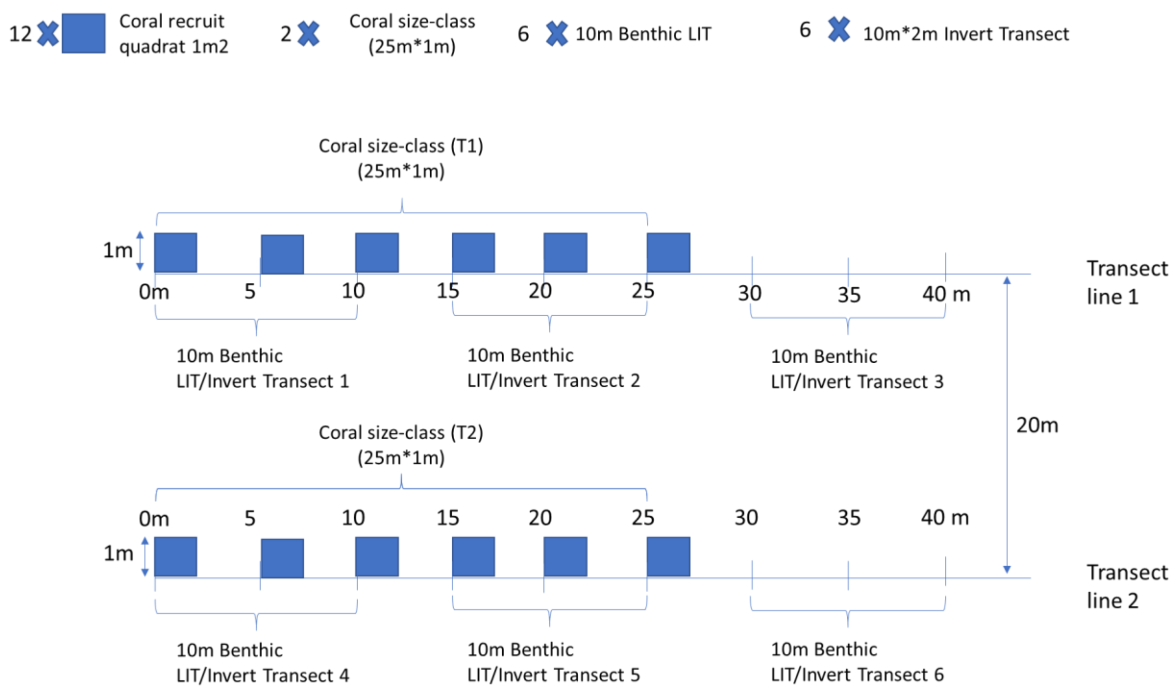



**Figure 3: Illustration of belt transect layout for Fish survey**

**Safety precaution measures**

SCUBA based activities is always a risky activity, Precaution measures were undertake including clear understanding on the nature and current of the diving sites. Accounting on precautions provided by the Tanzania Metrology Agency (TMA) of which precaution measures resulted to suspend two sites till November 2022. Equipment safety including using of certified SCUBA tanks under the hydrostatic test and maintaining all PADI diving procedures for the certified divers to dive within their dive limit

### 3.3. Data organisation, analysis and report writing phase

Data organisation included merging and cleaning, data analysis for coral reef, fish biomass, abundance and population structure estimation as well invertebrate data for the selected sites where tables and graphs were generated using Microsoft excel.

### 3.4. Data Analysis and Report Writing

Benthic cover data were analysed using computer software GraphPad InStat rn 3 and results generated in form of descriptive statistics. Data for coral sizes, macro invertebrates, and fish counts were organised using Microsoft Excel and analysed using GraphPad InStat rn 3 and likewise producing descriptive statistical results. If possible, *PRIMER* multivariate data analysis software was applied to perform similarity analysis among sites of the benthic cover, colony sizes, fish densities, biomass and coral genera.

The MPRU Monitoring team of ten (10) members participated in all activities from field work, diving survey, to data analysis, graphing and interpretations. Thereafter a team of three members continued with literature review and finalised draft report preparation that was shared to WWF for review. The 10 MPRU Monitoring Team had 4 members categorised as Trainees who were involved for the purpose of improving more their technical coral and grouper monitoring skills for management effectiveness and staff succession plan. MPRU technical team and their roles are detailed (Table 2) while a detailed schedule of activities and responsible team members is provided in the (Annex II).

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

<table>
<tr><th>S/N</th><th>Participant</th><th>Qualification & Competence</th><th>MPA</th><th>Recording role</th></tr>
<tr><td>1</td><td>Mr. Pagu Julius</td><td>MSc, Certified Rescue diver PADI, Fish and Benthic cover assessment expert, Trainer fish & coral</td><td>DMRs</td><td>Trainer coral & fish<br>Fish count,<br>Data analysis,<br>Report writing<br>Team Leader</td></tr>
<tr><td>2</td><td>Mr. Musa Hamisi</td><td>MSc, Certified Advanced Open water diver - PADI S, LIT technique & Invertebrate counting</td><td>MBREMP</td><td rowspan="8">Benthic, corals (cover and size-class) and invertebrates, Data analysis,<br>Report writing</td></tr>
<tr><td>3</td><td>Mr. Humphrey Mahudi</td><td>Msc, Certified Advanced Open water diver – PADI, Benthic cover assessment Trainer (Coral reef, benthic cover)</td><td>TACMP</td></tr>
<tr><td>4</td><td>Mr. Amos Singo</td><td>BSc, Certified Open water diver PADI, Benthic cover assessment</td><td>MBREMP</td></tr>
<tr><td>5</td><td>Mr. Masanja Joram</td><td>BSc, Certified Open water diver SSI, LIT technique, Invertebrate counting</td><td>MIMP</td></tr>
<tr><td>6</td><td>Mr. Davis Urio</td><td>MSc, Certified Rescue diver PADI Trainee</td><td>MBREMP</td></tr>
<tr><td>7</td><td>Mr. Nelson Mdogo</td><td>BSc, Certified Open water diver PADI, Trainee</td><td>TACMP</td></tr>
<tr><td>8</td><td>Mr. Shamte Mohamed</td><td>BSc, Certified Open water diver PADI, Trainee</td><td>MIMP</td></tr>
<tr><td>9</td><td>Mr. Michael Elisha</td><td>BSc, Certified Open water diver SSI, Trainee</td><td>DMRs</td></tr>
</table>

| | | | | |
|---|---|---|---|---|
| 10 | Bernard Ngatunga | BSc, Benthic cover assessment | MIMP | |

Table 3 describes sites in MIMP that were monitored in 2018 and their respective baseline from the 2018 monitoring report and table 5 is the plan for coral reef and grouper monitoring plan with a tentative time table with survey dates per site.

**Table 4: Monitoring sites in MIMP (Monitored in 2018)**

| s/n | Site | Lat (S) | Long (E) | Cover 2018 | Cover 2022 | Zone | Management |
|---|---|---|---|---|---|---|---|
| 1 | Msumbiji | 07°57.730' | 039° 47.690' | 41.19% | 52.19% | Chole bay, patchy reef | Specified use |
| 2 | Kisiwa kikubwa | 07°57.645' | 039° 47.893' | 26.6% | 18.9% | Chole bay, lagoon | Specified use |
| 3 | Utumbi | 07°56.870' | 039° 47.240' | 54.03% | 55.72% | Chole bay, channel | Specified use |
| 4 | Kitutia | 08°07.145' | 039° 39.003' | 58.3% | 56.13 | Outer, sheltered slope | Core / no take |
| 5 | Mange | 08°04.737' | 039° 35.860' | 30.03% | 19.72% | Inner, semi exposed | Specified use |
| 6 | Chawe | 07°55.650' | 039° 46.798' | 54.41% | 53.99% | Chole bay, patchy reef | General use |
| 7 | Nyamalile North | 08°01'42.6 " | 039°30'39.0' | 48.4% | 47.72% | Inner | Core / no take |
| 8 | Nyamalile South | 08°02'31.2 ' | 039°30'31.2' | 30.7% | 32.18% | Inner | Core / no take |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | Yuyuni | 07°58'56.4' | 039°48'49.8' | 23.4% | 30.5 | Outer, Exposed | Core / no take |
| 10 | Kifinge | 07°50'58.2' | 039°51'48.6' | 37.2% | 46% | Outer, Exposed | specified |

**Table 5: Sites with survey dates**

| s/n | Site | Lat (S) | Long (E) | Area | Zone | Dates |
|---|---|---|---|---|---|---|
| 1 | Msumbiji | 07°57.730' | 039° 47.690' | MIMP | Chole bay, patchy reef | 20/06/2022 |
| 2 | Kisiwa kikubwa | 07°57.645' | 039° 47.893' | MIMP | Chole bay, lagoon | 22/06/2022 |
| 3 | Utumbi | 07°56.870' | 039° 47.240' | MIMP | Chole bay, channel | 18/06/2022 |
| 4 | Kitutia | 08°07.145' | 039° 39.003' | MIMP | Outer, sheltered slope | 25/06/2022 |
| 5 | Mange | 08°04.737' | 039° 35.860' | MIMP | Inner, semi exposed | 17/06/2022 |
| 6 | Chawe | 07°55.650' | 039° 46.798' | MIMP | Chole bay, patchy reef | 21/06/2022 |
| 7 | Nyamalile North | 08°01'42.6" | 039°30'39.0' | MIMP | Inner | 29/06/2022 |
| 8 | Nyamalile South | 08°02'31.2' | 039°30'31.2' | MIMP | Inner | 29/06/2022 |
| 9 | Yuyuni | 07°58'56.4' | 039°48'49.8' | MIMP | Outer, Exposed | 01/11/2022 |
| 10 | Kifinge | 07°50'58.2' | 039°51'48.6' | MIMP | Outer, Exposed | 02/11/2022 |

# CHAPTER FOUR

## 4.0 RESULT AND DISCUSSION

### 4.1. Monitored indicators and their ecological implication

Hard coral substrate, percentage (%) cover - Lower percentage (%) cover is an indicative of declining reef accretion, reef topographic complexity, benthic diversity, and abundance of coral-dependent species and associated processes including larval recruitment. Macroalgae percentage (%) cover- Greater macro algal cover is an indicative of declining palatable algal production and calcification, declining herbivory, and possibly increased nutrient inputs; The ratio of macroalgae against hard coral- Increased macroalgae relative to coral indicative of rates of algal production and declining calcification; Urchin predation index- The metric is indicative of top-down control of processes influenced by sea urchin predators (e.g., grazing). Lower index indicates lower rates of predation on invertebrates; Fish species richness - Reflects changes and loses in functional groups important for ecological redundancy and maintaining key processes; Sea urchin abundance/biomass- Increasing biomass suggests increased biological erosion rates of reef substratum, loss of coralline algae, and reef decay; Herbivorous fish as percentage of total fishable biomass. Reduced percentage suggests declining secondary production available to fisheries and reduced herbivory processes; Calcifying substrates % (hard coral and calcifying algae) Lower percentage (%) indicative of declining reef accretion and loss of reef complexity and habitat structure (McClanahana *et al.*, 2011) ;

### 4. 2 Health Status of the Surveyed Reef Sites

The ten (10) surveyed sites are located in areas of different oceanographic conditions and management regimes covering core zone (no take areas) with high level of protection, specified use zone with intermediate level of protections and general use zone with low level of protections. Hence sites are subjected to varying degrees of stresses and resilience **(Fig. 4**). Generally, Kitutia, Utumbi, Chawe and Msumbiji reefs have relatively high benthic substrates dominated by live hard coral cover with over 50% cover whereas Mange and Nyamalile north and South were mostly algal dominated while Kisiwa kikubwa were soft coral dominated.

For overall coral cover there is increase from 40.42% in 2018 to 42.19% cover in 2022 with 1.77% cover increase for the live coral cover in Mafia Island Marine Park. Main possible reason for the slightly increase of coral cover is due to strengthen of management in protecting and monitoring of park resource and maintain sustainable resource use.

Even though data show there is a slightly increase of coral cover but evidence reveal that, there is high variation in coral cover response whereby some sites have slightly increased and some have slightly dropped but the overall trend is skewed to the left evidenced by the existence of dead corals and rubbles which were widespread across sites. **Plate A1 & A2** indicates some of the stressors (fishing related) to coral reefs at Mange reef.


**Plate A1 - A2.** Pull net fishing at Mange reef

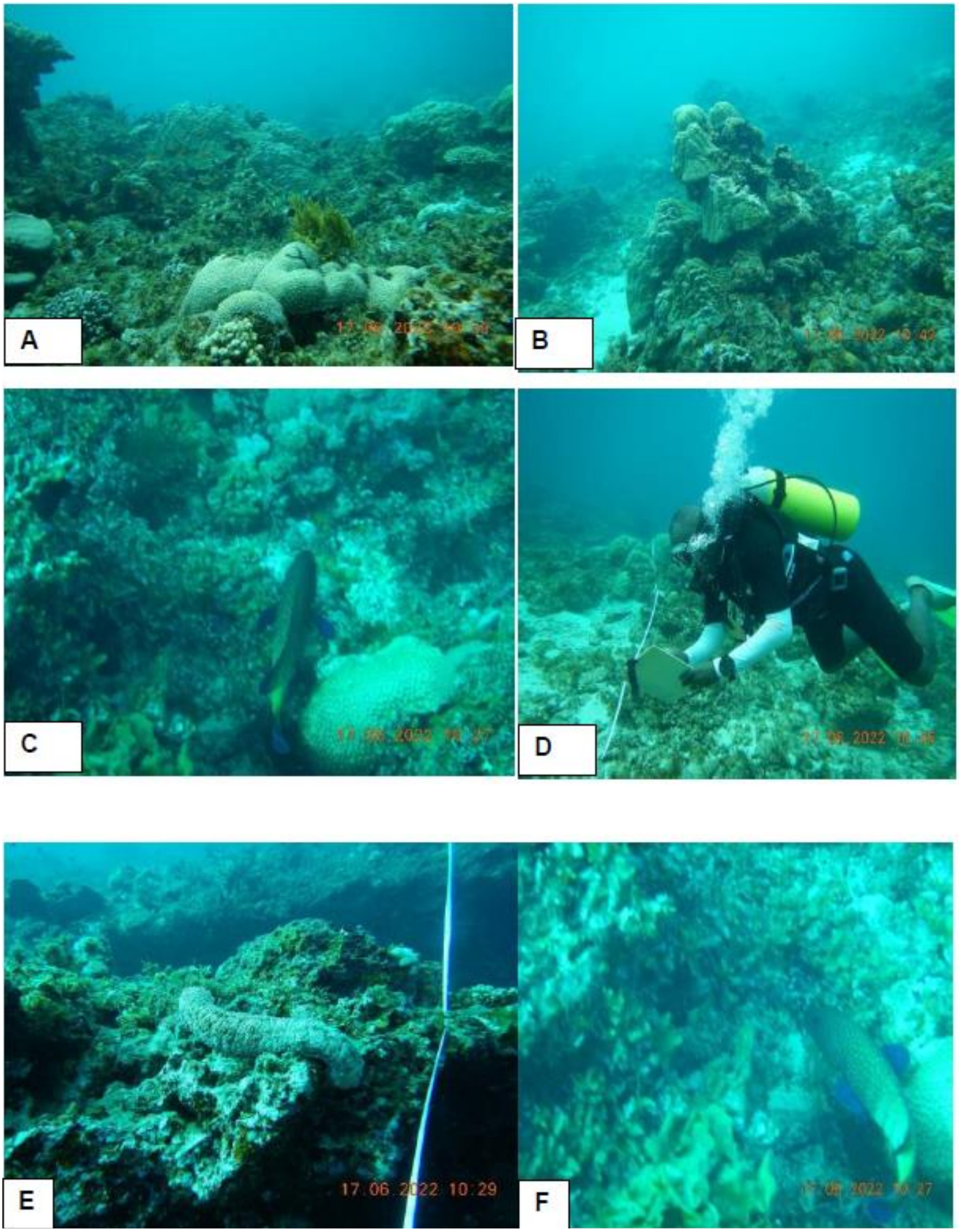



**Plate 2: A-F; The representative bottom features at Mange reef**

***(Source, WWF/BAF field work in June, 2022)***

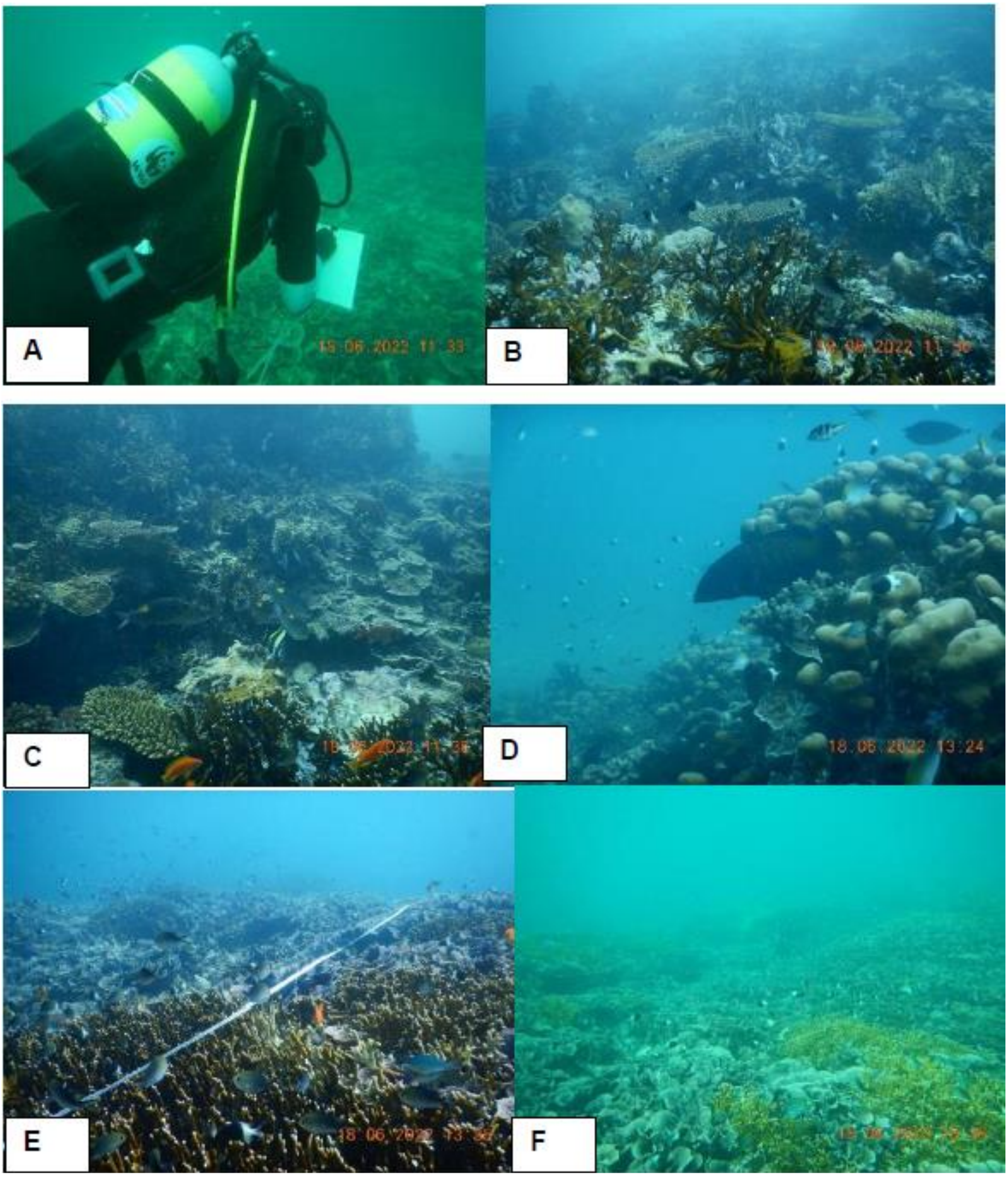



**Plate 3: E-F; The representative bottom features at Utumbi reef**

***(Source, WWF/BAF field work in June, 2022)***

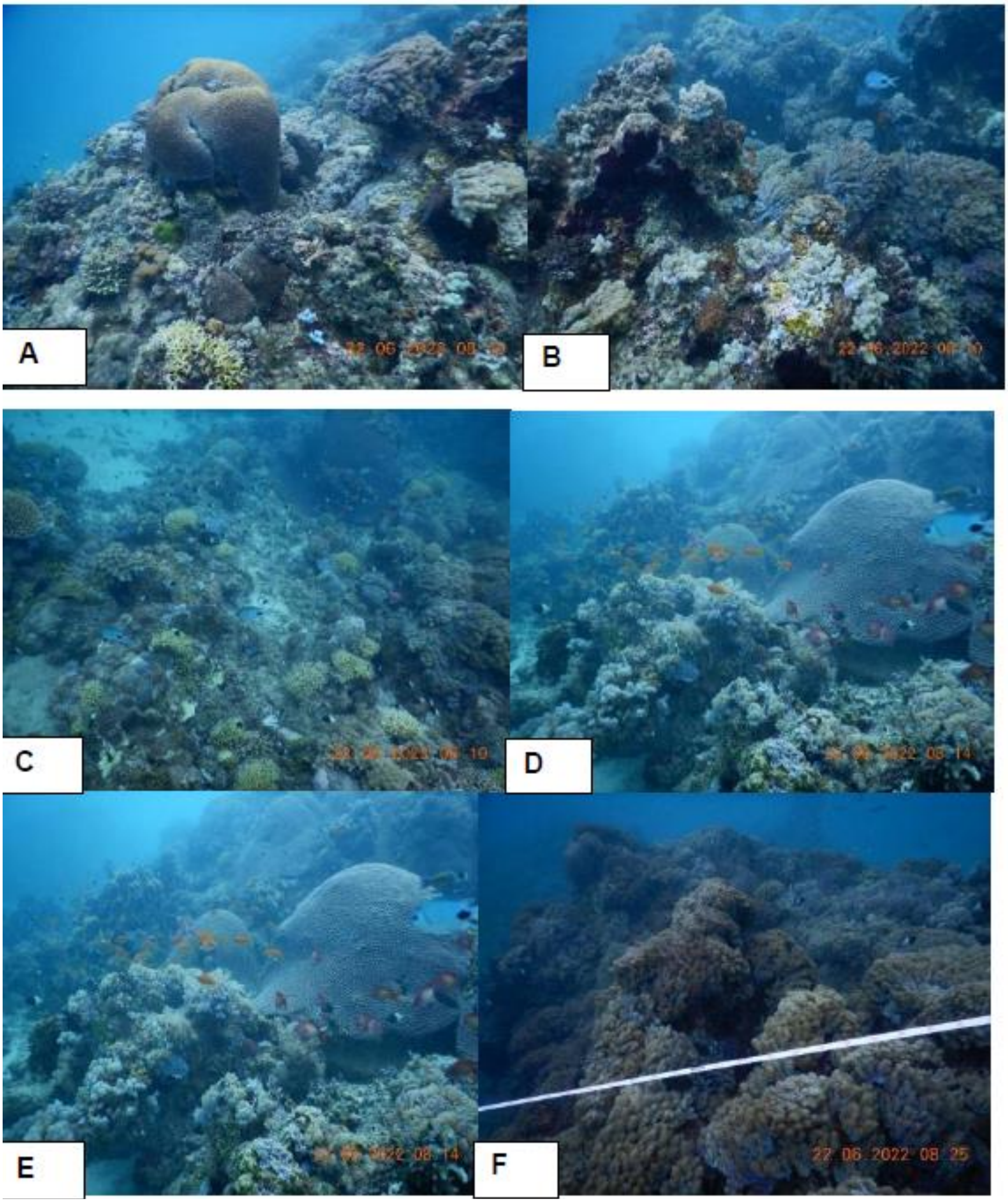



**Plate 4 A-F; The representative bottom features at Kisiwa kikubwa reef**

*(Source, WWF/BAF field work in June, 2022)*

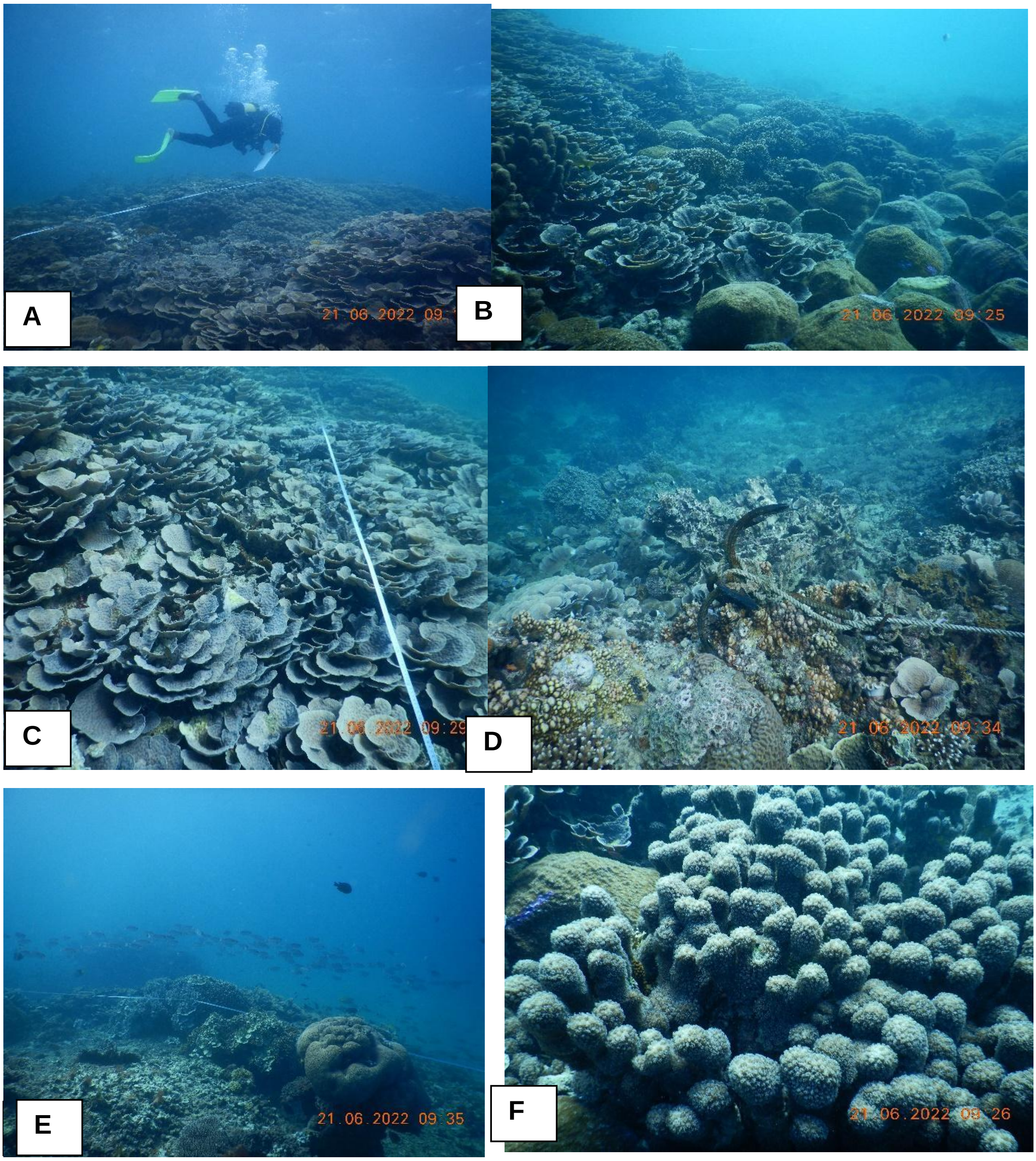



**Plate 5: A-F; The representative bottom features at Mange reef**

***(Source, WWF/BAF field work in June, 2022)***

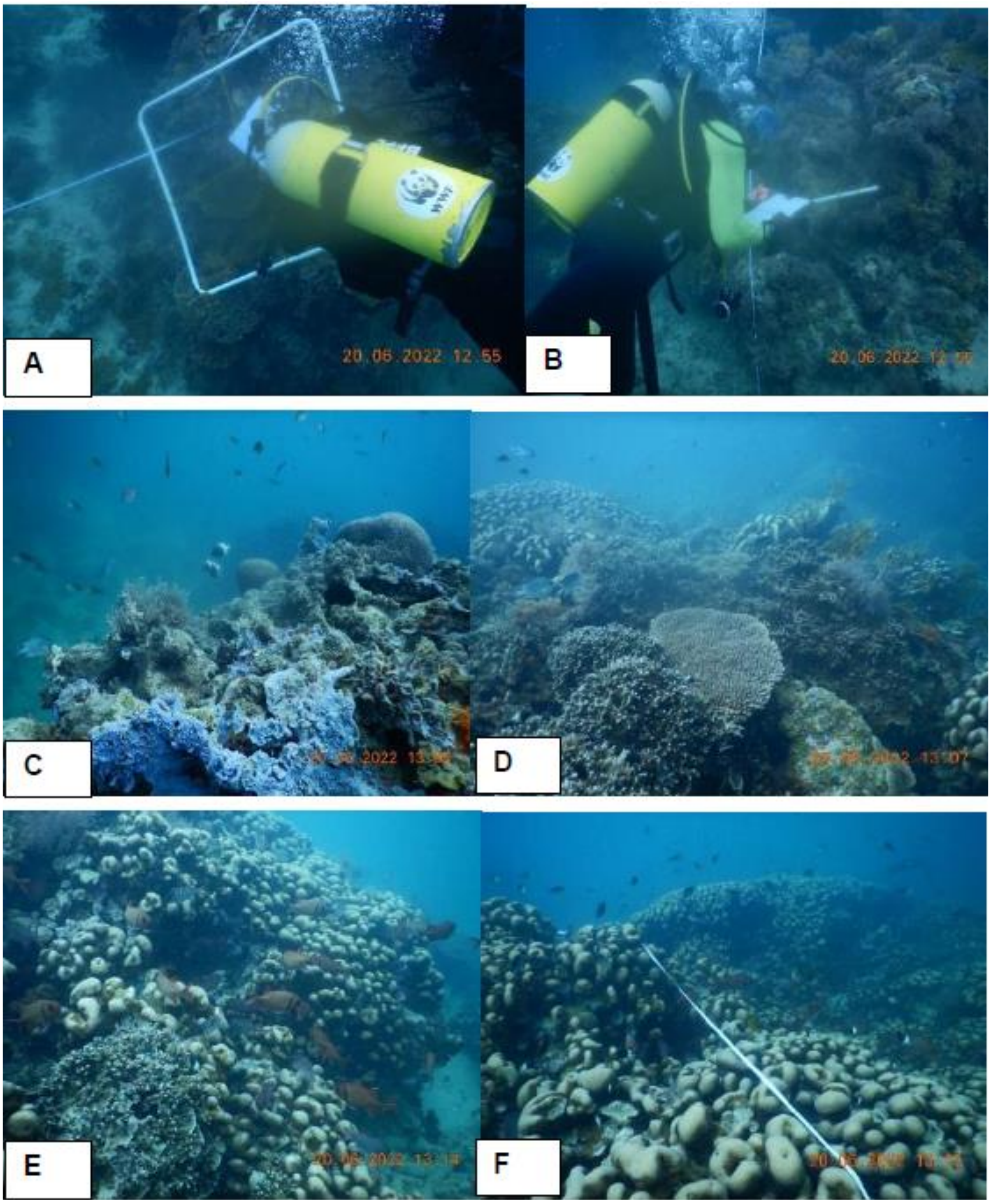



**Plate 6:  -F; The representative bottom features at Msumbiji reef**

*(Source, WWF/BAF field work in June, 2022)*

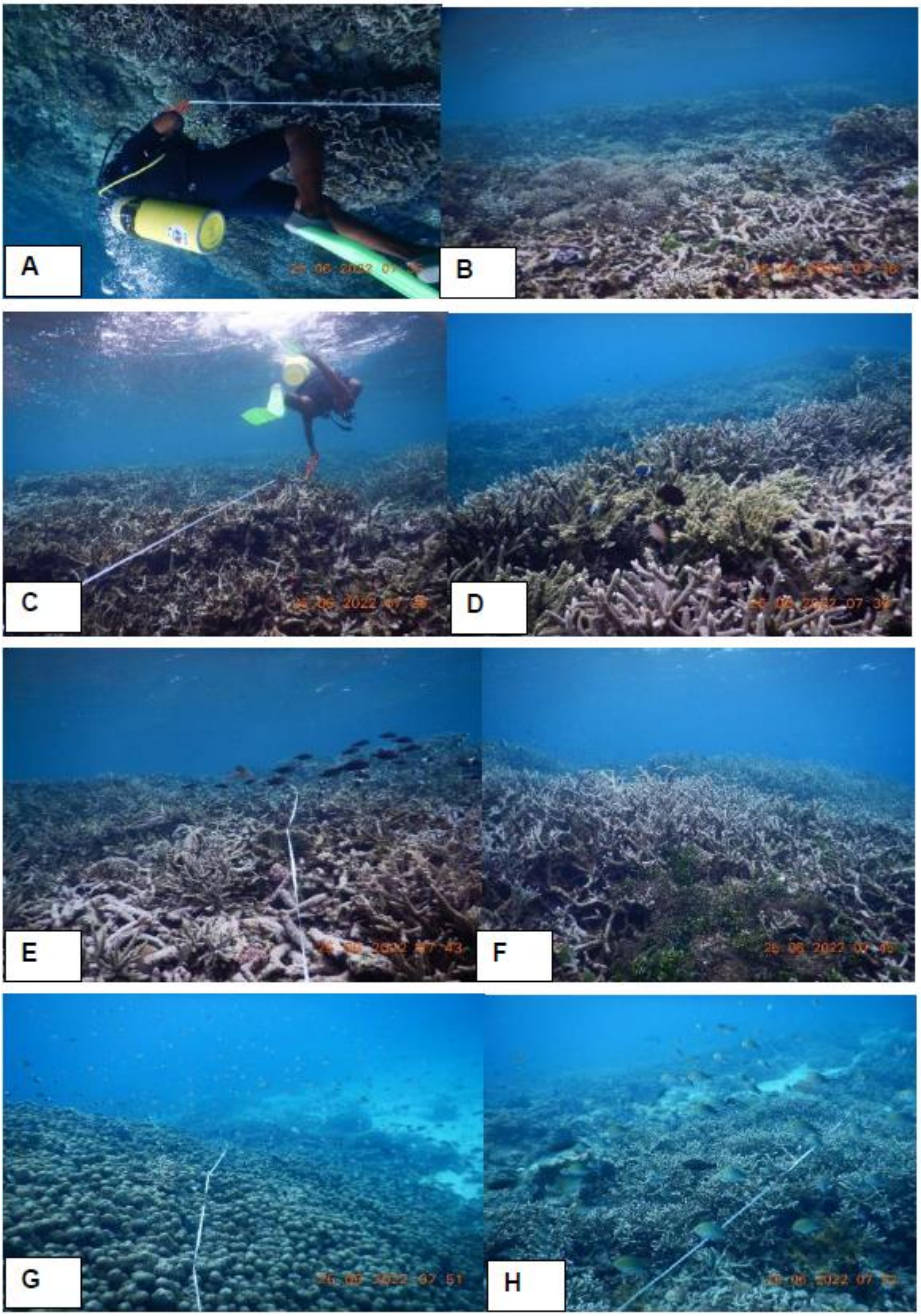



**Plate 7: A-H; The representative bottom features at Kitutia reef**

*(Source, WWF/BAF field work in June, 2022)*

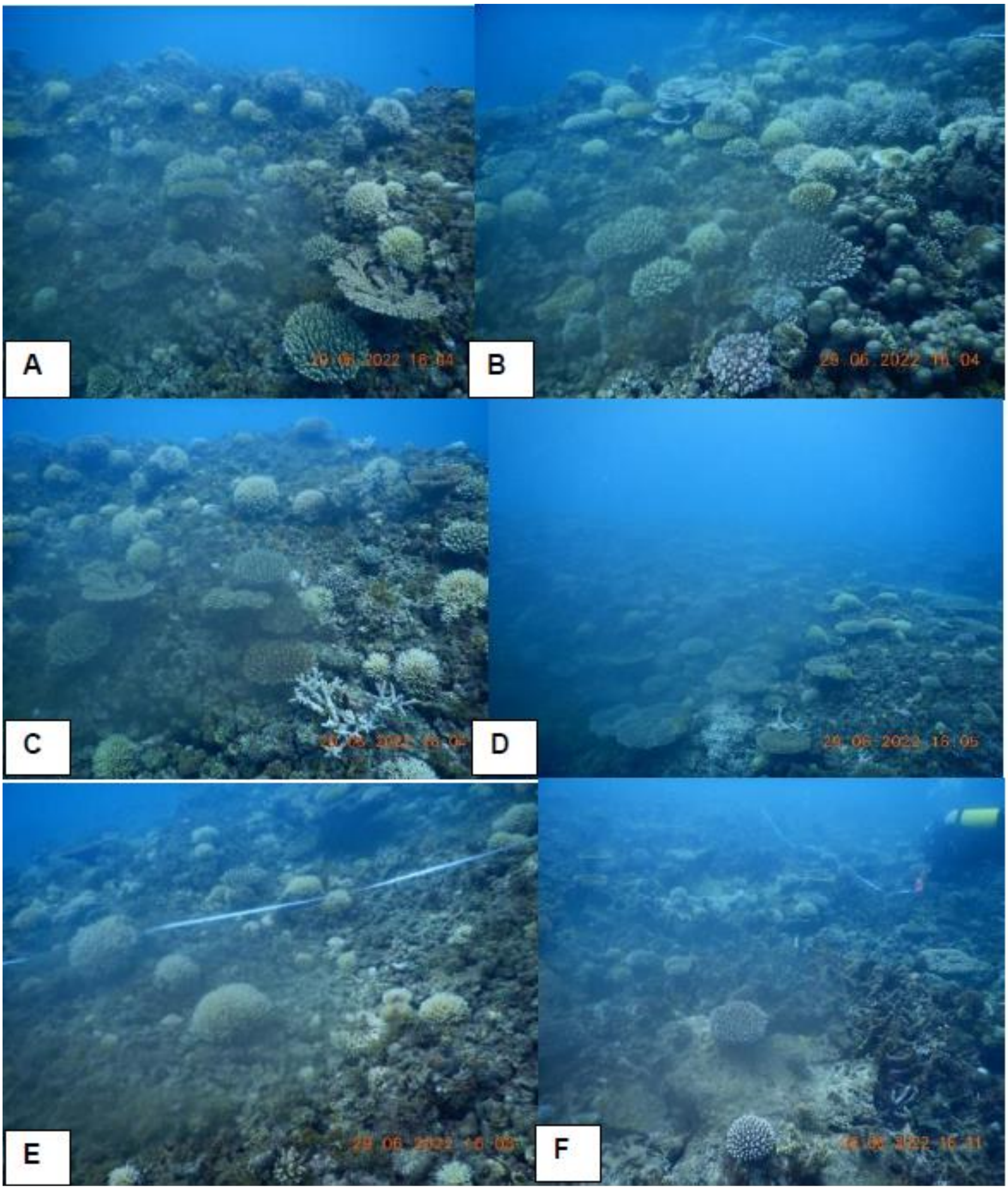



**Plate 8: A-F; The representative bottom features at Nyamalile north reef**

*(Source, WWF/BAF field work in June, 2022)*

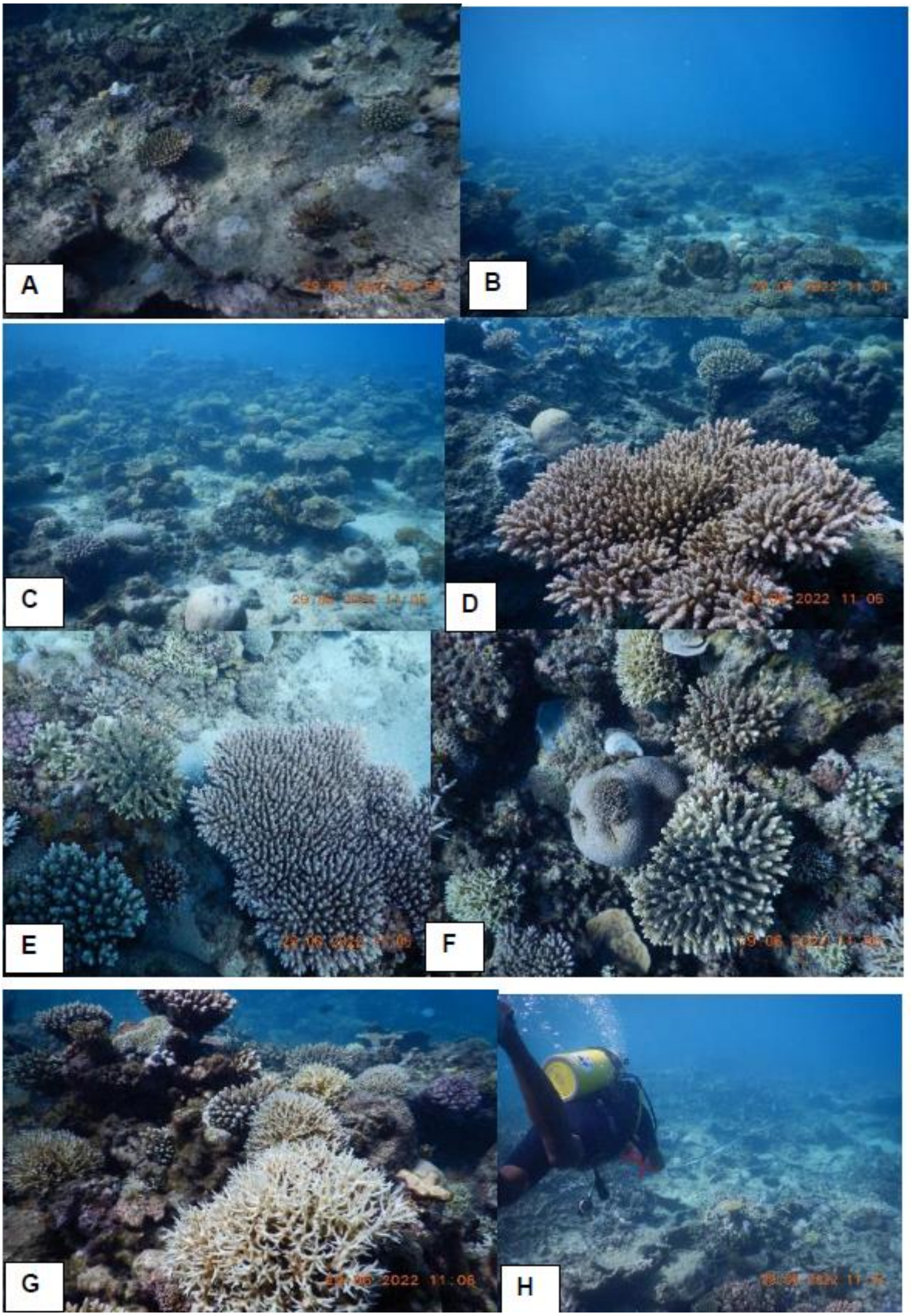



**Plate 9: A-H; The representative bottom features at Nyamalile South reef**

*(Source, WWF/BAF field work in June, 2022)*

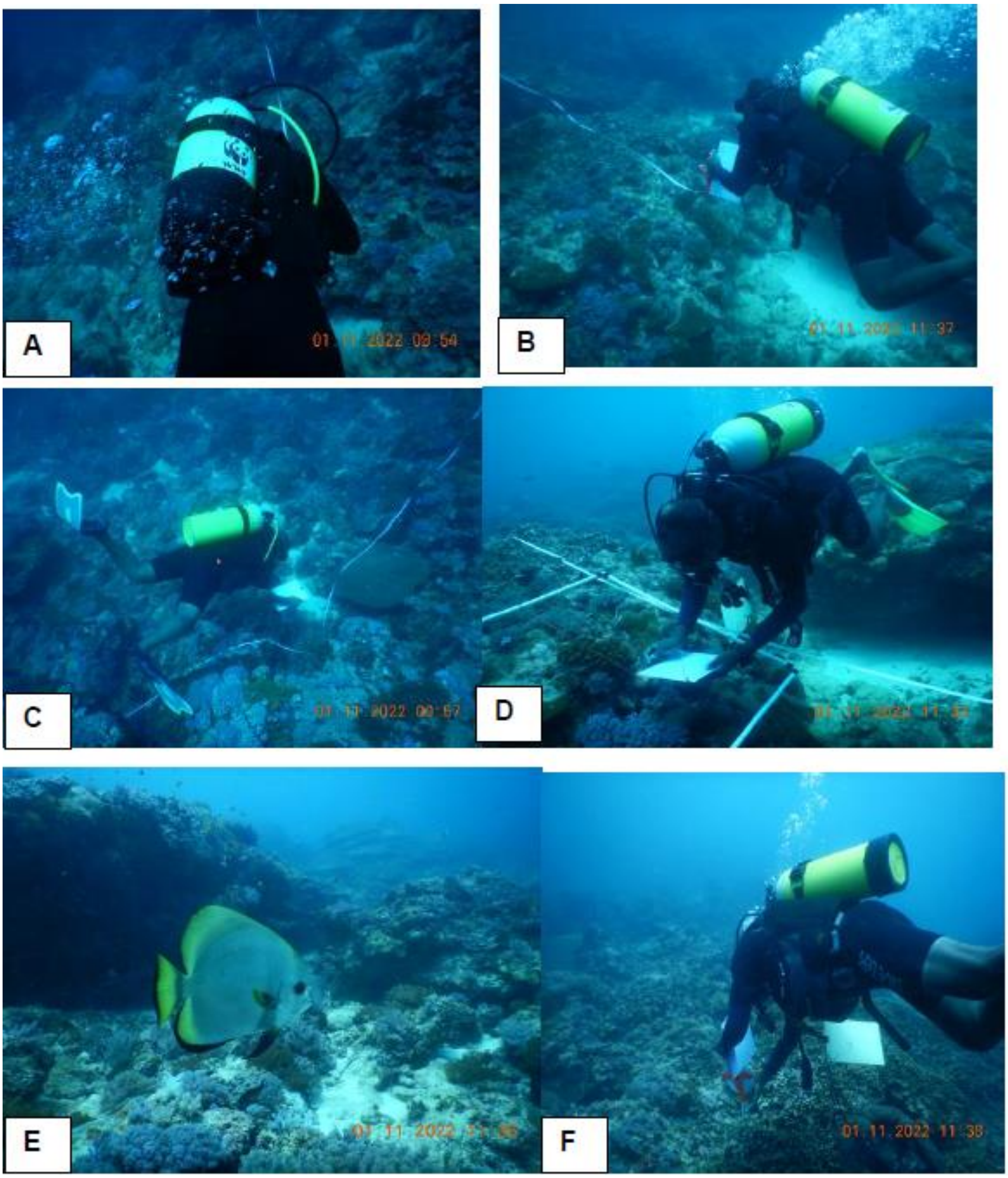
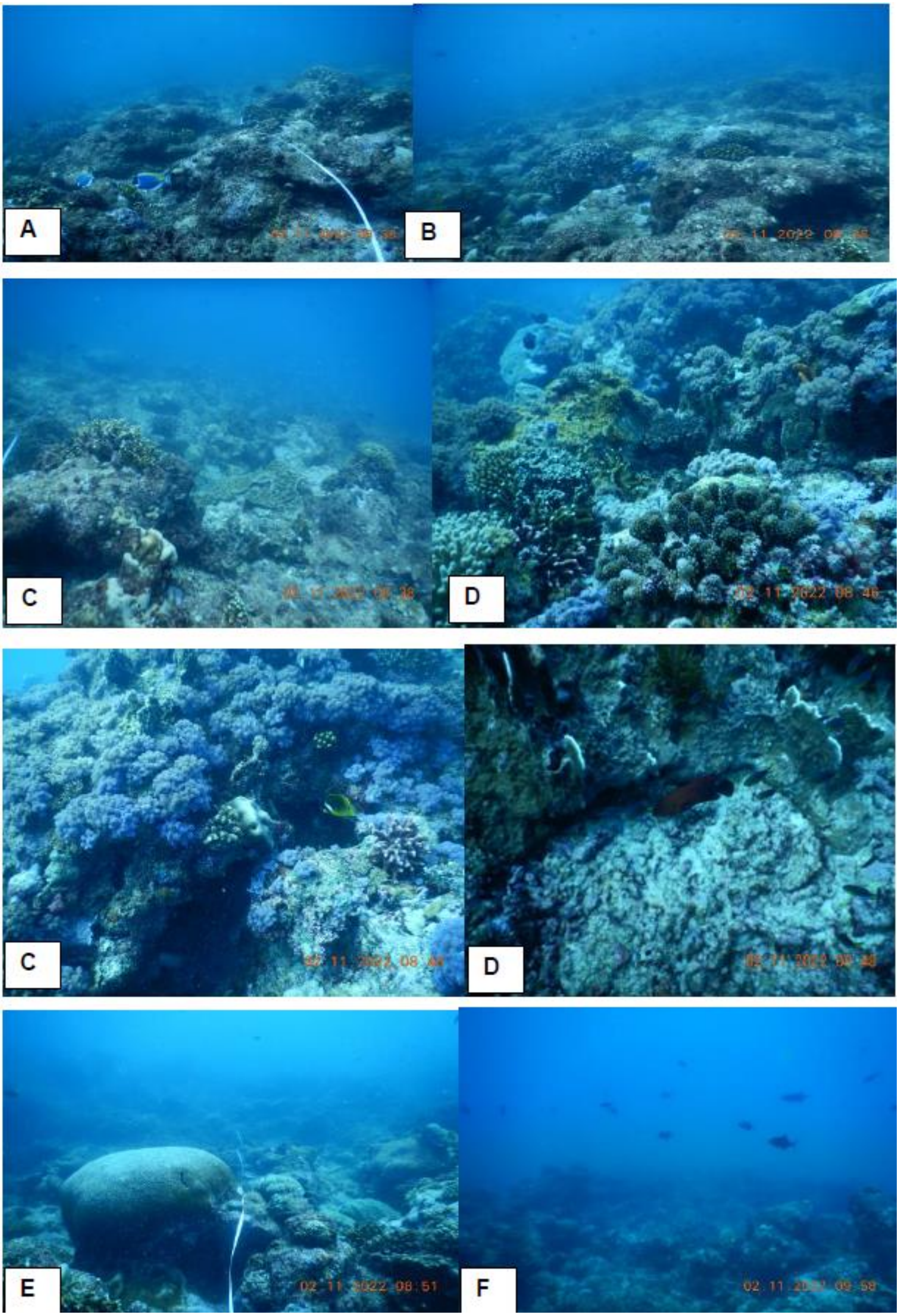



**Plate 10: A-F; The representative bottom features at Kifinge reef**

*(Source, WWF/BAF field work in November, 2022)*


A
B
C
D
C
D
E
F

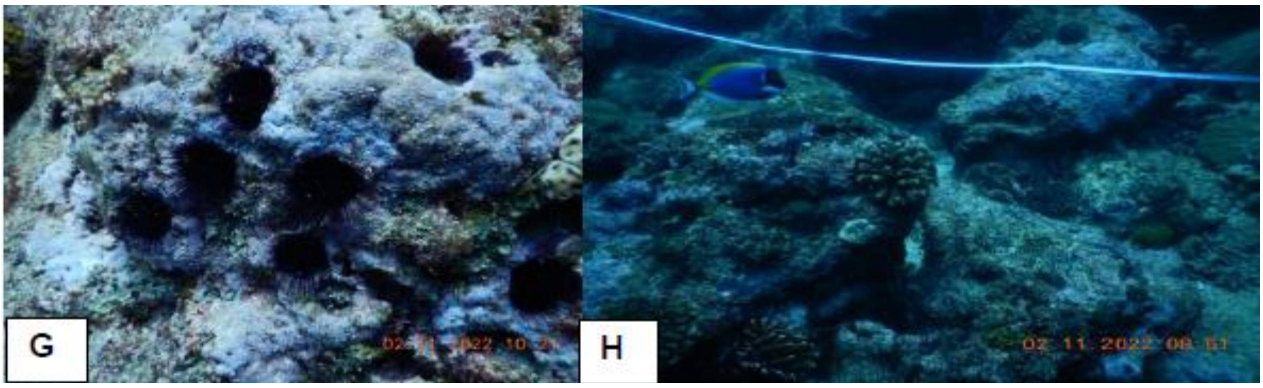



**Plate 11: A-H; The representative bottom features at Yuyuni reef**

*(Source, WWF/BAF field work in November, 2022)*

### 4.3 Benthic Cover in MIMP

Most of MIMP sites had fairly high percentage cover of live hard coral compared to other benthic cover categories (42.19% ± 6.9). Coral cover was the highest 42.19% compared to other categories (Fig.4). Rubbles were the second most abundant (12.6% ± 2.1) followed by soft corals (9.3% ± 6.1), bare rock and dead coral were 8.2%±1.3 and 8.1%±1.4 respectively, The rest of categories ranged between 5.12% to 0.22%.

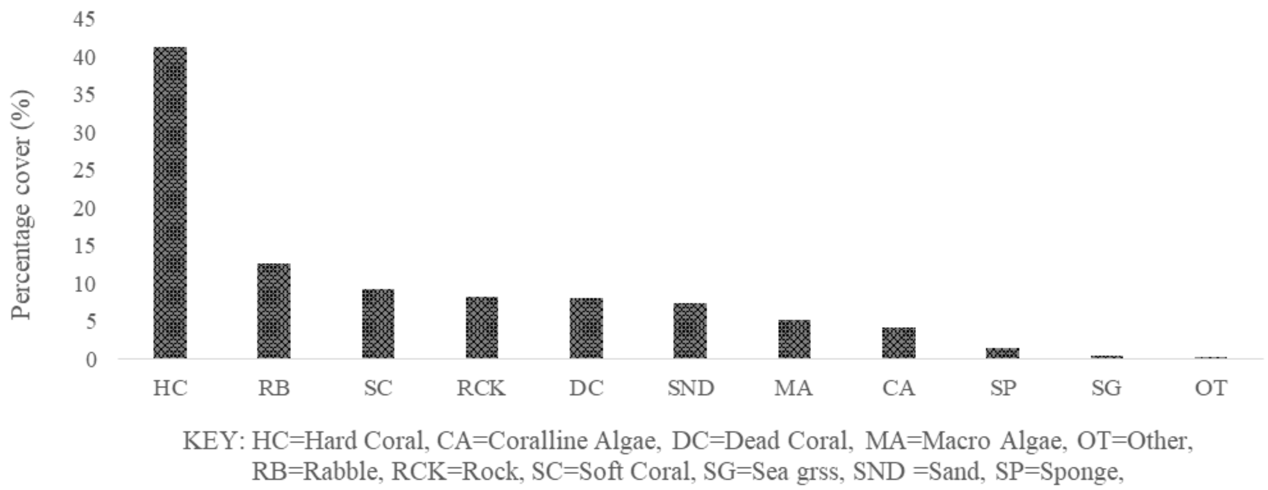



**Figure 4 Overall Benthic cover category status (%) in Mafia Island Marine Park Monitoring**

#### 4.3.1 Benthic cover comparison

The overall hard coral cover in MIMP increased slightly by 1.77% compared to the previous 2018 survey. The average percentage cover was approximately 41.31% ± 6.5 in 2022 whereas that of 2018 was 40.4%. In this survey, the data show an increase in rubbles and dead corals by 4.13% and 2.8%

respectively (Figure 5). The decrease in coral cover and an increase in rubbles and dead corals is probably a result of destructive fishing practices and the bleaching disturbances of the 2020 bleaching event. However, live coral cover was not significantly different between the 2018 and 2022 monitoring surveys (two sample t test; $t_{(7)} = 0.3867$; $P = 0.7105$, considered not significant).

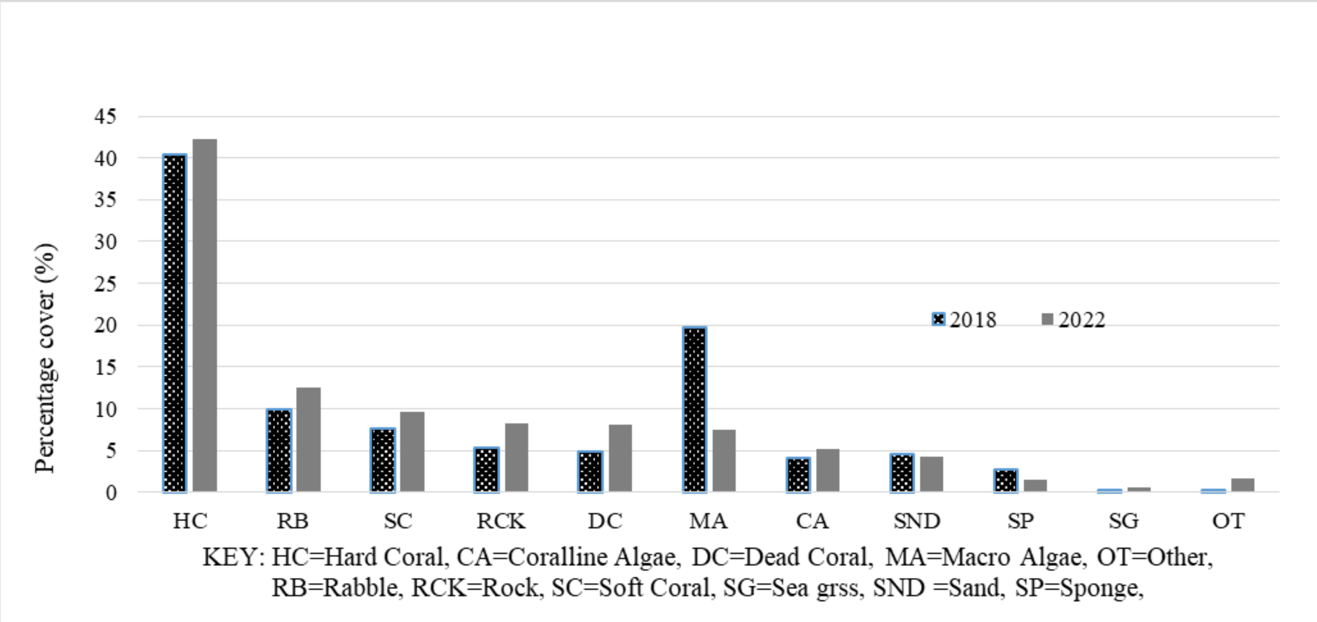



**Figure 5: Overall benthic cover comparison between 2018 and 2022**

### 4.3.2 Sites comparison in coral cover

Normally, when the live hard coral cover is above 25% of all reef benthos, the reef framework is judged to be in good condition (Bruno 2013). The average coral cover overall in MIMP reefs and the sites' specific covers are above the WIO Region level (25%) except for the reef of Mange has 19.7%± 5.2 and Kisiwa kikubwa 18.9% ± 2.8. During this survey the result show that MIMP average cover was 41.31% ± 6.5, site of kitutia have highest coral cover of 56.2% followed by Utumbi 55.7%, Chawe 54%, Msumbiji 52.2%, Nyamalile North 47.7%, Kifinge 46.0%, Nyamalile South 32.2%, and Yuyuni 30.5%, (Figure. 6). The low coral cover in Mange and Kisiwa kikubwa could be caused by 2016 coral bleaching phenomenon (climate change) and unsustainable fishing practices. Fresh water from the Rufiji delta normally flows through Mange reef particularly during rainy season where the Rufiji river floods frequently especially in heavy rain season. Kisiwa kikubwa there over growth of soft coral and macroalgae reducing live hard coral recruitment substratum.

**Figure 6: Hard coral cover status (%) in the 2022 monitored sites**

### 4.3.3 Hard coral cover comparison

Coral cover in MIMP sites was slightly decreased in most of the reef except reef at Kifinge, Utumbi, Msumbiji and Nyamalile South which revealed a slight increase. Kifinge reef recorded the highest increase by 17.59% from the previous 2018 survey, followed by Msumbiji with 11%, Yuyuni 7.1, Utumbi 1.7% and Nyamalile South 1.5%. Mange has the highest decrease of coral cover by 10.3% followed by Kisiwa kikubwa 7.7%, Kitutia 2.1%, Nyamalile 0.7% and Chawe 0.5% from the last survey of 2018 (Figure.7). Slightly decrease of cover mostly influenced by frequent occurrence of bleaching events and unsustainable fishing practice, in 2020 MIMP reef had severe effect due to this event, but most of the reef show incredible resilience.

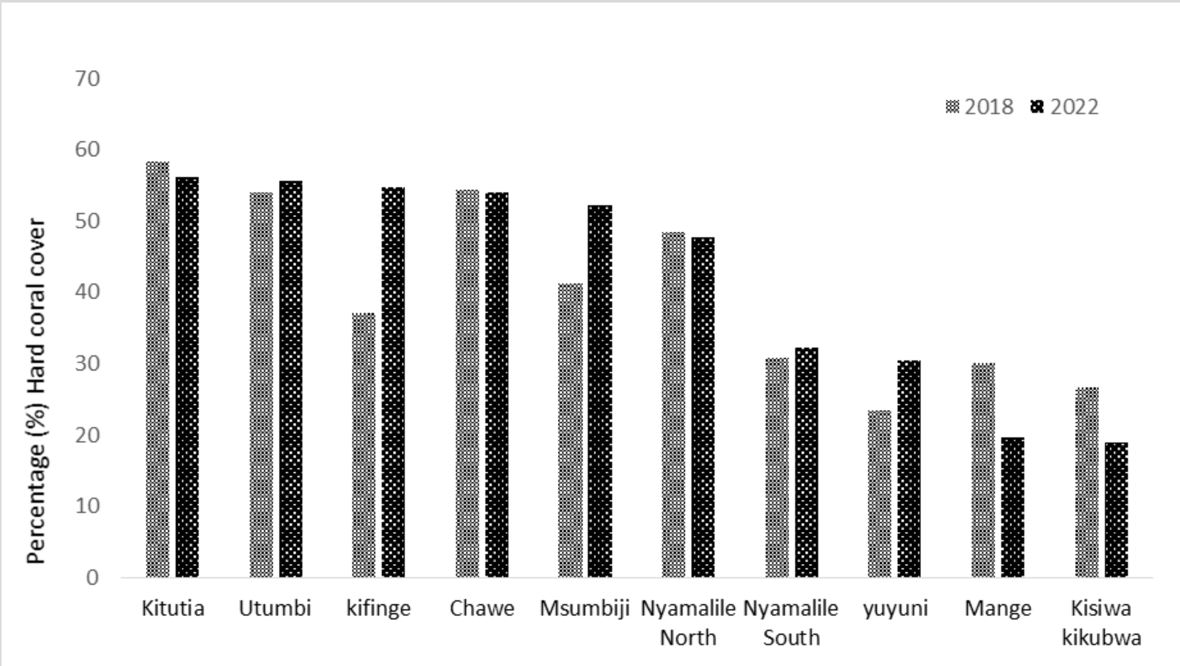



**Figure 7: Live hard coral cover (%) comparison for 2018 and 2022**

### 4.3.4 Benthic cover by site

Kitutia reef has the highest recorded coral cover among all surveyed in MIMP under the current monitoring with 56.2% ± 4.965439 while Kisiwa kikubwa recorded the lowest coral live coral cover of 18.9% ± 2.8. Mange and Utumbi observed to have high percentage of rubbles, 28.7% ± 5.1 and 28.4 ± 7.8 respectively while Yuyuni has the lowest percentage of 3.7% ± 1.8,followed by Kifinge 4.29% ± 2.0 Other site rubble ranged from14.3% to 7.5%. Unsustainable fishing practice has high contribution with regard to coral breakage. Kitua and Nyamalile South recorded high percentage of dead coral 19.6% each with standard error (SE) of ±4.5 and ± 8.5 respectively followed bay Chawe 11.4% 3.4 and Nyamalile North 10.6% ± 2.3. Mange observed to have the lowest dead coral percentage 0.7% ± 0.4. All four sites having a high percentage of dead coral were severely affected by the bleaching event of 2020. Five sites with high percentage cover of coralline algae i.e, site of Yuyuni 9.9 ± 3.46, Nyamalile South have 8.8% ± 4.7, Kitutia 7.1 ± 1.9, Mange 6.9 ± 2.9 and chawe 5.0% ± 1.6. Presence of coralline algae provide reasonable substrate for coral recruitment hence promise reefs sustainability at given sites. Three reefs have high percentage of macroalgae, Mange cover 24.3% ± 3.8, Nyamalile North 17.5% ± 2.3, and Nyamalile South 17.4% ± 6.7 and other reefs have less than 7% of macroalgae. All three sites having higher macroalgae cover are both subjected to fresh water flood from the Rufiji delta yearly. four reefs observed to have high percentage of soft coral, Kisiwa kikubwa have highest 44.3% ± 6.6, Kifinge 16.3 ± 3.4, Msumbiji 12,5% ± 3.2 and Yuyuni 9.8 ± 5.5 the remain reef has less tha 3%. Kisiwa kikubwa and Msumbiji located in the same area hence share same physical-chemical parameter, but Kisiwa kikubwa is close to the Juani Island, reef is subjected more run off.

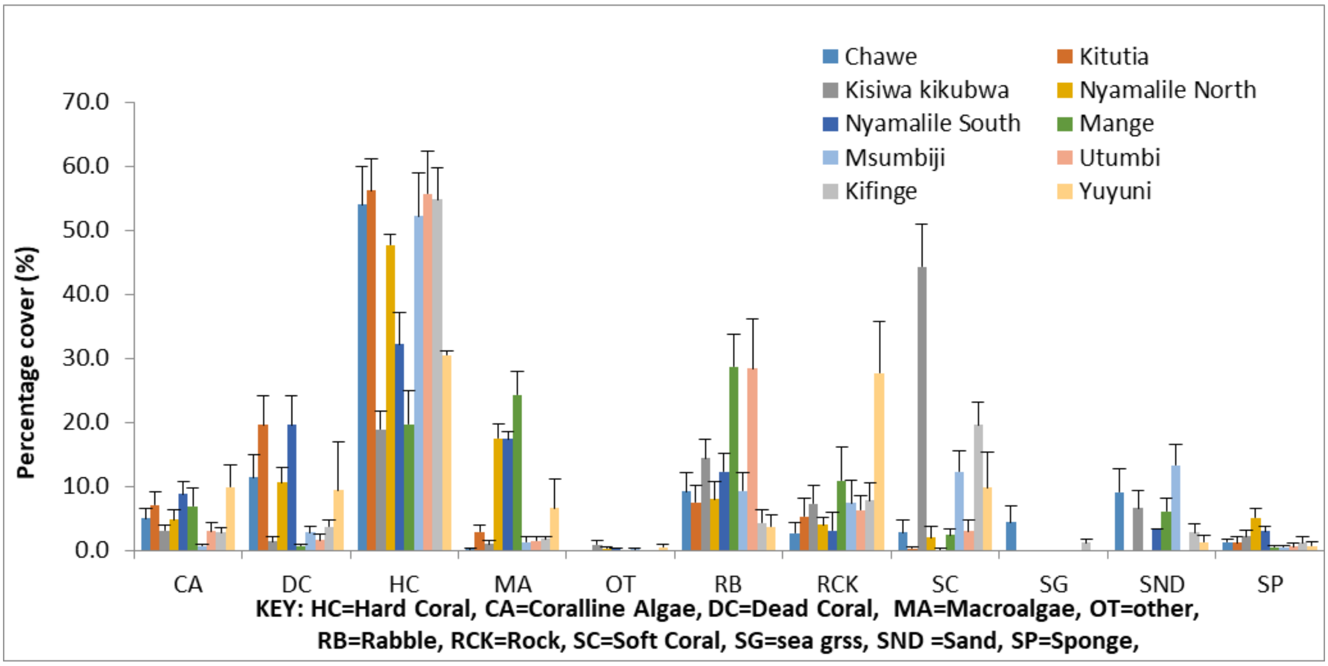



**Figure 8: Sites specific for all category in all monitored sites under current survey**

### 4.3.5 All Categories comparison in all sites

Generally, most of MIMP surveyed reef show slightly decreases on hard coral cover except reef of Kifinge, Yuyuni, Utumbi, Msumbij and Nyamalile South slightly increased compare to the previous survey of 2018 (Figure 7 & 9). Five sites observed to have higher number of corals compare to 2018 monitoring survey. Kitua has high increase of dead coral for 14.26% from 2018 (5.32% in 2018 and 19.58% in 2022), followed by Nyamalile South 12.10% (7.52% in 2018 and 19.62 in 2022), Yuyuni by 8.9% (0.4% in 2018 and 9.38% in 2022), Chawe by 4.9 (6.44% in 2018 and 11.41% in 2022), Nyamalile North by 3.58%, (6.94% in 2018 and 10.52% in 2022) and Kifinge by 2.81% (0.9% in 2018 and 3.71% in 2022), (Figure. 9). All these sites severed affected by 2020 bleaching events, Nyamalile North and South fresh water flood from Rufiji delta hence become stressor ending up with coral mortality. The most affected general was *Acropora*. Mange has highest increases in rubble percentage by 14.47% (14.21% in 2018 and 28.68% in 2022) from previous 2018 survey, followed by Kisiwa kikubwa  and Utumbi by 10.60% (3.74% in 2018 and 14.34% in 2022 for Kisiwa kikubwa  & 17.83% in 2018 and 28.43 in 2022 for Utumbi), kitutia was 5.41% (2.06 in 2018 and 7.47 2022), Kifinge by 2.7% (1.6% in 2018 and 4.3 in 2022) and Nyamalile South by 0.43% (11.90% in 2018 and 12.33% in 2022). Four sites have decrease in rubbles, Yuyuni by 10.9% Chawe by 1.72, Nyamalile by 2.21 and Msumbiji by 3.06. Increased rubble in MIMP mostly contributed by anthropogenic activities include unsustainable fishing practice and anchoring from tourist boats. Data show that there was small difference between the percentage cover of coralline algae from 2018. Mange have increase by 6.25% from 2018 survey followed by Chawe by 4.74%, Kisiwa kikubwa  3.84%, Yuyuni by 0.95% and Kifinge by 0.44%. Four reefs show the decreases of coralline algae from previous survey, Kitutia by 6.50%, Msumbiji by 3.15%, Nyamalile South by 0.38 and Utumbi by 0.3%. Presence of coralline algae indicate the promise of conducive environment for coral recruit. Macroalgae coverage reduced in all site from previous survey of 2018. The average cover in 2018 was 19.13% while in 2022 was 8.25%, these indicate that there is an increase of herbivores particularly those which eat macroalgae.

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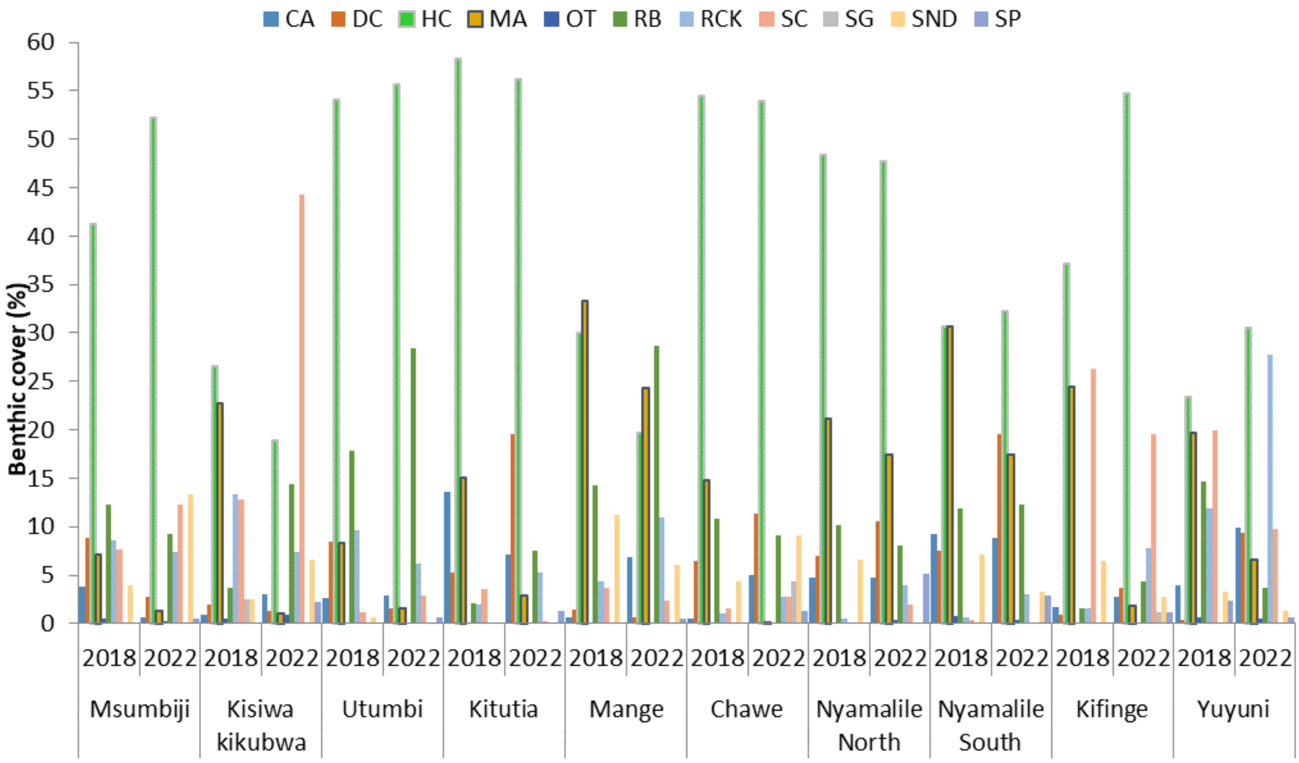



**Figure 9: Site specific comparison in benthic covers (%) between 2018 & 2022**

#### 4.3.6 Coral Community Structure from Benthic Cover Data

A total of 33 coral genera were recorded collectively across all monitored sites. *Acropora* was the most dominant genera estimated to cover 23%, followed by *Galaxea* 13.7%, *Echinopora* 12%, and *Seriatopora* 7.7%, whereas all other genera ranged between 5 and 0.05% (Table 6). Kitutia and Msumbiji had the highest genus diversity compared to other reefs where Msumbiji recorded 40 genera, followed by Chawe and Utumbi which recorded 19%, Nyamalile North 17%, Mange 16%, with Nyamalile South and Kisiwa kikubwa recording 15% and 14% respectively.

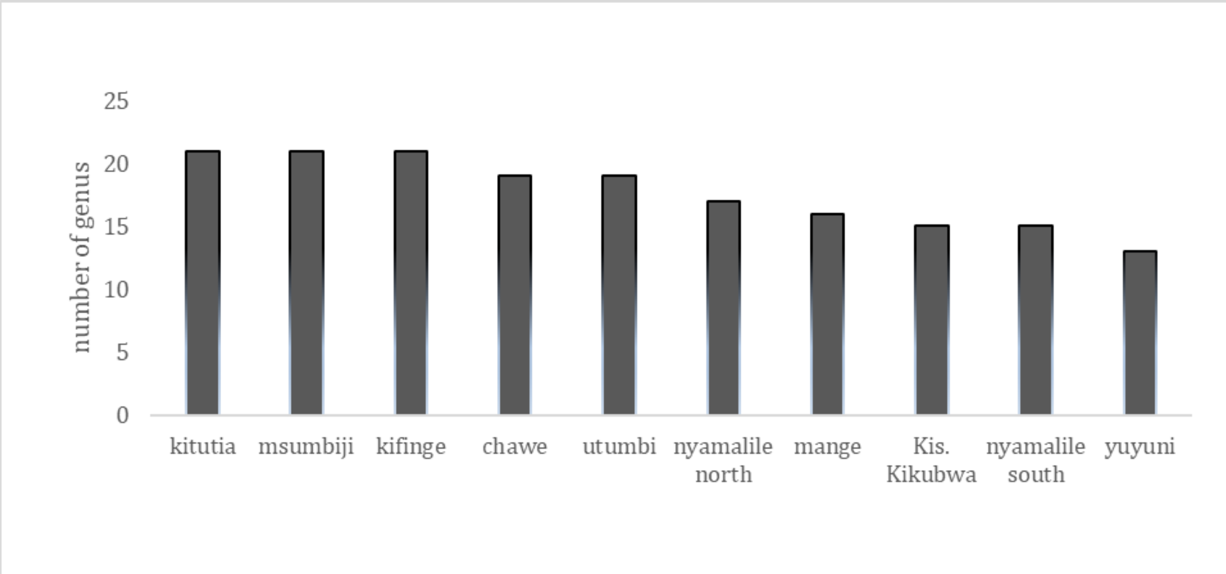



**Figure 10: Number of coral genera recorded from benthic cover data.**

**Table 6: Common genera recorded in Mafia Island Marine Park**

Common genera recorded in Mafia Island Marine Park

| Coral General recorded in MIMP | |
|---|---|
| Genus | Mean % cover |
| Acropora | 2.3 |
| Alveopora | 0.6 |
| Astreopora | 0.1 |
| Caulastrea | 0.0 |
| Coscinaraea | 0.0 |
| Diploastrea | 0.0 |
| Echinopora | 14.4 |
| Favia | 0.3 |
| Favite | 0.0 |
| Fungia | 0.8 |
| Galaxea | 11.4 |
| Goniastrea | 0.0 |

| | |
|---|---|
| Goniopora | 2.1 |
| Halomitra | 4.4 |
| Hydnophora | 0.3 |
| Leptoseris | 0.0 |
| Lobophyllia | 0.0 |
| Merulina | 0.0 |
| Millepora | 1.5 |
| Montipora | 12.4 |
| Mycedium | 0.3 |
| Oxyora | 0.0 |
| Pachseris | 0.0 |
| Pavona | 0.1 |
| pysogyra | 0.0 |
| Platygyra | 0.0 |
| Pocillopora | 1.0 |
| Podabacia | 0.9 |
| Porites | 0.6 |
| Seratopora | 0.5 |
| Stylophora | 0.2 |
| Symphyllia | 0.0 |
| Turbinaria. | 0.0 |

## 4.4 CORAL COMMUNITY STRUCTURE

### 4.4.1. Community Structure from Benthic Cover data

#### 4.4.1.1. Site diversity and abundance of various coral genera among study

This study recorded 40/28 coral genera cumulatively from 8 study sites. The largest number - 40 genera were counted at Msumbiji, and the smallest number 28 observed at Chawe (Table 7).

**Table 7: Number of genera recorded at MIMP sites**

| Sn | Kitutia | Mange | Utumbi | Msumbiji | Kisiwa kikubwa | Chawe | Nyamalile S | Nyamalile N | Kifinge | Yuyuni |
|---|---|---|---|---|---|---|---|---|---|---|
| N | 33 | 29 | 35 | 40 | 36 | 28 | 38 | 29 | 22 | 21 |
| 1 | Acropora | Acanthastrea | Acanthastrea | Acanthastrea | Acanthastrea | Acropora | Acropora | Acropora | Acanthastrea | Acropora |
| 2 | Cyphastrea | Acropora | Acropora | Acropora | Acropora | Cyphastrea | Astreopora | Echinopora | Acropora | Astreopora |
| 3 | Echinophyllia | Astrepora | Ctenactis | Astreopora | Astreopora | Echinophyllia | Coscinarea | Favia | Astreopora | Coscinaraea |
| 4 | Echinopora | Coscinaraea | Echinopora | Coscinarea | Coscinaraea | Echinopora | Cyphastrea | Favites | Coscinaraea | Echinopora |
| 5 | Favia | Coscinarea | Favia | Ctenactis | Cyphastrea | Favia | Echinophyllia | Fungia | Favia | Favia |
| 6 | Favites | Echinopora | Favites | Echinophyllia | Echinophyllia | Favites | Echinopora | Galaxea | Favites | Favites |
| 7 | Fungia | Favia | Favites | Echinopora | Echinopora | Fungia | Favia | Goniastrea | Fungia | Fungia |
| 8 | Galaxea | Favites | Fungia | Favia | Favia | Galaxea | Favites | Goniopora | Galaxea | Galaxea |
| 9 | Gardinoseris | Galaxea | Galaxea | Favites | Favites | Gardinoseris | Fungia | Halomitra | Goniastrea | Herpolitha |
| 10 | Goniastrea | Gardinoseris | Goniastrea | Fungia | Galaxea | Goniastrea | Galaxea | Herpolitha | Leptoseris | Leptoseris |
| 11 | Goniopora | Goniastrea | Goniastrea | Galaxea | Gardinoseries | Goniopora | Gardinoseris | hydnophora | Pavona | Lobophyllia |
| 12 | Halomitra | Goniopora | Halomitra | Gardinoseris | Goniastrea | Halomitra | Goniastrea | Leptastrea | Platygyra | Oxypora |
| 13 | Herpolitha | Hydnophora | Herpolitha | Goniastrea | Goniopora | Herpolitha | Halomotra | Lobophyllia | Galaxea | Pachyseris |
| 14 | Hydnophora | Leptastrea | Hydnophora | Goniastrea | Halomitra | Hydnophora | Herpolitha | Merulina | Pocillopora | Pavona |
| 15 | Leptastrea | Leptoria | Leptastrea | Goniopora | Herpolitha | Leptastrea | Hydnophora | Mycedium | Porites (b) | Platygyra |
| 16 | Leptoria | Leptoseris | Leptastrea | Halomitra | Hydnophora | Leptoria | Leptastrea | Oxypora | Porites (m) | Pocillopora |
| 17 | Lobophyllia | Lobophyllia | Lobophyllia | Herpolitha | Leptoria | Lobophyllia | Leptoria | Oxypora | Seroiatopora | Porites (b) |
| 18 | Merulina | Merulina | Lobophyllia | Hydnophora | Merulina | Merulina | Lobophyllia | Pachyseris | Stylophora | Porites (m) |
| 19 | Millepora | Montipora | Millepora | Leptastrea | Millepora | Millepora | Lobophyllia | Pavona | Symphillia | seriatopora |
| 20 | Montipora | Mycedium | Montipora | Leptoria | Montipora | Montipora | Merulina | physogyra | Tubipora | Stylophora |
| 21 | Mycedium | Physogyra | Oxypora | Leptoseris | Mycedium | Oxypora | Millepora | Platygyra | Lobophyllia | Montipora |
| 22 | Oxypora | Platygyra | Pachyseries | Lobophyllia | Oxypora | Pavona | Montipora | Plerogyra | Montipora | |
| 23 | Pavona | Plesiastrea | Pavona | Merulina | Pachyseris | Physogyra | Mycedium | Plesiastrea | | |
| 24 | Platygyra | Pocillopora | Pavona | Millepora | Pavona | Platygyra | Oxypora | Pocillopora | | |
| 25 | Plerogyra | Porites (b) | Physogyra | Montastrea | Physogyra | Pocillopora | Pachyseris | podabacea | | |
| 26 | Pocillopora | Porites (m) | Platygyra | Montipora | Platygyra | Porites (b) | Pavona | Porites (b) | | |
| 27 | Porites (b) | Seriatopora | Plerogyra | Mycedium | Plerogyra | Seriatopora | Physogyra | Porites (m) | | |
| 28 | Porites (m) | Stylophora | Plerogyra | Oxypora | Plerogyra | Synarea | Platygyra | Seriatopora | | |
| 29 | Seriatopora | Turbinaria | Pocillopora | Pachyseris | Pocillopora | | Plesiastrea | Turbinaria | | |
| 30 | Stylophora | | Podabacea | Pavona | Podabacea | | Pocillopora | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Stylophora | | Porites (b) | Physogyra | Porites (b) | | Podabacea | | | |
| 32 | Synarea | | Porites (m) | Platygyra | Porites (m) | | Porites (b) | | | |
| 33 | Tubipora | | Seriatopora | Plerogyra | Psammocora | | Porites (m) | | | |
| 34 | | | Stylophora | Plesiastrea | Seriatopora | | Seriatopora | | | |
| 35 | | | Symphyllia | Pocillopora | Tubipora | | Stylophora | | | |
| 36 | | | | Podabacea | Turbinaria | | Symphyllia | | | |
| 37 | | | | Porites (b) | | | Turbinaria | | | |
| 38 | | | | Porites (m) | | | | | | |
| 39 | | | | Seriatopora | | | | | | |
| 40 | | | | Stylophora | | | | | | |

### 4.4.2. Coral population structure

#### 4.4.2.1 Community Structure for Coral Size Class and 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 identifying the colonies to genus level. Coral reef size analysis was based on seven size classes including 11-20cm, 21-40cm, 41-80cm, 81-160cm, 161-320cm and >320cm.

#### 4.4.2.2 Coral Genus Abundance by Number and Area

The coral genus number was estimated by using belt method of by laying two transects of 25m*1m (50m$^2$) each. *Acropora* and *Echinopora* were the most abundant genera overall, both by number and area **(Fig 11)** probably because the former highly dominated coral genera at Kitutia, Nyamalile S, and Nyamalile North, and the latter highly dominant at Chawe, Utumbi, and Msumbiji **(Fig 12).** The results are relatively similar to that of the 2018 survey at which Acropora and Echinopora showed higher numbers of colonies and percent coverage (URT 2018). *Galaxea* and *Fungia* were also important in terms of coral area recording (8.9%) and 8.5% respectively. Other important genera by number of colonies include *Pocillopora*,, branching *porites* and *porites massive* **(Fig 11).** Majority of the recorded genera ranged below 5% in coral cover with *Favia*, *Goniastrea*, *Plerogyra*, *Coscinarea*, *Turbinaria*, *Leptastrea*, *Acanthastrea* and *Stylophora* probably because of their significantly low counts in most of the sites.

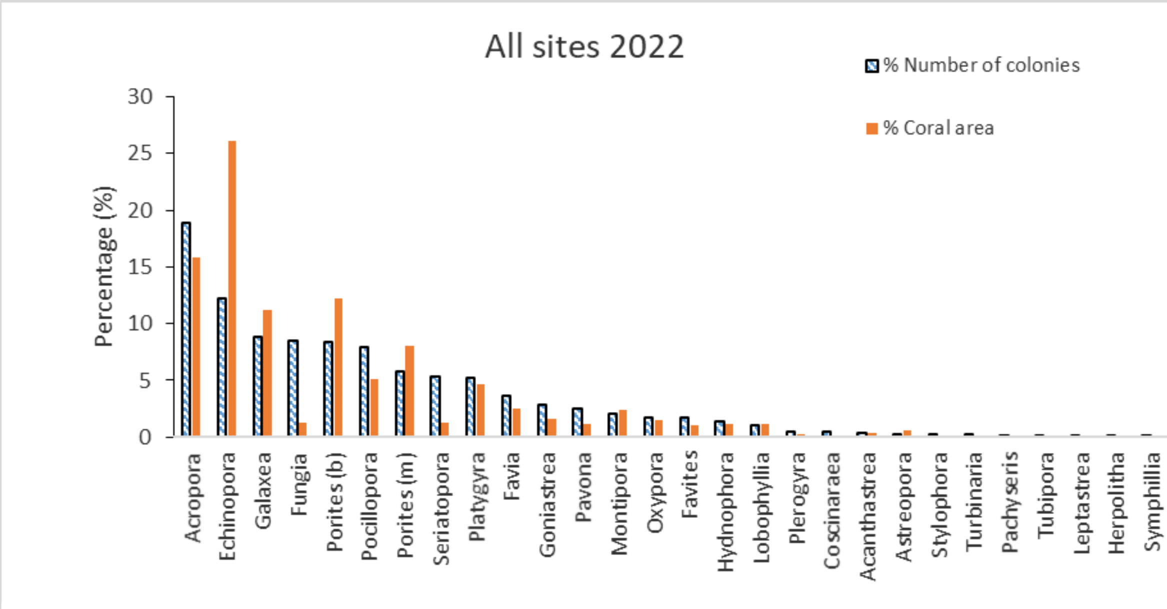



**Fig 11a**

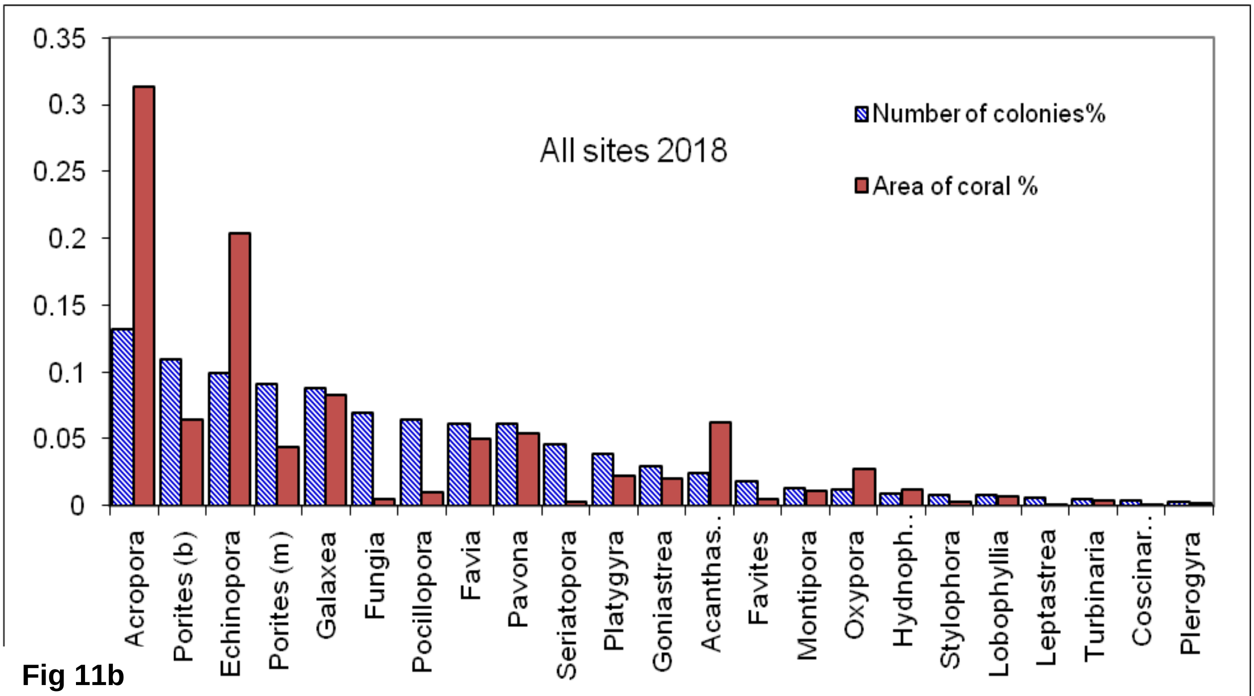



**Fig 11b**

**Figure 11: Coral genera distribution (%) by number of colonies and area for all site combined Fig 11a for 2022 and Fig 11b for 2018 survey**

#### 4.4.2.3 Coral Genus Abundance by sites

For site specific, Utumbi, Kisiwa kikubwa and Chawe was found to have genus *Echinopora* (>40%) with highest percent of coral area, while Kitutia and Nyamalile North have highest area of coral by more than 30% which is dominated by Acropora, Porites massive is observed to dominate at Mange (39%). At Nyamalile south is dominated by *Galaxea* which have 31% area of coral. The sites of Kifinge and Yuyuni is dominate by Porites massive in Kifinge has 30% number of colonies which covers 42% area of coral and Yuyuni has 24% number of colonies which covers 31% coral area. (**Fig 12g**).

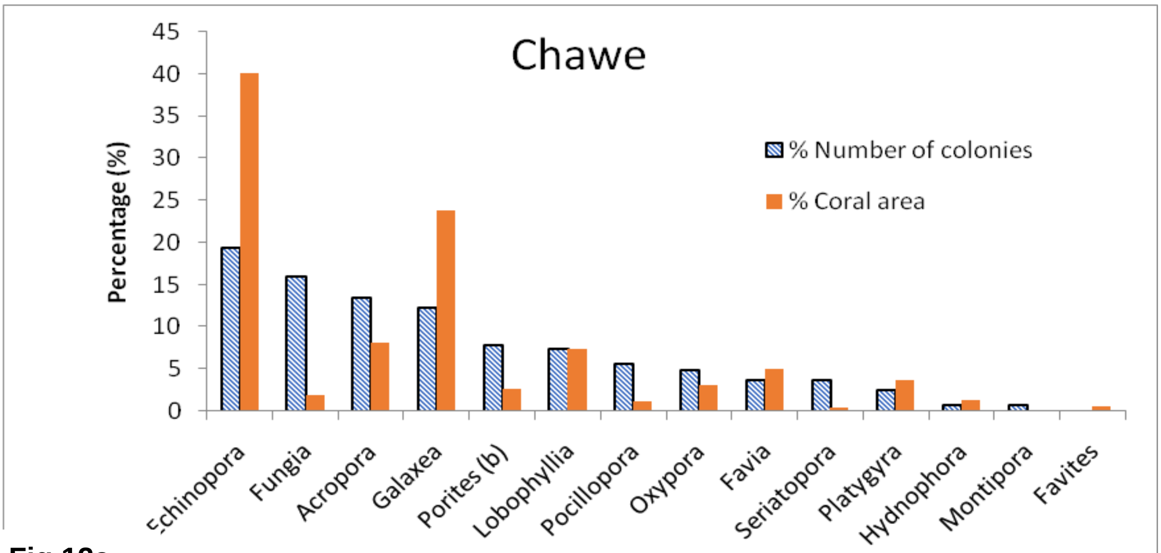



**Fig 12a**

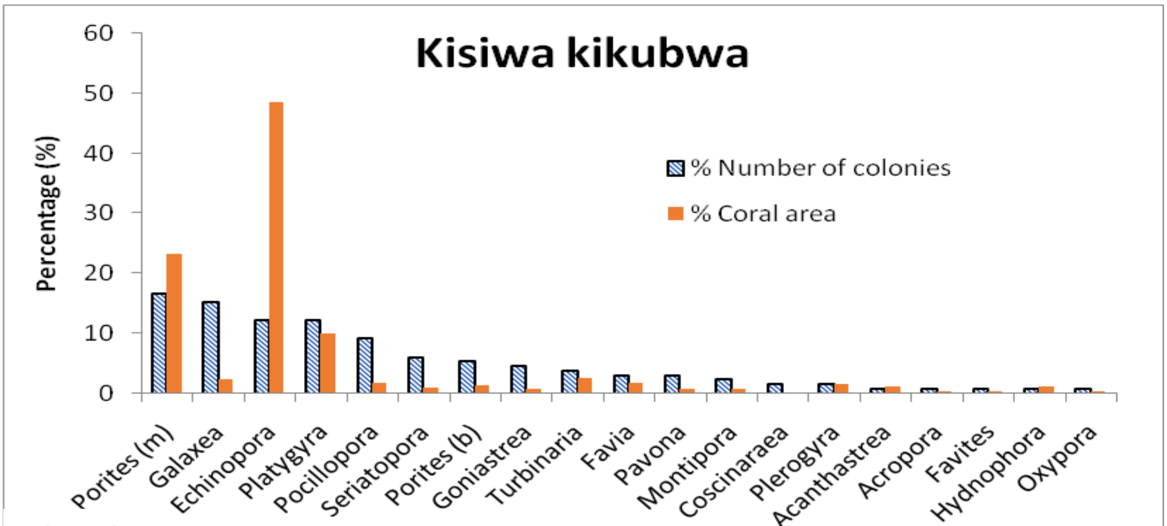



**Fig 12b**

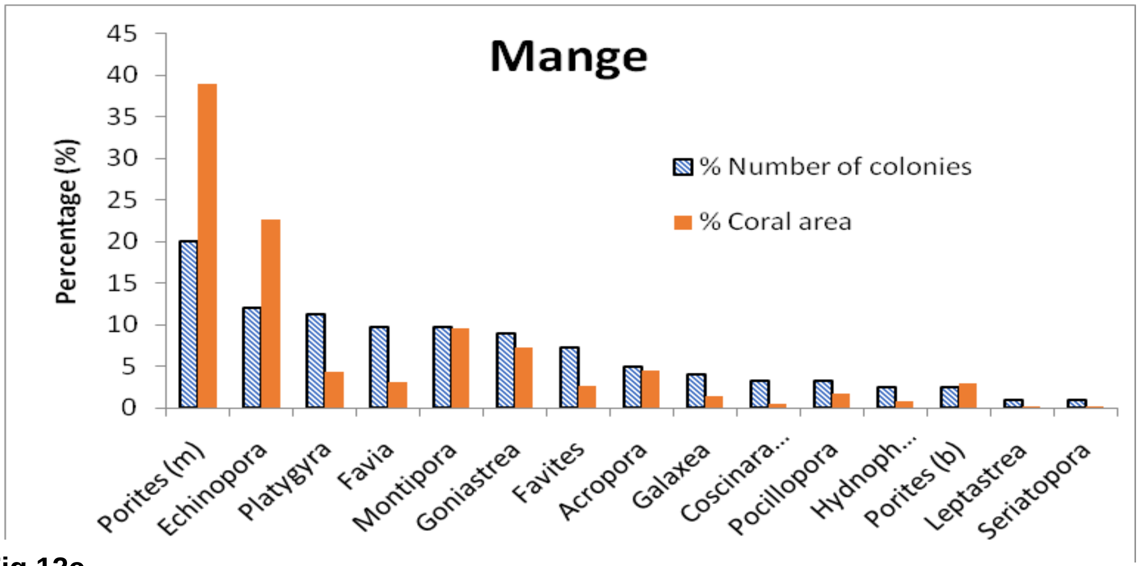



Fig 12c

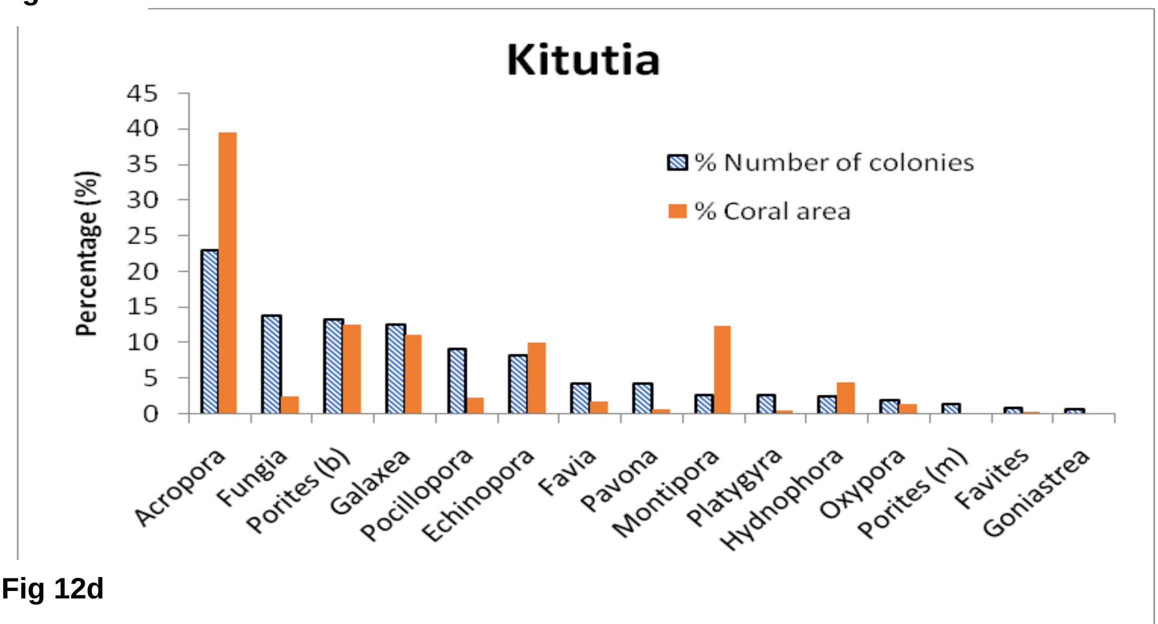



Fig 12d

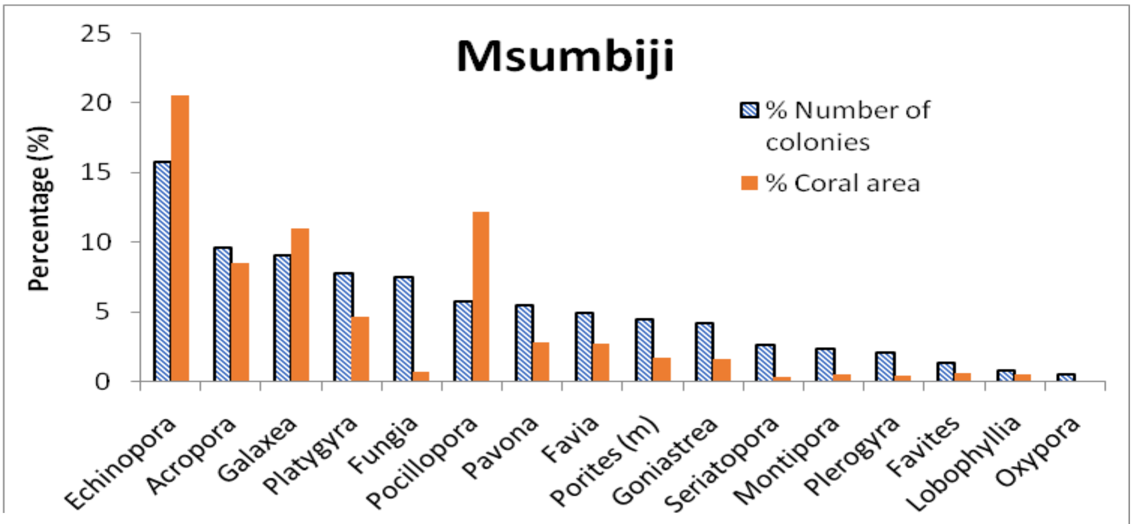



Fig 12e

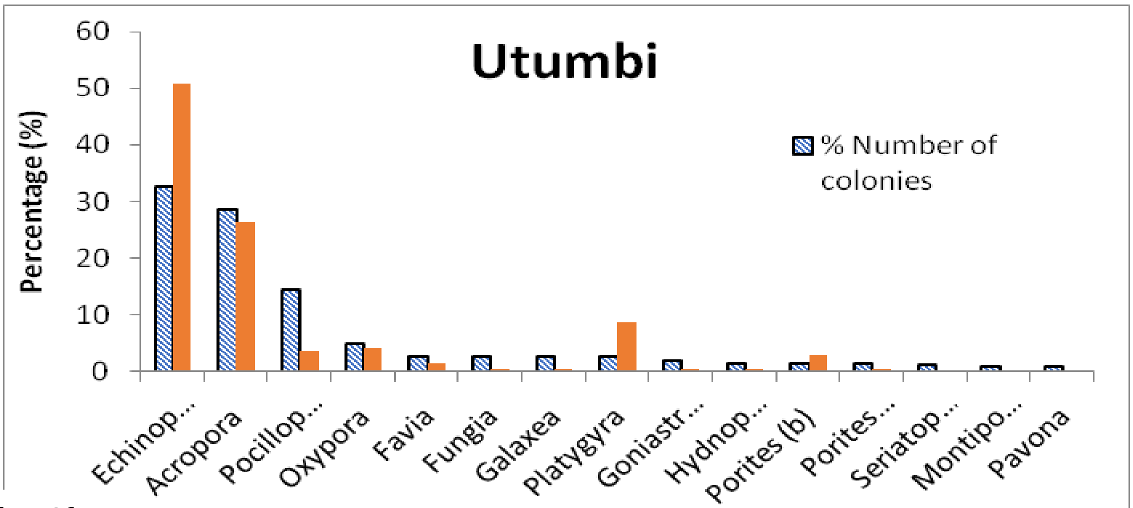



Fig 12f

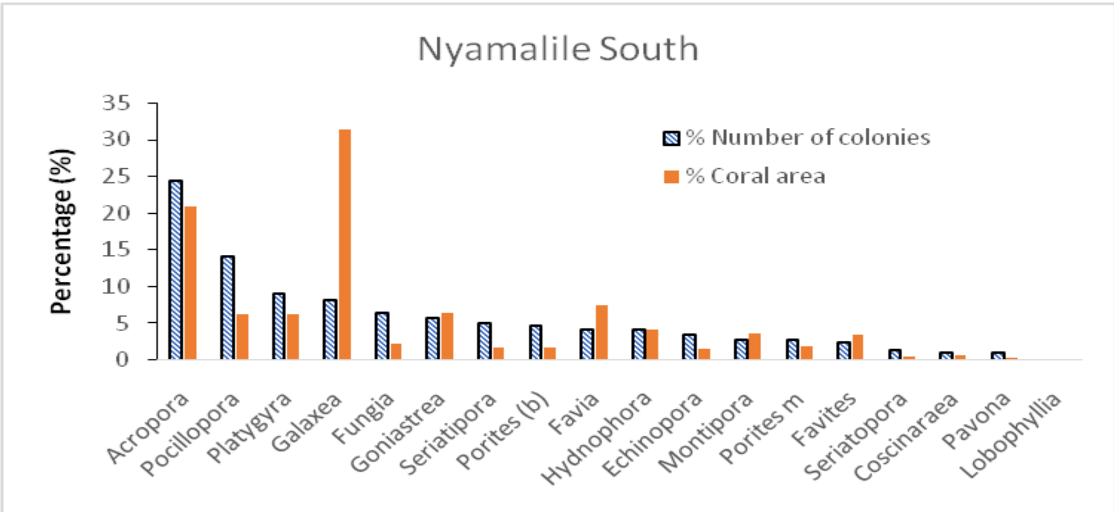



Fig 12g

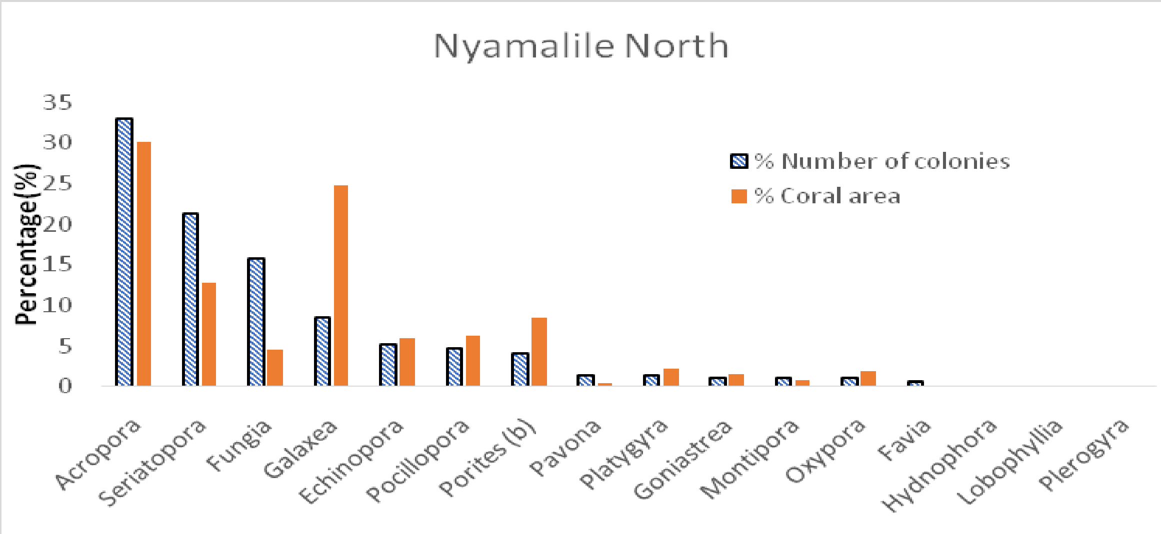



Fig 12h

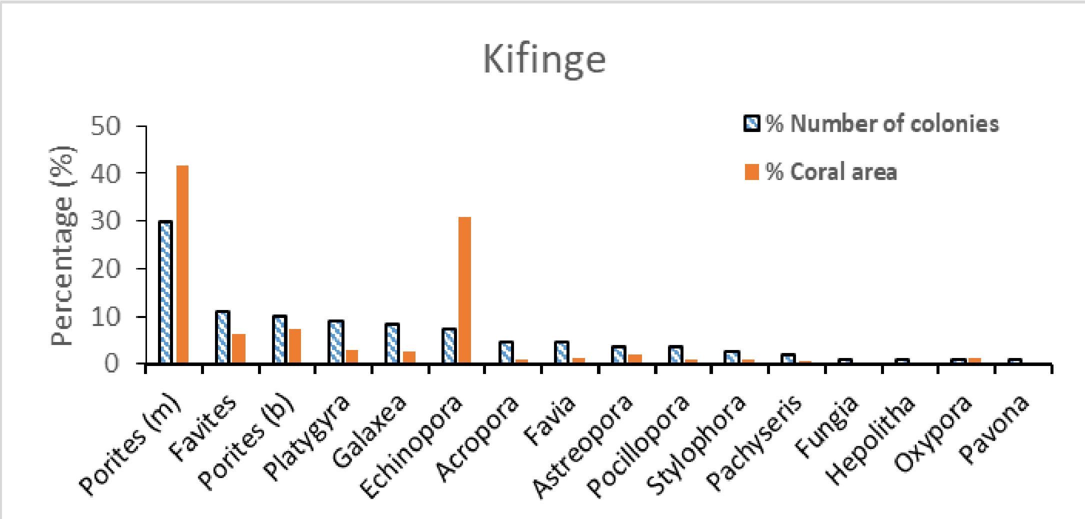



Fig 12i

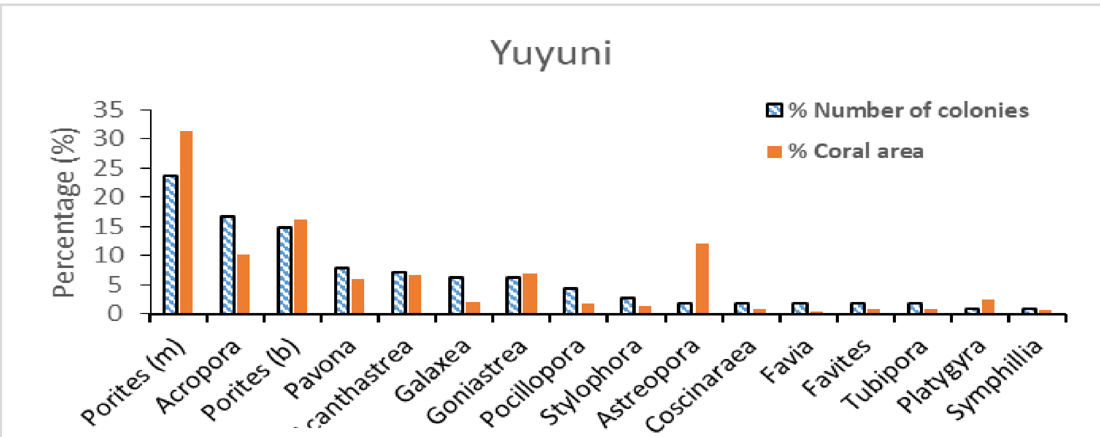



Fig 12j

**Figure 12: Coral genera distribution (%) by number of colonies and area in each site Fig 12a-12j**

### 4.5 CORAL POPULATION STRUCTURE

#### 4.5.1 Coral Size Class Distribution by sites

Generally, the coral cover at MIMP was dominated by corals in medium size ranges 41-80cm, 81-160cm and 160-320 cm (**Fig 8**). This reveals that the coral at MIMP 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 (**Fig 13**). This result was similarly recorded in 2018 (URT, 2018).

Furthermore, the curve in **Fig 13** shows an increasing trend in number of young corals from recruits (0 – 2.5cm) to juvenile (2.5-5cm) to post juvenile stage (5-10cm) colonies. This implies a positive survivorship happening across the size class spectrum, suggesting better environmental conditions prevailing around them and reduced human induced disturbances. However, the curve at 0 – 10cm size colonies is relatively at a highly lower level mainly because of the small number of colonies counted, which could be attributed to inefficiency by the observer given the complexity of the reef structure. However, the usual curve is shown of the decreasing colony numbers towards higher, adult size classes. The 160 – 320cm size colonies was the largest contributor to the overall coral area, whereas, despite appearing in many of the sites, only 2 of the largest (>>320cm) colonies appeared in transects **(Fig 13)**. Only Msumbiji recorded the largest >>320cm colonies in its transects.

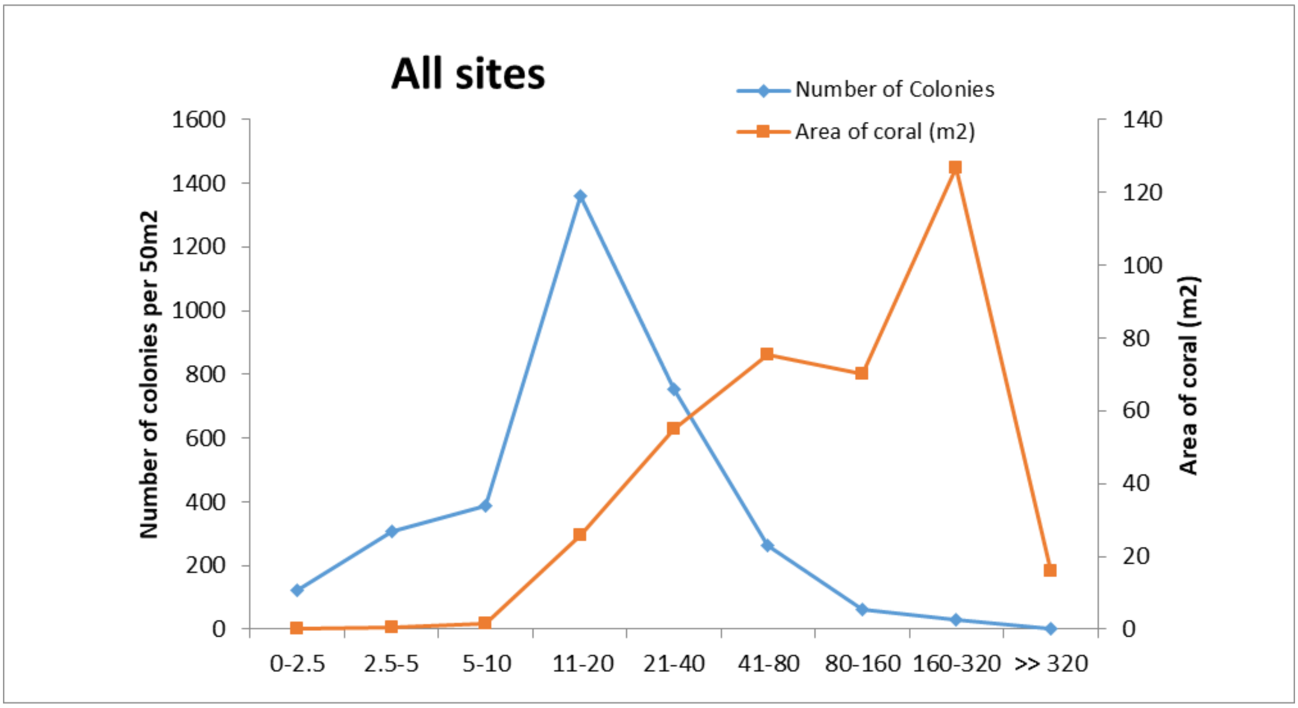



**Figure 13: Size class distribution (number of colonies and area) of all corals**

Site-wise, the results indicates that most of the site have numerous colonies of size class of 21-40 cm contrary to Nyamalile North, Nyamalile South Kitutia and Msumbiji have many corals with size class 11-20 above 200 colonies Msumbiji and Chawe have acute cover at size class 160-320 cm but few number of colonies which indicates that the main contributor is *Galaxea* and *Echinopora*. This genus has a growth characteristic of covering large area. Moreover, coral areas at Chawe, Msumbiji, and Utumbi were dominated by 160-320cm colonies, and at Kisiwa kikubwa and Kitutia by 80-160cm colonies. Nyamalile South and Nyamalile North recorded coral areas largely dominated by corals in the early adult stage (21-40cm) in size **(Fig 14g & 14h).**

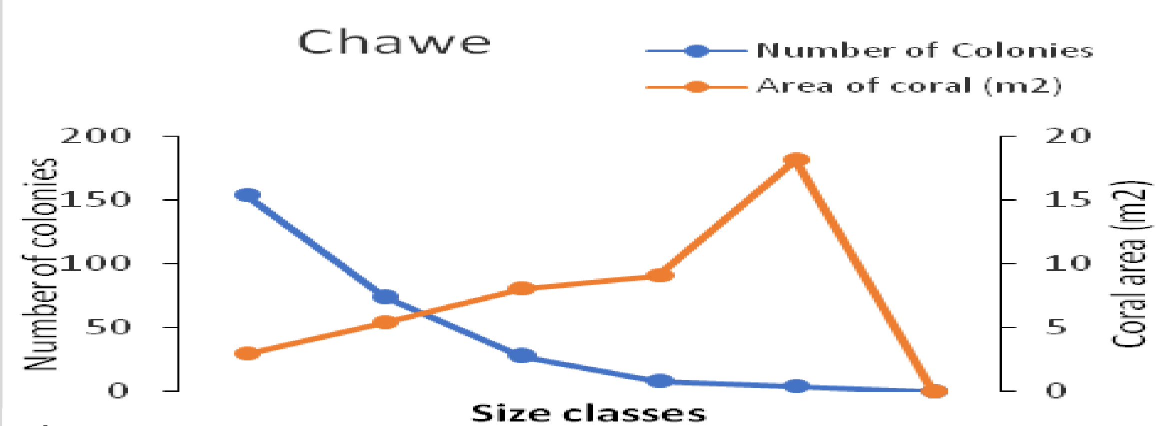



Fig 14a

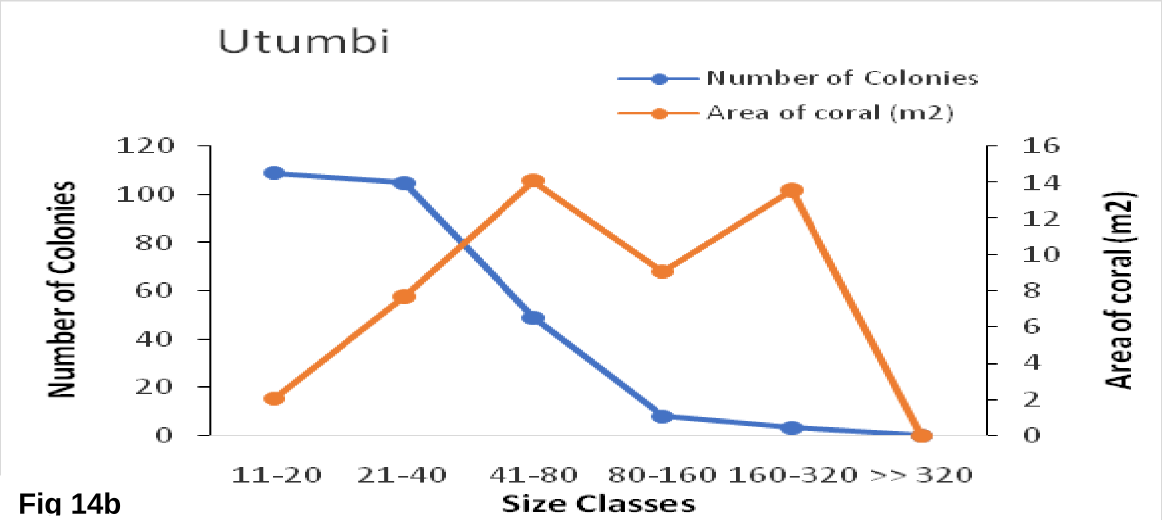



Fig 14b

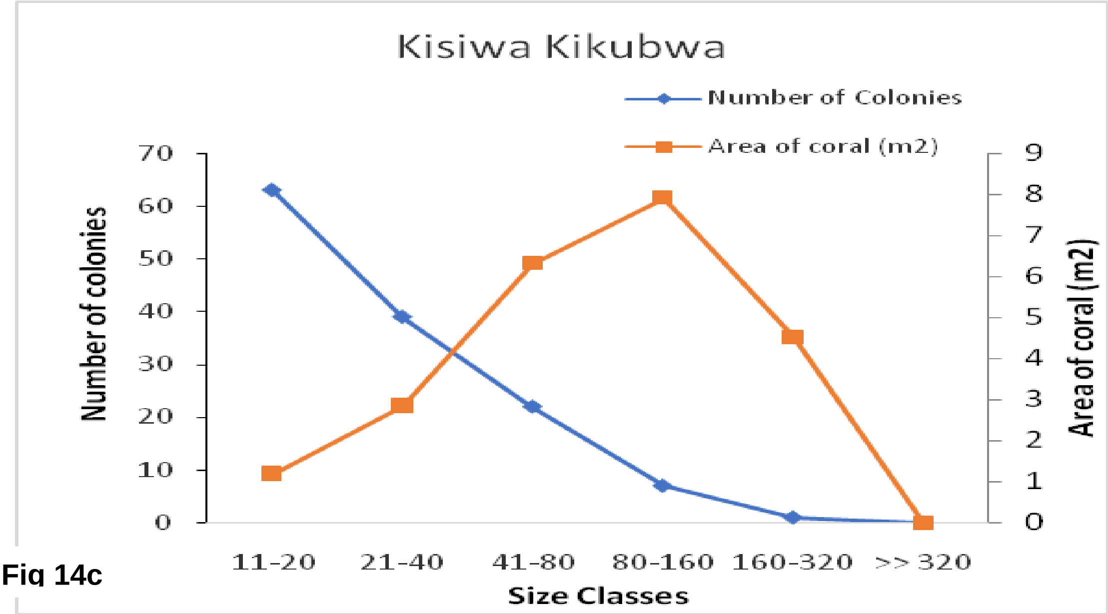



Fig 14c

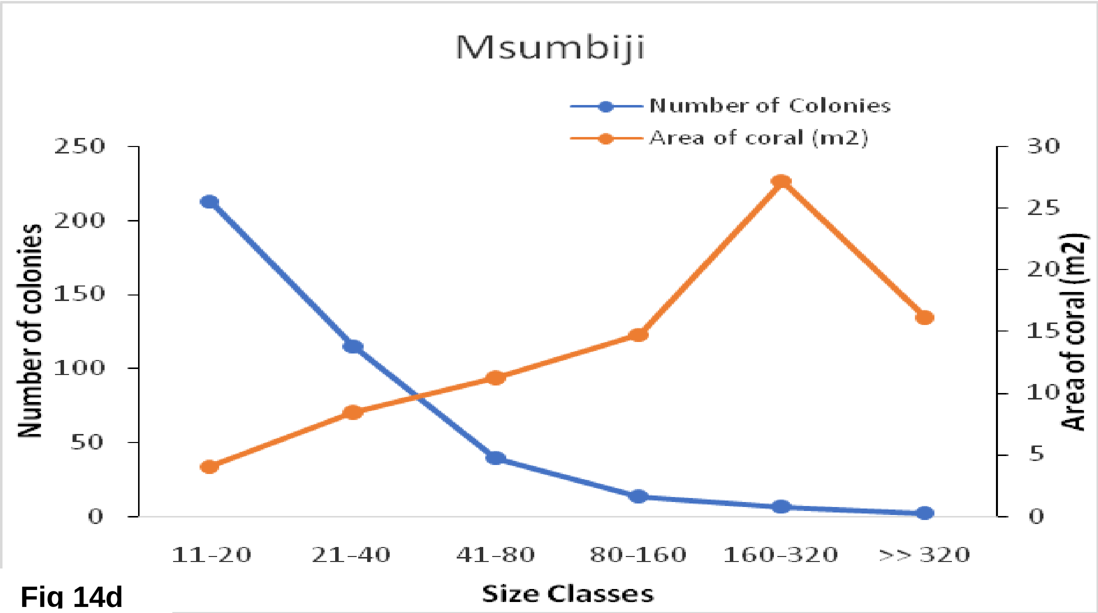



Fig 14d

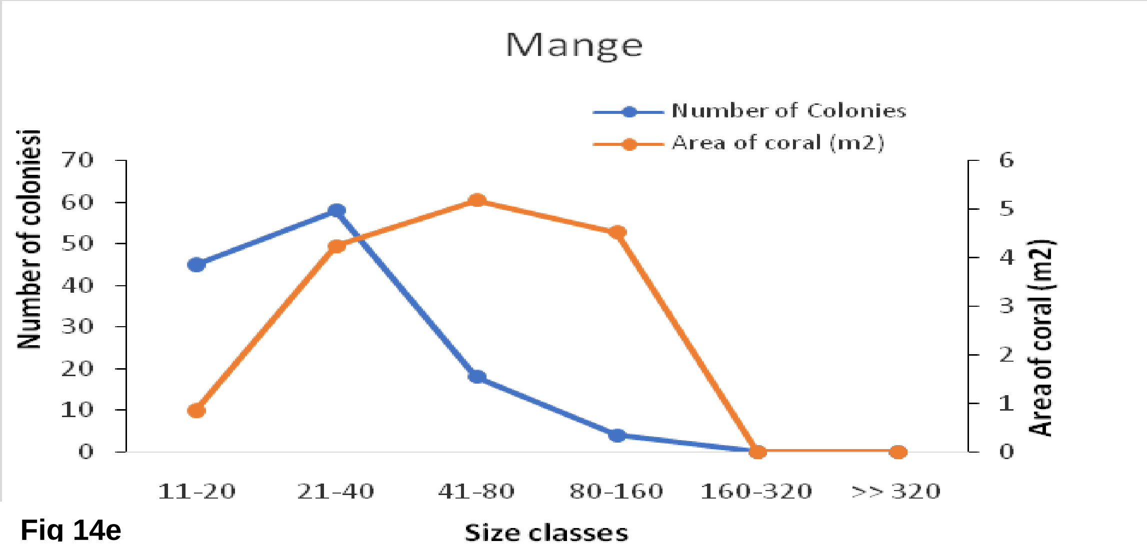



Fig 14e

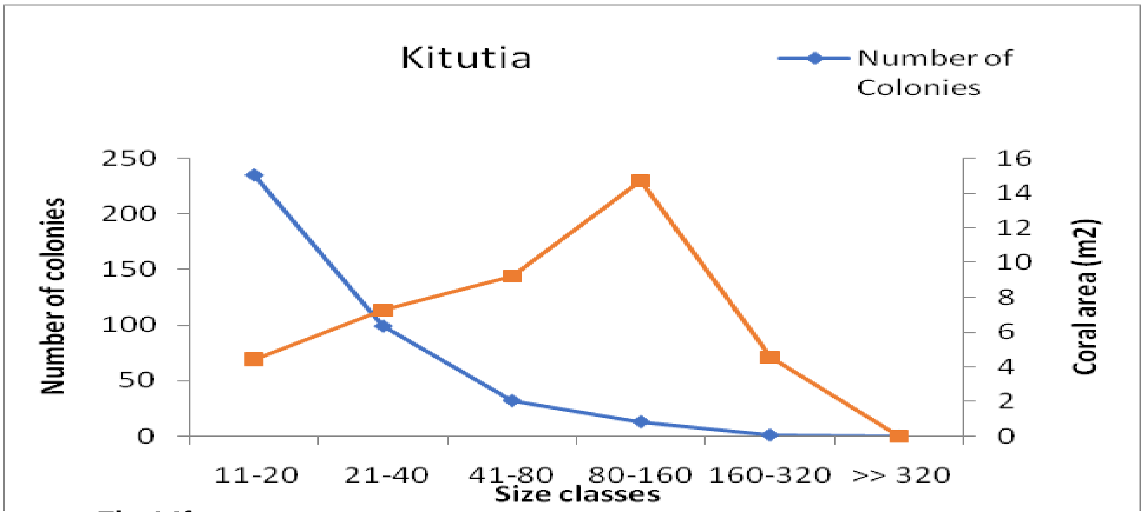



Fig 14f

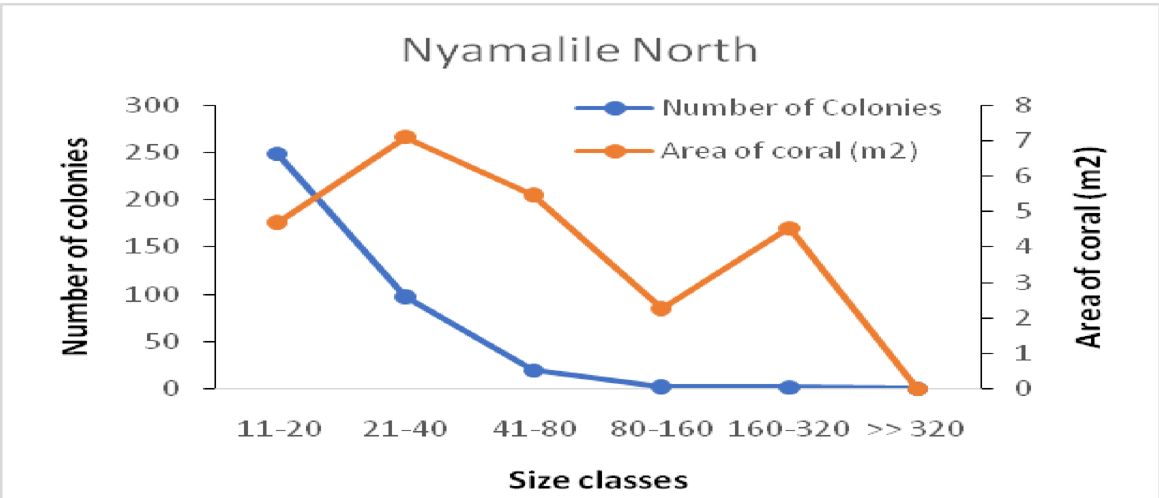



Fig 14g

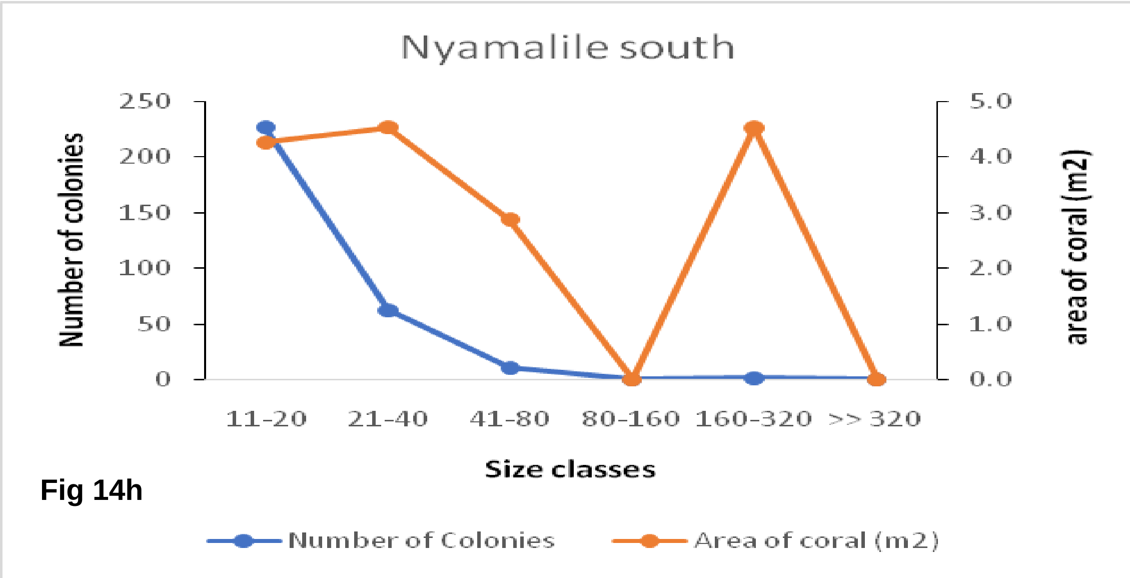



Fig 14h

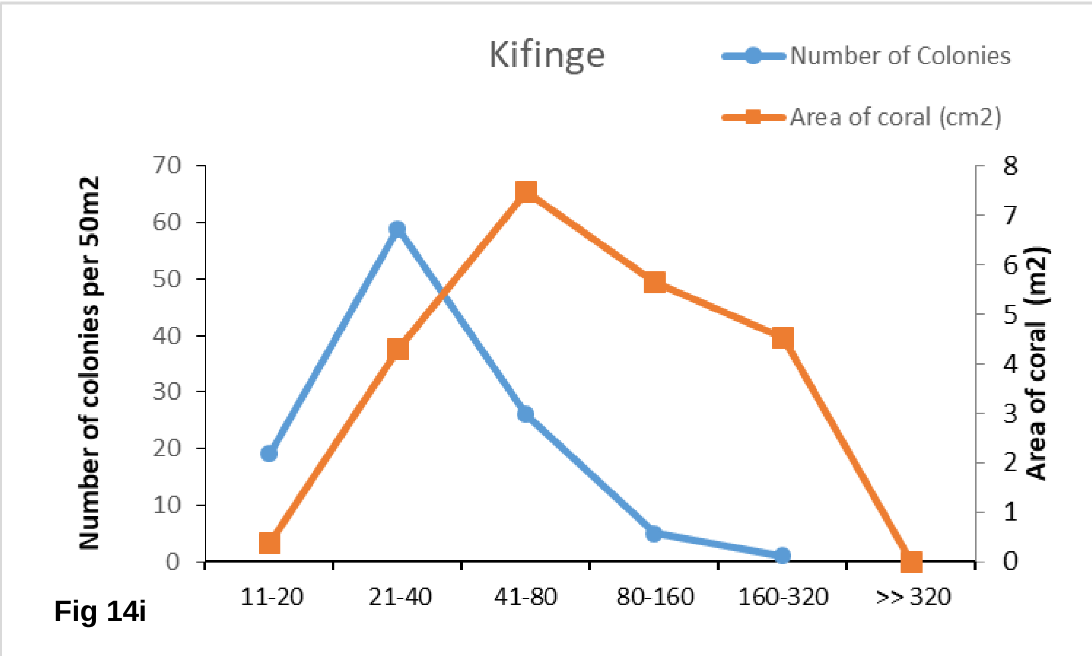



Fig 14i

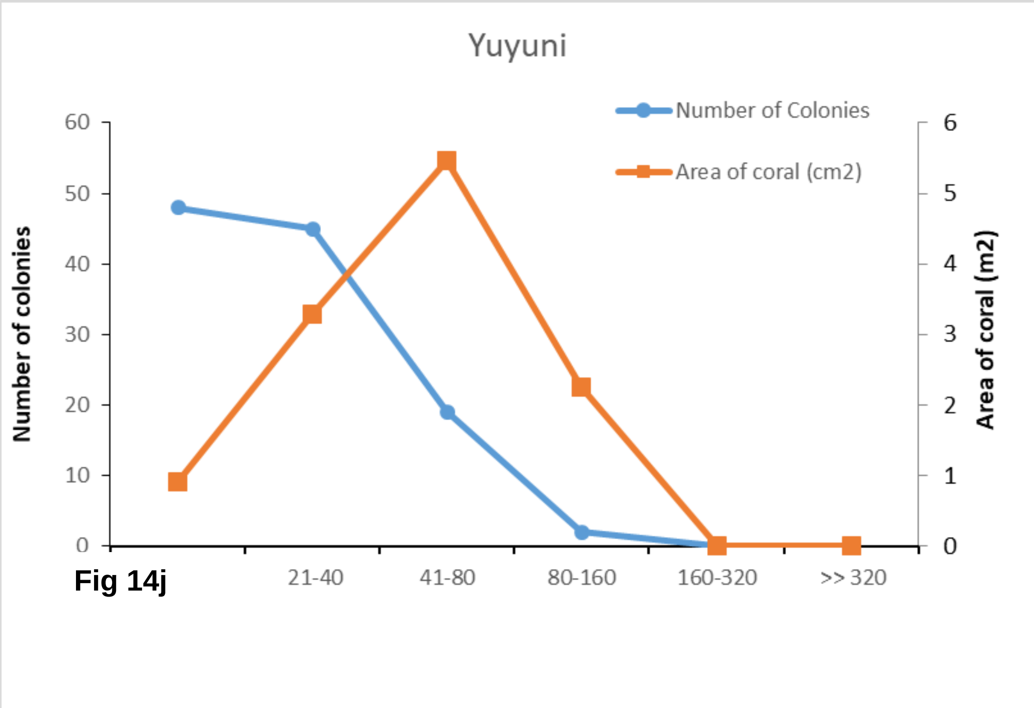
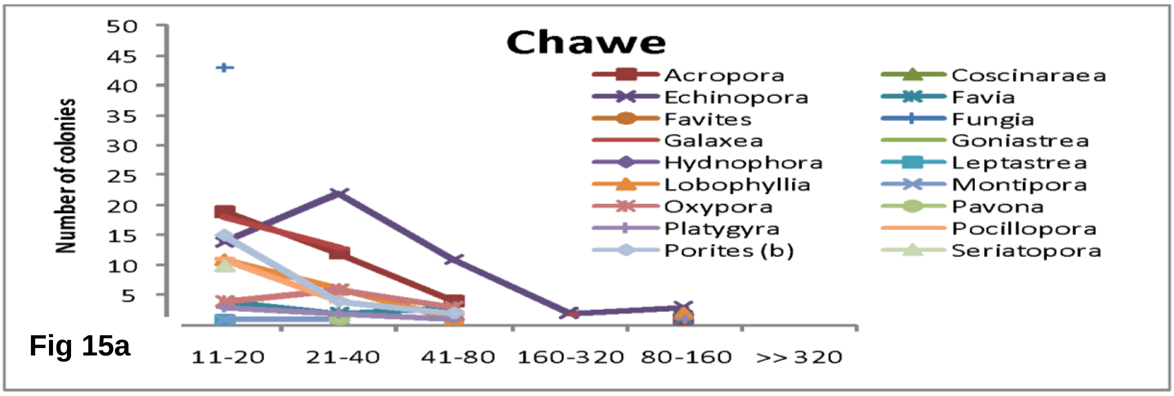
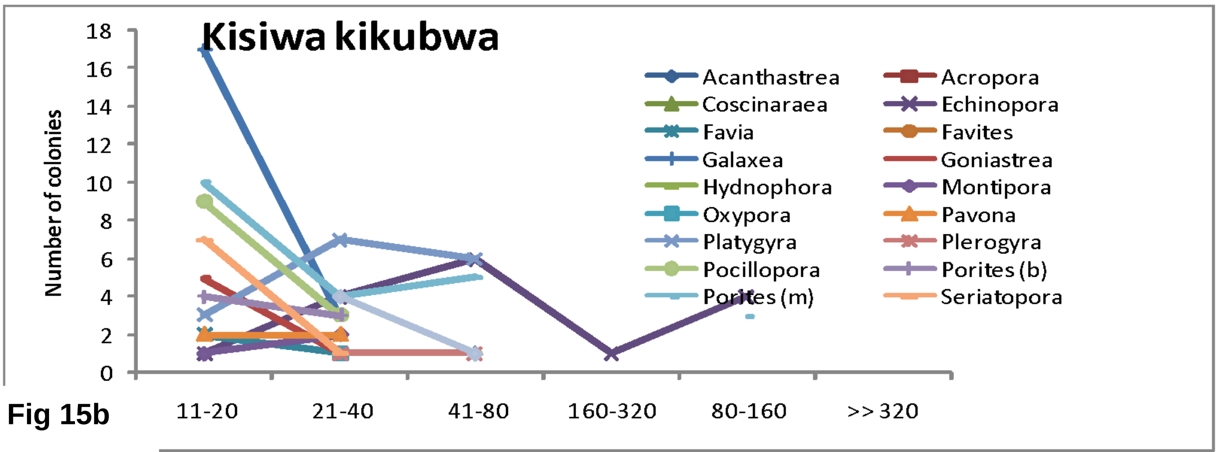



**Figure 14: Size class distributions (number of colonies and area) of all coral by sites Fig 14a-Fig14j**



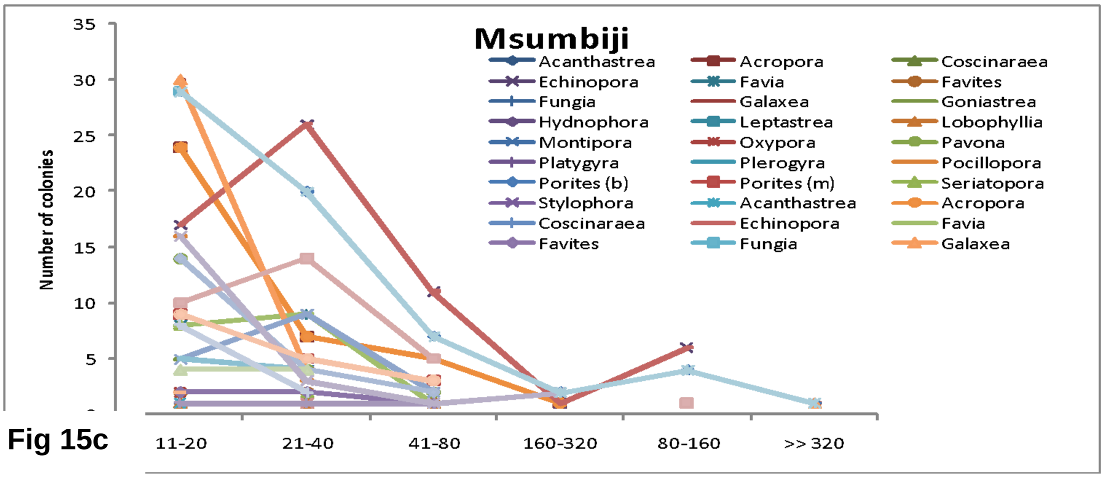



Fig 15c

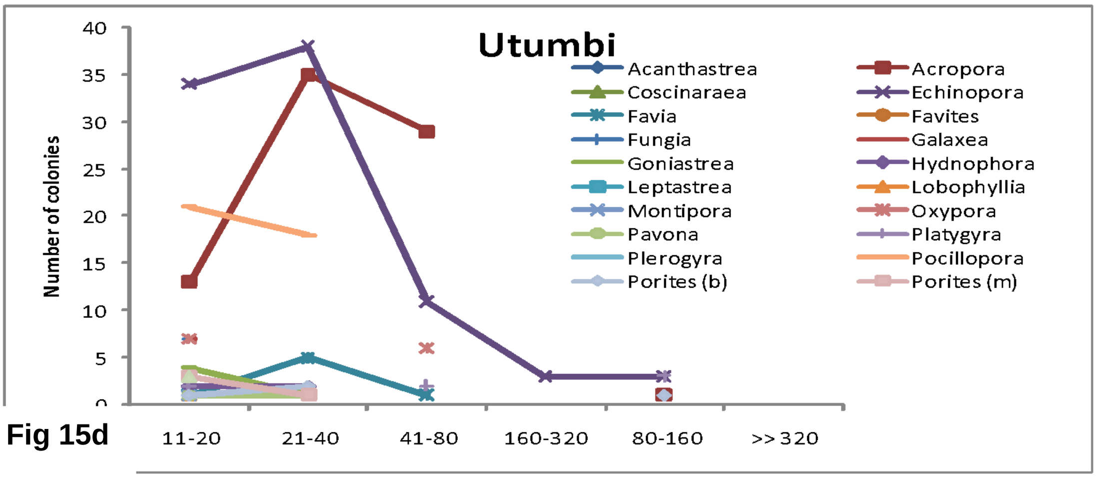



Fig 15d

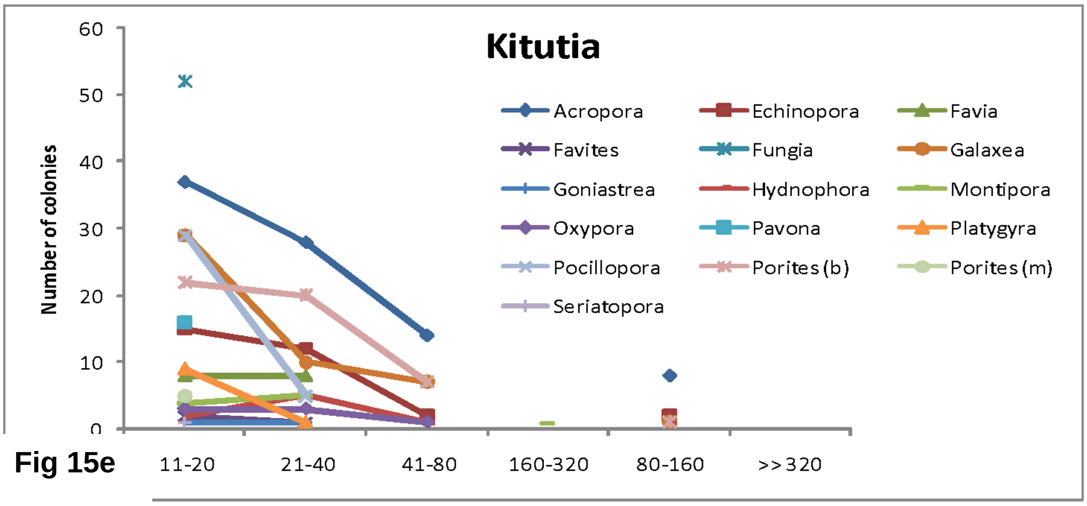



Fig 15e

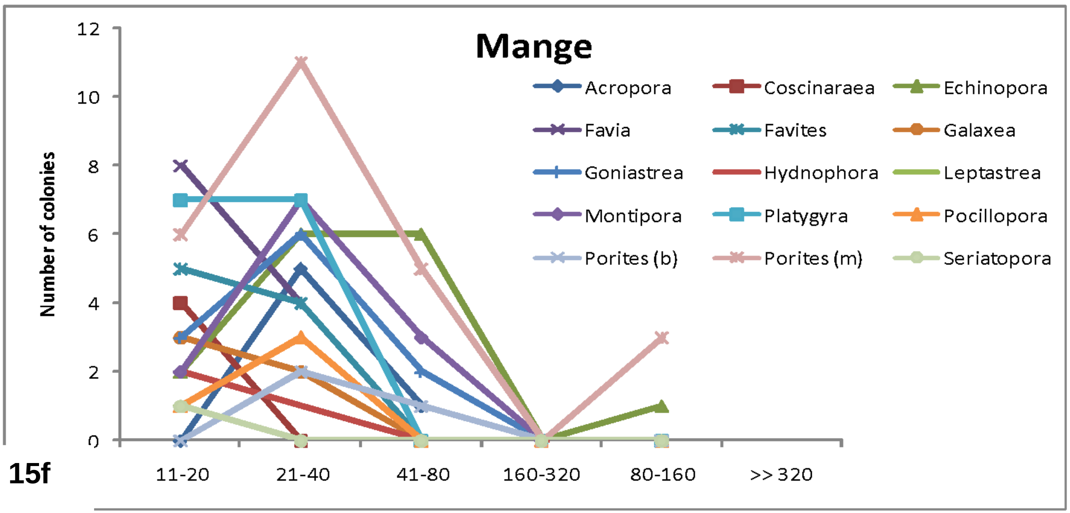



Fig 15f

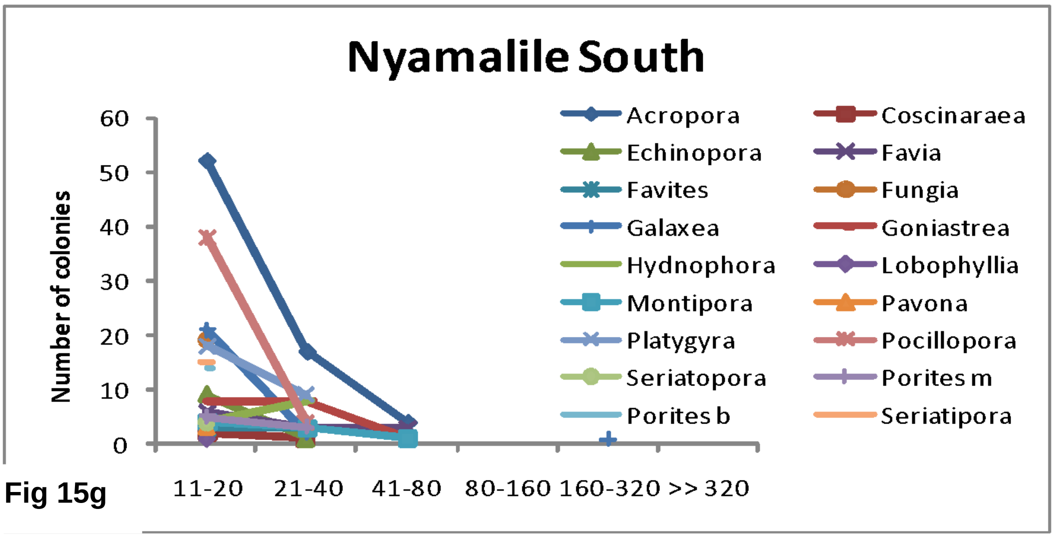



Fig 15g

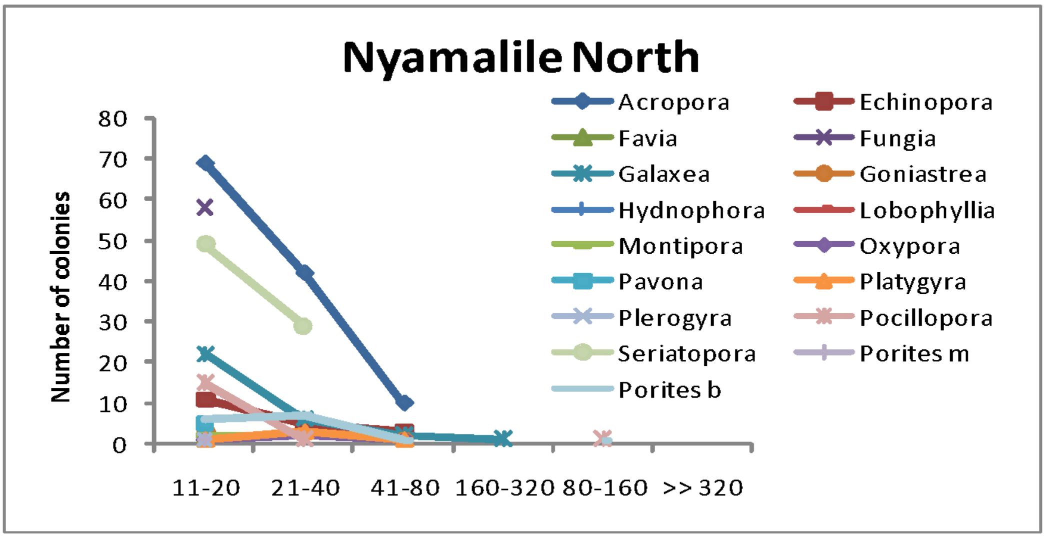



Fig 15h

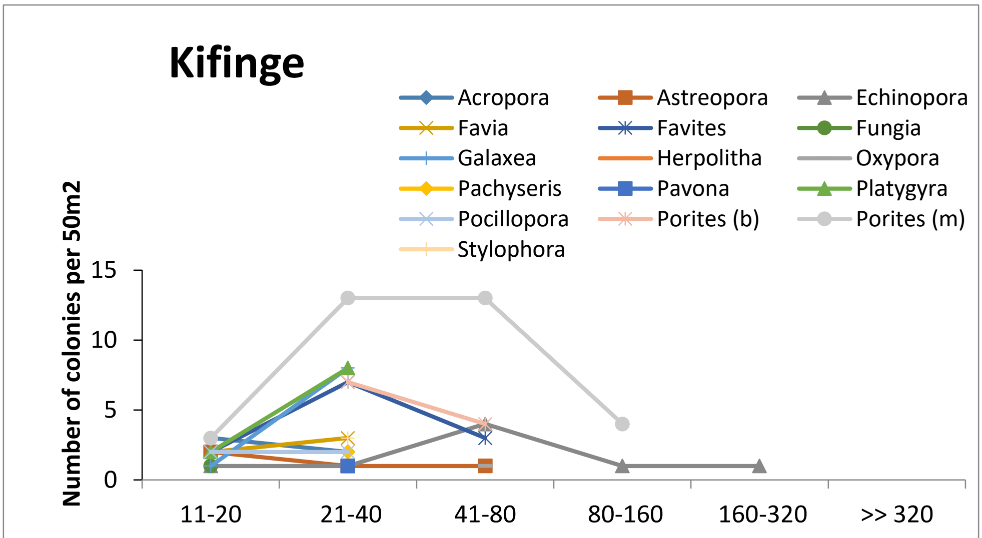



Fig 15i

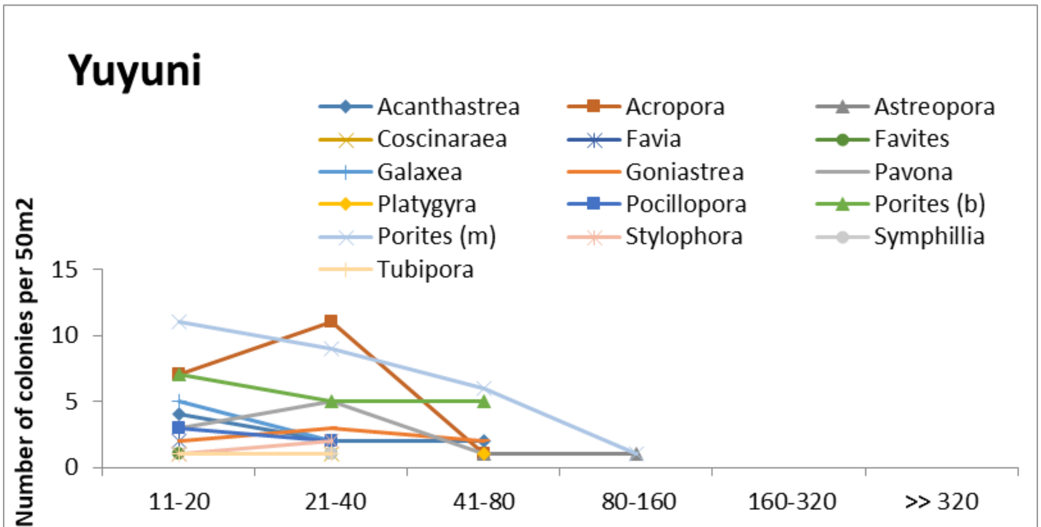



Fig 15j

**Figure 15: Size class distributions (number of colonies) of all corals recorded from each site Fig 15a-Fig 15b.**

### 4.5.2 Coral Recruits and Juveniles

In this study, coral recruitment counted from the range of 1-10cm diameter using 1 $m^2$ quadrat placed 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.

#### 4.5.3.1 Recruits and Juvenile density

Generally, the average recruits and juveniles for all sites in MIMP is (6.8± SE) per $m^2$ the result revealed an increase by 51% to the average of (4.5±SE) colonies observed during the survey conducted in 2018 (URT 2018). The highest recruitment was observed at Nyamalile north site with mean of (13.3 + SE) colonies per $m^2$, followed by Msumbiji (11.3 ± SE) colonies per $m^2$ and Chawe (9.8 ± SE) colonies per $m^2$ and the lowest density (1.7±SE) observed at Kisiwa kikubwa (2.8+SE) and (2.8+SE) Kifinge **(Fig 16).** Nyamalile North is dominated by small size *Seriatopora* and *Acropora* colonies that probably contributed to its dominance overall and across the recruit – juveniles size ranges **(Fig 16 & 17).**

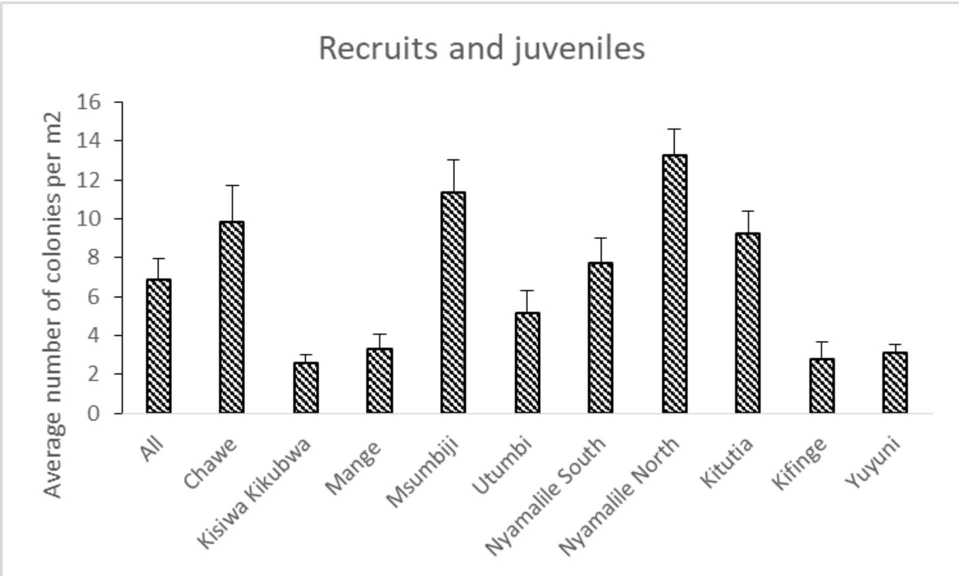



**Figure 16: The average number of colonies for each site in each coral recruitment categories (0-2.5 cm, 2.5-5 cm and 5-10 cm) in 1 m2**

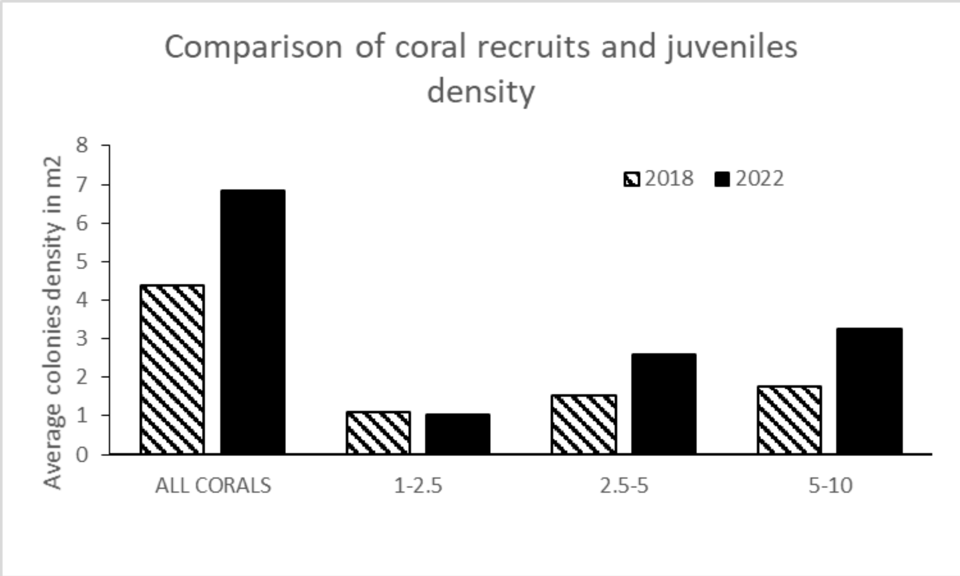



**Figure 17: Comparison of average number of colonies per m2 in recruits and juveniles in all sites**

Msumbiji recorded the highest average density (6.8 +SE) per $m^2$ of 5-10cm juveniles (**Fig. 17**.) probably because of the natural survivorship capacity of recruits and lower range (2.5-5cm) juveniles, or due to large number of fragments of broken *Echinopora lamellosa*. Other important sites in terms of this size class include Nyamalile North, (5.3 + SE) and Chawe (4.7 + SE) and Kifinge has no colonies of 2.5-5cm size class while Yuyuni showed lower number of colonies (0.7 + SE) this could be because the sites are just close to cliff which experience high wave action after hitting the cliff hence difficult for larvae settlement.

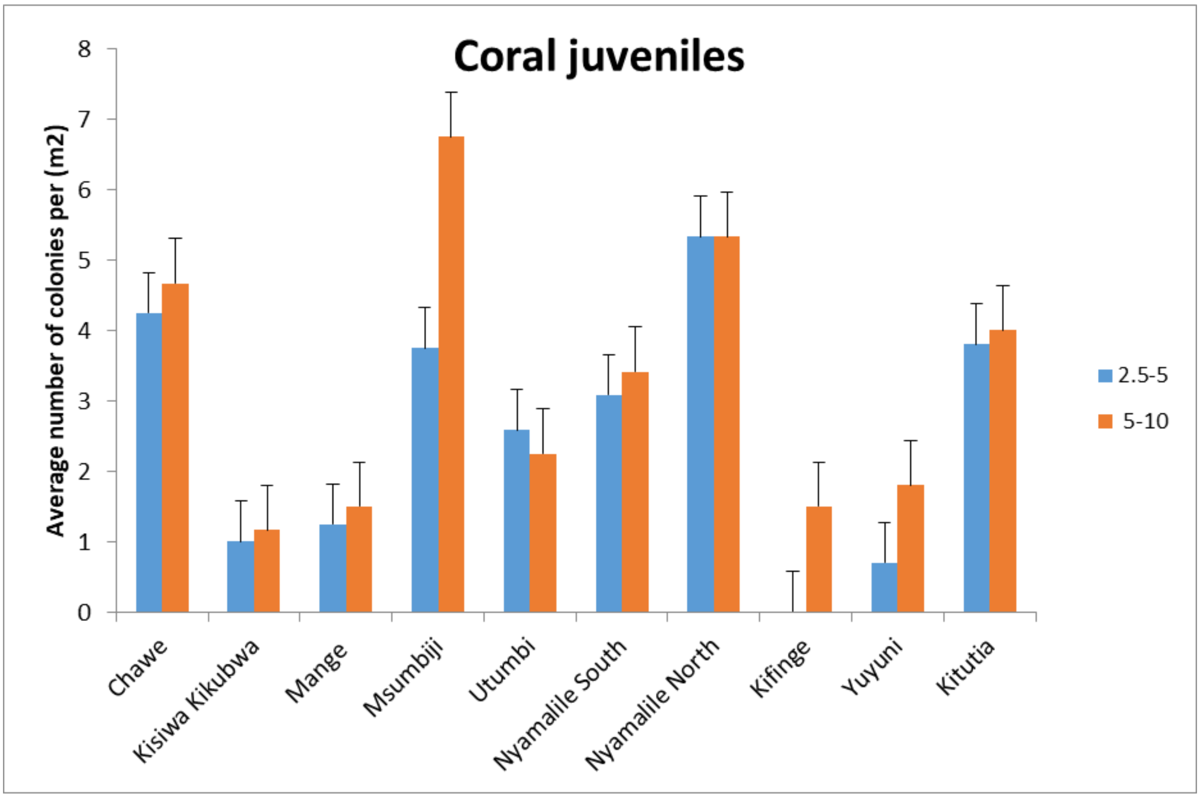
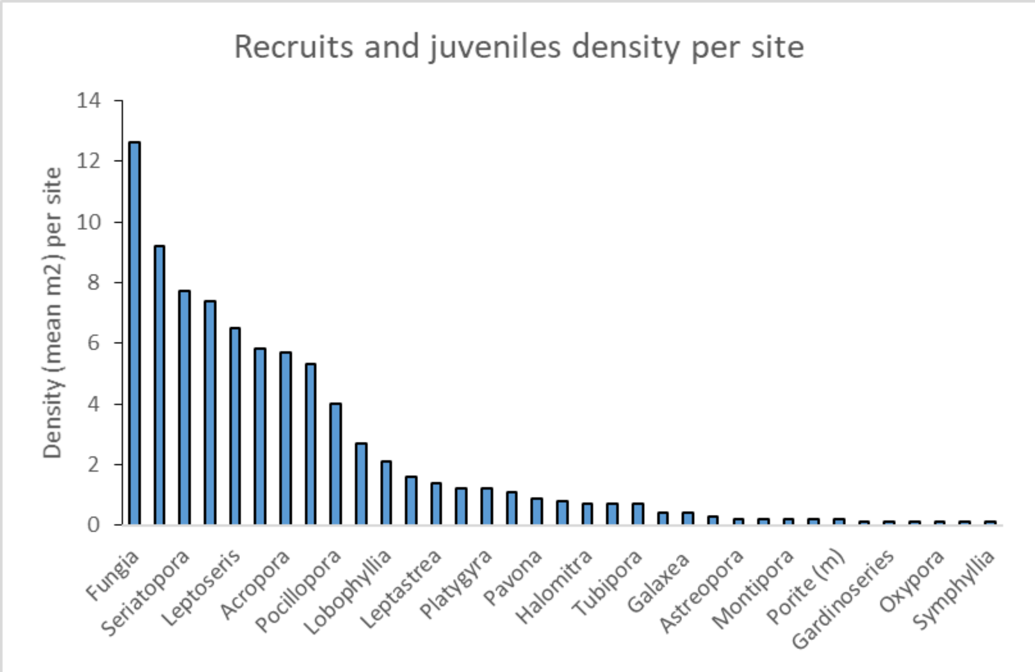
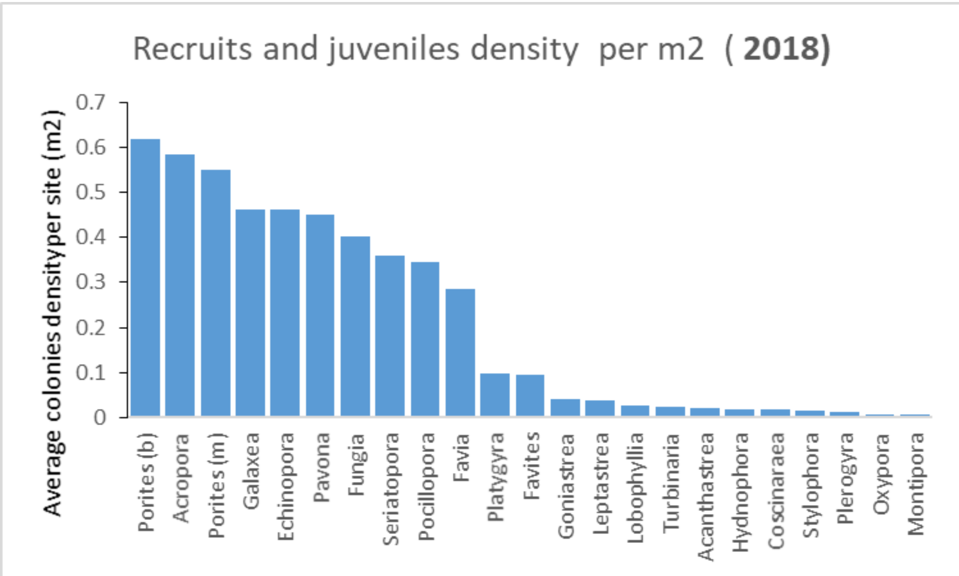



**Figure 18: Comparison of number Juveniles coral recruitment categories (2.5-5 cm and 5-10 cm corals), for all sites presented as Mean (± SE) per m2**

The coral recruits and juvenile 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 Fungia with mean of (7) colonies per 1 $m^2$, followed by Galaxea (5.1) and Seriatophora (4.2) (Figure. 19)


Recruits and juveniles density per site
Density (mean m2) per site
14
12
10
8
6
4
2
0
Fungia
Seriatopora
Leptoseris
Acropora
Pocillopora
Lobophyllia
Leptastrea
Platygyra
Pavona
Halomitra
Tubipora
Galaxea
Astreopora
Montipora
Porite (m)
Gardinoseries
Oxypora
Symphyllia


Recruits and juveniles density per m2 ( 2018)
Average colonies densityper site (m2)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Porites (b)
Acropora
Porites (m)
Galaxea
Echinopora
Pavona
Fungia
Seriatopora
Pocillopora
Favia
Platygyra
Favites
Goniastrea
Leptastrea
Lobophyllia
Turbinaria
Acanthastrea
Hydnophora
Coscinaraea
Stylophora
Plerogyra
Oxypora
Montipora

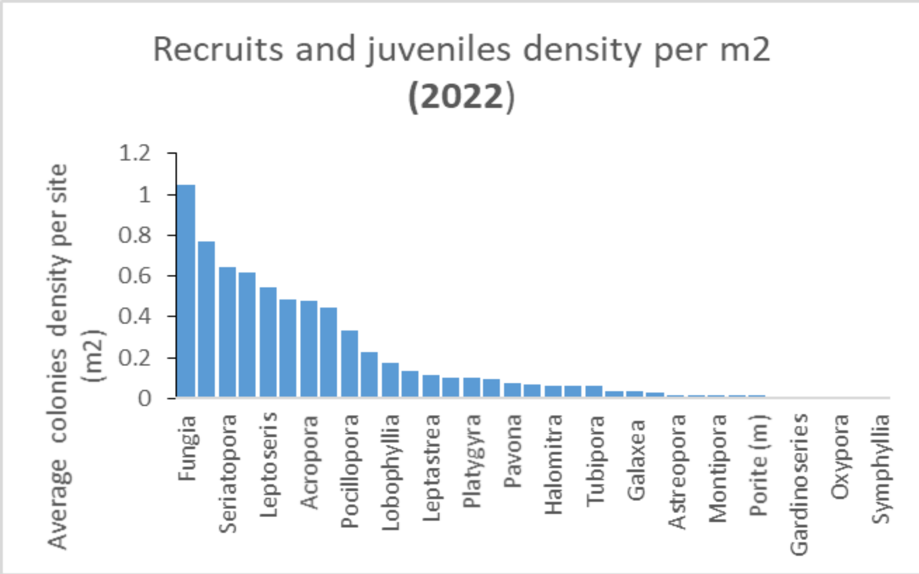



**Figure 19: Average density of coral recruits per m2 by genus – all sites pooled**

#### 4.5.3.2 Coral Recruitment

The smallest size class 0-2.5cm represents recruits. The highest recruitment density (2.6±SE) was recorded at Nyamalile North, followed by kitutia (1.4± SE) and Nyamalile (1.3± SE) whereas the lowest recruitment densities (0.4+SE) and (0.3+SE) were recorded at Kisiwa kikubwa and Utumbi respectively (Fig 20). Both Kisiwa kikubwa and Utumbi are located within chole bay, and influenced by high tidal currents, which could be washing away coral larvae limiting their settlement on the benthic substrate.

On the contrary, both the north and south Nyamalile sites were dominated by two reproductively prolific genera – *Acropora* and *Seriatopora* robustly recovering from the 2020 coral bleaching.

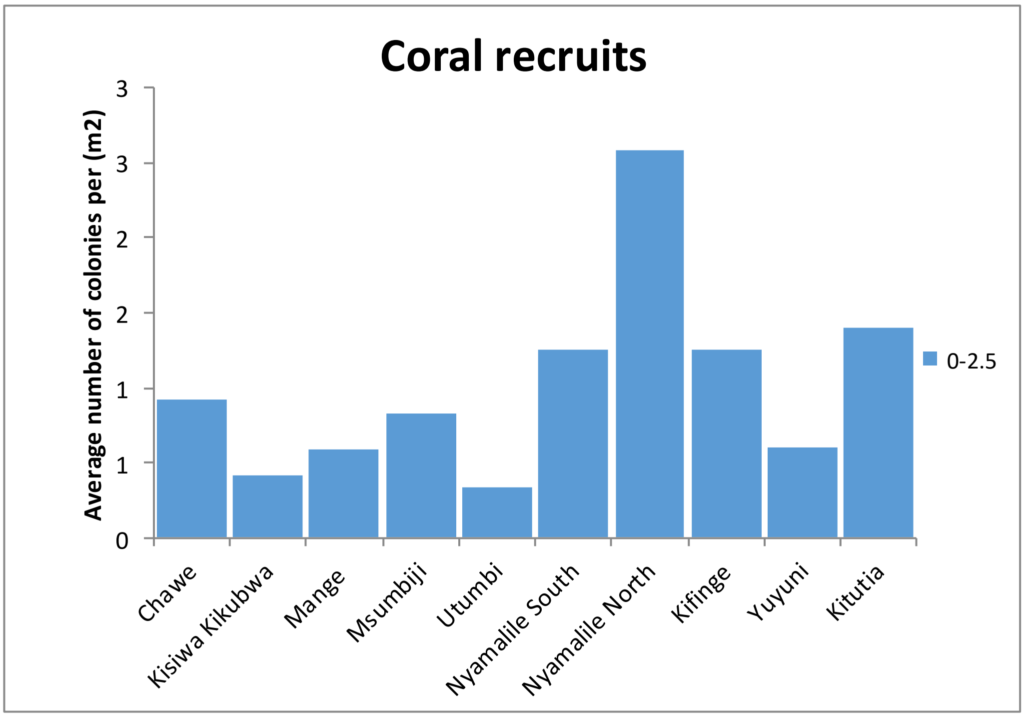



**Figure 20: Comparison of coral recruitment (1-2.5cm coral) for all surveyed sites presented as mean (+SE)**

#### 4.5.3.3 Coral recruitment by genus

*Seriatopora* was the highest recruiting coral genera overall, with an average density (1.2 per m2), **Fig 21**). Other important genera in terms of recruitment include *Echinopora*, *Leptoseries* and massive *porites.* The highest *Seriatopora* recruits occurred at Nyamalile sites

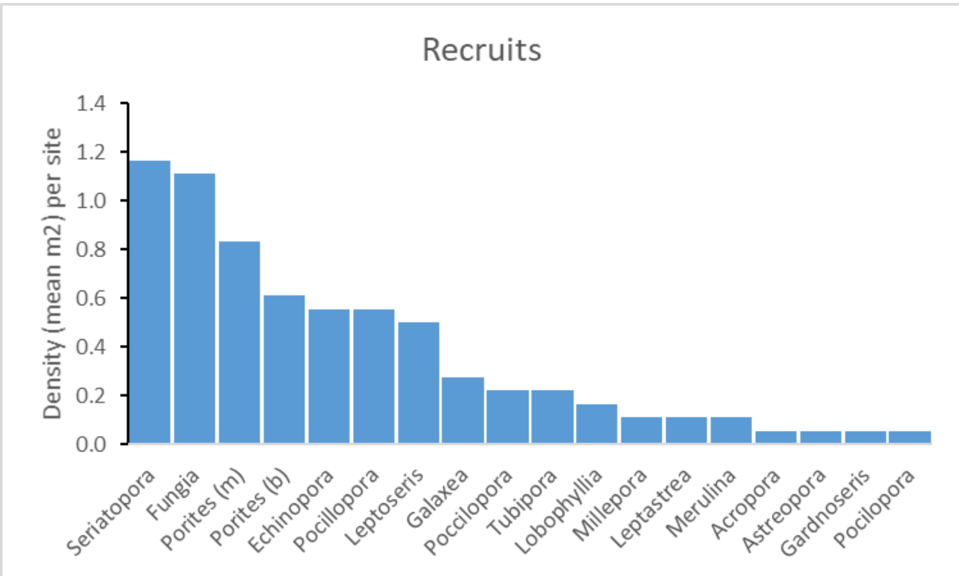


**Figure 21: Average density of coral recruits per m2 by genus – all sites pooled.**

## 4.6 INVERTEBRATES STATUS

Both invertebrates of commercial and ecological importance were monitored under the current survey at ten monitoring sites. Accounting on sea urchin abundance as indicator of stressed reef, Nyamalile north has the highest record with 11individual per $20m^2$, followed by Kifinge with 9 individuals per $20m^2$, Nyamalile south with 8 individuals per $20m^2$ and Mange reef with 4 individuals per $20m^2$ **(Fig 22**). Sites with substantial reduction in sea urchin population were recorded with substantial number of their respective predator reef fish which are the *Balistidae* and *Labridae*. Current sea urchin abundance was recorded high if compared to the 2018 survey (**Fig 23**) where all sites except Yuyuni which recorded highest abundance in 2022 with over 20 individuals per transect was not surveyed currently, the sea urchin abundance were less than three individuals per $20m^2$

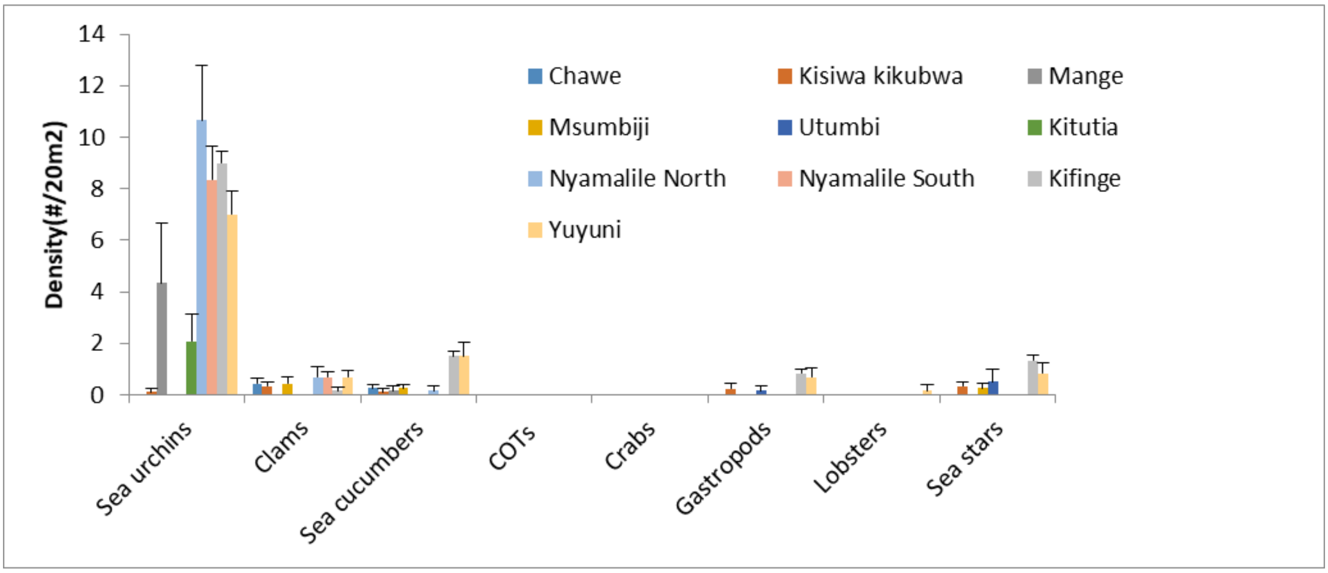



**Figure 22: Invertebrates abundance (Mean + SE) for Monitored sites in 2022 survey**

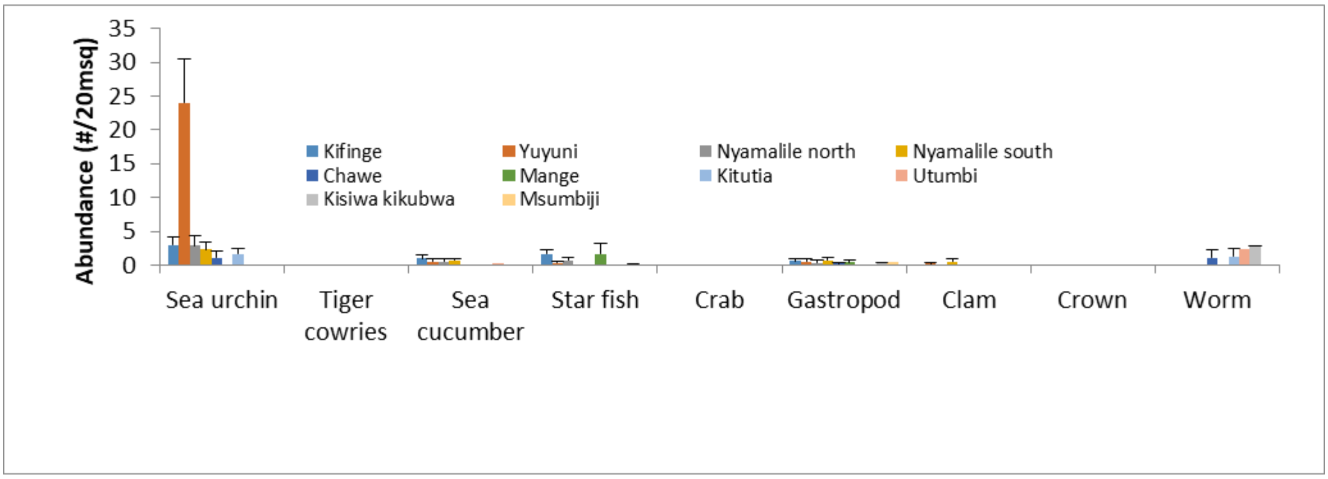



**Figure 23: Invertebrates abundance (Mean + SE) for Monitored sites in 2018 survey**

## 4.7 Ecological threshold

For the Western Indian Ocean Scientist has established a tangible targets for the ecosystem based Management of coral reef fisheries. Reef fish Baseline, Benchmark Biomass, Critical thresholds and tangible targets in kg $ha^{-1}$ has been established including Pristine biomass (1000 $kgha^{-1}$), Highest Conservation priority maintain biomass above 600$kgha^{-1}$, Biomass at Sustainable yield ($B_{MSY}$) 500 $kgha^{-1}$ and Critical thresh hold biomass >300 $kgha^{-1}$(McClanahan *et al*, (2011); McClanahan 2015).Fish biomass (as an indicator of fishing intensity) It provides a tangible management targets for multispecies coral reef fisheries and highlight key tradeoffs required to achieve different fisheries and conservation goals including the basis for prioritizing conservation and management investments (McClanahan 2015).

## 4.8. OTHER REEF FISH STATUS AMONG MONITORED SITES.

Reef other than grouers fish their abundance was significant difference among surveyed sites; Kruskal-Wallis Test (Nonparametric ANOVA) H; p=0.0002. With Kitutia having the highest abundance of 2014 ± 407.28 individuals per ha while Nyamalile south with the least abundance of 226 ± 17.60 individuals per ha.

Fishable biomass was significant difference among surveyed sites Kruskal-Wallis Test (Nonparametric ANOVA); H; p= 0.0053; With Yuyuni has the highest fishable biomass of 637.08. ± 81.49kg per ha and least at Nyamalile South with 185.56 ± 26.70kg per ha

Target reef fish biomass was not significant difference Kruskal-Wallis Test (Nonparametric ANOVA) between monitored sites; H; p=0.1894;Yuyuni had the highest target biomass of 415.37± 49.88kg per ha and lowest target biomass at Nyamalile South with 77.90 ±.31.58kg per ha

Non target biomass was significant difference among ten monitored sites Kruskal-Wallis Test (Nonparametric ANOVA); H; p= 0.0437; Utumbe reef had the highest biomass with 488.44 ± 87.22kg per ha and Nyamalile south had the lowest non target biomass of 107.67 ± 10.81kg per ha and total biomass; Utumbi had the highest biomass of 844.55± 129.51 kg per ha and lowest at Nyamalile south with 194.12 ± 42.07kg per ha

The complihensive study on abundance and biomass for most ecological and commercial important species is inadequate. Few studies exist on selected species and families. In the WIO region Vicent *et al.,* (2011) elucidated reef abundance and biomass only for four reef fish families Acanthurid, Siganids; Pomacentrid and Scarid. McClanahan & Jadot 2017 reported on 23 reef fish familes in Madagascar finding indicated fair biomass with ~65% of the study sites having biomass >600 kg ha−1.

### 4.8.1. Grouper fish scientific baseline

#### 4.8.1.1 Groupers Abundance and Biomass

Grouper fish abundance and biomass was established in all monitored sites, Yuyuni reef revealed the highest abundance with a total of 20 individuals both being juvenile, Kitutia reef ranked second the highest population with 11 individuals of which all were juvenile eight with 3cm-10cm size range, two individuals with 10-20cm size range and one with 20-30cm size ranges. Third was Mange reef with eight individuals in 3-10cm, 10-20cm and 20-30cm size classes with 2, 2 and 4 individuals respectively. Utumbi reef was the fouth in terms of grouper abundance with seven individuals recorded in 10-20cm, 20-30cm and 30-40cm size classes containing 2, 3 and 2 individuals respectively. Two groupers were recorded at Chawe reef falling in 3-10cm size class revealing both were juveniles likewise at Kifinge reef. One individual was recorded at Msumbiji in a 20-30cm size class. At Nyamalile north one groper was recorded in 10-20size class and no grouper were recorded at Kisiwa kikubwa and Nyamalile south reef (**Fig 24**)

For biomass status, Utumbi reef recorded the highest grouper biomass with 65.3kg perha but ranked third on grouper abundance. The highest biomass record was attributed by the largest size class of 30-40cm which were not recorded in any of the sites, additionally the lowest size class of 3-10cm were not recorded at the reef which reflect all groupers recorded at the site were relatively larger. Yuyuni reef which recorded the highest abundance with 20 individuals total observations as it ranked fouth on biomass after Utumbi, Mange and Kitutia reef. Similarly Kitutia reef which ranked second for grouper abundance ranked third on biomass 11.6kg/ha after Mange reef 32.9kg/ha and Utumbi reef 65.3kg/ha. Msumbiji ranked fifth with 7.4kg/ha, Sixth Chawe 0.27kg/ha and last Nyamalile north with 0.13kg/ha while no biomass recorded at Kisiwa kikubwa and Nyamalile South similar reflecting similar record as for abundance (**Fig 25 & 26**)

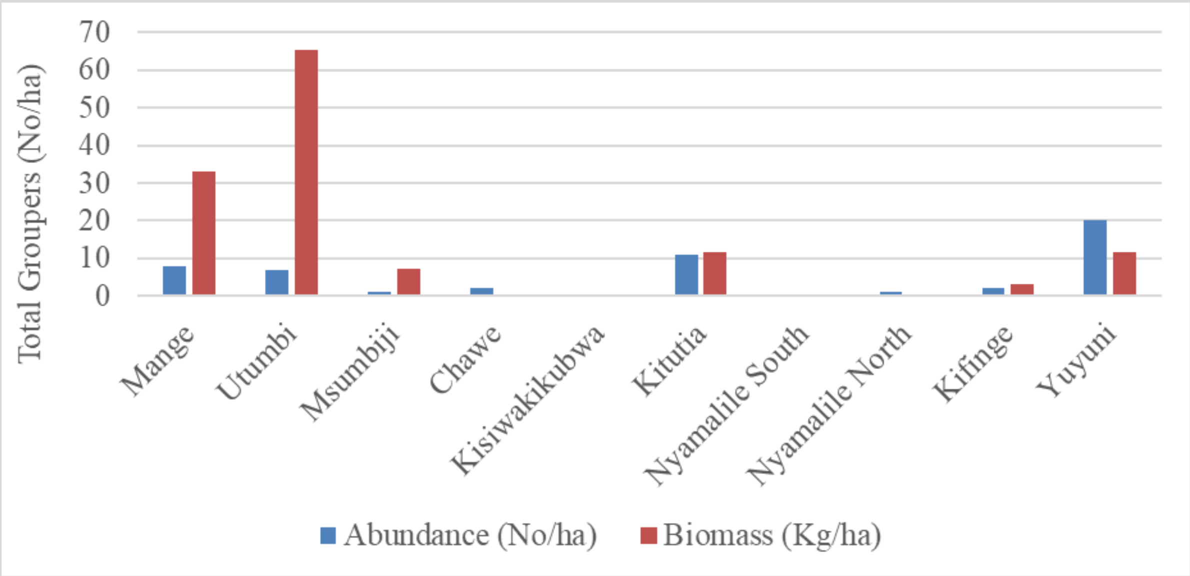



**Figure 24: Total Groupers abundance observed and respective Biomass per site**

### 4.8.3. Groupers size population size structure in Mafia Island Marine Park

Figure with size classes for groupers biomass contribution with high biomass at Utumbi, Mange and Kitutia reef with no biomass at Kisiwa kikubwa and Nyamalile south reef.

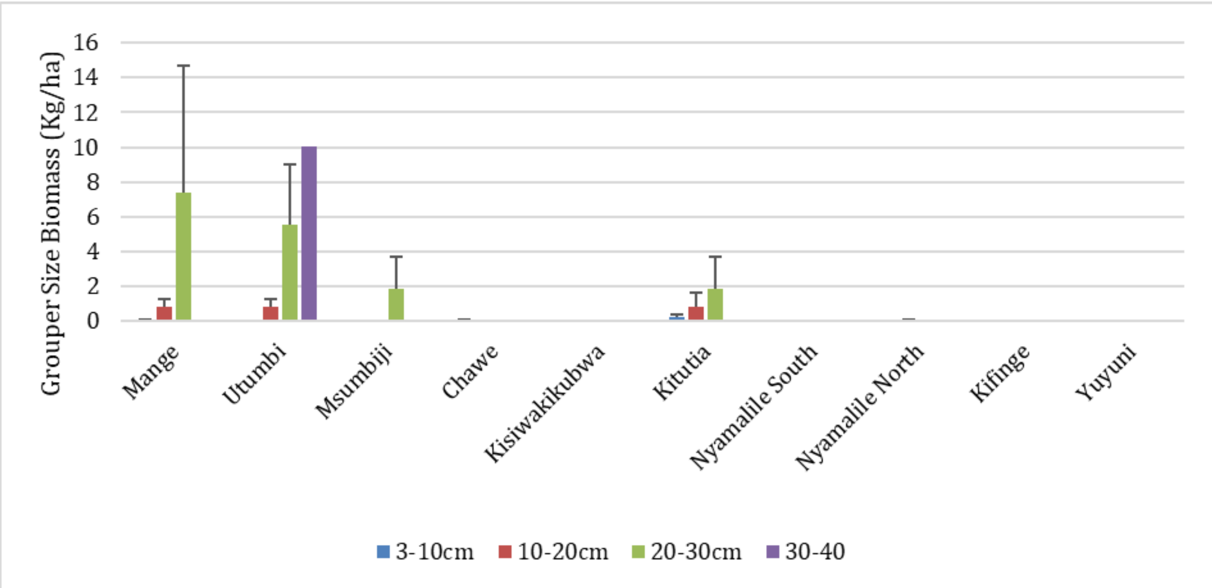



**Figure 25: Groupers size class Biomass contribution (Mean + SE) per site.**

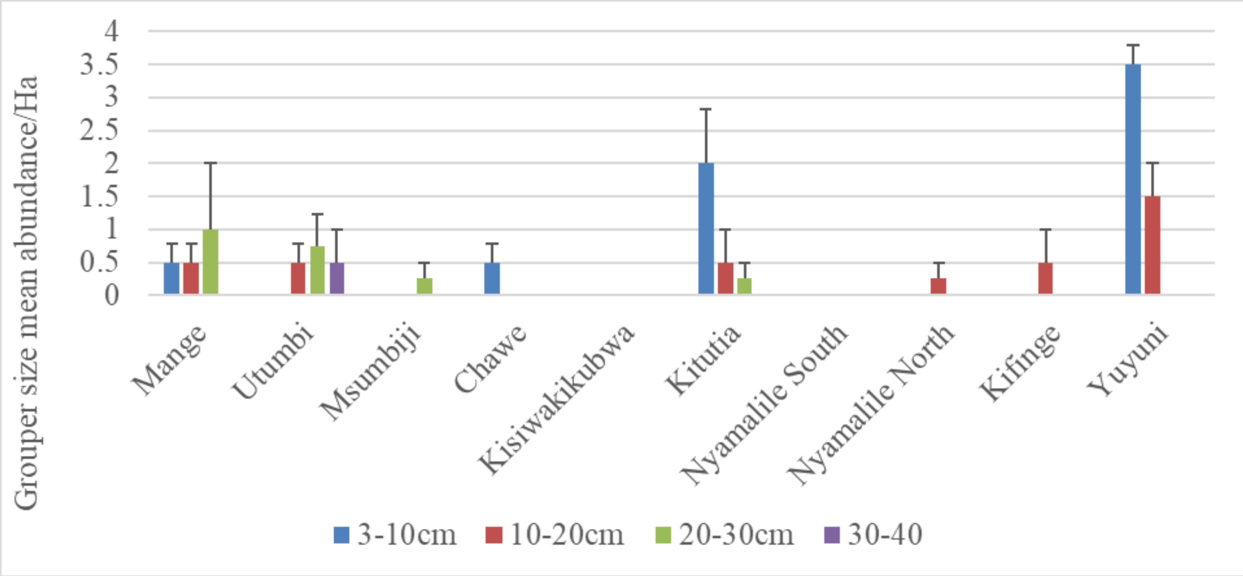



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**Figure 26a: Groupers mean abundance in monitored sites in Mafia Island Marine Park.**

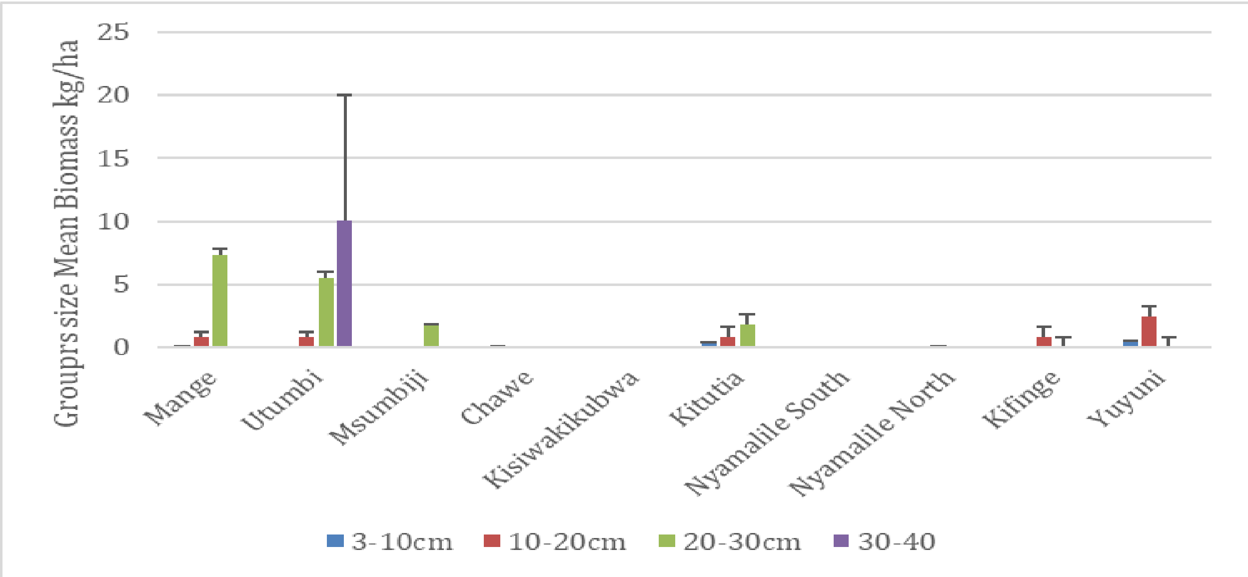


**Figure 27: Groupers Biomass mean size class abundance in monitored sites in Mafia Island Marine Park.**

### 4.8.2. General Reef fish abundance and biomass status in Mafia Island Marine Park

Kitutia reef has the highest Reef fish abundance and lowest at Nyamalile south (**Fig 27**) Status was significant difference among sites Kruskal-Wallis Test (Nonparametric ANOVA); P= 0.0013 which was considered very significant. Fish abundance recorded showed a positive correlation with benthic cover, particularly hard coral cover. Sites with high abundance record, it recorded similar trend on live coral cover where sites with lowest live coral cover recorded low fish abundance (**Fig 27**)

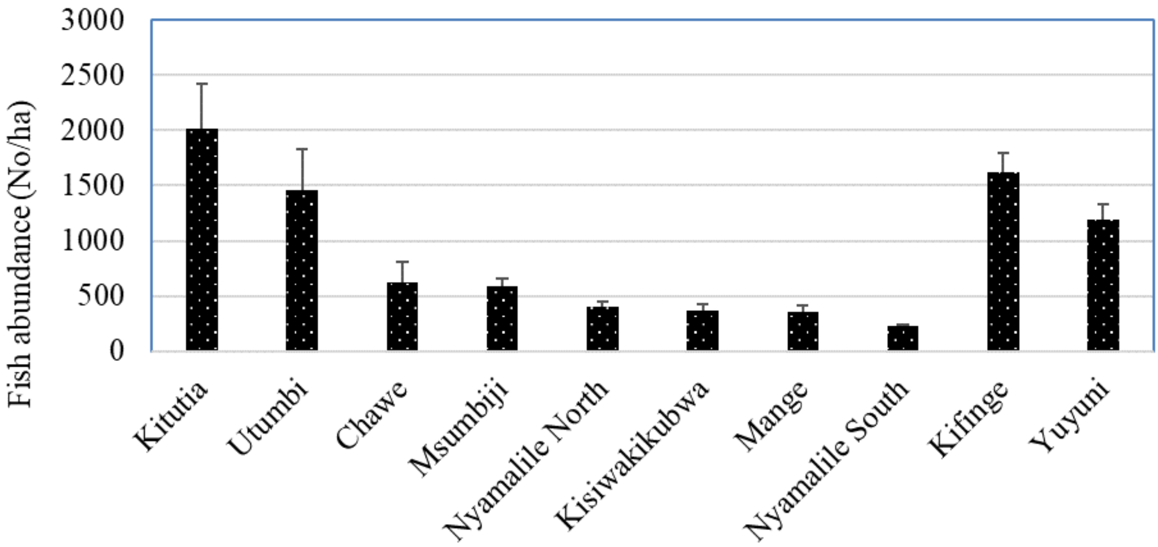


**Figure 28: General Reef fish status (Mean Abundance +SE) in all monitored sites**

### 4.8.3. Total biomass, Fishable biomass, Target biomass and Non target biomass

Utumbi reef recorded the highest total fish biomass with 844.55 ±129.51kg per ha next Yuyuni with 828.33 ± 97.28kg/ha, third Kitutia with 635.17 ± 98.78kg per ha fourth Kifinge with 625.45 ± 108.79kg per ha while Nyamalile North recoded the lowest biomass with 194.12 ± 42.07kg per ha (**Fig 28**)

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 (**Fig 28**). Across monitoring sites fish abundance were dominated by small size individuals mostly fish which are not targeted by fishers such as *Pomacentrida*e (damsel fishes) where over 80% of the population dominated except at Mange and Nyamalile south only (**Fig 29 & 30**). Other taxa dominated were the *Acathuridae*, *Holocentridae*, *Muraenidae*, and *Diodontidae*). The higher value target fisheries taxa recorded at low proportional were the*Lethrinidae*, *Haemulidae, Serranidae, Sphyraenidae*, *Labridae, Scaridae* and *Mullidae*) Kitutia, Nyamalile and Kifinge were dominated by low value non-target fisheries families

For biomass contribution small size individuals (**Fig** 31 & 32) had substantial biomass contributions. At Kitutia reef which recorded the highest percentage contribution on small bodied fish. It has the highest biomass contribution defeating the larger body fish across all monitoring sites. This is due to the fact that, across sites larger size fish which are mostly of commercial importance and frequently targeted fish (**Fig** 33,34, &35) was substantially reduced probably by overharvesting and application of un sustainable gear as were noted at Mange reef.

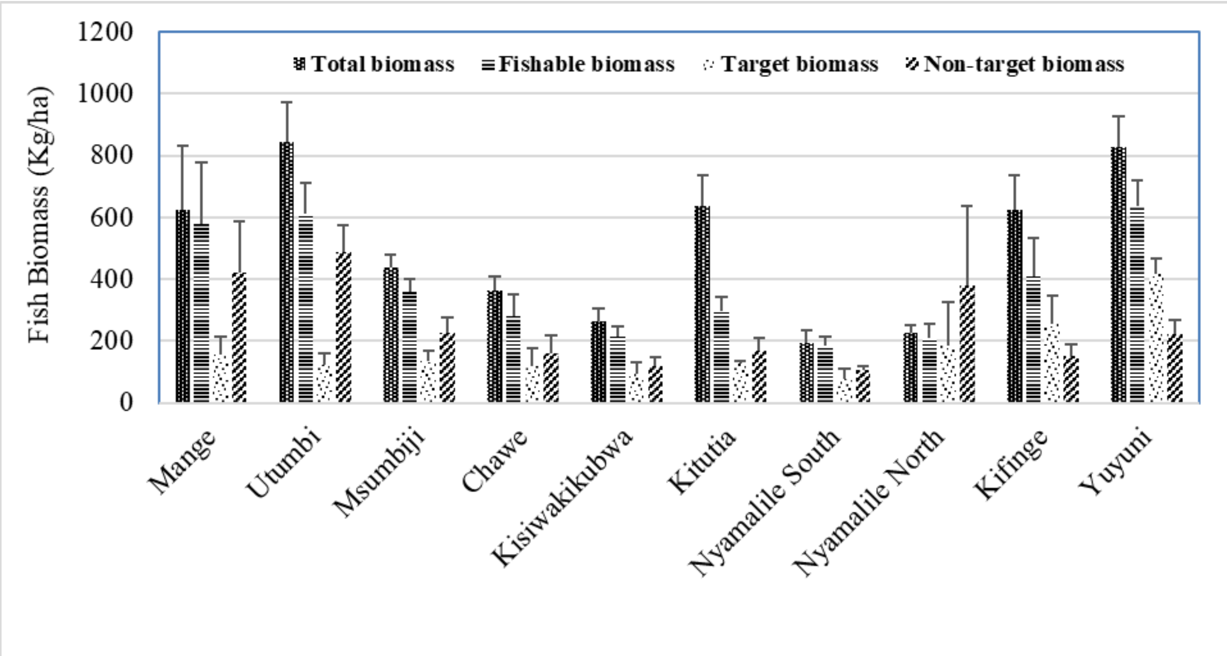


**Figure 29:Total biomass, Fishable biomass, Target biomass and Non target biomass (Mean + SE)**

For reef fish abundance Kitutia was ranking first next Utumbi and Nyamalile south ranking least.

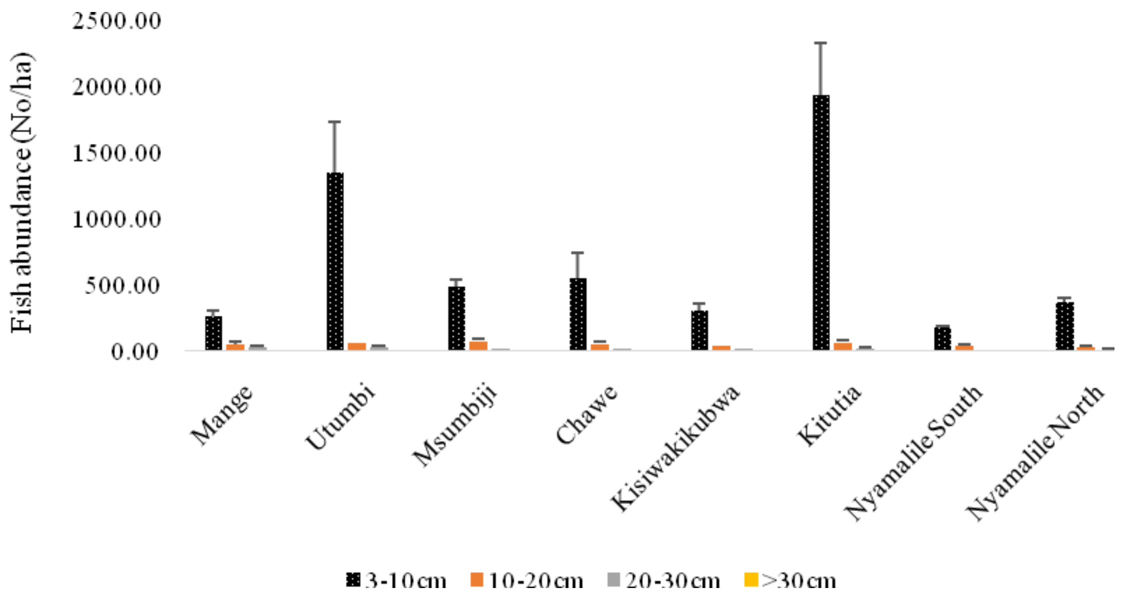


**Figure 30: Size class Reef fish abundance (Mean + SE) in monitored sites**

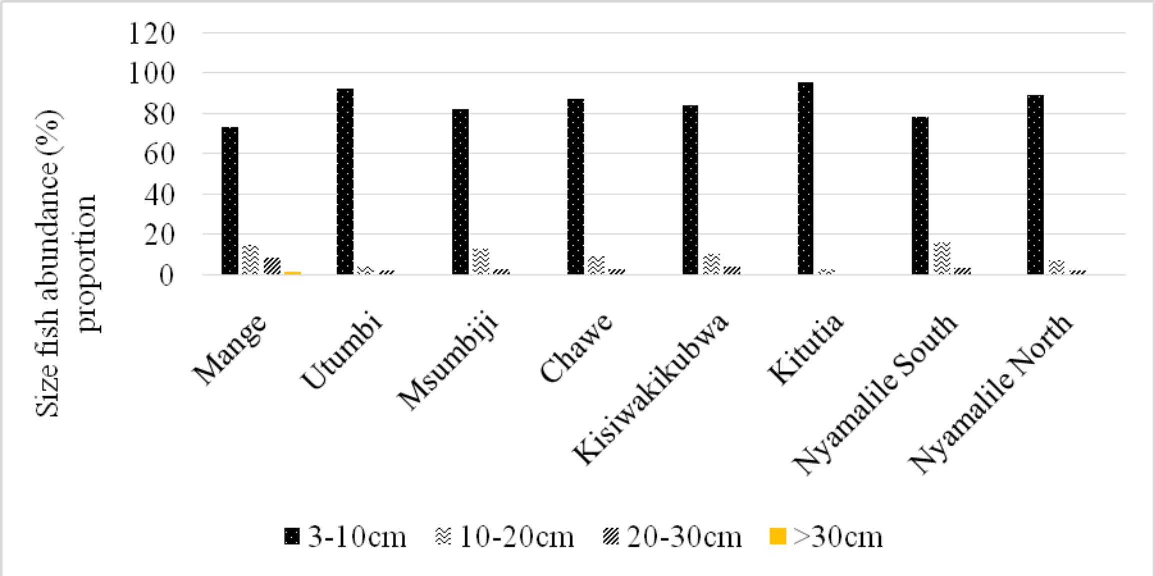


**Figure 31: Size class Reef fish abundance percentage (%) proportion in monitored sites**

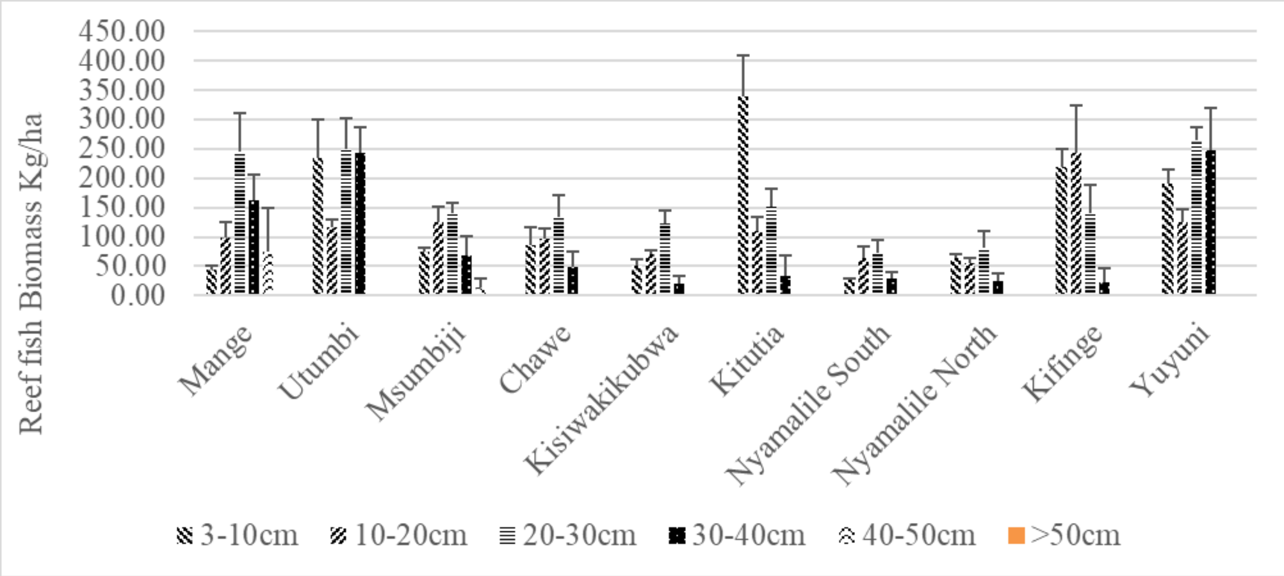


**Figure 32:Size class Reef fish Biomass (Mean + SE) in monitored sites**

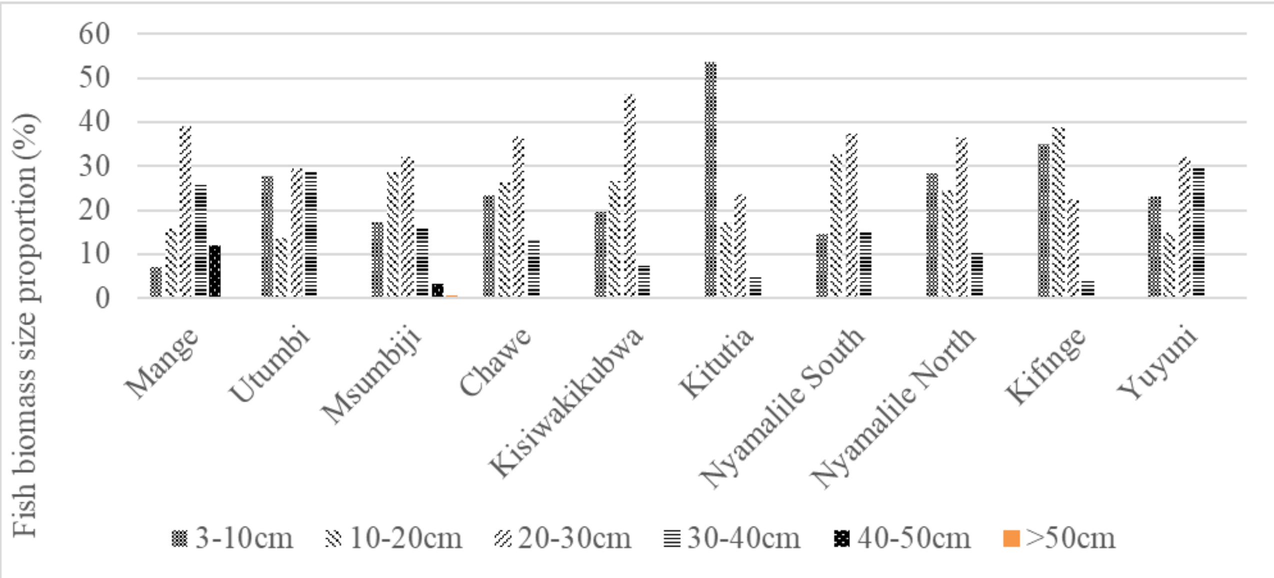


**Figure 33: Percentage proportion for Size class Reef fish Biomass (%) in monitored sites**

### 4.8.4. Reef fish abundance and Biomass composition with population structure

Reef fish population structure were mainly dominated by fish members from 21fish families in all surveyed reefs (**Fig 33, 34, & 35**). The leading abundant fish family were the *Pomacentridae* represented by small-sized species (3-10cm) size class. Subsequently even other fish which grow to over 10cm including Groupers were recorded in the same class. It implies the larger size class is over harvested in the ecosystem. Other families recorded were the *Acathuridae*, *Labridae, Pomacentridae and Holocentridae*, *Chaetodontidae, Scaridae* and *Pomacanthidae*.Larger bodied and common reef fish species such the *Lutjanidae, Lethrinidae, Serranidae, Haemulidae, Mullidae*, and *Balistidae* were very little represented as reported in the baseline report but currently was significantly reduced for both abundance and biomass.

The absence of ecologically important species such as members in the family *Balistidae* has resulted to an ecosystem imbalance that triggered proliferation of lower trophic levels including Sea urchin proliferation in most sites above the 2018 abundance; thus, threatening the survival of the reefs (Cinner et al., 2013, Maire et al., 2016, and McClanahan et al., 2016

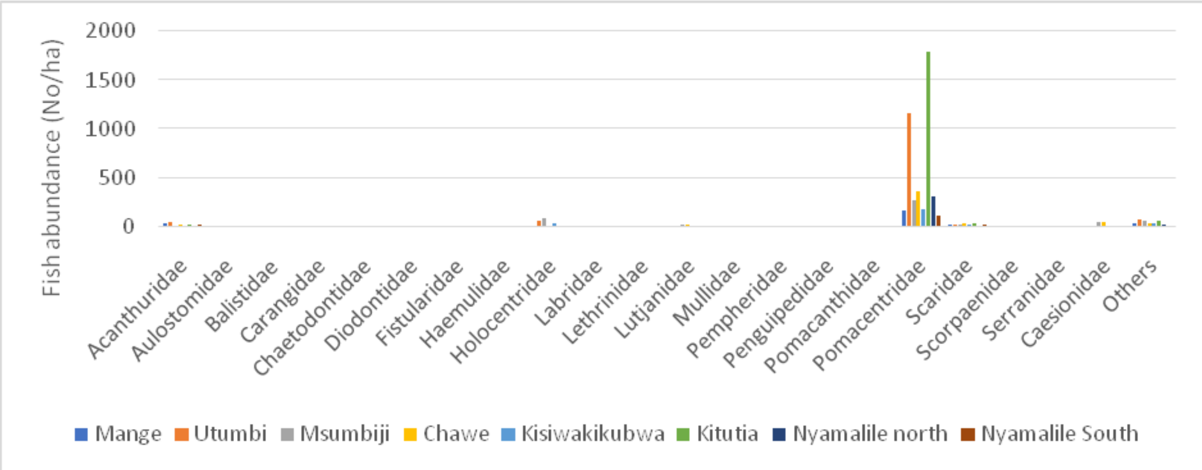


**Figure 34: Fish composition abundance composition in monitored sites**

Fish family's composition, abundance and respective population structure was dominated by *Pomacentridae* (Figure 34) Kitutia reef leading with 89% of *Pomacentridae* contribution.

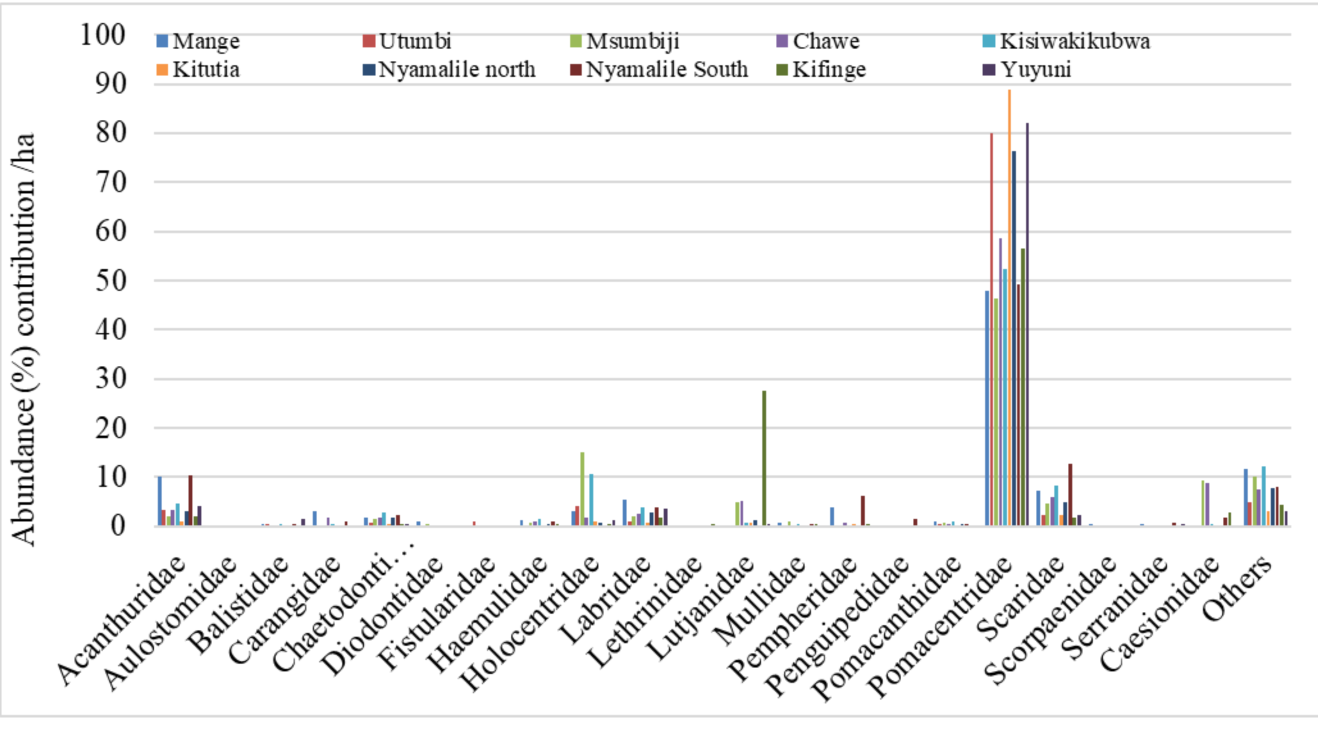

**Figure 35: Fish composition abundance composition in monitored sites**

Fish abundance was attributed by members from the family *Acanthuridae, Labridae, Pomacentridae, Scaridae, Holocentridae and Lutjanidae (***Fig** 35*)* however their size class both were skewed to the left.

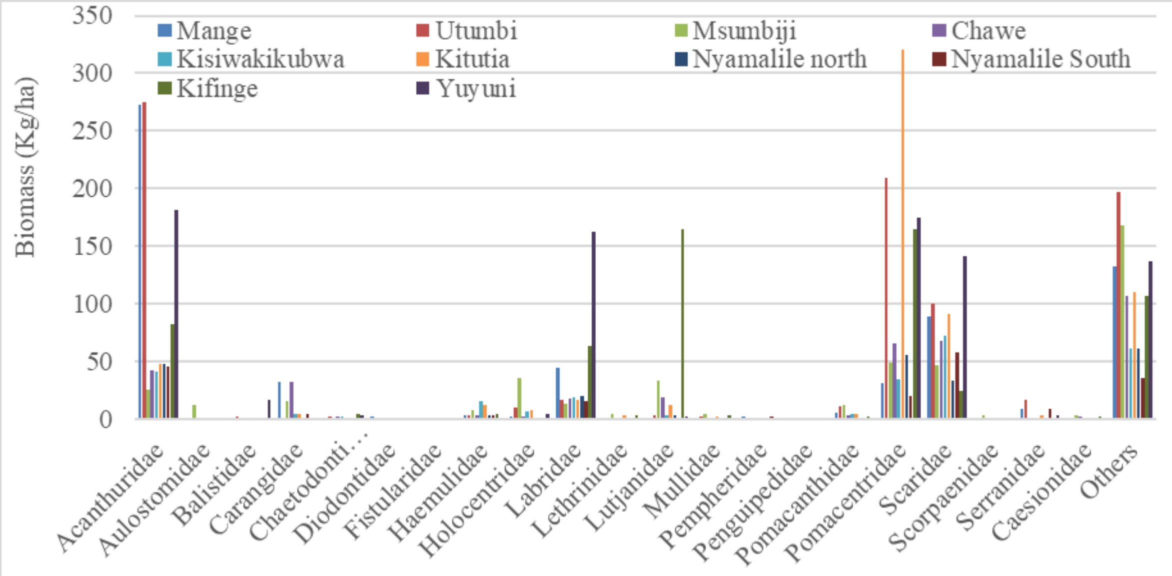


**Figure 36: Percent composition and abundance of various fish families in monitored sites**

Fish biomass contributions across monitoring sites presented under **Fig** 36 were the *Pomaentridae, Scaridae, Acanthuridae and Labridae.* Other families were site specific i.e Mange reef was an addition of Carangidae.

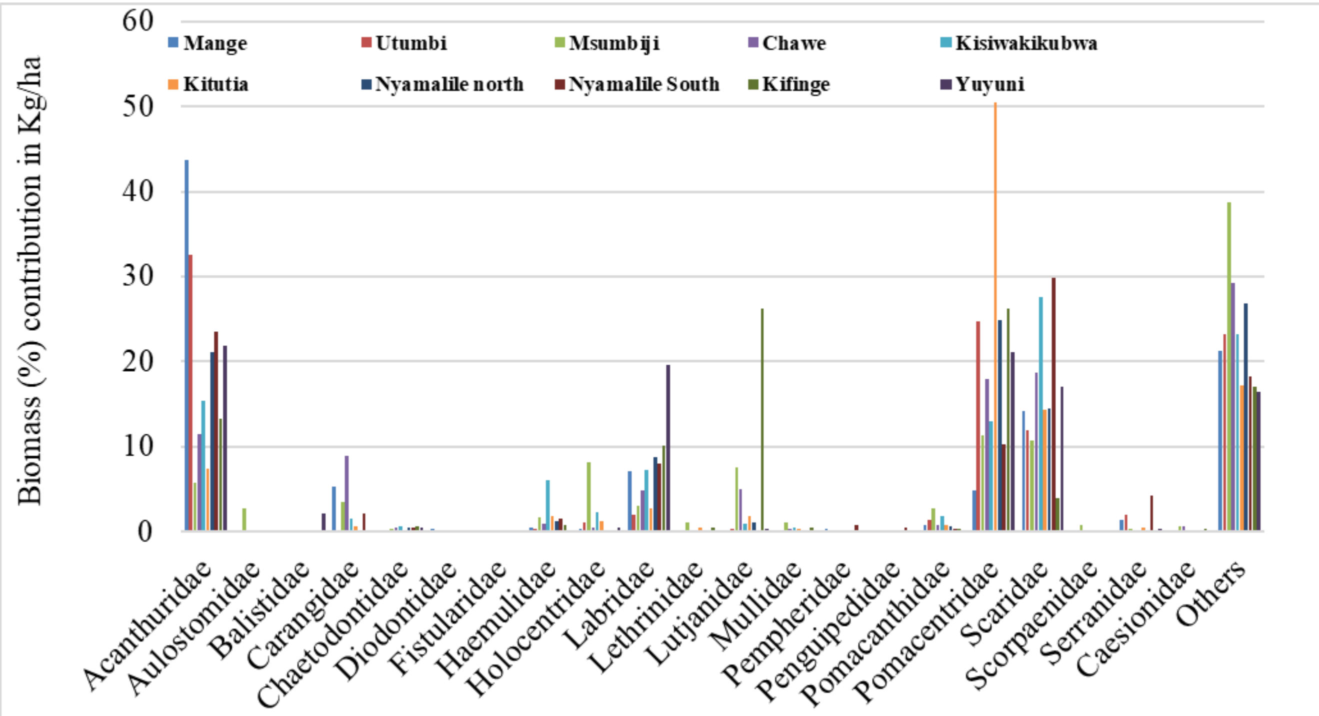

**Figure 37: Biomass Composition of various fish families in monitored sites**

# CHAPTER FIVE

# 5.0. CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

Live Coral reef cover was statistically not significantly different between the 2018 survey and the 2022 survey however result indicated there is a slight decline in coral cover which is suggested due to unsustainable fishing and coral bleaching events. Grouper baseline has been established where by its population is skewed to the left dominated *by Cephalopholis argus* (Peacock Grouper) in most sites and were not observed in few sites which suggest a significant reduction of its population in the ecosystem and the current survey concludes the followings

Coral cover is highest with over fifty percent at Kitutia, Utumbi, Msumbiji and Chawe reef with below average hard coral cover at Nyamalile North, Nyamalile South and Kisiwa kikubwa with an overall decline when compared to the previous monitoring.

- The overall hard coral cover in MIMP increased slightly by 1.8,% compared to the previous 2018 survey. The average percentage cover was approximately 42.19% ± 6.5 in 2022 whereas that of 2018 was 40.42%.

- There is an increase on overall rubbles by 2.6% in all monitored sites has increment in proportion except Msumbiji, Chawe and Nyamalile north

- There was a decline on macro algae across all ten monitoring sites by 12.3% when compared to the last coral reef monitoring in 2018. This could be attributed by the increase of fishes particularly herbivores as observed in this study.

- It was observed an increase of coralline algae by 1.02% as compared to the study in 2018 which implies on the increase of substrate for coral larvae settlement category at across all ten monitoring sites

- There is increase of overall recruits and juveniles for all sites (6.8± SE) per $m^2$ the result revealed an increase by 51 % to the average of (4.5±SE) colonies observed during the survey conducted in 2018 (URT 2081). This has been contributed by many factors including the coralline algae that is the conducive for coral larvae settlement.

- There is dominated by juvenile of *Cephalopholis argus* (Peacock Grouper) fish populations structure in most of monitored sites except at Yuyuni which was dominated by *Cephalopholis nigripinnis*

Based on current coral and grouper status and previous monitoring the following are recommended

### 5.2. Recommendations

i. The team recommend consistent 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 unsustainable fishing practices.

vi. Coral reef restoration programme is recommended to sites with the lowest coral cover percentage to enhance the ecosystem functioning within MPAs.

vii. Coral reef in MIMP has indicated the highest potential on resilience for both anthropogenic and natural threat hence full protection should be implemented to enhance natural ecosystem recovery

viii. Fish communities are depleted throughout the system. Fisheries controls will be essential for long term sustainability and productivity of the fisheries in MIMP.

ix. Strengthening the efforts and needs of coverage of well-managed areas envisaged in SDG 14 Target 2 and Aichi Target 11 by 2020, with a clear long term goal that this should increase to the broadly accepted 30% MPA target by 2030.

x. Coral reef monitoring should be continued, supported and expanded to include more sites beyond MPAs for justification of protection rationale and accounting on physiochemical water parameters

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# ANNEXES

Annex 1. Tables for groupers baseline

| Abundance | 3-10cm | 10-20cm | 20-30cm | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | >80 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Mange | 2 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| Utumbi | 0 | 2 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 7 |
| Msumbiji | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Chawe | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Kisiwa kikubwa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kitutia | 8 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| Nyamalile South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nyamalile North | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Kifinge | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Yuyuni | 14 | 6.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20.0 |
| | | | | | | | | | | |
| **Biomass** | 3-10cm | 10-20cm | 20-30cm | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | >80 | Total |
| Mange | 0.266765 | 3.214778 | 29.41224 | 0 | 0 | 0 | 0 | 0 | 0 | 32.89379 |
| Utumbi | 0 | 3.214778 | 22.05918 | 40.03665 | 0 | 0 | 0 | 0 | 0 | 65.31061 |
| Msumbiji | 0 | 0 | 7.353061 | 0 | 0 | 0 | 0 | 0 | 0 | 7.353061 |
| Chawe | 0.266765 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.266765 |
| Kisiwa kikubwa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kitutia | 1.067059 | 3.214778 | 7.353061 | 0 | 0 | 0 | 0 | 0 | 0 | 11.6349 |
| Nyamalile South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nyamalile North | 0 | 0.133382 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.133382 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Kifinge | 0 | 3.214778 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.214778 |
| Yuyuni | 1.867353 | 9.644333 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11.51169 |
| | | | | | | | | | | |
| **Mean Abundance** | **3-10cm** | **10-20cm** | **20-30cm** | **30-40** | **40-50** | **50-60** | **60-70** | **70-80** | **>80** | **Total** |
| Mange | 0.5 | 0.5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Utumbi | 0 | 0.5 | 0.75 | 0.5 | 0 | 0 | 0 | 0 | 0 | 1.75 |
| Msumbiji | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0.25 |
| Chawe | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Kisiwa kikubwa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kitutia | 2 | 0.5 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 2.75 |
| Nyamalile South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nyamalile North | 0 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.25 |
| Kifinge | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Yuyuni | 3.5 | 1.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Mean Biomass | 3-10cm | 10-20cm | 20-30cm | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | >80 | Total |
| Mange | 0.066691 | 0.803694 | 7.353061 | 0 | 0 | 0 | 0 | 0 | 0 | 8.223446 |
| Utumbi | 0 | 0.803694 | 5.514795 | 10.00916 | 0 | 0 | 0 | 0 | 0 | 16.32765 |
| Msumbiji | 0 | 0 | 1.838265 | 0 | 0 | 0 | 0 | 0 | 0 | 1.838265 |
| Chawe | 0.066691 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.066691 |
| Kisiwa kikubwa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kitutia | 0.266765 | 0.803694 | 1.838265 | 0 | 0 | 0 | 0 | 0 | 0 | 2.908724 |
| Nyamalile South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nyamalile | 0 | 0.033346 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.033346 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| North | | | | | | | | | | |
| Kifinge | 0 | 0.803694 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.803694 |
| Yuyuni | 0.466838 | 2.411083 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2.877922 |
| | | | | | | | | | | |
| **SE Mean abundance** | **3-10cm** | **10-20cm** | **20-30cm** | **30-40** | **40-50** | **50-60** | **60-70** | **70-80** | **>80** | **Total** |
| Mange | 0.288675 | 0.288675 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1.57735 |
| Utumbi | 0 | 0.288675 | 0.478714 | 0.5 | 0 | 0 | 0 | 0 | 0 | 1.267389 |
| Msumbiji | 0 | 0 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0.25 |
| Chawe | 0.288675 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.288675 |
| Kisiwa kikubwa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kitutia | 0.816497 | 0.5 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 1.566497 |
| Nyamalile South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nyamalile North | 0 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.25 |
| Kifinge | 0 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 |
| Yuyuni | 0.288675 | 0.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.788675 |
| | | | | | | | | | | |
| **SE Mean Biomass** | 3-10cm | 10-20cm | 20-30cm | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | >80 | Total |
| Mange | 0.038504 | 0.464013 | 7.353061 | 0 | 0 | 0 | 0 | 0 | 0 | 7.855578 |
| Utumbi | 0 | 0.464013 | 3.52001 | 10.00916 | 0 | 0 | 0 | 0 | 0 | 13.99319 |
| Msumbiji | 0 | 0 | 1.838265 | 0 | 0 | 0 | 0 | 0 | 0 | 1.838265 |
| Chawe | 0.038504 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.038504 |
| Kisiwa kikubwa | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kitutia | 0.108906 | 0.803694 | 1.838265 | 0 | 0 | 0 | 0 | 0 | 0 | 2.750866 |
| Nyamalile South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nyamalile North | 0 | 0.033346 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.033346 |
| Kifinge | 0 | 0.803694 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.803694 |
| Yuyuni | 0.038504 | 0.803694 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.842199 |

Annex II: Provisional Detailed Work Plan Activities Programme Schedule

| **Day/** | **Activities description** | **Responsible** |
|---|---|---|
| **Day 1** 13/6/2022 | Team members from different centers travel to Mafia (MIMP) | All |
| **Day 2** 14 /6/2022 | • Logistics, equipment assemblage and Team organization<br>• Staff Team members training on monitoring protocol and coral/fish identification skills | Team Leader |
| **Day 3-Day 5** 15-17 /6/2022 | Theory training in class on the first days and second and third day Learn by doing field training for on job trainee Team members at the nearest site for testing skills and data collection harmonization protocol. | Team Leader and Monitoring team |
| **Day 6** 18/6/2022 | Field work Kifinge (SCUBA) diving & data entry | Team Leader |
| **Day 7** 19/6/2022 | Field work Nyamalile North (SCUBA) diving & data entry | Team Leader |
| **Day 8** 20/6/2022 | Field work Kitutia (SCUBA) diving & data entry | Team Leader |
| **Day 9** 21/6/2022 | Field work Mange (SCUBA) diving & data entry | Team Leader |
| **Day 10** 22/6/2022 | Field work Utumbi (SCUBA) diving & data entry | Team Leader |
| **Day 11** 23/6/2022 | Field work Chawe (SCUBA) diving & data entry | Team Leader |
| **Day 12** 24/6/2022 | Field work Yuyuni (SCUBA) diving & data entry | Team Leader |
| **Day 13** 25/6/2022 | Field work Kisiwa kikubwa (SCUBA) diving & data entry | Team Leader |
| **Day 14** 26/6/2022 | Field work Msumbiji (SCUBA) diving & data entry | Team Leader |
| **Day 15** 27/6/2022 | Field work Nyamalile south (SCUBA) diving & data entry | Team Leader |
| **Day 16 & 17** 28-29/6/2022 | Data cleaning, compilation & preliminary Data analysis | Team Leader and Monitoring team |
| **Day 18, 19 & Day 20** 30/6/ - 02/7/2022 | Data cleaning, compilation & preliminary Data analysis | Team Leader and Monitoring team |
| **Day 21-Day 27** 03-09/7/2022 | Trainee departure and Special Small Team (3 members) strategically selected to review literature, finalize data analysis, graphing, interpretation, draft report Draft report writing in Mafia and first draft share with WWF for comments. | Team Leader |

| | | |
|---|---|---|
| **Day 28** 10/July/2022 | Special Small Team members travel back to respective centers. | Report writing team |
| **Day 29** 01/November/ 2022 | Field work  Kifinge (SCUBA) diving & data entry | Team Leader |
| **Day 28** 02/November/ 2022 | Field work Yuyuni  (SCUBA) diving & data entry | Team Leader |

## Annex III: MPRU Staff Training report

### MPRU CORAL REEF MONITORING TRAINING

**Introduction**

With an objective of capacity building at MPAs site level certified divers were the target under the training. A total of 22 participants were involved in the current training covering both practical and theory part where eleven being MPRU Staff, nine being University students from the Sokoine University of Agriculture who were participating in their field practical training and 2 were WWF Staff. Skills equipped to participants were the techniques applied to identify coral reef for the beginners. Morphological structures and taxonomy were covered. Emphasis was given on key terminologies used in different coral identification guides.

**Training and capacity building of Marine Parks and Reserves Unit Staff**

In order to harmonize and produce accurate field data during the just ended coral reef monitoring exercise, all participants, regardless of their knowledge status in coral reef monitoring were subject to a one intensive training. The training involved class lectures and on-class practices on coral reef identification and recording of coral genus, growth forms, fish species and invertebrates.

**Key terms covered and their definition covered were:**

**Coral morphology**

- The skeleton of an individual polyp is the Corallite, which is a tube that contains vertical plates radiating from the centre.
- The tube itself is the corallitewall and the plates are the septo-costae
- The tubes are joined together by horizontal plates and other structures, collectively called the Coenosteum
- Some polyps have an additional thin film of skeleton around the wall called epitheca
- The wall is formed by five skeletal elements which vary in proportion in different coral families and genera:

(a)The Septo-coastae(which become thickened within the wall)

(b)Coenosteum(which forms a sponge like structure)
(c)Synapticulae (which are horizontal rods forming a lattice between the septo-costae)
(d)Sterome (which form a non-porous layer within the wall)
(e)Epitheca (which forms a layer outside of the wall)

The wall is prominent in some corals, but inconspicuous in others where polyps are indistinct.
The septo-costae are divided (by the wall) into two: Septa which are inside the wall and costae, which are outside the wall. Where the wall is indistinct (Sidastrea, Agariciidae and fungidae) the septo-costae are single uniform

General Morphologic Features of a Corallite
•corallite= skeleton of a solitary individual or an individual within a colony
•calice= a cup-shaped depression on the corallitesurface
•coenosteum(-a) [or peritheca(-ae)]= skeleton between corallites within a colony
•septum(-a)= radially-arranged vertical partition(s) within a corallite
•costa(-ae)= extension of a septum beyond the wall
•columella(-ae)= central axial structure (vertical rod) within a corallite
•dissepiment= horizontal partition (flat or curved) within or outside of a corallite
•wall[or theca (-ae)]= vertical structure enclosing a corallite

| **No** | **Name** | **Institute** |
|---|---|---|
| 1 | Ms. NZUNDA SARAH.M | Student - Sokoine University of agriculture |
| 2 | Mr BATHOLOMEO MSENYENYA | Student - Sokoine University of agriculture |
| 3 | Mr PALLANGYO NICKSON N | Student - Sokoine University of agriculture |
| 4 | Mr MBWAMBO KELVIN B | Student - Sokoine University of agriculture |
| | Mr MOLLEL, MOSES D | Student - Sokoine University of agriculture |
| | Mr NICOLAUS JOSEPH. J | Student - Sokoine University of agriculture |
| | Mr PETER HERMENEGILD D | Student - Sokoine University of agriculture |
| | Mr NYESELA, KANDI SUZO | Student - Sokoine University of agriculture |
| | Mr NDOSI, HILARY | Student - Sokoine University of agriculture |
| | MPRU Staff | |
| 1. | Mr PAGU JULIUS | MPRU staff-DMRs |
| 2. | Mr SHAMTE MOHAMED | MPRU staff-MIMP |
| 3. | Mr MASANJA JORAM | MPRU staff-MIMP |
| 4. | Mr DAVIS URIO | MPRU staff-MBREMP |
| 5. | Mr AMOS SINGO | MPRU staff-MBREMP |
| 6. | Mr MUSA ALLY | MPRU staff-MBREMP |
| 7. | Mr NELSON MDOGO | MPRU staff-TACMP |
| 8. | Mr HUMPHREY MAHUDI | MPRU staff-TACMP |
| 9. | Mr MICHAEL ELISHA | MPRU staff-DMRs-HR |
| 10 | Mr BENARD NGATUNGA | MPRU staff-MIMP |
| 11 | Mr RAMADHANI NYUMBA | MPRU staff-MIMP |
| 12 | M/S KULWA MTAKI | MPRU staff-MIMP |
| 13 | Mr ALBERT MAKALA | MPRU staff-MIMP |
| 14 | Mr PASCAL | MPRU staff-MIMP |

| | | |
|---|---|---|
| 15 | RAMADHANI NYUMBA | MPRU staff |
| | **WWF STAFF** | |
| 1. | Mr January Ndagala | WWF staff |
| 2. | Mr. Julian Easton | WWF staff |
| 3. | Mr Jairfos Mahenge | WWF staff |

## 2.0 RESULTS

The given Plates i-vii, is presented with detailed results for each MPRU staff participated in the training in relation to coral reef monitoring as well as report writing skills. Generally, staff were able to master theoretical part and apply in the field, collect data, analyse and participate in the report preparation.

## 3.0 DISCUSSION AND CONCLUSION

The training was conducted smoothly and each participant was able to follow and master the training. At the end participants were very well acquainted with coral reef identification skills and monitoring techniques.

In order to keep participants updated as well as getting up to date skills, I strongly recommend a monthly coral monitoring program conducted at each MPA (SAM Program) to be strengthened by application of SCUBA where participants can be easily apply acquired coral identification skills.

Although the work under SAM is done in relatively shallow waters, the sustenance and intensity of data collection provided appropriate and reliable scientific information upon which some management decisions can be made.

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