ESTABLISHMENT OF BASELINE SCIENTIFIC INFORMATION ON REEF FISH BIOMASS, ABUNDANCE AND POPULATION STRUCTURE IN SELECTED SITES OF MAFIA ISLAND MARINE PARK, TANZANIA

FINAL REPORT SUBMITTED

TO

WWF TANZANIA COUNTRY OFFICE

BY

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LIST OF ABBREVIATIONS AND ACRONYMS

BAF	Blue Action Fund
BRP	Biological Reference Point
BTLS	Biomass trophic level spectra
SCUBA	Self-Contained Underwater Breathing Apparatus
CFMA	Collaborative Fisheries Management Area
CZ	Core Zone
GMP	General Management Plan
GN	Government Notice
GUZ	General Use Zone
LRUC	Local Resident User Certificate
MIMP	Mafia Island Marine Park
MKUKUTA	Mkakati wa Kukuza Uchumi na Kupunguza Umaskini Tanzania
MPRU	Marine Park and Reserve Unit
NGO	Non-Government Organisation
RUMAKI	Rufiji-Mafia-Kilwa
SUZ	Special Use Zone
TCO	Tanzania Country Office
TDHS	Tanzania Demographic and Health Surveys
ToR	Terms of Reference
URT	United Republic of Tanzania
UVC	Underwater Visual Census
WWF	World Wide Fund for Nature
VLCs	Village Liason Committee
MPA	Marine Protected Area
TCO	Tanzania Country Office
WP	Work Package

Disclaimer

The views expressed in this report are those of the authors and do not necessarily reflect those of the World Wide Fund for Nature (WWF), Marine Parks and Reserves Unit (MPRU) of the government of the United Republic of Tanzania. Correctness of the information presented herein is bound to the time of field data collection and compilation of this report.

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EXCUTIVE SUMMARY

This report provides detailed findings of a survey undertaken to establish baseline scientific data and information on reef fish biomass per hectare, abundance, and population structure of selected fish species in Mafia Island Marine Park (MIMP). The accomplishment of this consultancy work is based on the Terms of Reference (ToR) provided by WWF Tanzania Country Office through the Marine Programme, and they included (i) Review and documentation of fish biomass of Mafia Island Marine Park; (ii) Establish the fish abundance of the Mafia Island Marine Park; (iii) Establish baseline information of population structure of MIMP based on different length size classes; (iv) Establish baseline of fish composition and total biomass from target and non-target fish in specific zones of Mafia Island Marine Park; and (v) Provide key issues to be considered in the future for fish biomass assessment/monitoring.

The Consultants employed intensive literature review and Underwater Visual Census (UVC) supplemented with video in order to achieve all these five objectives. The selected five study sites represent core zone (CZ), special use zone (SUZ), and general use zone (GUZ) which are the management zonation as per the General Management Plan (GMP) of MIMP. So, there were Kitutia CZ, Mange SUZ, Utumbi SUZ, Kifinge SUZ and Nyamalile GUZ. The selection was made such as to represent different management zones that are spread across an area of the Park. The CZ areas those which no human activity is permitted; SUZ areas, fishing is permitted only for local residents living within the Park by using legal gear; whereas in GUZ areas fishing is open for all Mafia district and beyond by acquiring MIMP permit, but again by using legal gear. In all cases, fishing is permitted only for those who have been qualified by the Government through acquiring fishing licensing as per requirements of Fisheries Act Number 22 of 2003 Section 22 (1) (a) & (b) with its associated Fisheries Regulations of 2009 with an amendment of 2020. This also includes the Local Resident User Certificate (LRUC) from MIMP which is provided to MIMP residents only.

The results indicated that, the benthic form in the surveyed reef sites was highly diversified ranging from live coral cover, algal, sea grasses, dead corals, rubbles and others conforming to two monitoring studies done in the previous recent years. Fish abundance was observed to be non-significant different among sampled sites. 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 abundance of small sized individuals

was highest at Kitutia CZ outnumbering all other large species. A trend was similar in Utumbi, Nyamalile and Kifinge whereas Mange was different by having both forms, small and large-sized individuals. On trophic level, there was high abundance of pisci-invertivores in Kitutia, micro-invertivores and macro-invertivores in Nyamalie, Utumbi, Kifinge and Mange (Fig. 4) with little presence of predators. The apex predators' reef-associates such *Epinephelus* spp, *Cephalopholus* spp., *Cheilinus undulates*, *Sphyraena* spp., *Scomberomorus* spp were represented mostly by juvenile while adult *Caranx melampygus* was observed at Utumbi (1 individual) and Mange (5). Fish biomass was observed to be significant different among sampled sites (Kruskal-Wallies; P=0051) in which Mange SUZ (521kg/ha) had the highest followed by Utumbi SUZ (403kg/ha), Kifinge SUZ (348kg/ha), Nyamalile (294kg/ha) and Kitutia CZ (208kg/ha. Kitutia CZ had the lowest biomass per hectare among the five sites factor attributable to the presence of large numbers of small-sized individuals when compared to other reefs. The detection of a large number of small-sized individuals in the families of *Pomacentirdae, Labridae, Holocentridae, Acanthuridae* and *Scaridae* is indicative of intensive fishing in the respective reef sites. Generally, absence of top predators during the time of this survey is associated with proliferation of small-sized reef fish contributing significantly to the low than expected biomass in all reefs. Likewise, the fishing pressure exerted in Kitutia CZ was accountable for the lower total (all fish sizes) and fishable biomass (removing damselfish and all fish <10cm). Based on the existing GMP, it was expected Kitutia to preform higher in biomass than the SUZ and GUZ. Kitutia is close to Jibondo village where modified (illegal) seine net fishers are centred and fishers have free access regardless of being a no-take area. This is also true to Utumbi, Nyamalile and Mange where large number of fishermen were observed during this study. some regions (Brewer et al. 2013, Cinner et al. 2013, Maire et al. 2016, and McClanahan et al. 2016). However, in the absence of historical data on fish population ecology including connectivity, it is very hard to make a precise conclusion on these statuses. This is because, the absence of larger fish at Kitutia and Nyamalile may actually be a natural function of their physical features (ie. they are shallow, sheltered sites) and that is precisely what makes them important nursery grounds for juvenile fish (ie. absence of larger predatory fish). That in fact is why they were selected as core protection zones in the first place. A long term time series data collection may help in revealing the actual reef fish dynamics in the park.

On the other side, political events running to Tanzania's 2020 general election and after it are linked to be the current situation. This is because the Government directed the marine parks to allow fishermen free access to all reefs. The study concludes that (i) The access to the parks' reefs by fishermen from the park and outside the park is free regardless of the management zoning (ii) there exist unmanaged and intensive fishing activities which is impacting negatively on the reefs, (iii) in many cases, fishing is done by using unsustainable fishing gears and practices such as modified seine nets, (iv) the use of illegal fishing gears has led to depletion of large sized fish including the reef associated predators and (v) human disturbance observed at all reef sites cannot go unabated if we are to conserve the reefs for the purpose of improving the livelihoods of the people inside the park and beyond as a result of the fish spill-over effect. While we consider studied reefs at Mafia Island as relatively better when compared to others along the Tanzania coastline, emphasis should be attached at high importance to safeguard these ecosystems. "Based on the conclusion of the study following the results obtained, we recommend the following:

i. The government, non-governmental organisations, non-state actors as well as other environmental entities should increase and strengthen the exiting support in the management of MIMP in operational activities such as monitoring, control and surveillance of coral reefs and the fisheries and fisheries in general.
ii. Strategic Ranger Posts should be established in remote areas close to core and special use zones (e.g., at Jibondo and Bwejuu villages) to warrant availability of immediate response in case of breaching of the park's law.
iii. An existing network with local practitioners such as hoteliers, district council and NGO for operation in the park should be strengthened and maintained.
iv. There should be active political will and support in strengthening management of the park. Instability or poor cooperation with other law enforcers such as the police and judiciary undermine fulfilment of the intended achievements.
v. Illegal fishing or un-sustainable fishing within MIMP as described in this report is attributed to the existing defective regulations which were formulated in 2006. For instance, offences related to illegal beach seine net fishing in the park are fined only TShs 20,000/= (section 3(a)(i), (ii) & 18 (1)) of the MIMP (prohibited and Regulated Activities) Regulations, 2006. Government Notice No 129 published on 15/9/2006 which is contrary to the management regime outside the protected areas which is TShs. 500,000 (Fisheries Regulation of 2009 and its amendments of 2020) where illegal gear in a boat without engine and TShs. 2,000,000/= for a motorised vessel.
vi. Government authority and MIMP management should stick to rules and regulations regardless of political situation or any turmoil.

vii. Since this was a baseline study, frequent monitoring accounting for season variation on coral reef and fish status should be done each year so that before the phase out of the project on which biomass trend can be established and results compared with established baseline.

viii. Absence of population connectivity information is another serious problem to the management of the park. We strongly recommend establishment of fish population connectivity information among park's reefs and between parks and neighbouring reef.

1.0.Background Information

The World Wildlife Fund for Nature (WWF) is an International Non-Governmental Organisation that deals with conservation of nature through a number of environmental management programmes. Its mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature. The WWF - Tanzania Country Office (TCO) contracted a Tanzanian competent and qualified 'Individual Consultant' to undertake the above assignment.

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 effectively started in August, 2019. One of the main work packages is 'Improved management effectiveness of Mafia Island Marine Park – MIMP' which is work package number one (WP 1). The Parks boundaries (Figure 1) was established in 1996 under GN 200 which was published on 6/9/1996 with an overall purpose of ensuring the continued survival of rich varieties of living organisms for the benefit of people. Therefore, this assignment seeks to establish baseline for reef fish biomass in kg/ha with focus on priority families: top-predator reef-associates (Epinephelus spp, Cephalopholus spp., Cheilinus undulatus, Caranx melampygus, Sphyraena spp., Scomberomorus spp.), and was confined in five priority sites of Kitutia, Utumbi, Kifinge, Mange and Nyamalile - pre-selected by the project.

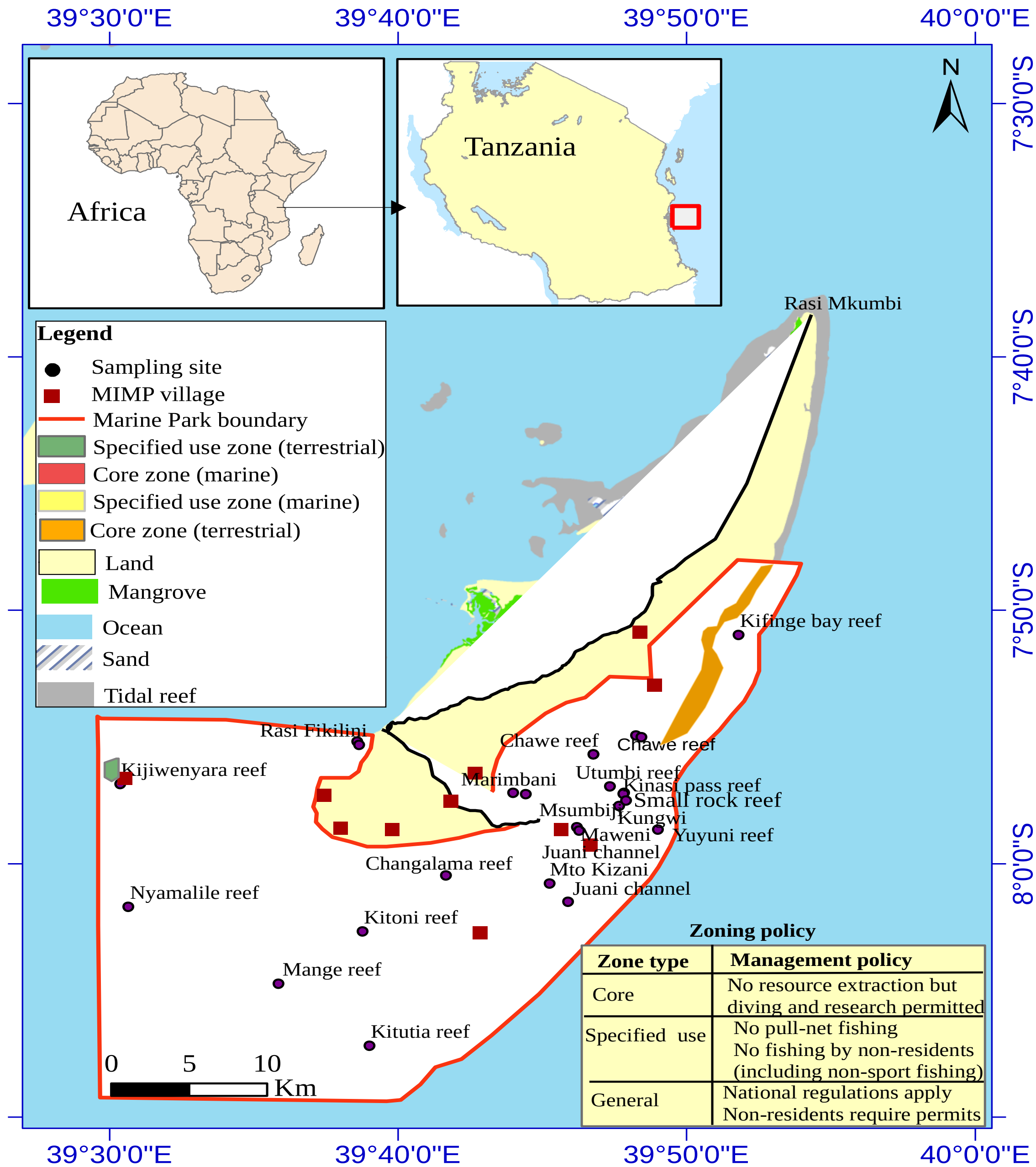

Figure 1: Location and management zones of Mafia Island Marine Park

1.2 The Overall Objective of the Consultancy

The overall objective of this special consultancy was to establish baseline scientific data on reef fish biomass per hectare, abundance and population structure of selected fish species in MIMP, Tanzania.

1.3 Specific Objectives

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

(i) Review and documentation of fish biomass of MIMP;

(ii) Establish the fish abundance in MIMP;

(iii) Establish baseline information of population structure of MIMP based on different length size classes;

(iv) Establish baseline of fish composition and total biomass from target and non-target fish in specific zones of MIMP, and;

(v) Provide key issues to be considered in the future for fish biomass assessments/monitoring.

1.4 Scope of Consultancy Work

The consultant has undertaken study of similar nature within MIMP and beyond. This study expected to deliver on the following:

i) Inception report, including methodological approach, data collection procedures/tools and analysis;

ii) A draft report on fish baseline survey on fish biomass, abundance and population structure) all the above objectives – overall and specific for survey sites and management zones;

iii) Final report on fish baseline survey with scientific and management recommendations, and

iv) At least 20 high quality underwater photo and 10 video clips taken during the field work.

2.0 Methodology for the Assignment

2.1 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 first multiple uses 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, cays, and coastal forest (UTR 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 Park has three different marine management zones including core zone 5%, specified use zone 25% and the general use zone 70% (Appendix 1).

The consultancy as per workplan (Table 1) concentrated within five priority sites identified by WWF RUMAKI-BAF project, namely Kifinge- SUZ, Kitutia –CZ, Utumbi – SUZ, Mange SUZ and Nyamalile North –GUZ, to assess fish biomass, abundance and population structure within MIMP (Figure 2; Table 1).

The contract started on the 15th May 2021 by reviewing literature and other information relevant for the work. The literature as cited in the reference list included available gray such as students' reports, hotel records and fliers, several recent publications on MIMP, management documents including the General Management Plan.

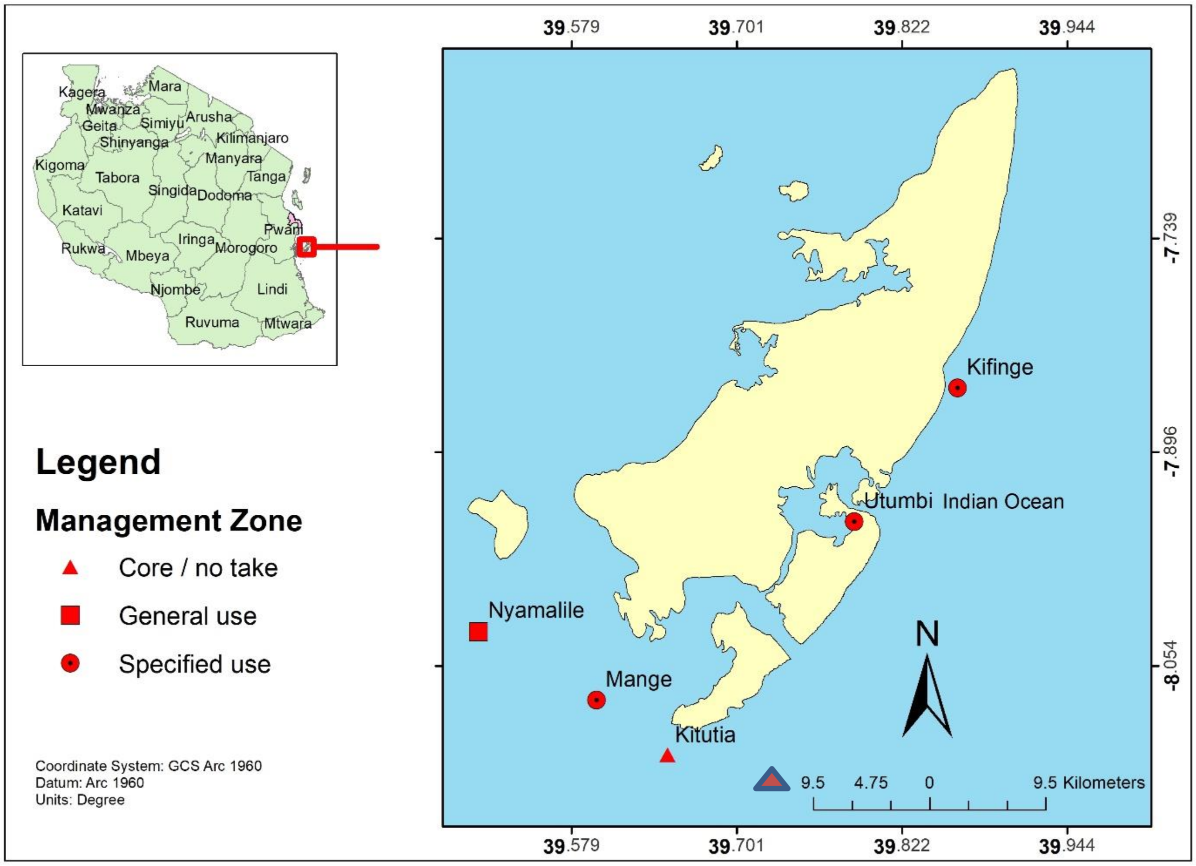

Figure 2: Mafia Island map showing locations of sampling sites

Table 1: Description of the surveyed water reef sites

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s/n	Site	Lat (S)	Long (E)	Area	Zone	Management
1	Utumbi	07°56.870'	039° 47.240'	MIMP	Chole bay, channel, sheltered	SUZ
2	Kitutia	08°07.145'	039° 39.003'	MIMP	Outer, sheltered slope	CZ / no take
3	Mange	08°04.737'	039° 35.860'	MIMP	Inner, semi exposed	Specified use
4	Nyamalile	08°01'42.6"	039°30'39.0'	MIMP	Inner, semi exposed	GUZ
5	Kifinge	07°50'58.2'	039°51'48.6'	MIMP	Outer, Exposed	SUZ

2.2 Field Approaches and Methods

Consultants applied the regional and global scale techniques in order to make comparison of fish biomass, abundance and population structure result with others' findings and these were:

(i) Underwater visual census (UVC) techniques that was used to assess fish biomass, abundance and population structure;

(ii) A 100m x 5m belt transects (Fig. 3; Plate 1) that were used to assess fish biomass, abundance and population structure, and fish size classes. This was estimated in centimetres (cm); therefore, there were 3-10cm, 10-20cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm and > 80cm as described by McClanahan *et al*., 1999. Each individual fish feeding mode fish was used to determine its feeding functional group as described by Samoilys *et al*., (2019). Belt transects were deployed in such a way that they covered the reef slope and reef flat in all sampling sites. Fish counting and swimming speed was undertaken by swimming at low and constant speed along the belt transect covering $33m^2\ min^{-1}$ and approximation of 3 - 4metre min^{-1} depending on fish abundance and complexity of the habitat or rugosity of coral reef as adopted from Samoilys and Carlos (2000). A period of 20 minutes after laying out a transect was given to allow fish to return to the area before census. During Underwater visual census process, fish observed were recorded on slate with its respective required details such as length and species name. For field species quantifications, a field guide as described by Bianch 1985; Lieske and Myers 2002; Allen and Steene 2007 were applied. A minimum of 9 transects were made per site, and

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

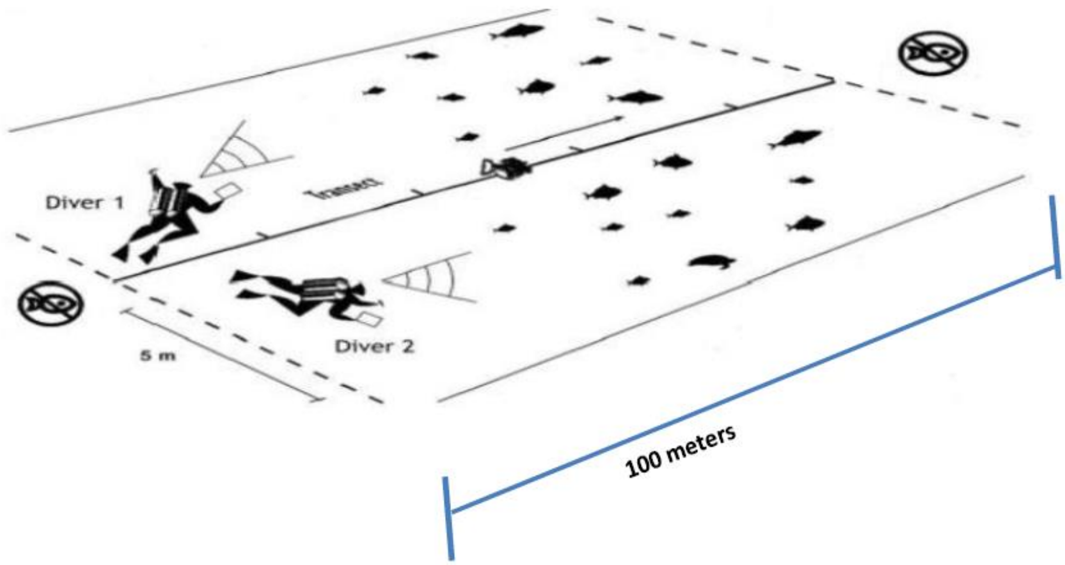


Figure 3:Illustration of belt transect layout

Plate 1: A 100m x 5 m belt transect at Nyamalile site (SUZ).

2.3 Implementation Phases of the Assignment

This consultancy was implemented in three phases:

2.3.1 Phase 1: Planning and preparation phase

Key documents related to the consultancy were reviewed. The review provided an appropriate platform to collect secondary data and get theoretical orientations of the ToR for the work as well as prepare the inception report. The reviewed documents included the fisheries reports at the park headquarters, RUMAKI documents related to fishers, National policies guiding the coastal marine and fisheries, social and economic information from the three districts under RUMAKI seascape which included; MKUKUTA reports, Tanzania Demographic and Health Surveys (TDHS), and Tanzania Poverty and Human Development Reports.

2.3.2 Phase 2: Information collection phase

Information was collected from a variety of sources (both primary and secondary) including underwater sampling, literature searches, consultations and field observation. The information collection approaches were as follows:

i) Addressing objective number (ii) to establish overall fish abundance for MIMP (#/ha) and objective number (iii) to establish baseline for fish family population structure for MIMP based on 3-10 cm, 10-20 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm and > 80 cm fish size classes#. Scuba-based survey was hereby applied where a 100*5m belt transect was used in data collection, and was purposely adopted to allow for comparison with other biomass findings reported in the WIO region. Fish sizes were estimated in centimetres (cm) and categorised in 8 size classes (3-10cm, 10-20cm, 30-40cm, 40-50cm, 50-60cm, 60-70cm, 70-80cm to > 80cm) and their respective abundance (count) computed as described by McClanahan *et al.*, 1999. Fish density was computed in terms of the number of individuals per hectare (#/ha). Fish biomass in kg/ha was estimated based on published standard length-weight relationships (See www.fishbase.org) using conversion equations ($W = a * L^b$), where a and b are constants for each of the fish species (Julius *et al*, 2016). To aid in species identification, field guides and underwater images/videos were used whereby different fishes (families) in video footages/ images were validated using a fish identification tool (“the fish base”). A total of 12 transects were performed per site. Additionally, data were pooled to their respective user zones as described in number (i) above (the core, specified, and general use zones) and grouped based on fish feeding patterns for Corallivores, Detritivores, Grazers, Macro-invertrivores, Micro – invertivores, Pisci-invertivores, Piscivores, Planktivores, Scrapers and Top predators as described by Samoilys *et al*., (2019).

ii) Addressing objective number (iv) to establish baseline on fish composition (percentages/proportions) for total biomass, fishable biomass, target fish biomass and non-target fish biomass (kg/ha) for MIMP. All fishes were recorded to the species level, then pooled to family level and further sorted out based on their relative biomass contribution - either to fishable biomass, target fish biomass or non-target fish biomass.

iii) Objective number (v) was to propose key issues to be accounted for in the future fish biomass assessments/monitoring. This was based on current findings in relation to other findings where a line was created to establish issues to be accounted in the future, or in subsequent monitoring including sampling timing consistence and the methods applied.

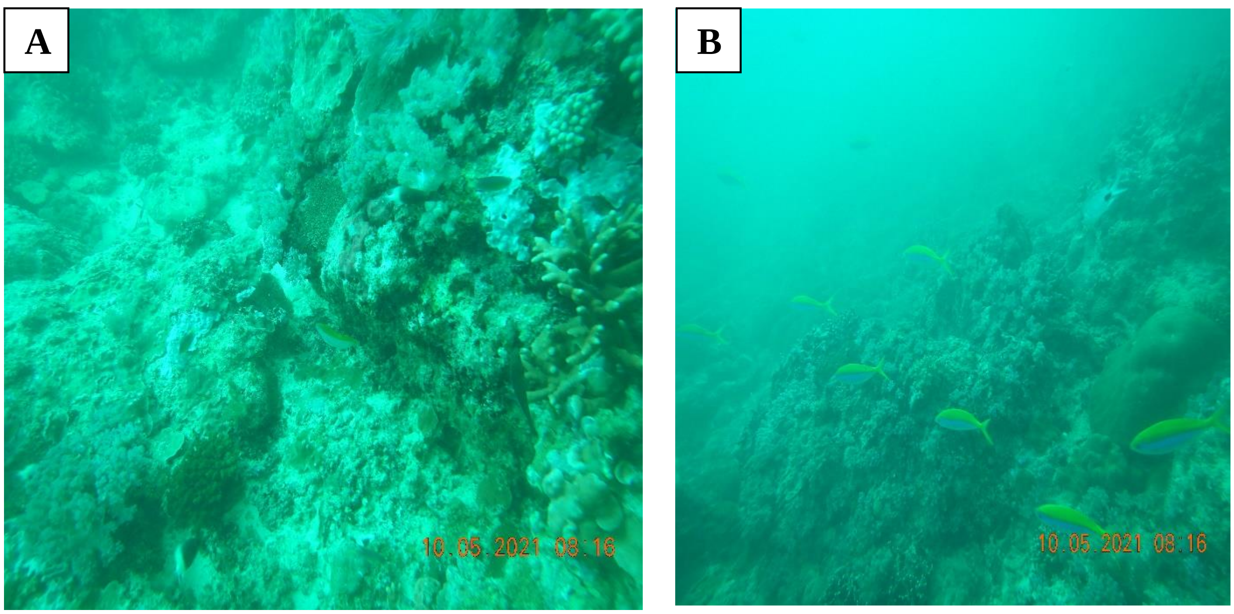
2.3.3 Phase 3: Data organisation, analysis and report writing phase

Data organisation included merging and cleaning, data analysis for fish biomass, abundance and population structure estimation for the five study sites where tables and graphs were generated. Kruskal-Wallis test was used to compare differences among study sites.

3.0 Results

3.1 Health Status of the Surveyed Reef Sites

The five surveyed sites are located in areas of different oceanographic conditions and management regimes and therefore subjected to varying degrees of stresses and resilience (Fig. 1). Generally, Utumbi, Kifinge and Kitutia reefs have fairy diverse benthic substrates dominated by hard coral cover whereas Mange and Nyamalile were mostly algal dominated. In all reefs, dead corals and rubbles were widespread. Genus *Acropora* was the most noticeable dead tabulate forms likely as a result of bleaching mortality and unsustainable fishing. Severe *Acropora* mortality was observed at Nyamalile. Plates 2-6 below show representative benthic features of the different survey sites while Plate 7 indicates some of the stressors (fishing related) to coral reefs.



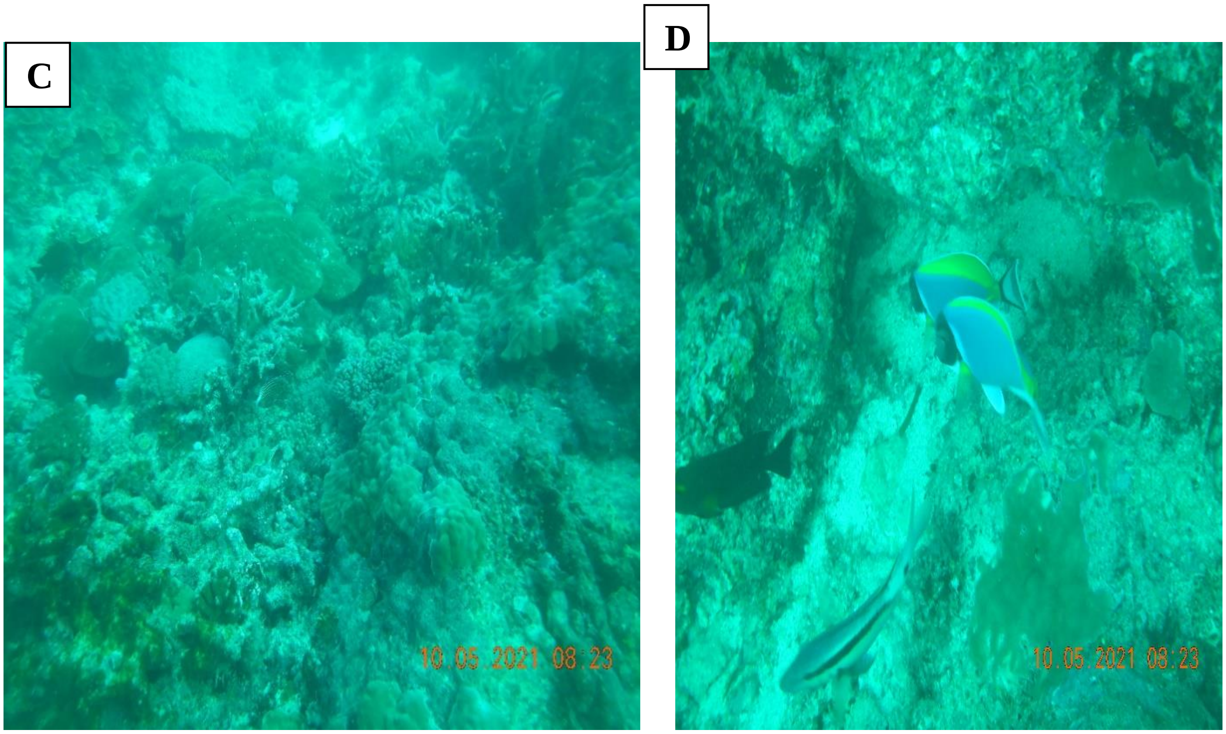
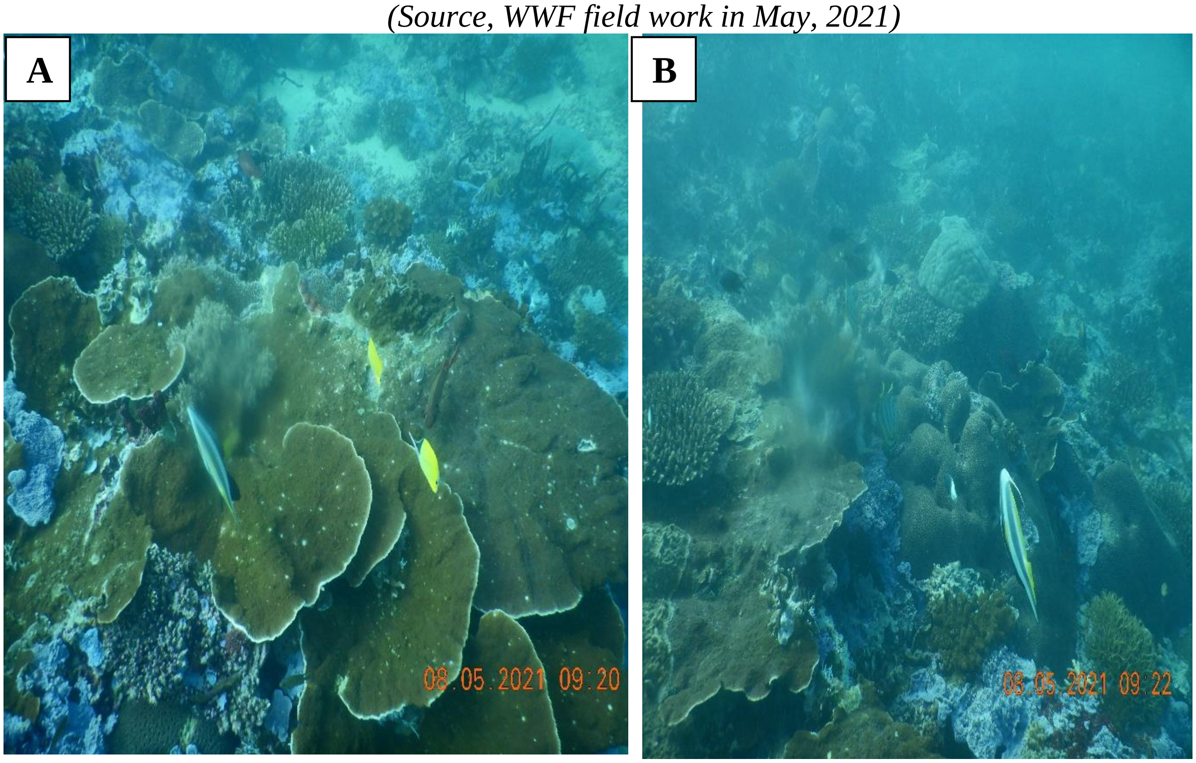


Plate 2 a-d; The representative bottom features at Kifinge reef

(Source, WWF field work in May, 2021)



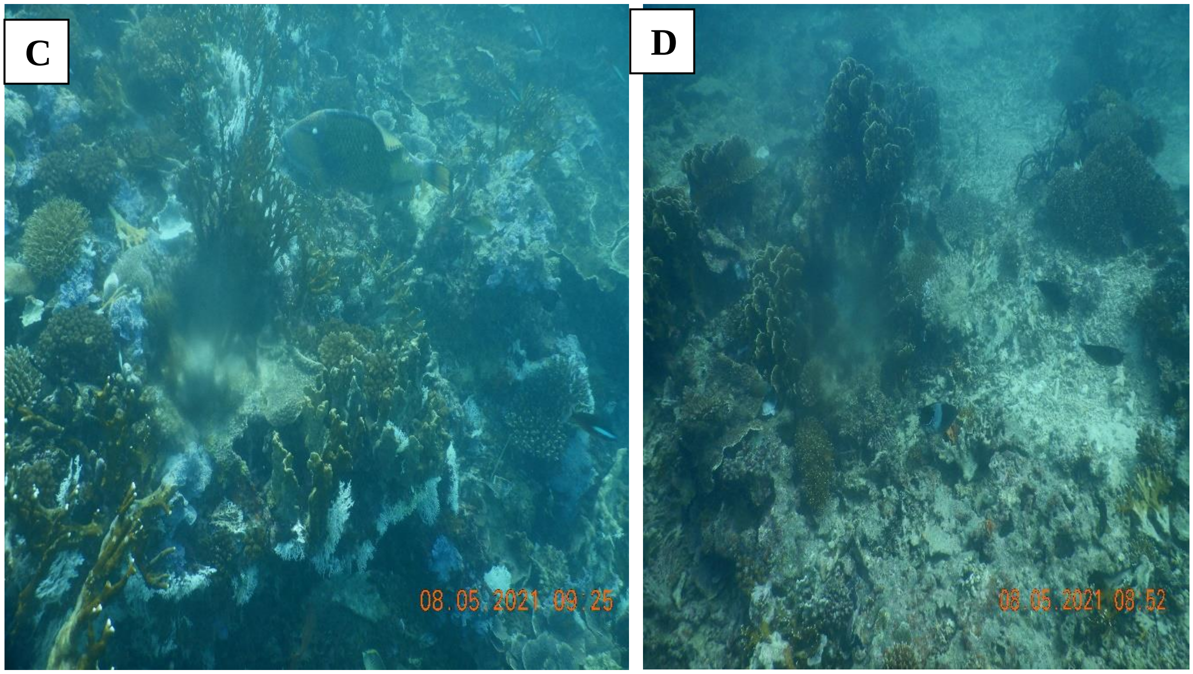


Plate 3 a-d: Representative bottom features at Utumbi reef

(Source: WWF field work in May, 2021)

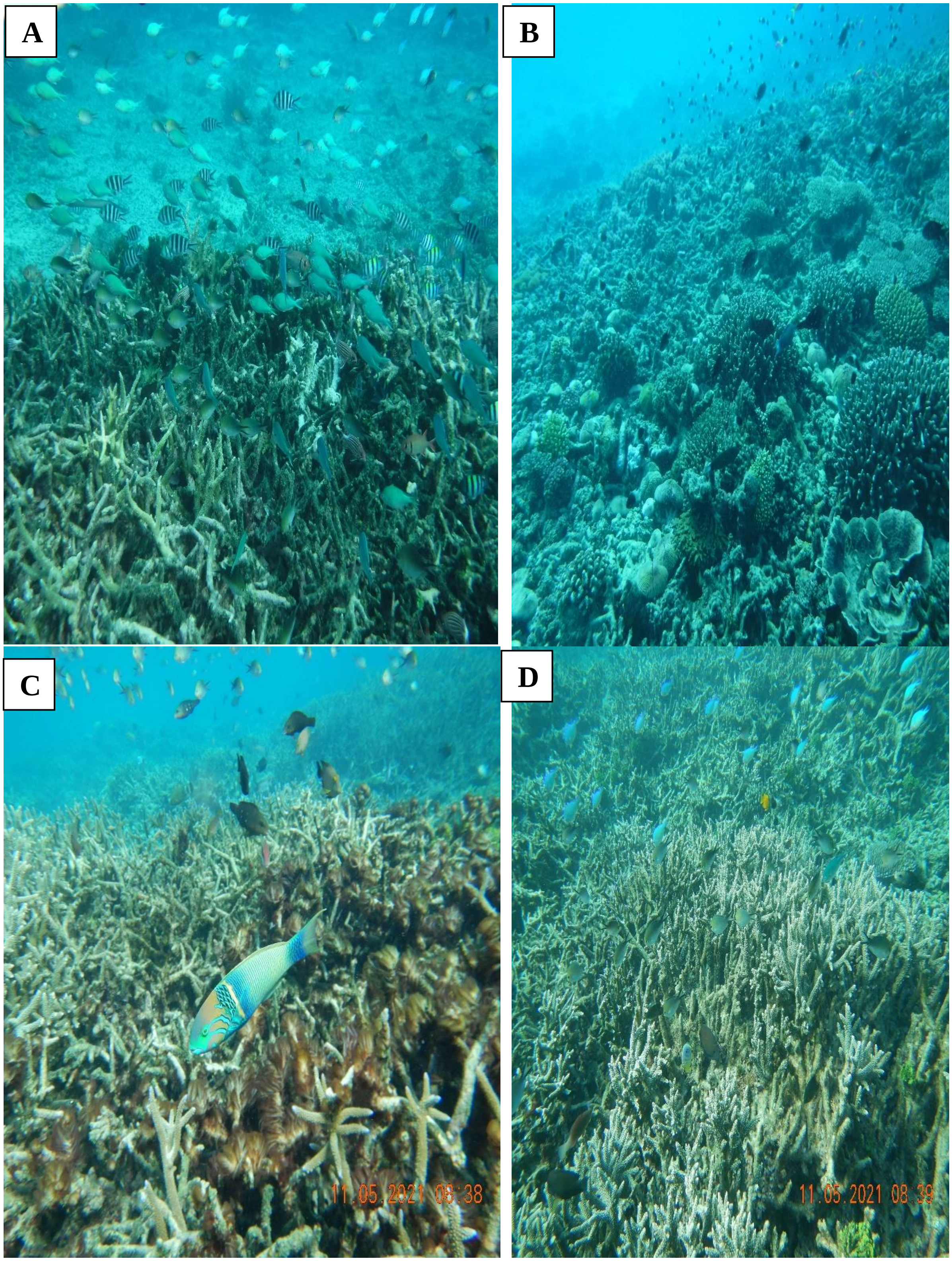


Plate 4 a-d: Representative bottom features at Kitutia reef

(Source: WWF field work in May, 2021)

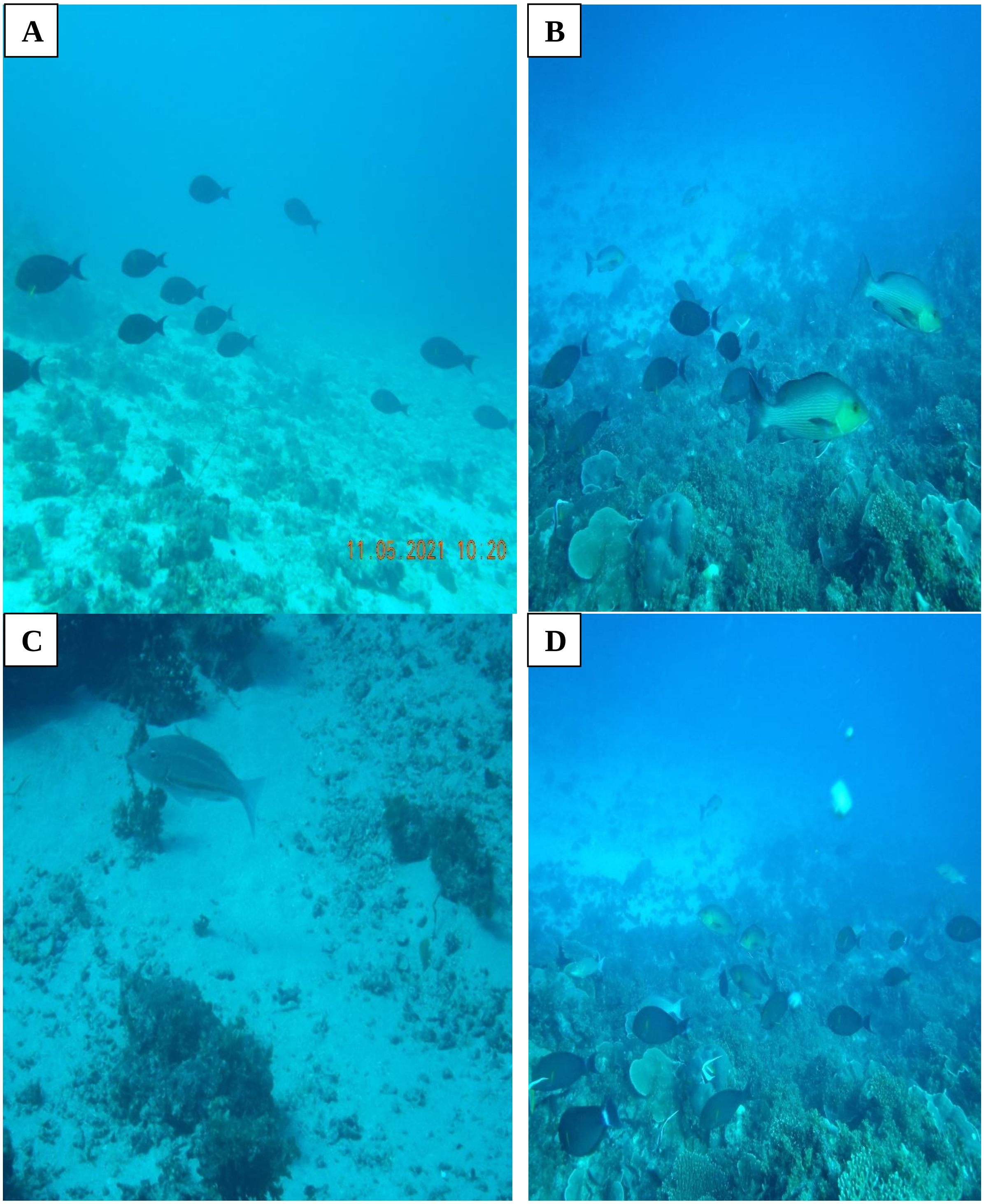


Plate 5-d: Representative bottom features at Mange reef

(Source, WWF field work in May, 2021)

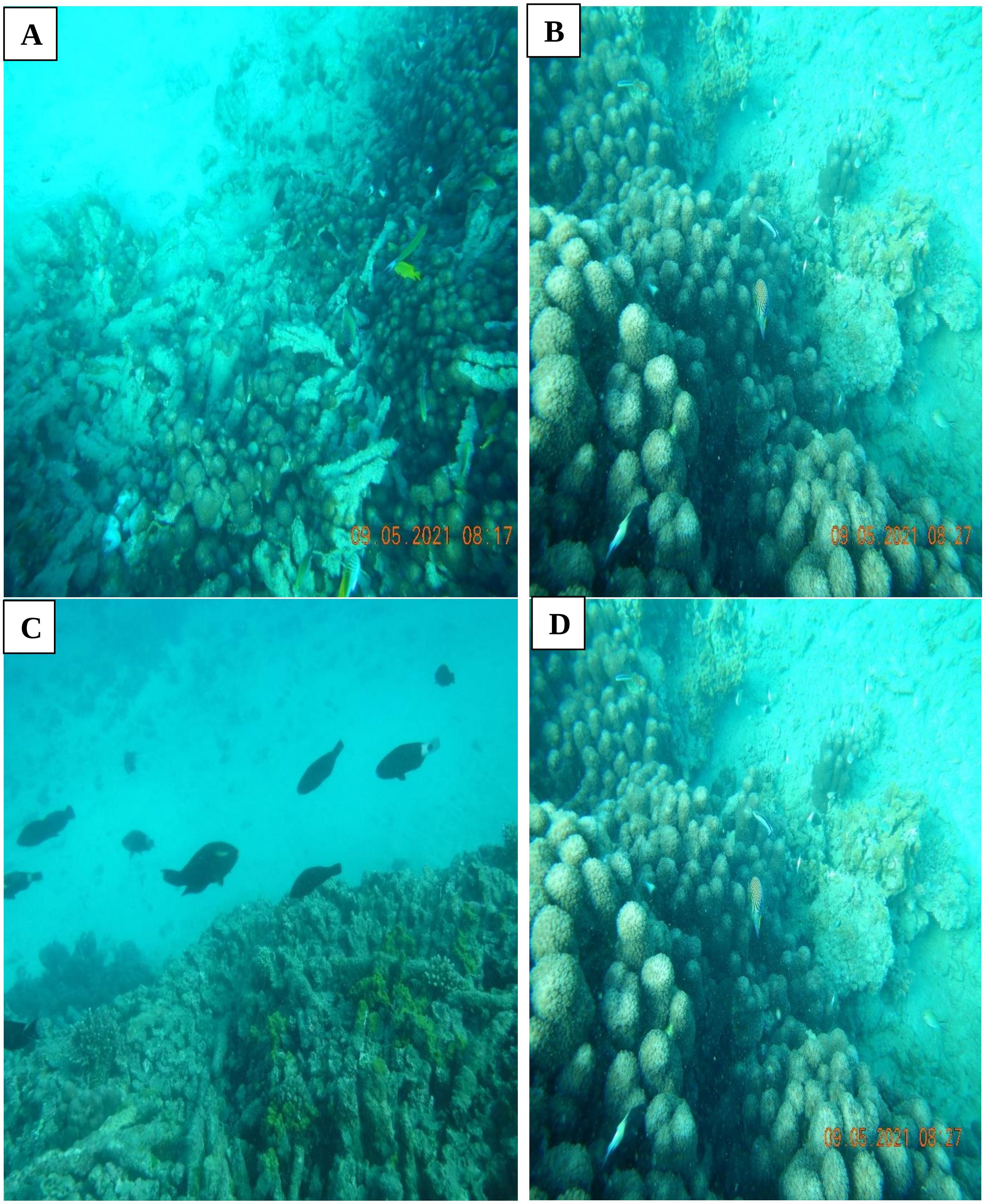


Plate 6 a-d: Representative bottom features at Nyamalile reef

(Source, WWF field work in May, 2021)

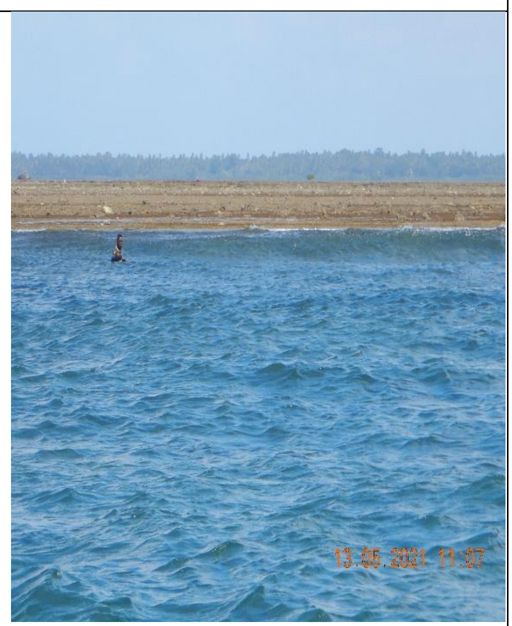
A) Illegal fish trap

B) Gillnet at the Kinasi Pass core zone

C) Abandoned longline and net at Kinasi Pass core zone

D) Fishing activities at Kinasi pass core zone

E) Fishing boats at Kinasi Pass Core Zone



A fisherman at Kinasi Pass Core Zone

Plate 7: Some of the human activities (A-E) observed in the surveyed reef sites

(Source: WWF field work in May, 2021)

3.2 Fish status in the surveyed reef sites

3.2.1 Fish composition on studied reefs

A variety of common reef fish families found in Tanzania dominated the study sites (Fig 4). Family *Pomacentridae* and juveniles of the families *Labridae*, *Acathuridae* and *Holocentridae* were the most dominant by > 80% (Fig 4). These small-sized fish were most abundant at Kitutia followed by Utumbi, Kifinge, Nyamalile and Mange. Other families observed in the reefs in large numbers were *Scaridae*, *Haemulidae* and *Lutjanidae*. On the one hand, we recorded a few individuals from predatory families of *Ballistidae*, *Sphyraenidae*, Carangidae and *Aulostomidae*. We did not notice presence of top predators such as those in the family *Carcharhinidae*. Other fish include families which are rare and commercially not important. These include; *Apogonidae*, *Bleniidae*, *Centriscide*, *Cirrhitidae*, *Dsyatidae*, *Ephippidae*, *Echeneidae*, *Kyphoidae*, *Monacanthidae*, *Monodaclidae*, *Nemipteridae*, *Ostraciidae*, *Plotosidae*, *tetradontidae* and *Synodontdae*.

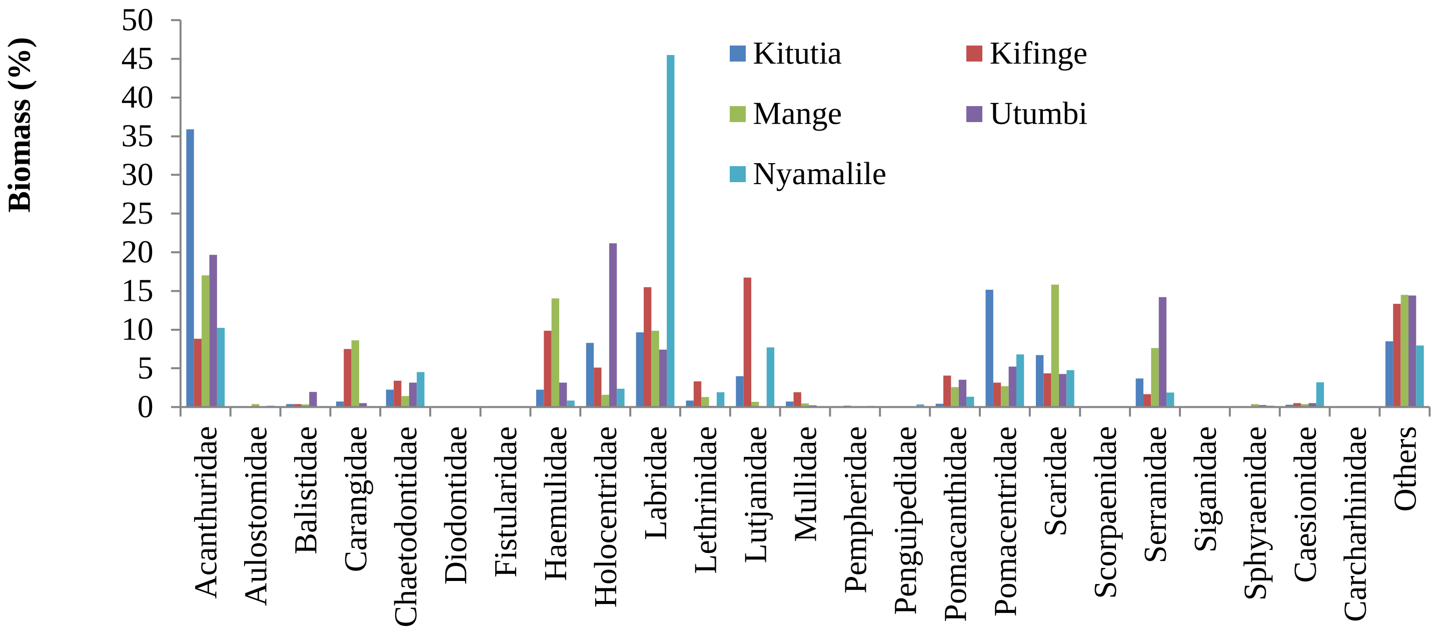


Figure 4: Percentage composition of fish families in the surveyed sites

(Source: WWF field work in May, 2021)

3.2.2 Fish class size distribution

Different fish class sizes were found to occupy the reefs where class size of 3-10cm exhibited dominance (Fig. 5.). Kitutia exhibited the highest for 3-10cm class size per ha (2,750/ha), followed by Nyamalile and Kifinge with Mange recording the lowest abundance (700/ha). The dominance was followed by a class size of 10-20cm and 20-30cm with a small contribution from other classes. The 10-20cm fish class size was the highest at Kifinge followed by Kitutia, Utumbi, Mange and Nyamalile. Differences among class sizes were very significant (Kruskal-Wallis; $p < 0.05$). The major families in the two classes (3-10 and 10-20cm) were represented by *Pomacentridae* and juveniles of the families *Labridae*, *Acathuridae* and *Holocentridae*. On the other hand, fish family of class size greater than 50cm-60cm were low in numbers dominated by carnivores mostly of the family *Serranidae*.

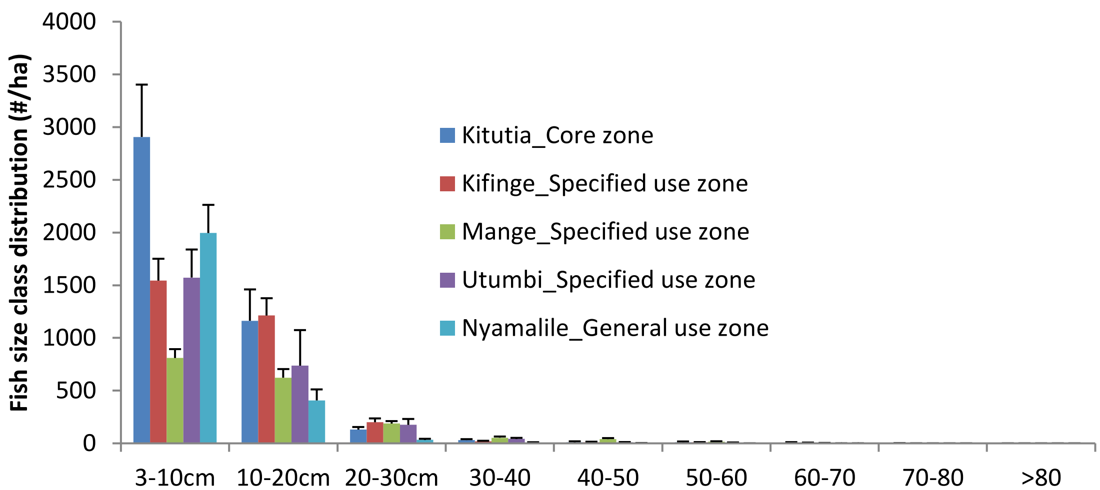


Figure 5: Fish size class distribution at the five surveyed reef sites

(Source: WWF field work in May, 2021)

3.2.3Fish abundance

There was no significant difference in fish abundance among sites (Kruskal-Wallis test; P = 0.1682). Nyamalile reef had the highest abundance when compared to other four reefs (Fig. 6). Among the species that made significant contribution included wrasses, parrot fish, goatfish, surgeonfish, butterfly fish, Soldierfish, Squirrelfish, Angelfish, filefish, Batfish, Fusiliers, sweetlips, emperor snappers and *Pomacentridae*.

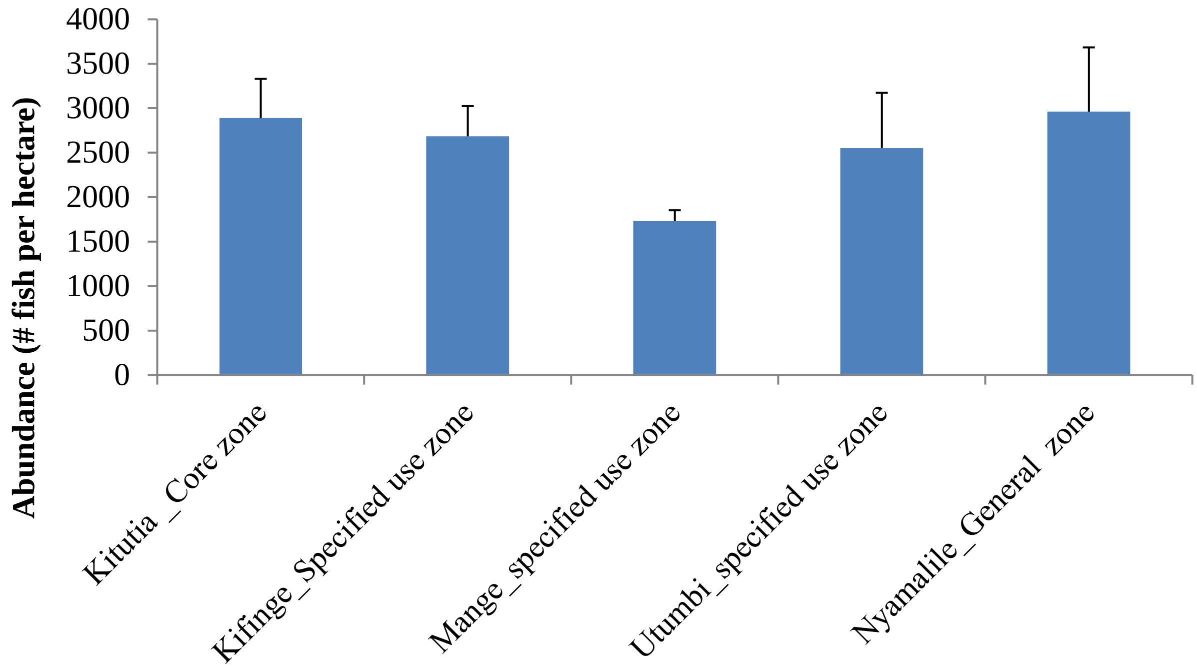


Figure 6: Fish abundance at the five surveyed reef sites

(Source: WWF field work in May, 2021)

3.2.4 Functional composition and fish total biomass

Function group are important indicators of reef fish conditions. Dominance of one level suggests food web collapse. In this study, the cumulative relative biomass trophic level spectra (BTLS) showed increase in grazers, micro-invertivores, macro-invertvoires and Pisci-invertvoires eliminating the lower to top predators (Figure 7). Composition of Corralivores, Piscivores, Planktivores and Detritivores was lower in all sites whereas top predators such as *Epinephelus* spp, *Cephalopholus* spp., *Cheilinus undulates*, *Sphyraena* spp., *Scomberomorus* spp were altogether insignificantly juveniles. The only top reef associated predator observed as an adult was *Caranx melampygus* and this was Utumbi (1) and Mange (1). Statistically, there was no significant difference in functional group biomass among sampled sites (Kruskal-Wallis Test; P = 0.4579).

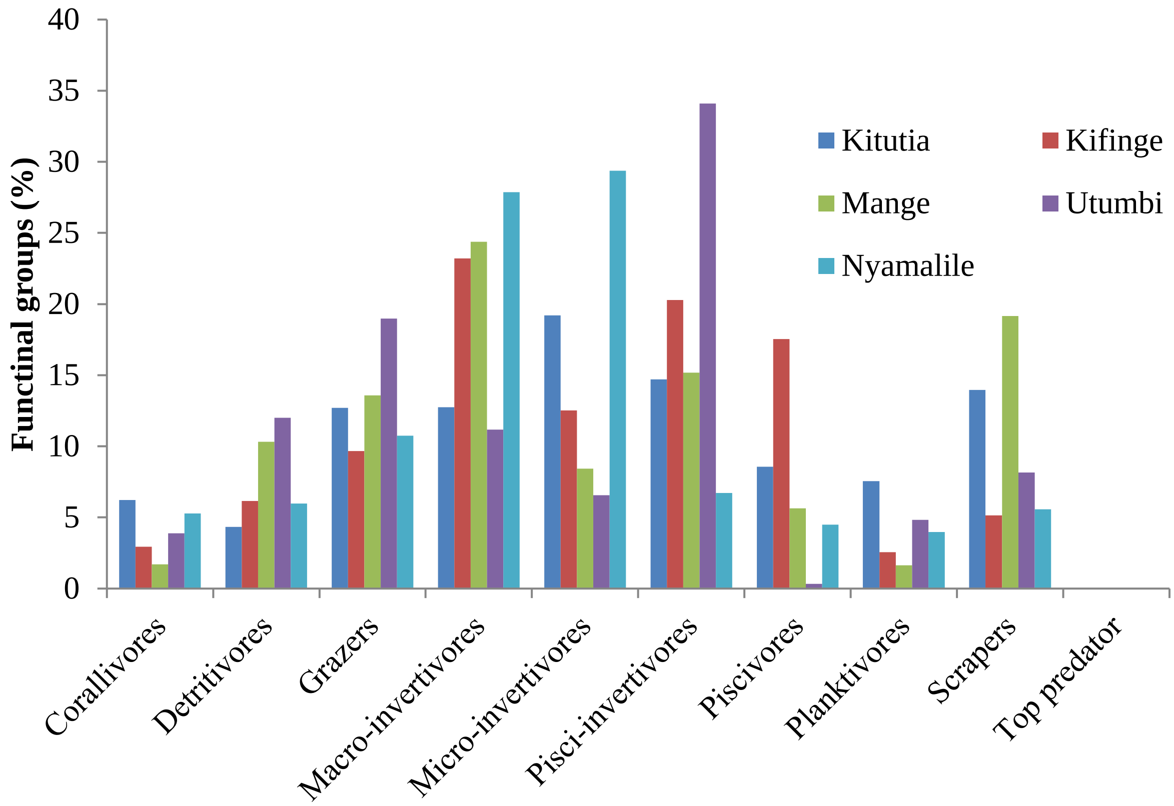


Figure 7: Fish functional groups observed in the study sites

(Source: WWF field work in May, 2021)

The population biomass estimates resulting from the analyses were expressed as percentages of the average total biomass for each zone and among zones (Figure 8). These results suggest differences in biomass among all sites (Kruskal-Wallis; P = 0.0051. Total fish biomass was higher at Mange and Utumbi when compared to Kitutia, Kifinge and Nyamalile. The lowest biomass was recorded at Kitutia which was attributed to the largest number/ha of small sized (3-10cm) individuals as described in Figure 5 above. This suggests that fish biomass is driven by the fish sizes and family composition. The presence of large members of families *Scaridae*, *Haemullidae* and *Serranidae* contributed to high fish biomass at Mange and Utumbi when compared to other reefs whose families constituted small sized individuals.

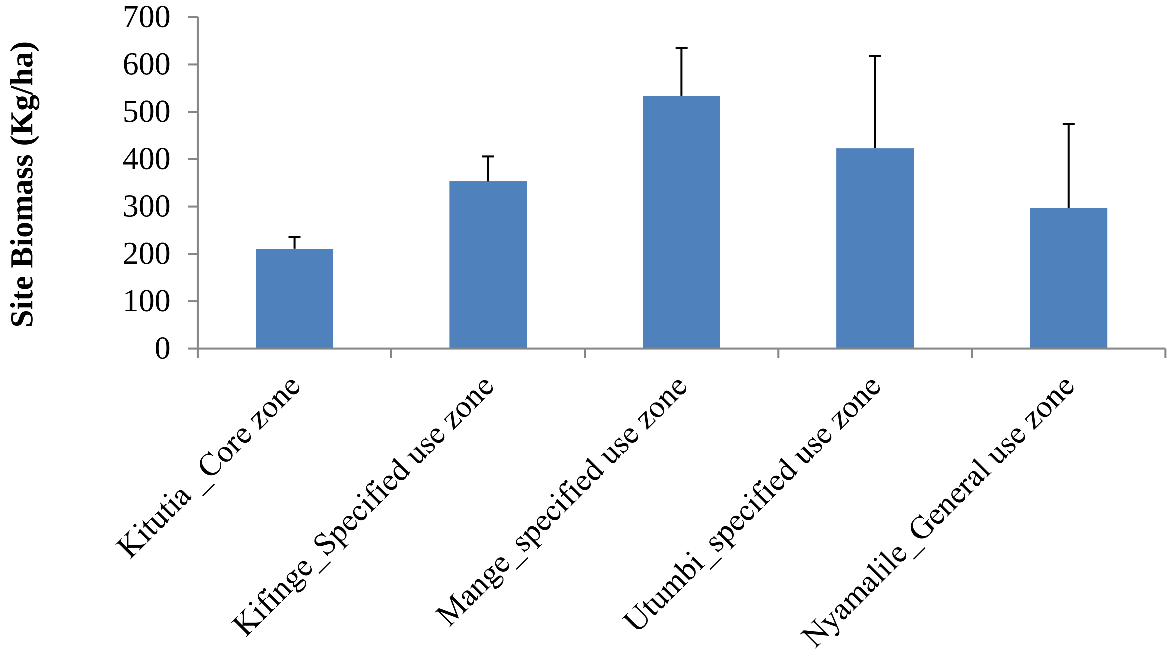


Figure 8: Fish biomass per site as observed in the surveyed reef sites

(Source: WWF field work in May, 2021)

In this study fish biomass was observed to be significant different among sampled sites (Kruskal-Wallies; P=0051) in which Mange SUZ (521kg/ha) had the highest followed by Utumbi SUZ (403kg/ha), Kifinge SUZ (348kg/ha), Nyamalile (294kg/ha) and Kitutia CZ (208kg/ha. Kitutia CZ had the lowest biomass per hectare (Fig. 8). Again, this can be expressed by the presence of large numbers of non-target, small-sized fishes such as those observed in the families *Pomacentridae*, *labridae*, *Holocentridae* and *Acanthuridae*. As a matter of fact, no fish bigger than 40cm in size was observed at Kitutia, a core zone which is a no-take area in the park.

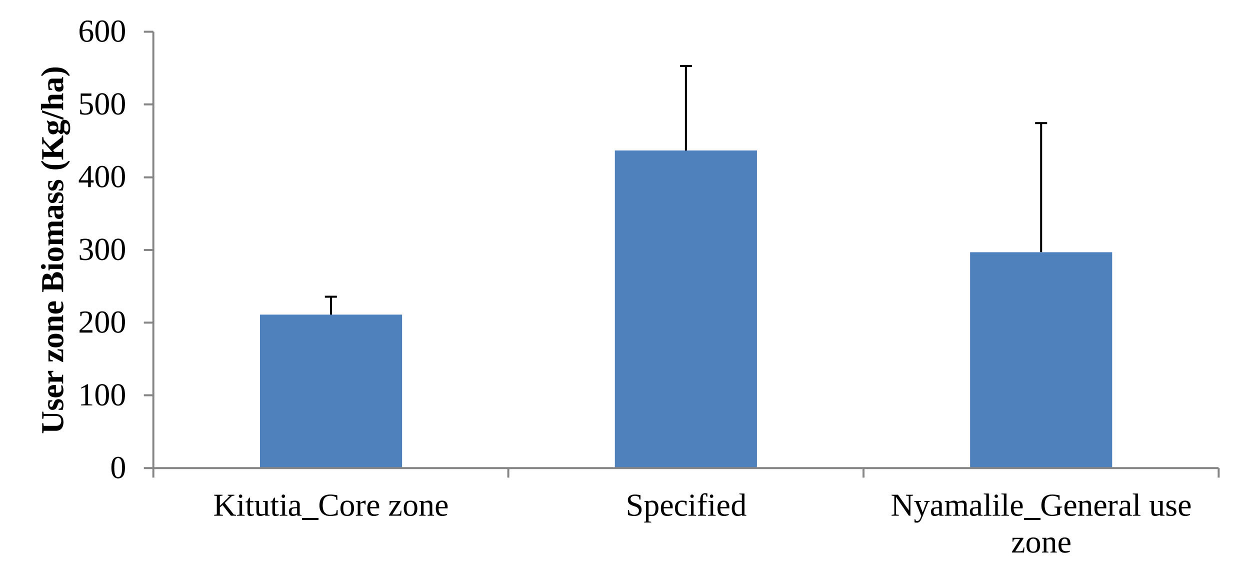


Figure 9: Fish biomass by user zone observed in the surveyed reef sites

(Source: WWF field work in May, 2021)

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

Target biomass (B_{TARG}) **is** the desired biomass of the stock, chosen to be the management target within a harvest strategy**.** The target biomass is also termed as Target Reference Points (TRP), TRP is a Biological Reference Point (BRP) also defined as the level of fishing mortality of the biomass which permits a long-term sustainable exploitation of the stock with the best possible catch. For this reason, these points are also designated as Reference Points for Management. It is characterised as the fishing level F_{target} or Biomass $B_{target.}$ The observed fishable population biomass (B) relative to the total biomass is expressed in Figure 10. Kitutia, Nyamalile and Kifinge were dominated by low value non-target fisheries families (i.e., *Pomacentridae* and juveniles of the families *Labridae*, *Acathuridae*, *Holocentridae*, *Muraenidae*, and *Diodontidae*). The higher value target fisheries taxa (i.e., *Lethrinidae*, *Haemulidae*, *Serranidae*, *Sphyraenidae*, *Labridae*, *Scaridae* and *Mullidae*) were more commonly found in deeper waters at Mange and Utumbi. Mange was unique in having large numbers of large sized *Scaridae* and *Haemullidae* but low numbers of *Pomacentridae*. As such, for the fishable biomass (>10cm), Mange had high exploited population biomass values to other sites. Non target biomass is the stock that is unavailable for fishing and was lowest in all sites (Fig. 10). Analysis showed that all surveyed reefs were in high both total and fishable biomasses except Nyamalile where non-target value was higher than fishable. Presence of large numbers of small-sized *Labridae* at Nyamalile had a significant contribution to the observed values.

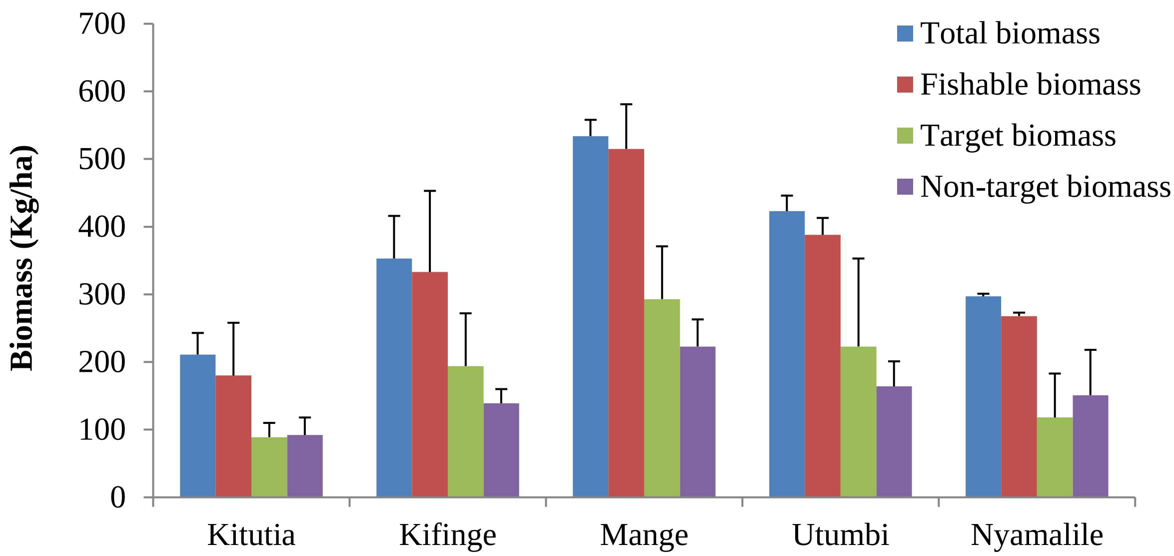


Figure 10: Average fishery exploited population biomass status expressed as total and fishable in each of the surveyed sites.

(Source: WWF field work in May, 2021)

4.0. DISCUSSION

4.1 Fish composition and size in Mafia Island Marine Park

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

We recorded a total of 28 families in all surveyed reef sites which were abundantly represented by small-sized species in the families *Pomacentridae*, *Holocentridae, Acathuridae* and *Labridae* (Figure 4). The families *Pomacentridae and Holocentridae* reached their peak at Kitutia where the dominance was unparalleled to any of the other surveyed reefs. Other families were from typical coral reef fish represented by juveniles (> 80%) and they included *Chaetodontidae, Labridae, Scaridae* and *Pomacanthidae*. Larger bodied and common reef fish species such the *Lutjanidae*, *Lethrinidae, Serranidae*, *Haemulidae, Mullidae*, and *Balistidae* were very little represented. The absence of carnivores, especially the top notch created an imbalance that triggered proliferation of lower trophic levels; thus, threatening the survival of the reefs. This is associated with heavy human influence which has been shown to be culprits for removal in some regions (Brewer et al. 2013, Cinner et al. 2013, Maire et al. 2016, and McClanahan et al. 2016). However, in the absence of historical data on fish population ecology including connectivity, it is very hard to make a precise conclusion on these statuses. This is because, the absence of larger fish at Kitutia and Nyamalile may actually be a natural function of their physical features (ie. they are shallow, sheltered sites) and that is precisely what makes them important nursery grounds for juvenile fish (ie. absence of larger predatory fish). That in fact is why they were selected as core protection zones in the first place. A long term time series data collection may help in revealing the actual reef fish dynamics in the park.

In the same context of small sized fish dominance, there are significant changes in the trophic structure of the reef fish community within the reefs whereby micro-invertivores, macro-invertivores, grazers and pisci-invertivores dominate. Because the absence of top predators and carnivores at all reefs signifies of intensive fishing pressure (Sandin et al., 2008). Similarly, sharks constitute as an important trophic level in healthy marine ecosystems (DeMartin et al, 2008). This is bound to perturb the coral reef ecosystems as a removal of fish species characterized as intermediate trophic levels and carnivores promotes proliferation of reef gnawers and eroders (McClanahan and Muthiga 2017). Co-existence of all functional groups in coral reef ecosystems is important for two main reasons: they provide a broad picture of the dynamics in the reef ecosystem that could be useful for managers to prioritise conservation planning and management, and secondly, they contribute to resilience enhancement of the coral reef ecosystem.

While there were differences in *Pomacentridae* abundance among reefs, *Holocentridae* was the second most abundant family in all reefs which together with the *Labridae* make a significant contribution in the total reef fish abundance in the studied sites. This status for the families were also reported in the same reefs by Lindahl *et al.* (2001), Garpe *et al*. (2007), Obura (2007, 2009) and URT (2017). Other important families in terms of abundance include the juveniles of commercially important *Lutjanidae*, *Serranidae*, *Carangidae,* and *Scarridae*, and the ecologically important reef fishes such as *Acanthuridae* (the Surgeons, and Unicorn fishes). On one hand, territorial damselfishes have been considered to have a negative influence on coral recruitment by allowing algae and other fouling organisms to grow and out-compete coral recruits for space (Green and Bellwood 2009). Generally, there were numerous herbivores including scrapers/small excavators, large excavators/bioeroders, grazers/detritivores, and browsers. Trophic levels or functional groups balance and resilience is of high potential for ecosystem balance, functioning and therefore quality fisheries yields or profit in MIMP.

4.2 Total biomass, fishable biomass, target biomass and non-target biomass

From this study, fish population density appears to be very high in core zone of Kitutia CZ. A factor that is attributable to the presence of large number of small-sized fish (< 10cm) as stated above. This is because large body sized fish contribute significantly to biomass more than small body sizes (Kulbicki et al. 2015; Froese *et al*., 2018). Similar studies done in the Western Indian Ocean region indicates varying degrees of biomass apparently depending on the level of protection. Samoilys *et al*. (2019) showed that fish biomass varied significantly though in most countries it was dominated by 300 kg/ha. A study by McClanahan and Jadot (2017) provided an evidence on the significance of large bodied individuals contribution to biomass where fish from families *Acanthuridae* (Surgeonfish), *Sphyraenidae* (Baraccuda), *Serranidae* (Groupers) and *Scaridae* (Parrrotfish) had very high biomass (>2000 kg ha−1) compared to small sized individuals which recorded biomass as low as 300 kg ha−1. Similarly, a recent study by Pagu *et al*. (2021) in the less protected and overfished reefs of Dar es Salaam Marine Reserve revealed that presence of high number of small sized fish was responsible for the low biomasses (<500 kg ha−1). In this study, the small sized fish was a common trend for Kifinge, Nyamalile and Utumbi but different at Mange where some amount of target deeper water fish species were observed. A few small-sized carnivorous individuals from families *Ballistidae* and *Serranidae*, which otherwise when grown to the maximum sizes carry large biomass, were observed in deeper parts of all reef sites.

The absence of large species which are target for fishing explains the level of fishing pressure that is exerted to the reefs. While no-take zones in marine parks are considered as effective management tools to restore fish biomass and community structure in areas depleted by overfishing, the situation was opposite at Kitutia. Poaching into Kitutia was evident despite its *no-take* status. Specifically, at Kitutia the absence of carnivores and other higher trophic level communities has resulted in proliferation of micro- and macro-invertivores (small sized fish) leading to the lowered biomass. As pointed out above, interpretation of the causes for absence of the large sized individuals is based on (i) the fact that the reef is freely accessible; hence fishing restriction is minimal if not absent and (ii) shallowness of the reef. Overfishing has impacted fisheries both directly (through removal of significant biomass) and indirectly (by changing ecological linkages). McClanahan et al, (2009, 2015), reported that although there was high variability of fish biomass in the western Indian Ocean ranging from15 to 2900 kg/ha, increased management in Tanga reefs in the year 1994 to 2007 resulted in the fish biomass rise continuously from 260 to 770 kg/ha.

The linkages between biomass and fish functional groups are important in informing priority reefs that require conservation and management focus. It is worth noting that the decreased fish biomass is correlated with a decreased proportion of top predators (Newman et al., 2006). In this study, the absence of top predators and the lowered biomass were closely associated with the fishing pressure. Reef associate's apex predators such *Epinephelus* spp, *Cephalopholus* spp., *Cheilinus undulates*, *Sphyraena* spp., *Scomberomorus* spp were mostly juvenile and adult were altogether missing except *Caranx melampygus* which was observed at Utumbi (1 individual) and Mange (5). A study by

McClanahan and Jadot (2017) indicated that biomass was the strongest predictor of number of species which in turn defines functional groups in a reef. On the other side, despite absence of apex predators, Mange and Utumbi reefs had the highest fishable and total biomass, followed closely by Kifinge. This is attributable to existence of large body sized families dominated by *Haemulidae*. The biomass at Kitutia CZ is a vivid example of the effects of the fishing pressure on total and fishable biomass. Generally, absence of top predators is associated with proliferation of small-sized reef fish contributing significantly to the low than expected biomass in all reefs.

On the other and serious side, we partially link the observation from this study to the prevailing political situation following 2020 general election in Tanzania. When we paid courtesy call at the park headquarter to brief on the findings, it was reported that currently, the park had no power to implement the park's laws and regulations. Before Government released an order to allow fishermen access all fishing sites uncontrolled. The same was echoed by the Police Officer Commanding District where he insisted that the order has not been rescinded yet and therefore cannot cooperate. The resulting uncontained mass movement of fishermen into reefs within the park is plausible for the recorded relatively low biomasses when compared to other studies as indicated above.

5.0 Conclusion

The findings from the study conform to others done in different marine environments using the same methodology for estimating biomass of exploited populations with more limited spatial and population coverage (Myers and Worm, 2003; Tremblay-Boyer *et al*., 2011; Gascuel *et al*., 2011; Watson *et al*., (2013; Christensen et al., 2014). Ecosystem-level experimental studies in protected areas, where human activities are carried out, are appropriate for detection of both the direct and indirect effects of management. No take zones have been proved to effective in restoring denuded ecosystems thus leading to greater abundance and biomass of fish than in fished areas. On the contrary, in this survey, we have noted that there is a significant decrease in commercially important fish species. Probably because of the Government order, several fishermen were spotted in all reefs regardless of management status. While we consider Kitutia CZ status as a shallow no-take zone most appropriate for nursery, the presence of several fishing vessels coming all the way from Dar es Salaam gives an indication of presence of large commercially important species. The significant increase of small-sized fish especially of the families *Pomacentridae* and *Labridae* specifically at Kitutia CZ is in response to loss of higher trophic levels mostly caused by intense fishing pressure. This also had effects in Nyamalile GUZ with some impacts on Mange SUZ, Utumbi SUZ and Kifinge SUZ. In all these reefs, the presence of small-sized fish was also noticeable. As a combined effect, the total biomass was significantly affected reading for Mange 521kg/ha, followed by Utumbi (403kg/ha), Kifinge (348kg/ha), Nyamalile 294kg/ha and Kitutia 208kg/ha. In the same order, quantities for the fishable biomass (>10cm) were equally low just below the level of minimum acceptable limits. Finally, the survey on fish biomass in the MIMP was the first contribution of its kind and aimed at understanding the ecological processes which are pertinent for advising a better way for management of fisheries.

6.0 Management recommendations

The human disturbances observed at all reef sites cannot go unabated if we are to conserve the nature for the purpose of improving livelihoods of the people inside the park and beyond. While we consider studied reefs at Mafia Island as ecologically healthier compared to other reefs along the Tanzania coast, emphasis should be placed at high importance to safeguard these treasure and national heritages. We therefore recommend the following;

ix. The government, non-governmental organisations, non-state actors as well as other environmental entities should increase and strengthen the exiting support in the management of MIMP in operational activities such as monitoring, control and surveillance of coral reefs and the fisheries and fisheries in general.

x. Strategic ranger posts should be established in remote areas close to core and special use zones (e.g., at Jibondo and Bwejuu villages) to warrant availability of immediate response in case of breaching of the park’s law.

xi. An existing network with local practitioners such as hoteliers, district council and NGO for operation in the park should be strengthened and maintained.

xii. There should be active political will and support in strengthening management of the park. Instability or poor cooperation with other law enforcers such as the police and judiciary undermine fulfilment of the intended achievements.

xiii. Illegal fishing or un-sustainable fishing within MIMP as described in this report is attributed to the existing defective regulations which were formulated in 2006. For instance, offences related to illegal beach seine net fishing in the park are fined only TShs 20,000/= (section 3(a)(i), (ii) & 18 (1)) of the MIMP (prohibited and Regulated Activities) Regulations, 2006. Government Notice No 129 published on 15/9/2006 which is contrary to the management regime outside the protected areas which is TShs. 500,000 (Fisheries

Regulation of 2009 and its amendments of 2020) where illegal gear in a boat without engine and TShs. 2,000,000/= for a motorised vessel.

xiv. Government authority should stick to rules and regulations regardless of political situation.

xv. Since this was a baseline study, frequent monitoring of coral reef and fish status should be done each year so that before the phase out of the project we can compare the results of baseline and new findings.

xvi. Absence of population connectivity information is another serious problem to the management of the park. We strongly recommend establishment of fish population connectivity information among park's reefs and between parks and neighbouring reef.

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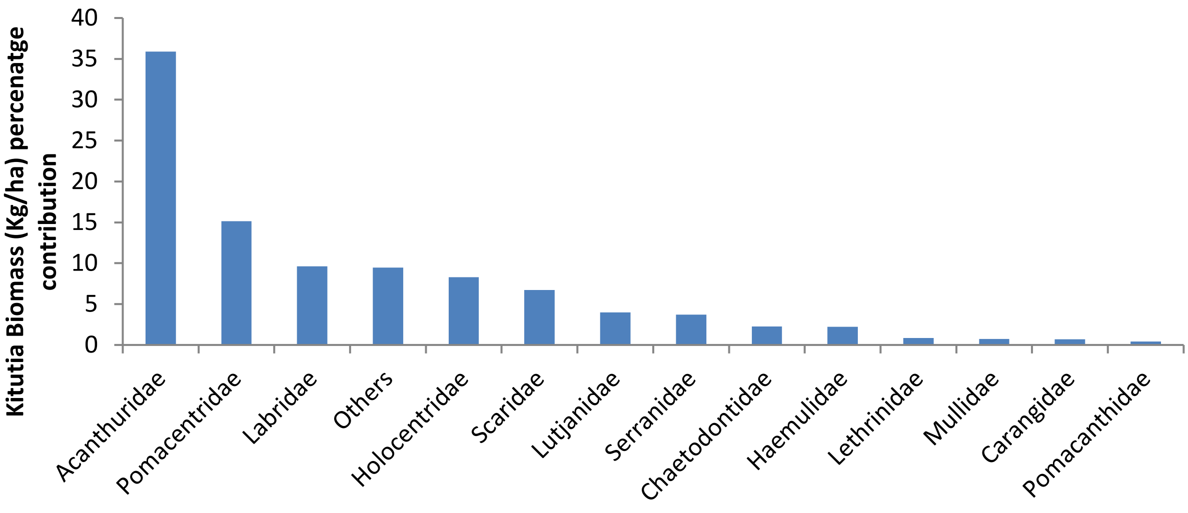
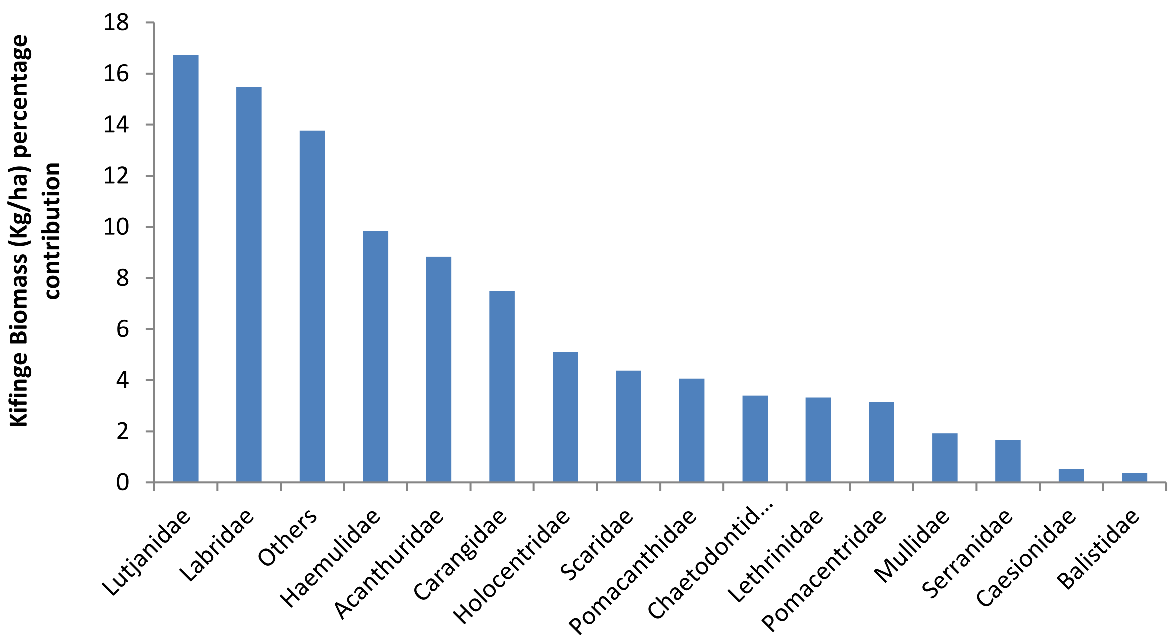
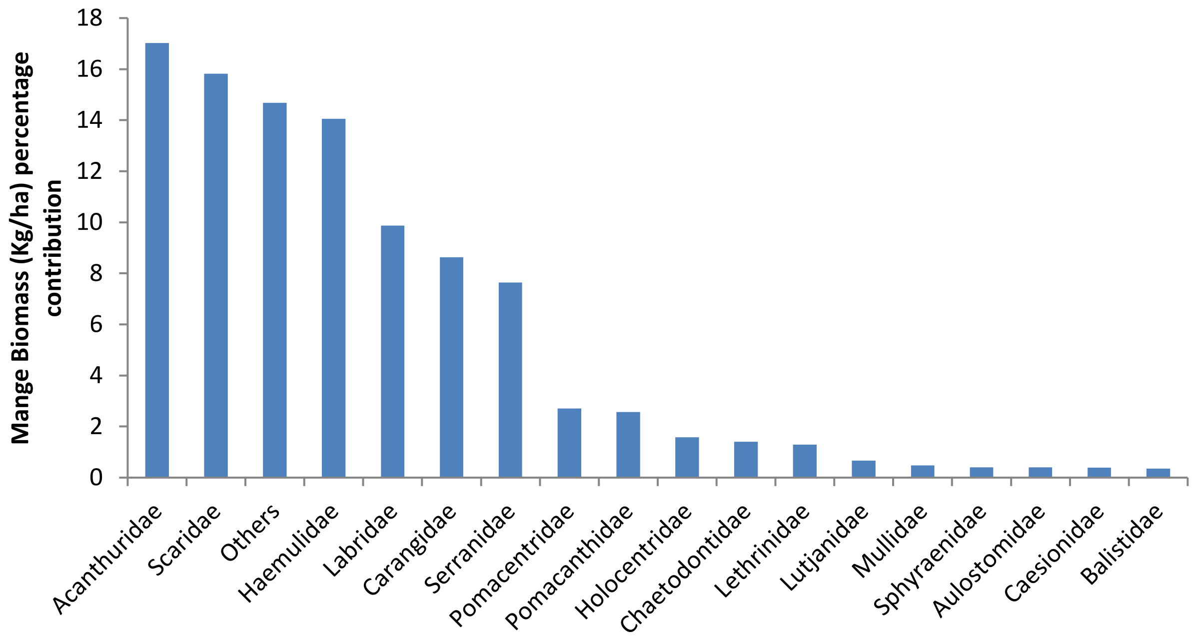
8. Annexes



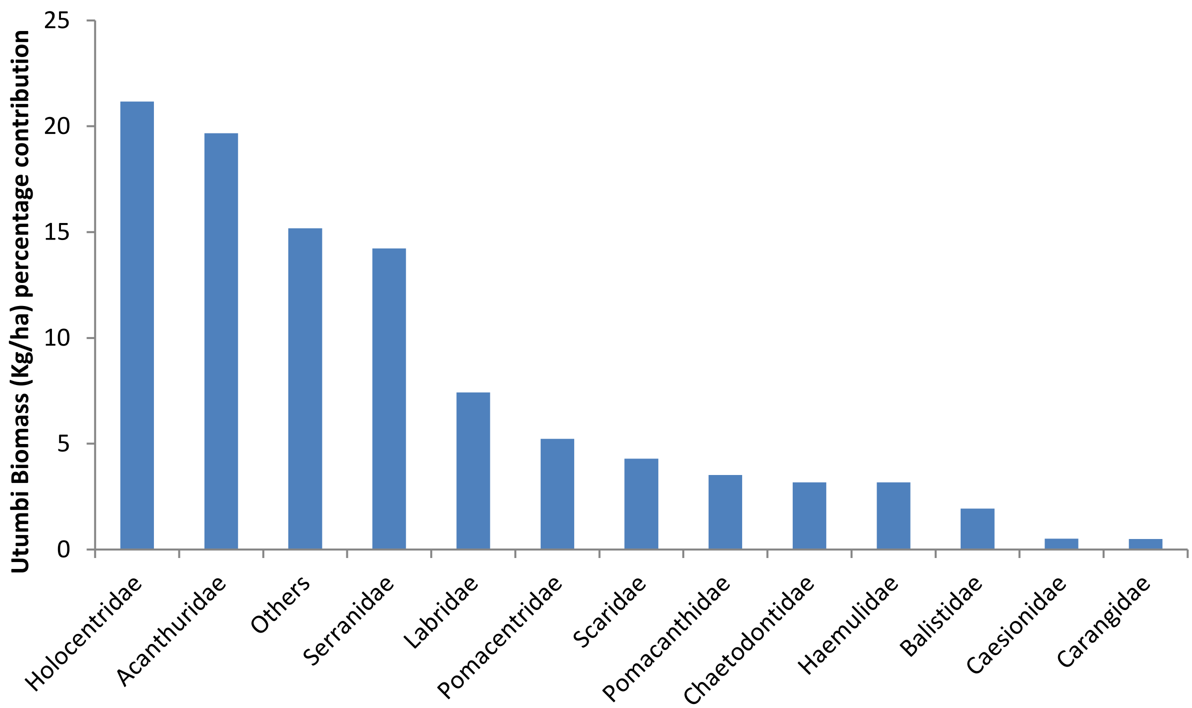
Annex 1: Percentage contribution of fish biomass by family at Kikutia



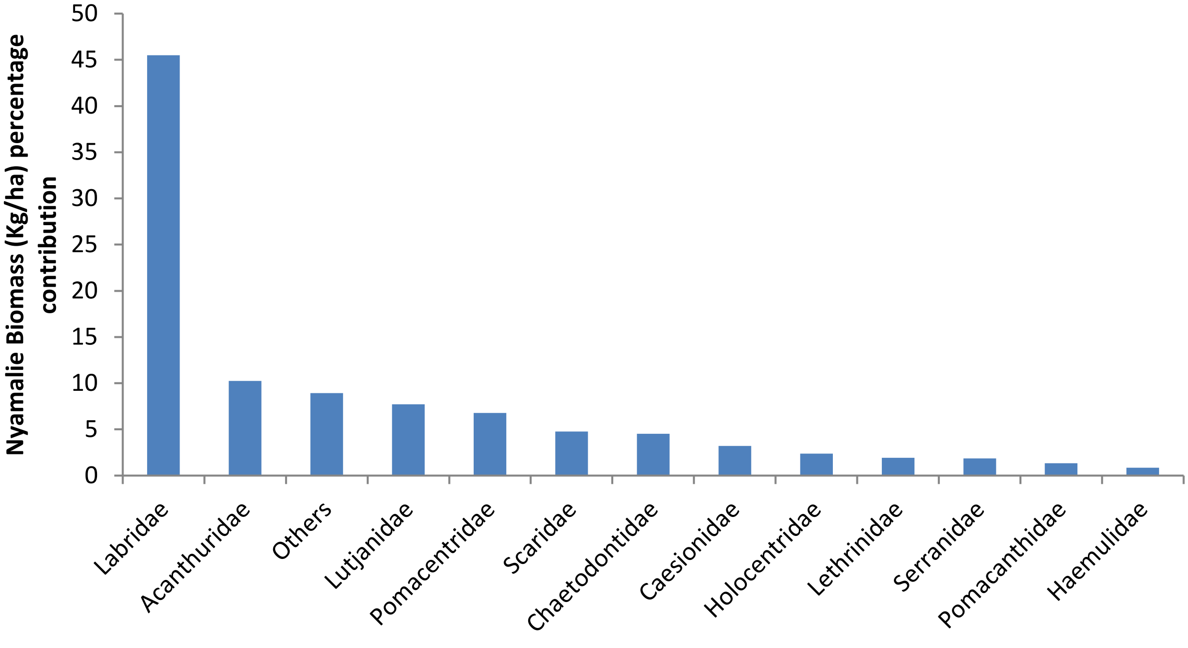
Annex 2: Percentage contribution of fish biomass by family at Kifinge



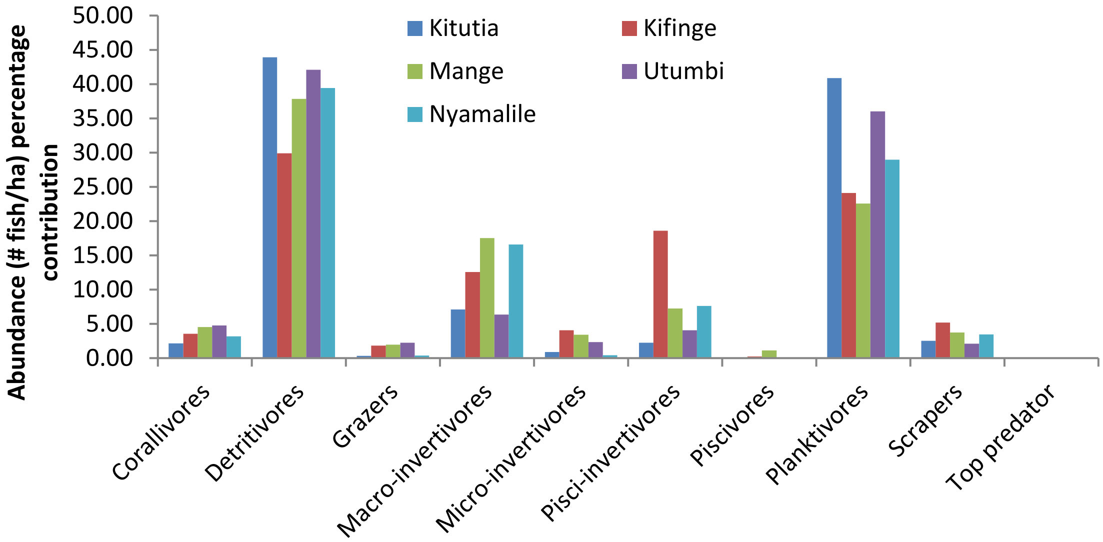
Annex 3: Percentage contribution of fish biomass by family at Mange



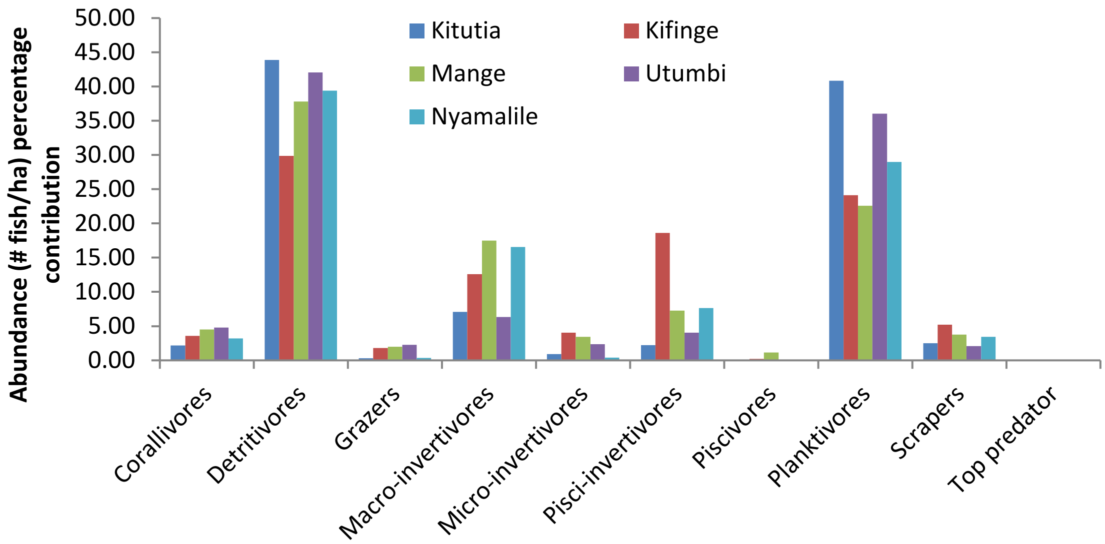
Annex 4: Percentage contribution of fish biomass by family at Utumbi



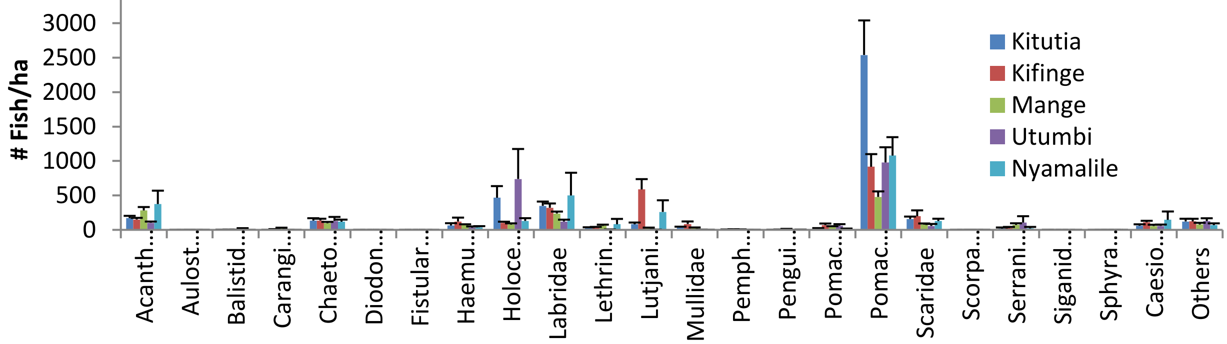
Annex 5: Percentage contribution of fish biomass by family at Nyamalile



i) **Annex 6 :** Fish abundance (# fish/ha) by functional group by site



Annex 6: Percentage contribution of fish biomass by family at Site fish biomass family percentage contribution



Annex 7: Site fish Abundance contribution

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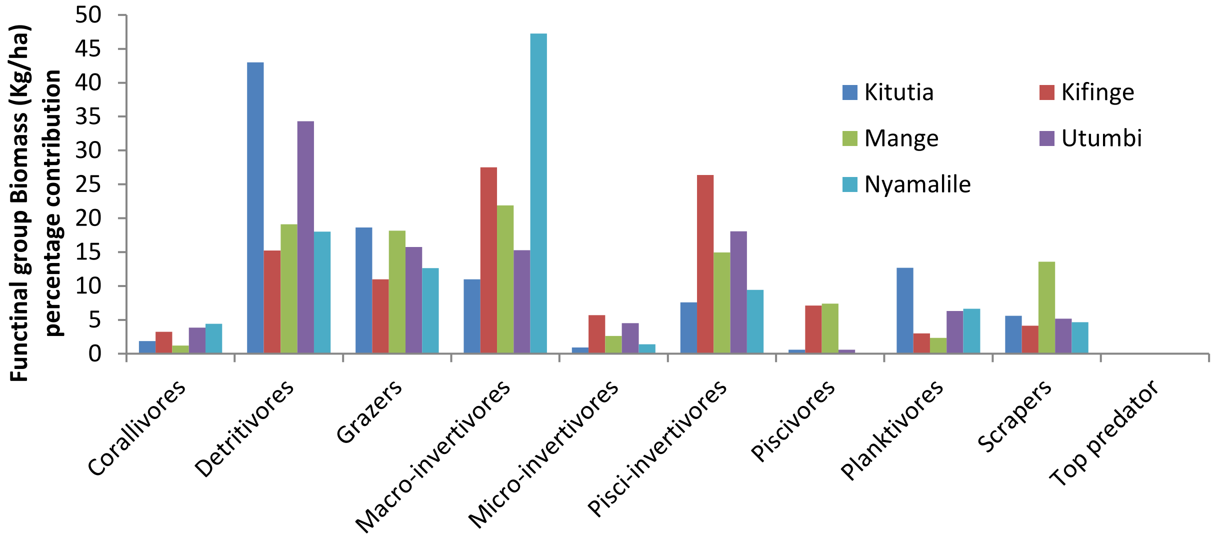

Annex 8: Site fish Biomass contribution

Appendix 1: Detailed Plan

S/n	**Activities**	**Responsible person**	**Days**	**First Month (W=Week)**				**Second Month**			
				W1	**W2**	**W3**	**W4**	**W1**	**W2**	**W3**	**W4**
1	Inception report, Negotiations, Contract signing	PI	3								
	Field work activities										
2	Travel to Mafia	PI & CO-PI	1								
3	Logistics, equipment assemblage/organisation	Skipper, Assistance skipper, PI & CO-PI	1								
4	Field work Kifinge (SCUBA) & data entry	Skipper, Assistance skipper, PI & CO-PI	3								
5	Field work Nyamalile North (SCUBA) & data entry	Skipper, Assistance skipper, PI & CO-PI	3								
6	Field work Kitutia (SCUBA) & data entry	Skipper, Assistance skipper, PI & CO-PI	3								
7	Field work Mange (SCUBA) & data entry	Skipper, Assistance skipper, PI & CO-PI	3								
8	Field work Utumbi (SCUBA) & data entry	Skipper, Assistance skipper, PI & CO-PI	3								
9	Decommissioning field work, returning hired gear to respective owner, one day waiting after dive before flying to DSM	PI & CO-PI	1								
10	Travel to Dar es Salaam	PI & CO-PI	1								
	Desk work activities										
1	Data cleaning & compilation	PI & CO-PI	4								
2	Data analysis, graphing and interpretation	PI & CO-PI	3								
3	Literature review addressing objective i	PI & CO-PI	4								
4	Report writing, sharing first draft with client, receiving comments and submission of final report.	PI & CO-PI	14								
	Total days		**47**								