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ECOLOGICAL ASSESSMENT REPORT

The Kwale-Tanga Transboundary Project

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LIST OF ABBREVIATIONS AND ACRONYMS

BA	Basal Area
BB	Braun Blanquet
BMU	Beach Management Units
CFA	Community Forest Association
CFMA	Collaborative Fisheries Management Area
CORDIO	Coastal Oceans Research and Development in the Indian Ocean
DBH	Diameter at Breast Height
FL	Focal Length
GCRMN	Global Coral Reef Monitoring Network
ha	Hectares
KCDP	Kenya Coastal Development Project
KeFS	Kenya Fisheries Service
KFS	Kenya Forest Service
KMFRI	Kenya Marine and Fisheries Research Institute
KWS	Kenya Wildlife Service
LMMA	Locally Marine Managed Area
MPA	Marine Protected Area
MPA	Marine Protected Area
POKICOFA	Pongwe Kidimu Community Forest Association
RACOFA	Ramisi Community Forest Association
SCUBA	Self-Contained Underwater Breathing Apparatus
Spp	Species
TAFORI	Tanzania Forestry Research Institute

TBCA	Transboundary Conservation Area
UVC	Underwater Visual Census
VAJIKI CFA	Vanga-Jimbo-Kiwengu Community Forest Association
VNRC	Village Natural Resources Committee
WIO	Western Indian Ocean

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EXECUTIVE SUMMARY

The Kwale–Tanga Transboundary Seascape, spanning southern Kenya and northern Tanzania, forms one of the most ecologically connected marine and coastal landscapes in the Western Indian Ocean (WIO). Coral reefs, seagrass meadows, and mangrove forests function as an integrated ecological system that sustains coastal fisheries, protects shorelines, supports biodiversity, and underpins local livelihoods. Recognising the transboundary nature of these ecosystems, Kenya and Tanzania have initiated efforts to establish the Kwale–Tanga Transboundary Conservation Area (TBCA) to strengthen coordinated ecosystem management and climate resilience.

This report presents the findings of baseline ecological assessments of coral reefs, mangroves, and seagrass ecosystems conducted across priority sites in Kwale County (Kenya) and the Tanga Region (Tanzania) under the GIZ-supported Transboundary Marine and Coastal Conservation Project. The assessment provides a scientific foundation to inform ecosystem-based management, fisheries governance reforms, and sustainable Blue Economy investment planning within the proposed TBCA.

The results reveal that while the region remains ecologically significant, several key habitats are experiencing degradation associated with fishing pressure, destructive fishing practices, sedimentation, and coastal resource use. Coral reef surveys show that benthic composition across the transboundary seascape is dominated by turf algae (32.7%) and macroalgae (13.6%), while hard coral cover averages only 9.8%, indicating a degraded reef state and reduced ecosystem resilience. Reef fish biomass averaged 314.9 kg/ha, considerably below levels typically associated with healthy reefs in the Western Indian Ocean. These patterns suggest that fishing pressure and ecological imbalance are limiting reef recovery potential.

Seagrass ecosystems remain widespread across the transboundary seascape and continue to serve as critical nursery habitats for coastal fisheries with mean seagrass cover across sites ranging from 67% to over 90%. However, spatial variation in seagrass cover, canopy structure, and macroinvertebrate abundance indicates localized habitat degradation, particularly in sites adjacent to human settlements. Physical disturbance, sedimentation, and fishing activities appear to be key drivers of habitat stress.

Mangrove assessments demonstrate considerable variation in forest structure and species composition. Some sites support structurally complex and regenerating forests, while others show signs of degradation linked to illegal harvesting, shoreline erosion, and land-based pollution. Narrow and single-species mangrove stands, particularly in areas of high community dependence, appear particularly vulnerable to environmental and anthropogenic pressures.

Importantly, the assessment highlights the ecological connectivity between mangroves, seagrasses, and coral reefs, with degradation in one habitat affecting the health and productivity of adjacent ecosystems. These interconnected habitats collectively support fisheries productivity, coastal protection, and biodiversity conservation across the Kenya–Tanzania border.

The findings underscore the urgent need for coordinated transboundary ecosystem management that integrates fisheries governance, habitat protection, and community-based conservation. Strengthening

collaborative governance structures between Kenya and Tanzania, supporting locally managed marine areas (LMMAs), and improving monitoring and enforcement mechanisms will be critical for restoring ecosystem resilience.

At the same time, the ecological assets of the Kwale–Tanga seascape present significant opportunities for sustainable Blue Economy development, including fisheries recovery, climate-resilient coastal management, blue carbon initiatives, and nature-based tourism. By aligning conservation investments with livelihood development and regional governance reforms, the proposed TBCA has the potential to become a model for transboundary marine conservation and sustainable coastal development in the Western Indian Ocean region.

Through the GIZ Transboundary Marine and Coastal Conservation Project, this baseline establishes the scientific foundation needed for formal recognition, joint governance, and priority setting for ecosystem-based management.

1. Introduction

The marine environment consists of diverse ecosystems, such as mangroves, seagrass beds, and coral reefs. These ecosystems interact to provide a range of services, including provisioning, regulating, cultural, and supporting services (Barbier et al., 2011). Their connectivity leads to trophic structuring, which cumulatively ensures the overall functioning of the environment.

The Western Indian Ocean (WIO) region accounts for around 5% of the world's mangrove cover and another 5% of the world's coral cover (Samoilys et al., 2015). Mozambique, Tanzania, and Kenya have the most diverse seagrasses in the region, comprising 12 species. Kenya has a mangrove cover of 5,300 to 6,100 km^2, with 67% in northern Lamu and 10% in the southern Kilifi and Kwale counties (Samoilys et al., 2015).

Transboundary conservation areas (TBCA) play a key role in ecological connectivity and preserving key species and habitats of ecological significance. The proposed TBCA will include current MPAs and many LMMAs, and it is expected that co-management structures will play a key role in the adaptive regulation of the transboundary maritime ecosystem. Kenya and Tanzania, recognizing that marine ecosystems transcend political boundaries, have partnered to conserve shared marine resources and mitigate the impacts of climate change (Horigue et al., 2025). The Kwale–Tanga Transboundary Seascape, launched in 2023 by the Kenya Wildlife Service (KWS) and Tanzania's Marine Parks and Reserves Unit (MPRU), represents a joint commitment to transboundary marine conservation (Horigue et al., 2025).

As part of the GIZ project "Transboundary Marine and Coastal Conservation and Sustainable Management in Kwale, Kenya, and Tanga, Tanzania", funded by the International Climate Initiative (IKI), a baseline ecological survey was conducted to establish reference conditions for coral reefs, mangroves, and seagrass ecosystems across the TBCA. The initiative aims to strengthen cross-border marine governance, support participatory management through LMMAs, and enhance regional conservation frameworks.

Ecological assessments were undertaken across eight targeted project locations in Kenya (Shimoni, Vanga, Jimbo, Wasini, Mkwiro, Kibuyuni, Majoreni, and Munje) as well as within the Mkinga District in Tanzania. By generating ecological baseline data across the TBCA, this report supports decision-making and strategic planning at local, national, and transboundary levels. The findings will inform management authorities and conservation partners about the current status of coral reef, mangrove, and seagrass ecosystems, providing a scientific foundation for adaptive management, potential designation of new conservation areas, and strengthened Kenya–Tanzania collaboration.

1.1 Study Objectives

This ecological assessment was conducted to address the following objectives:

1. Assess the ecological status of coral reefs, seagrass, and mangroves across the Kwale–Tanga TBCA.
2. Compare ecological conditions between Kenyan (Kwale County) and Tanzanian (Tanga Region) sites.
3. Identify key drivers and threats to ecosystem degradation in the transboundary seascape.

4. Provide evidence-based management recommendations to guide the establishment and management of the TBCA.

This report is organized into three chapters: Methods and Materials, Results and Discussion (each presenting an assessment of coral reefs, mangroves, and seagrasses) followed by an integrated synthesis that highlights cross-ecosystem linkages and management implications.

2. METHODS AND MATERIALS

2.1 STUDY SITES

The proposed Kenya-Tanzania Transboundary Conservation Area (TBCA) spans from Diani, Kwale County, in Kenya (39°0′0″ E, 4°25′0″ S) to the Tanga Region in Tanzania (39°40′0″ E, 5°10′0″ S) (Kamau et al., 2024), forming an ecologically connected seascape that integrates coral reefs, seagrass meadows, and mangrove forests. The area is linked through the shared Vanga-Moa Creek, lagoons, tidal flats, and the Umba River estuary, which originates in the Usambara Mountains of Tanzania and drains into the Indian Ocean at Vanga, near the Kenya-Tanzania border (Mungai et al., 2019). The numerous coastal and marine resources that characterise the proposed TBCA underpin local and national economies in both Kenya and Tanzania.

The Shimoni-Vanga seascape is located in Kwale County in the southern coastal region of Kenya, covering an area of 860 km^2 and is part of the Msambweni-Tanga seascape transboundary area (Tschentscher et al., 2023). The seascape comprises Wasini Island, Mpunguti ya juu, Mpunguti ya Chini, and coral islets that include Mako Kokwe, and Sii Island. The Tanga seascape assessments included Boma, Moa, and Mahandakini (Jasini) within the Boma Mahandakini Collaborative Fisheries Management Area (CFMA). These sites feature fringing reefs, estuarine mangroves, and seagrass beds that sustain small-scale fisheries and coastal livelihoods (Figure 1; Table 1).

Shared ecological processes and socio-economic linkages make the Kwale–Tanga seascape a priority for joint monitoring and ecosystem-based management.

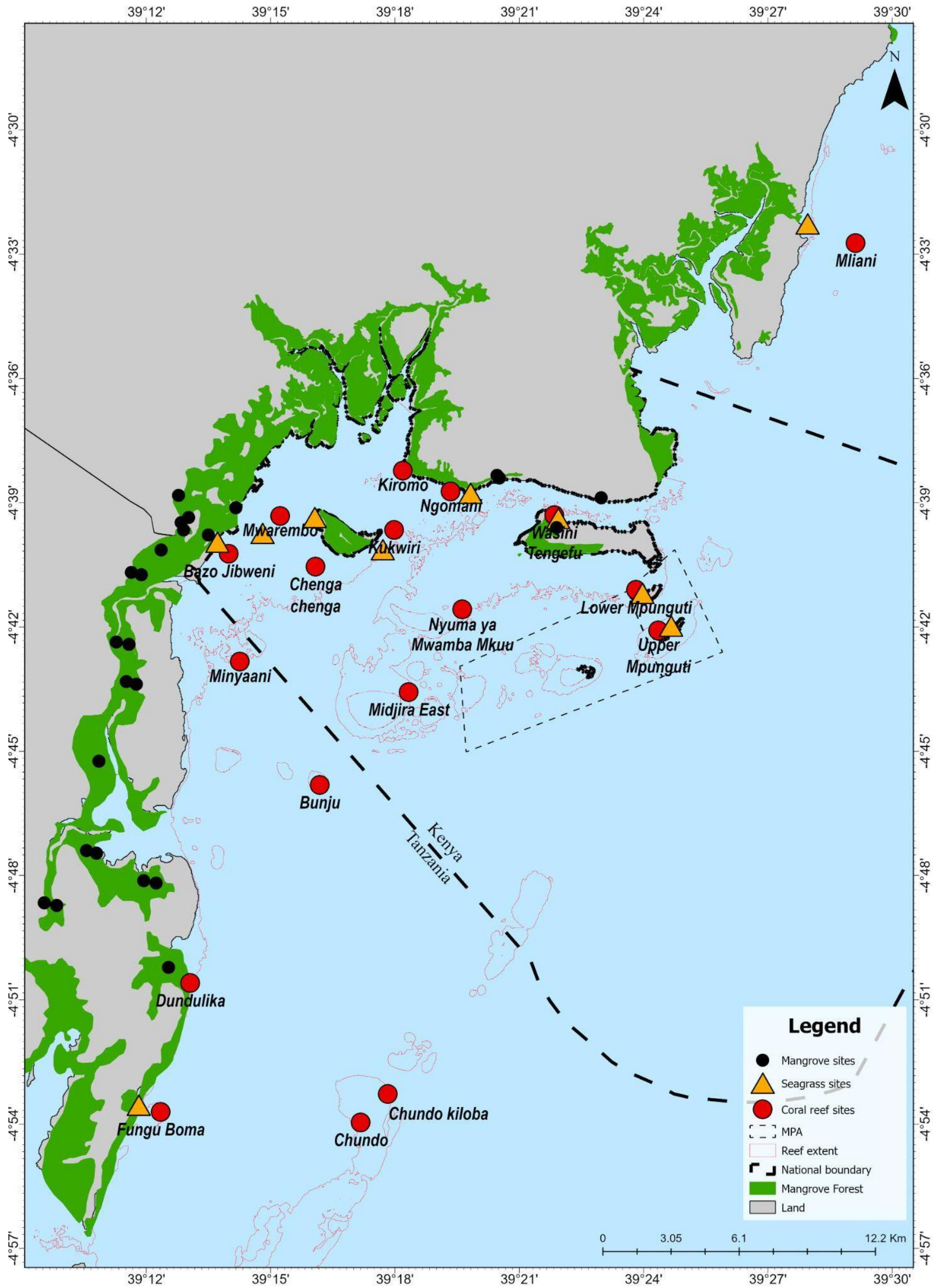

Figure 1. Surveyed ecological sites along the Kwale-Tanga transboundary area spanning southern Kenya (Kwale County) and northern Tanzania (Tanga Region), showing site locations and boundaries of existing marine protected areas (MPAs) and Community Fisheries Managed Areas (CFMAs).

2.1.1 Coral Reefs

Coral reef surveys were conducted between January 22nd and March 20th, 2025 at 18 sites across the Kwale–Tanga Transboundary Seascape. It included 12 sites within the Shimoni-Vanga seascape in Kwale County, Kenya, and six sites within the Boma Mahandakini Collaborative Fisheries Management Area (CFMA) in Tanga District, Tanzania (see Appendix B; Table B for full survey site information). Site selection involved multiple criteria aimed at identifying appropriate locations for the project implementation of this TBCA. The ecological site selection included fisheries-dependent areas with high resource use and areas within or in proximity to managed areas (i.e., Reserves, LMMAs). Additionally, the presence of key habitats and hotspots for vulnerable species was also considered as an important factor. The TBCA forms an ecologically connected and important transboundary coastal and marine ecosystem within the Western Indian Ocean (WIO). It comprises diverse reef types, seagrass beds, macroalgal communities, and sandy and rubble-dominated habitats. The Kwale-Tanga Transboundary Seascape comprises various management regimes from formal MPAs and Marine Reserves (i.e., Kisite Mpunguti), community-led (i.e., Vanga, Wasini), to informal community reserve (i.e., Dundulika) enforced areas.

2.1.2 Mangroves

On the Kenya side, sampling was done in the mangrove forests of Shimoni, Vanga, Jimbo, Wasini, Mkwiro, Kibuyuni, Majoreni, and Munje, which constitute part of the larger Kwale County mangrove that is estimated to be 8,354 ha. Vanga and Jimbo fall within the jurisdiction of the Vanga-Jimbo-Kiwengu Community Forest Association (VAJIKI-CFA)- latitude 4°40′0″S and longitude 39°13′0″E. Majoreni, Shimoni, Wasini, Kibuyuni, and Mkwiro fall under the Pongwe-Kidimu Community Forest Association (POKICOFA)- latitude 4°38′0″S and longitude 39°23′0″E, while Munje falls under the Ramisi Community Forest Association (RACOFA) previously MWABBOFU (VAJIKI PFMP, Pongwe-Kidimu PFMP, RACOFA PFMP) latitude of 4°38′0″S and a longitude of 39°23′0″E.

The intervention zone of the Pongwe Kidimu mangrove ecosystem is characterised by two rivers, namely River Ramisi and River Mwena, toward the boundary with VAJIKI. Both rivers drain into the Indian Ocean, originating from the Shimba Hills ecosystem. Munje falls under the Ramisi Community Forest Association (RACOFA). Together with Mwandamu, Bodo, Funzi, and Shirazi, the block covers approximately 2,300 ha.

On the Tanzania side, sampling was done in three wards, Mayombani, Moa, and Boma, located within Mkinga and Tanga Districts on the northern coastline of the country. Boma comprises Boma Mwambani, Boma Kichakamwiba, Boma Subutuni, and Boma Ndani. Mahandakini is situated towards the Northern most tip of the coastline locally known as Jasini. Moa lies in the estuarine zone of the Umba River and encompasses Zingibari, Mwaboza, and Vuo. Ecologically, Mayombani is characterised by tidal creeks and estuarine mangroves dominated by *Rhizophora mucronata, Avicennia marina*, and *Sonneratia alba*, supporting small-scale fishing and mangrove-based livelihoods.

2.1.3 Seagrass

The survey was done at 10 sites as shown in Table 1. Fish surveys were not done at Kukwiri and Bazo due to the turbid waters.

Table 1. Seagrass study sites assessed during the survey and their conservation status.

Country	Survey site	Status	Latitude	Longitude	Habitat
Kenya	Mpunguti ya Juu (Upper Mpunguti)	MPA and Reserve	S04°41. 943'	E 039°24.6641'	Seagrass Meadow
	Mpunguti ya chini (Lower Mpunguti)	MPA and Reserve	S04°41.15308'	E 039°23.97116'	Seagrass Meadow
	Bazo	LMMA	S04.53723°	E 039.466595°	Seagrass Meadow
	Mwarembo	Not Protected	S04°39. 70394'	E 039°14.80585'	Seagrass Meadow
	Chenga chenga	Not Protected	S04°39. 3217'	E 039°16.0640'	Seagrass Meadow
	Ngomani	Not Protected	S04.64561°	E 039.33040°	Seagrass Meadow
	Kukwiri	Not Protected	S04.668313°	E 039.295128°	Seagrass Meadow
	Mliani	Not Protected	S04.53723°	E 039.46595°	Seagrass Meadow
	Wasini Tengefu	LMMA	S04.66206°	E 039.40307°	Seagrass Meadow
Tanzania	Fungu Boma	LMMA	S04°53.5109'	E 039°11.81878'	Seagrass Meadow

2.2 Data collection and Analysis

2.2.1 Coral Reefs

2.2.1.1 Data Collection

Benthic Composition

Benthic cover was determined using an Olympus Tough TG-5 camera held perpendicular to the benthos with photo quadrats taken at regular intervals 0.7-1m above the benthic substrate on both sides of each 25m transect (3-5 flutter kicks), ensuring no overlap between consecutive photos. This standardised approach follows protocols developed by CORDIO East Africa for the WIO region (Obura, 2014; Obura et al., 2017) and is aligned with GCRMN recommended practice for diver-based photographic benthic surveys.

Coral Size Class and Condition

Adult coral size-class was recorded for 23 coral genera in a standard 25m × 1m belt transect using SCUBA diving (Obura and Grimsditch, 2009; Obura 2014), between 2-12m depth. This narrow belt width is designed for coral demographic surveys as it constrains the observation area to colonies within the transect, reducing ambiguity about inclusion of colonies near the boundary and minimising double-counting, which is recognised as a bias in wider belt transects used for coral size class (Obura, 2014; Obura et al., 2017). Coral sizes were classified into six categories: 11-20cm, 21-40cm, 41-80 cm, 81-160cm, 161-320cm, and >320cm.

Coral Recruits

Coral recruits were counted using a 1m^2 quadrat placed at 5m intervals (0, 5, 10, 15, 20, and 25m) along a 25m transect. Recruits were identified in all coral genera and categorised into three size classes: 0-2.5cm, 2.5-5cm, and 6-10cm.

Reef Fish Abundance

Quantitative surveys of the coral reef fish community recorded reef fish abundance (fish density and size) (English et al., 1994; Samoilys, 1997; Samoilys and Carlos, 2000; Samoilys et al., 2019). Eleven families covering 12 trophic groups were selected for abundance and size classes. The families were selected to provide a broad and representative cross-section of the reef fish community (Appendix A; Samoilys et al., 2018, 2019). Standard underwater visual census techniques for coral reef fishes using SCUBA diving along 50m by 5m belt transects were employed (English et al., 1994; Samoilys, 1997; Samoilys and Carlos, 2000; Samoilys et al., 2019). Five replicate transects on two dives were conducted at each location, with occasional exceptions where only three replicate transects were collected when only one dive was possible. The transects were placed randomly at different depths (between 3 and 12 m depth) spanning the depth range of the reef.

Fish sizes (Total Length, TL) were estimated in 5cm size classes (11-15cm, 16-20cm, 21-25cm, etc.). Periodic checks were made using a calibrated slate to ensure visual estimates were still accurate. The size of species smaller than 11cm was not estimated. For chaetodons, only their numbers counted, and the median size was taken as 8cm TL (this corresponds largely to the chaetodons). Other small species that were counted and sizes not estimated were: *Ctenochaetus* spp*, Acanthurus nigrofuscus, Acanthurus leucosternon, Zebrasoma scopas, Centropyge* spp*.* These were assigned to the 11-15cm size class. If individuals were larger, then their size was recorded (e.g. 16-20cm).

Species identifications were checked using photographs, taxonomic references (Lieske and Myers, 1996) and species names verified from the online Catalog of Fishes (California Academy of Sciences - https://www.calacademy.org/scientists/projects/eschmeyers-catalog-of-fishes)

2.2.1.2 Data Analysis

Benthic Composition

Twenty-four photos were randomly selected and used to assess the benthic community composition, including hard coral (to genus level), soft coral, turf algae, macro-algae, *Halimeda*, coralline algae, seagrass, dead standing coral, rock, rubble, sand, bare substrate, and other invertebrates. Benthic identification was determined by annotating the benthic attribute lying directly underneath a random point (25 points per photo quad). All photo quadrats were annotated using Coralnet (Beijbom et al., 2012). The percentage cover of each replicate (photo quadrat) was determined by calculating the proportion of points per benthos and multiplying by 4 to convert to percentage cover (given 25 points per image, each point represented 4% of cover). Mean cover for each benthic category at site level was calculated by averaging values across all replicate images.

CORAL SIZE CLASS AND CONDITION

Mean density of adult coral colonies by size class was calculated per $25m^2$ by averaging total counts across all transects. Colony condition was expressed as a proportion of total colonies surveyed at each site, to facilitate demographic interpretation across sites.

CORAL RECRUITS

Coral recruit density per square meter was calculated by averaging total recruit counts across all six quadrats per transect. Quadrats containing no recruits were included in the calculation with a count of zero to avoid overestimation of mean density.

FISH DENSITY AND BIOMASS

Biomass was computed using the formula W = a* L^b, where W = body weight (g), L = median of size class (cm), a and b are the species-specific constants based on published length–weight relationships (Letourneur, 1998; Kulbicki et al., 2005). Density and biomass were standardised to individuals/hectare and kg/hectare respectively. Density and biomass were determined at three levels: 1) Total density and biomass (mean of all families aggregated), 2) density and biomass at a family level, and 3) density and biomass for indicator trophic groups.

2.2.2 MANGROVES

2.2.2.1 DESKTOP REVIEW

A desktop review was conducted to gather information on biodiversity, degradation trends, threats, drivers, and socioeconomic importance of the Kenya-Tanzania transboundary mangrove forest. This was achieved through searches in scientific databases, institutional repositories, and government and NGO websites, covering publications between 1980 and 2025, focusing on the mangrove ecosystems within the proposed TBCA. Structured keyword strings combining terms for mangroves, geography, biodiversity, degradation, and socioeconomic value guided the searches, supplemented by citation chaining and targeted web queries.

All records were imported into a reference spreadsheet database, and duplicates were removed. Screening was carried out in two stages: title and abstract/executive summary review followed by full-text assessment, applying eligibility criteria based on geography, study type, timeframe, and thematic relevance. Relevant studies were coded by type and appraised for methodological quality. Data were extracted into a standardised template capturing bibliographic details, geographic scope, biodiversity records, mangrove forest extent and change, reported threats and drivers, and socioeconomic importance. Biodiversity information was standardised taxonomically, while mangrove extent and change data were compiled from published analyses. Threats and drivers were coded thematically, and socioeconomic importance was synthesised from household dependence, income contributions, and ecosystem service valuations.

2.2.2.2 MANGROVE ECOSYSTEM MAPPING

Landsat images of the study area with 30-meter spatial resolutions were acquired from various satellite data repositories (period 2014-2024). Unsupervised classification algorithms were applied to the processed remote sensing data, with a focus on delineating vegetated areas and bare grounds, creeks and channels, as well as mangrove adjacent land use types. Ground truthing was then conducted to verify the above classes and obtain training samples that were used in supervised classification. Maps displaying the identified classes, including degraded areas and temporal changes, were created using ArcGIS Pro version 3.0.0, and coverage of each classified class area was computed.

2.2.2.3 Mangrove structural survey

To enrich the report, the conventional structural survey was combined with key informant interviews to gather extra data. Information on community use of mangrove resources (to infer degradation and provide management options) and knowledge on biodiversity were collected.

Stratification of Mangrove Areas

Mangrove forests in the study area were stratified into different strata based on a previous inventory conducted by Semesi (1991) for the case of Tanzania and by Okello et al. (2022) Kenya. The stratification process was supported by the analysis of satellite imagery, which provided spatial information on vegetation cover and habitat types. Additionally, input from government officials from the Marine Park Authority (MPA) and the Tanzania Forest Service (TFS) in Tanga was incorporated to ensure that the strata reflected local knowledge and management priorities. This combined approach allowed for a systematic and comprehensive identification of distinct mangrove zones for subsequent sampling. In Kenya, CFA representatives and local guides provided the much-needed information to corroborate the stratified images.

Sampling Design

A cluster sampling approach was employed to capture the variability of mangrove structure and composition across the study area. In Kenya, 5-7 clusters were established across the survey sites in Kwale County, spanning the eight locations of Shimoni, Vanga, Jimbo, Wasini, Mkwiro, Kibuyuni, Majoreni, and Munje. In Tanzania, at least seven clusters were established, representing each of the villages: Moa, Zingibari, Mwamboza, Boma Subitini, Boma Kichakamimba and Mahandakini (Jasini) within Mkinga District. Each cluster comprised eight fixed-area sampling plots arranged in a straight line, with precise locations determined randomly and recorded using GPS. Clusters were 800 meters long and oriented perpendicular to the nearest water body, whether a river, major channel or the ocean, to ensure coverage across environmental gradients and habitat conditions.

Plot Design and in-situ tree measurements

Within each cluster, plots were established using a concentric circular design with two radii, 2 meters and 7 meters, following the methodology of Kauffman & Donato (2012). In the 2-meter sub-plot, all trees with a diameter at breast height (DBH) of ≤ 5 cm were measured and recorded, and regenerates, including seedlings and saplings, were counted and documented. In the 7-meter main plot, all trees and shrubs with a DBH of > 5 cm were measured and recorded. This design allowed for detailed quantification of both young and mature vegetation within each plot, providing a comprehensive assessment of forest structure. Trees were classified into utilisation categories, and the form and quality of the lead stem were documented. The smallest stems, with diameters of 2.5-3.9 cm, were referred to as Fito, while those measuring 4.0-4.9 cm were termed Pau. Stems within the range of 8.0-11.4 cm were classified as Mazio, whereas those between 11.5-13.9 cm were identified as Boriti. Medium-sized stems of 14.0-20.4 cm were categorised as Nguzo. Larger stems, ranging from 20.5-34.5 cm, were recorded as Vigingi, and the largest size class, with diameters exceeding 34.5 cm, was referred to as Bana or Mbao.

2.2.2.4 Mangrove degradation and its drivers

Field surveys were conducted to assess status of standing trees in designated plots, information that was used to infer forest health. Guided by local guides, sampling was done in selected degraded sites data used as training points for mapping degradation. Local communities provided further information on degradation trends and usage of mangrove resources in the respective areas. Respondents were asked to identify mangrove tree species present and to indicate which species were dominant. They were also asked to describe areas of the forest that were degraded, rank the severity of degradation, and identify primary threats in each area. Questions regarding community use of mangroves covered resources such as wood, fuel, medicine, and fishing.

2.2.3 Seagrass

2.2.3.1 Habitat assessment

Seagrass cover

Percentage cover data on seagrasses was estimated from the 50 cm x 50 cm ($0.25m^2$) quadrats placed randomly at each site. A minimum of 30 quadrats were surveyed at each site. The percentage cover (% cover) of each seagrass species by visual observations in each quadrat was estimated using a percentage cover standard of Seagrass Watch. Each species, % cover was obtained by calculating the fraction of the total quadrat area ($0.25m^2$) that was occupied by the particular species when viewed directly above the quadrat. Assessments were done during low tide with a tidal range of 0.5 to 3.0 m. The identification of seagrass was done to species level based on Seagrass Watch guide (www.seagrasswatch.org).

Abundance

In each $0.25m^2$ quadrat, the abundance of each seagrass species and the total seagrass community were evaluated using the globally standardized Braun Blanquet (BB) visual assessment method (Kenworthy et al., 1993). The score for each seagrass species and total seagrass was assigned a BB-scale value with corresponding ranges of cover for each score (Table 2).

Table 2. Braun-Blanquet (BB) score values and corresponding seagrass cover.

Braun-Blanquet Score (BB-Score)	% Cover Value	Seagrass density
0	Absent	No seagrass

1	<5%	Very sparse
2	5-25%	Sparse
3	25%-50%	Medium density
4	50%-75%	Dense
5	75%-100%	Very dense

Shoot density

Shoot density per seagrass species and total seagrass shoot density were assessed at each site by placing a 25 cm x 25 cm shoot counting quadrat and counting all of the shoots present. The shoot density values were reported per square meter (shoots/m^2).

Canopy height

Inside the 25 cm x 25 cm quadrat used for shoot counts, the canopy height of each seagrass species was measured in situ using metric tape. The average length of the seagrass shoots (cm) of each species inside the small counting quadrat was recorded by taking 5 random measures of height for each species present and rounding off to the nearest 0.5 cm.

2.2.3.2 Underwater fish surveys

Fish abundance

Underwater Visual Census (UVC) through snorkeling was used to determine the densities and composition of fish as described by English et al. (1997) using belt transects 50 m × 5 m (n = 3-5 per site; each 250m^2 area), in which we visually identified and counted each fish during daytime hours, at spring tides. The distance between the transects at each site was at least 10m. The enumerator waited for the fish to resume normal activity after placing the transect before taking their census. The fish sizes were also estimated to the nearest 5cm fork length (FL) for the estimation of fish biomass. For the species identified, we compiled functional traits in terms of trophic levels (Generalist carnivores, Herbivores, Invertivores, Omnivores, Piscivores, Planktivores) and available published literature (Samoilys et al., 2022; Cinner, 2009).

Estimating fish biomass

Fish biomass was estimated as the mass of fish per unit area per site (kg/ha). Fish length measurements were converted into biomass using Eq 1.

$$W = aL^b \qquad (1)$$

Where L represents the fish length in centimeters, *W* the wet weight in grams, and *a* and *b* published species-specific conversion constants from Fishbase (www.fishbase.org). Where conversion constants were not available, the genus means was used.

3. Results and Discussion

3.1 Coral Reefs

3.1.1 Results

3.1.1.1 Benthic and Corals

Benthic Composition

Overall, the Kwale-Tanga Transboundary Seascape showed a benthic composition across all reefs surveyed dominated by turf algae (32.7 ± 3.4%; mean cover ± SE), followed by sand (19.4 ± 3.1%), macroalgae (13.6 ± 2.6%), hard coral (9.8 ± 2.2%), and rubble (8.9 ± 1.5%; Figure 2). Combined algal cover (turf algae and macroalgae) of approximately 45% was more than four times higher than hard coral cover, a ratio that falls well below the threshold of 0.83 considered indicative of a functionally collapsed coral reef under the IUCN Red List of Ecosystems framework (Obura et al., 2021), indicating severely degraded reef conditions across the transboundary seascape.

At the regional level, patterns of benthic composition varied between Kwale and Tanga. In the Kwale region, turf algae, sand and macroalgae were the three dominant substrates, collectively representing 67.4% of the benthic cover. In the Tanga region, turf algae, rubble, and sand dominated, together representing 74.9% of the benthic cover together (Figure 2).

Site-level variation revealed a wide range of means across benthic categories. Turf algae was particularly dominant in Chundo Kiloba (59.0 ± 3.3%), Majoreni (52.8 ± 4.5%), Wasini (47.5 ± 6.5%), and Dundulika (46.2 ± 5.0%). The mean cover of sand ranged from 0.9 ± 0.4% in Munje to 28.4 ± 2.3% in Fungu Boma. Hard coral cover ranged from 0.5 ± 0.3% in Chundo Kiloba to 26 ± 2.5% in Munje. The macroalgae ranged from 3.2 ± 0.9 % in Chundo to 31.7 ± 4.6 % in Bunju, the latter reflecting severely reduced herbivore control at that site.

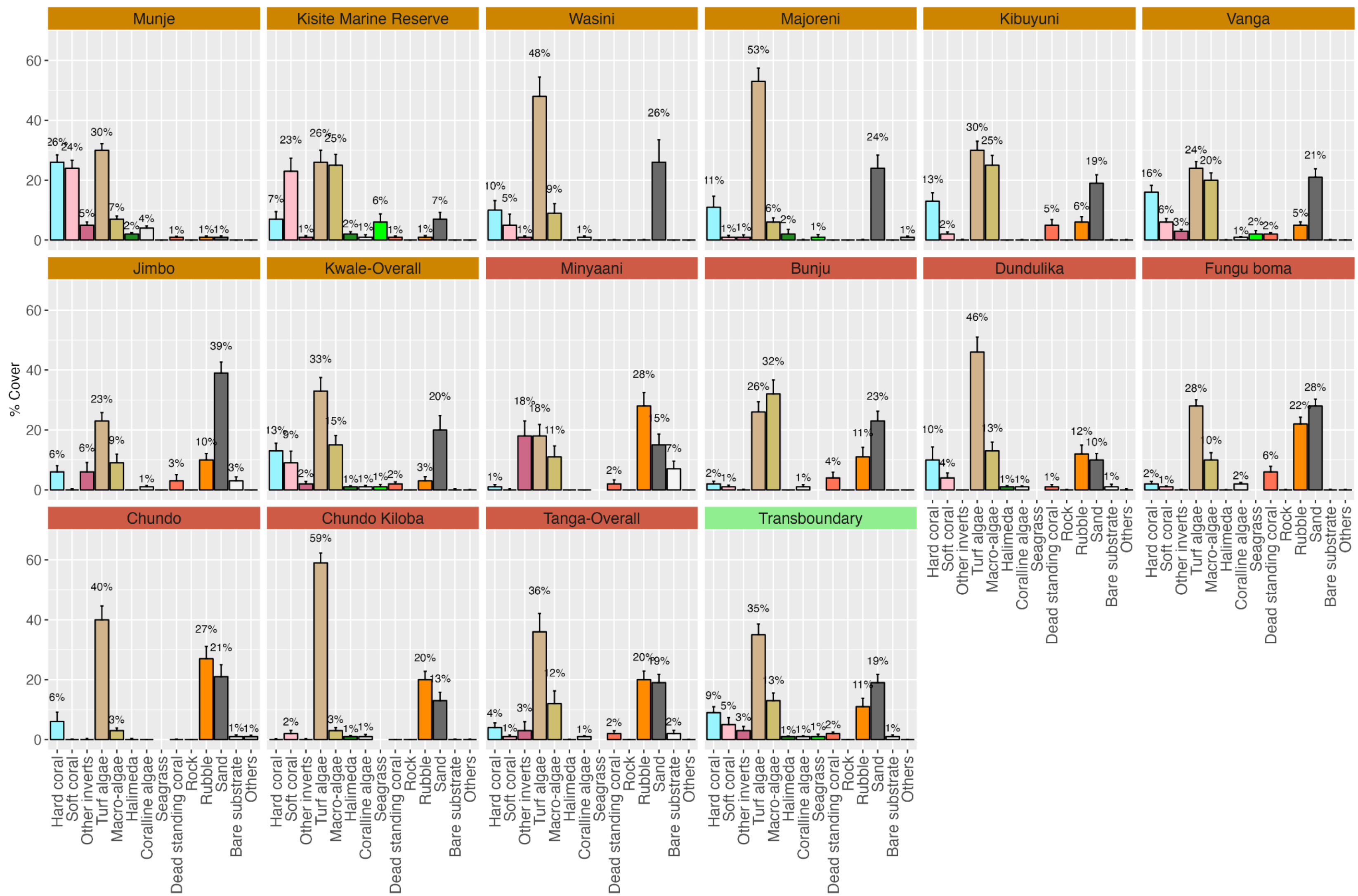

Figure 2. Percentage cover of benthic categories across surveyed sites (error bars represent the standard error). The site-based facets were color-coded by Location orange = Kwale County (Kenya), red = Tanga Region (Tanzania), and Light green = Overall mean for all the surveyed sites.

ADULT CORAL SIZE CLASS

Across all surveyed sites, adult hard coral colonies were predominantly small, with 41.1% in the 11-20 cm size class range and 36.3% in the 21-40 cm range (Figure 3). The proportion of these small colonies varied among sites, with the 11-20 cm size class ranging from 5.1% in Kisite Marine Reserve to 55.2% in Dundulika, while the 21-40 cm size class ranged from 1.8% in Tanga to 14.7% in Wasini.

The dominance of small colonies across the TBCA is ecologically significant. It is consistent with either recent large-scale disturbance, such as the 2024 bleaching event, which removed older, larger colonies and left a population skewed towards survivors and recent recruits growing into small adult size classes, or a recruitment recovery phase following earlier disturbance (Hughes & Tanner, 2000). The near-absence of large colonies at most Tanzanian sites, combined with high rubble cover, is more consistent with disturbance-driven mortality than active recovery.

The largest colonies, those over 320 cm, made up only 1.1% of the total, while the 161-320 cm size class accounted for just 1.5% of the corals surveyed. Large, old colonies typically represent long-term habitat stability and low chronic disturbance. Their near-absence across the TBCA therefore signals both historical and potentially ongoing pressure. The few largest colonies (>320 cm) were only observed in Wasini (0.1%), Dundulika (0.1%), Kibuyuni (0.5%) and Vanga (0.5%). All sites except Munje, Chundo Kiloba, Bunju and Dundulika had some colonies in the 81-160 cm size class, indicating that mid-sized colonies persist more broadly across the seascape, though recovery of the largest size classes will require sustained reductions in disturbance and fishing pressure.

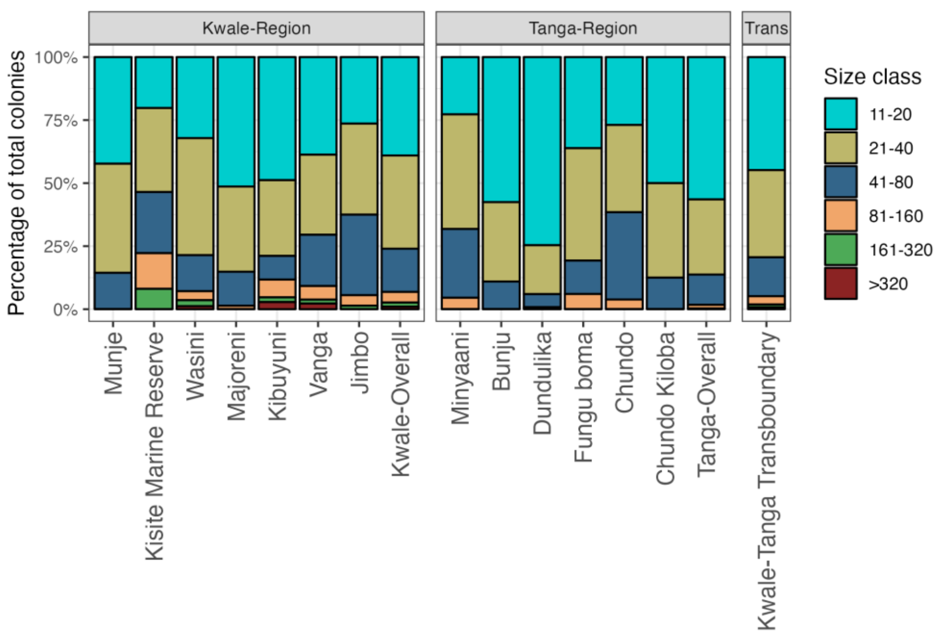

Figure 3. Distribution of adult Hard coral colonies by size class for all sites surveyed. The Kwale-Tanga Transboundary bar shows the aggregated size class across all the sites.

Coral Conditions

The majority (93.7%) of coral colonies recorded at the survey sites were classified as healthy in condition. In Munje, Kisite Marine Reserve, Wasini, Kibuyuni, and Vanga, only healthy colonies were observed, with no other condition categories recorded during the surveys. (Figure 4).

Given that mean hard coral cover across the TBCA was only 9.8%, the high proportion of healthy remaining colonies indicates that past mortality has been substantial therefore reducing the total coral community, but that surviving colonies are largely intact. The reef has lost much of its coral, but the coral that remains is mostly healthy, representing a residual population with potential for recovery if stressors are reduced.

Partially dead coral colonies were noted, ranging from 2.5% in Majoreni and Fungu Boma to 35.4% in Bunju, the highest proportion of any site, indicating severe or the most recent ongoing mortality in the Tanga region. Pale and Bleached colonies, each comprising 0.3% of the total colonies surveyed, were observed only in Fungu boma, alongside diseased colonies, accounting for 0.9% of the total colonies recorded. This suggests that this site may have experienced the most acute recent thermal, biological, or physical stress among those surveyed (Obura & Grimsditch, 2009; Obura et al., 2017).

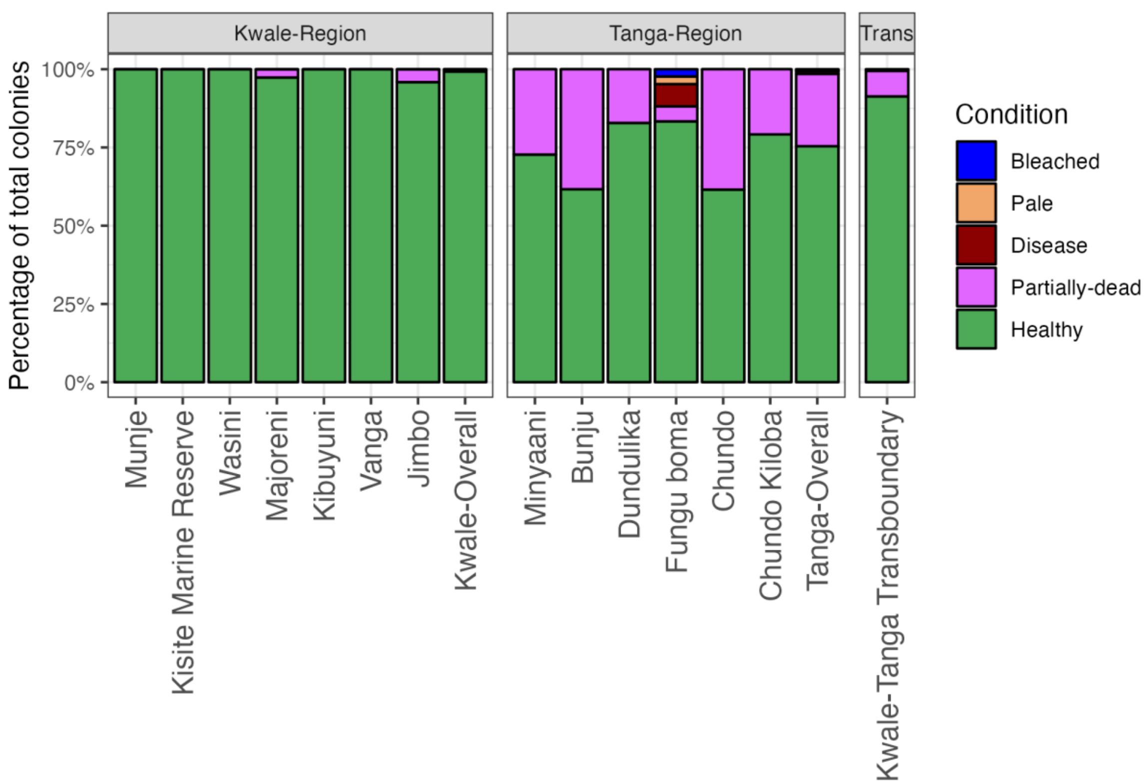

Figure 4. Distribution of hard coral colonies by condition status for all the sites surveyed. The Kwale-Tanga Transboundary bar shows the aggregation for all the sites.

CORAL RECRUITS

The coral recruit density varied across the surveyed sites, ranging from 2.0 ± 0.7m^{-2} (mean ± SE) in Jimbo to 8.6 ± 1.6m^{-2} in Kibuyuni (Figure 5). The overall mean density across all locations was 5.1 ± 1.1m^{-2}. Studies from relatively healthy reefs in the WIO, including sites in Seychelles and Madagascar, have reported recruit densities of 5–25 m^{-2} (Bigot et al., 2011), placing the TBCA mean at the lower boundary of the range associated with functional coral recruitment.

When comparing different reef areas, mean coral recruit densities were slightly lower in the surveyed sites of Kwale County (4.7 ± 1.2m^{-2}) than those in the Tanga Region (5.4 ± 1.0m^{-2}). Kwale showed greater variability and coral recruit density ranged from 2.0 ± 0.7m^{-2} to 8.6 ± 1.9m^{-2}, while in the Tanga reefs, it ranged from 2.5 ± 0.5m^{-2} to 6.8 ± 1.0m^{-2}. In Kibuyuni, Munje, Wasini, Bunju, Dundulika and Fungu boma, the coral recruit density was more than 5 recruits m^{-2}, a threshold associated with moderate recruitment success (Dela Cruz and Harrison, 2020). This indicates that larval supply and early post-settlement survival remain sufficient at these sites to support natural recovery, provided that herbivore grazing pressure is maintained and mortality stressors are reduced. The low recruit density at Jimbo (2.0 ± 0.7 m^{-2}) and several other open-access sites suggests that continued fishing pressure and poor benthic conditions are limiting settlement and early survival at those locations.

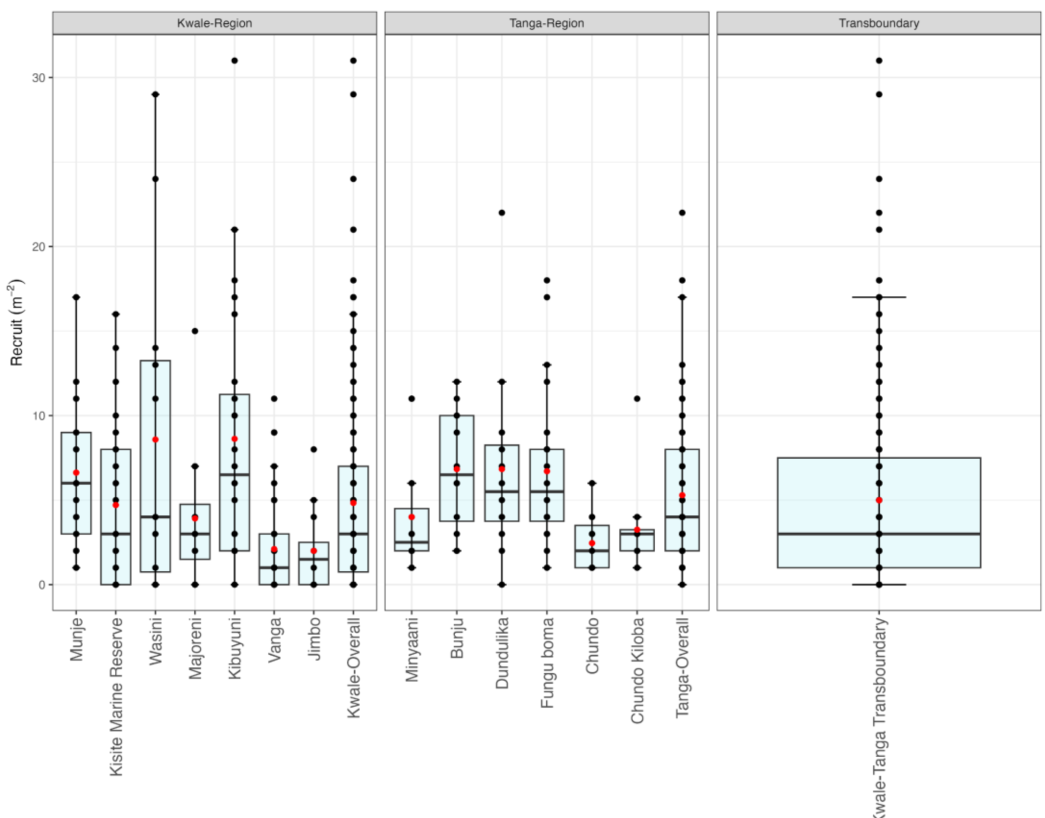

Figure 5. Proportion of recruits per m2. The red point represents the mean, the horizontal bar is the median, the black points represent quadrat values, and the box boundaries represent the quartile range.

3.1.1.2 Fish Abundance

At the transboundary outlook, the overall mean reef fish biomass was recorded at 314.9 ± 99.2kg/ha (mean ± SE) with a corresponding overall mean reef fish density of 2627.9 ± 628.2 fish/ha (Figure 6). Fish biomass on healthy, lightly fished coral reefs typically ranges from 800 to 1,500 kg/ha, and a management benchmark of 500 kg/ha has been identified as the minimum level necessary to maintain ecological integrity and reef resilience (MacNeil et al., 2015). The transboundary mean of approximately 315 kg/ha represents less than 40% of this ecological threshold, indicating critically low fish populations and widespread, chronic fishing pressure across the seascape.

In Kenyan sites surveyed, the overall mean fish biomass was 373.2 ± 60.1 kg/ha, with a mean density of 3593 ± 542.6 fish/ha. Notably, Kisite Marine Reserve had the highest fish density recorded at 6893.3 ± 466.7 fish/ha, alongside the highest fish biomass (574.8 ± 51.5 kg/ha) comparable to those at Munje, Vanga, and Wasini, all exceeding 450 kg/ha and demonstrating the measurable benefit of formal and community-led protection. In contrast, the lowest fish abundance was found at Jimbo (101.4 ± 30.3 kg/ha, 1160 ± 417.9 fish/ha) and Kibuyuni (23.4 ± 8.9 kg/ha, 1160 ± 417.9 fish/ha), the latter of which is exceptionally low and indicative of a severely depleted fish community on this open-access reef.

Within Tanzania's Tanga region, the mean fish biomass was 246.4 ± 57.6 kg/ha, with a mean density of 1521.6 ± 249.1 fish/ha. Among the Tanzania sites, Dundulika, the only community-managed area surveyed in the study, recorded the highest fish biomass at 588.4 ± 277.7 kg/ha, confirming the conservation value of community protection. Chundo recorded the highest fish density in Tanga at 3,020 ± 716.8 fish/ha, but a low biomass, indicating a population dominated by small-bodied individuals. The lowest fish abundance in Tanga was observed at the Fungu Boma and Bunju sites, with 78.4 ± 45.9 kg/ha and 125.6 ± 54.6 kg/ha in biomass, and 528 ± 156.7 fish/ha and 830 ± 134 fish/ha, respectively, consistent with the severely degraded benthic conditions recorded at those sites.

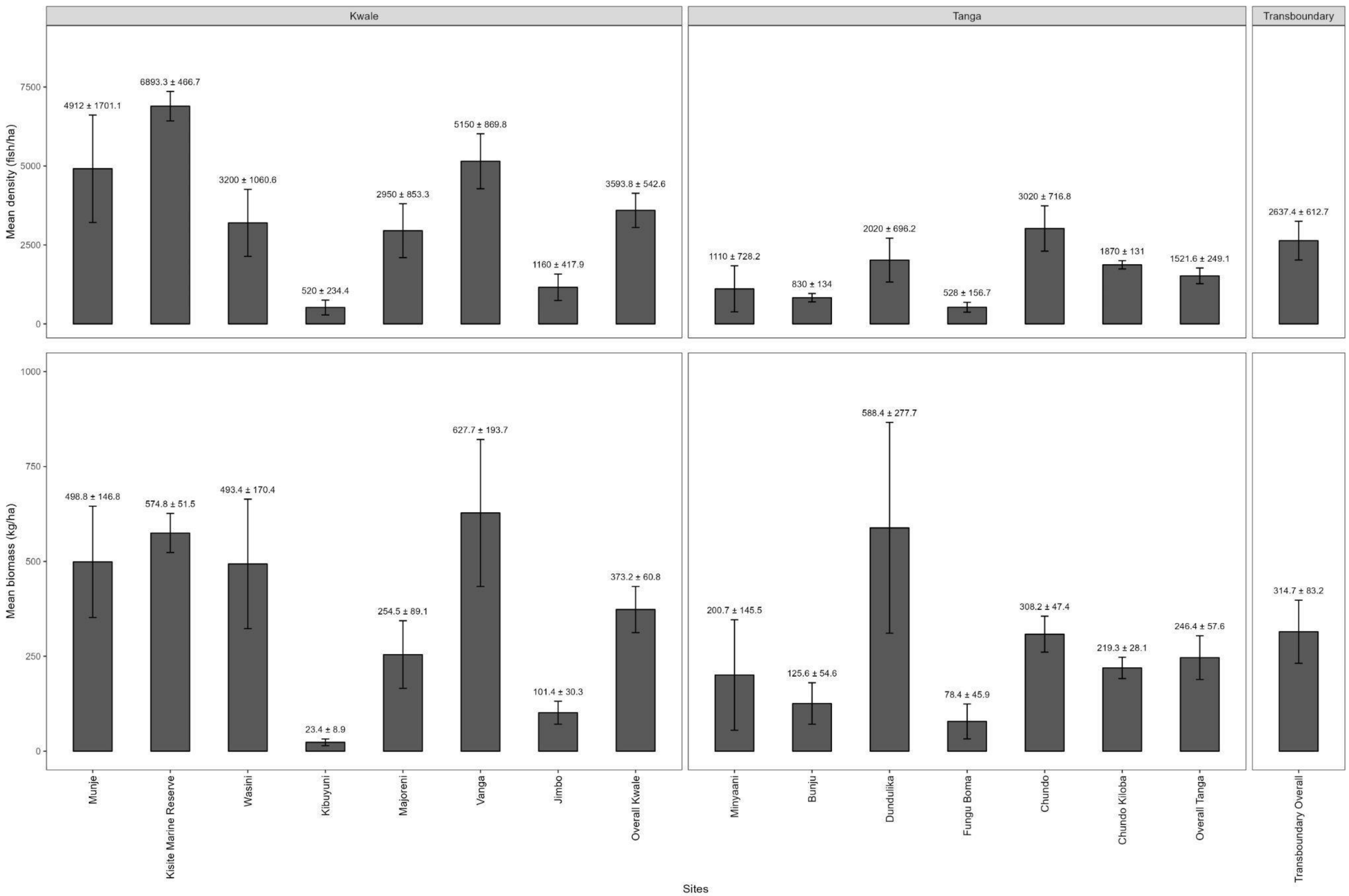

Figure 6. Fish abundance is represented by mean density (fish/ha) and mean biomass (kg/ha) of the surveyed sites in Kwale and Tanga locations. Error bars indicate standard errors.

Fish Families

The dominant fish family across the transboundary sites surveyed was Acanthuridae , with a mean biomass of 88.8 ± 32.8 kg/ha and a mean density of 708.3 ± 268.1 fish/ha (Figure 7). As grazer-detritivores, Acanthuridae play an important functional role in controlling algal turfs and processing organic matter on reefs. However, their strong dominance here, particularly at sites with high turf algae cover, likely reflects the abundance of algal food sources resulting from coral mortality rather than indicating a healthy reef state. Scarinae were also abundant, with a mean biomass, with 77.5 ± 27.01 kg/ha and a density of 607.7 ± 157.4 fish/ha. As bioeroders and scrapers, scarinae are critical for creating carbonate substrate suitable for coral settlement and for removing competing algae. However, the combination of high density and low biomass across the TBCA indicates populations dominated by smaller individuals with reduced functional capacity. This was followed by Lutjanidae, with a mean biomass of 60.8 ± 30.7 kg/ha and a mean density of 424.2 ± 217.2 fish/ha. As mid- to upper-level piscivores, lutjanidae help regulate prey communities and contribute to trophic balance , though their moderate biomass relative to healthy reef benchmarks reflects ongoing fishing pressure on this commercially important group.

In contrast, Epinephelidae (groupers), Siganidae, and Lethrinidae had the lowest abundance, each with a mean biomass of below 10 kg/ha. All three families are targeted in fisheries, and their collectively low biomass is an indicator of chronic fishing pressure across the seascape. Epinephelidae in particular, are slow-growing apex predators and are among the first to decline under fishing pressure, with their near-absence a reliable indicator of chronic overexploitation (Samoilys et al., 2019; Obura et al., 2021). The near-absence of rabbitfish is particularly concerning ecologically as they are important macroalgal grazers, and their loss may be further reducing algal control on these already algae-dominated reefs.

In the Kwale, Kenya, of the surveyed sites, Acanthuridae were dominant at 98.2 ± 31.9 kg/ha and 854.6 ± 315.3 fish/ha, followed by Lutjanidae with biomass of 91.10 ± 40.20 kg/ha and density of 714.7 ± 348.8 fish/ha. Scarinae also showed notable dominance with biomass of 77.6 ± 25.4 kg/ha and 723.4 ± 160.9 fish/ha. Haemulidae, Balistidae, Epinephelidae, Lethrinidae, and Siganidae exhibited biomass values of below 25 kg/ha, consistent with high fishing pressure. At the site level in Kwale, Wasini recorded the highest biomass of Acanthuridae 213.9 ± 74.5 kg/ha and a density of 1480 ± 683.5 fish/ha. In Vanga, the Acanthuridae family had a high mean density of 1080 ± 145.1 fish/ha and a mean biomass of 204.3 ± 54.9 kg/ha. Munje showed a high presence of Lutjanidae, with a mean biomass of 327.7 ± 141.9 kg/ha and a density of 2776 ± 1419.7 fish/ha. Scarinae were also notable in sites like Vanga, with a biomass of 231.1 ± 82 kg/ha and a density of 2160 ± 478.9 fish/ha. Caesionidae were also recorded in Kisite Marine Reserve with a biomass of 160.8 ± 97.9 kg/ha and density of 1426.7 ±869.1 fish/ha, consistent with the reduced fishing pressure in the reserve.

In Tanga, Tanzania, of the sites surveyed, Scarinae was the most dominant family, with a mean biomass of 77.4 ± 28.9 kg/ha and a density of 472.7 ± 153.3 fish/ha. Dundulika recorded the highest Scarinae biomass of all Tanga sites, at 171.2 ± 95.5 kg/ha, with a density of 108.40 ± 61.80 kg/ha, and the highest biomass of Acanthuridae at 232.8 ± 111.5 kg/ha and density of 620 ± 279.3 fish/ha, supporting the notion of higher fish biomass at the community managed area. Acanthuridae also showed high abundance, with a mean density of 297.80 ± 152.20 fish/ha and biomass of 77.7 ± 33.9 kg/ha. In addition, within the same family, Chundo had high densities of Acanthuridae at 1370 ± 518 fish/ha and biomass of 116.7 ± 27.2 kg/ha. Epinephelidae were most notable at Bunju, with a mean biomass of 53.7 ± 41.9 kg/ha and 100 ± 60 fish/ha. Families such as Lethrinidae, Caesionidae, and Siganidae were observed in low abundance throughout the Tanga sites surveyed, reflecting fishing pressure.

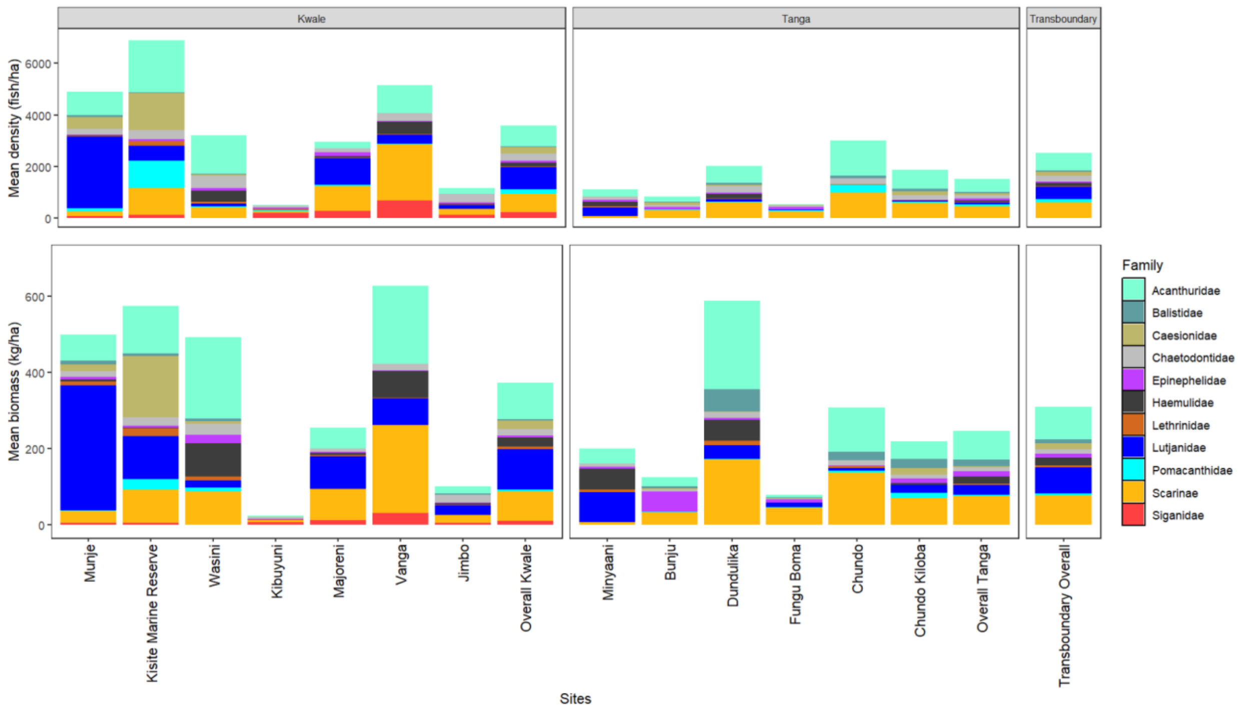

Figure 7. Families' mean density (fish/ha) and mean biomass (kg/ha) at surveyed sites in Kwale and Tanga locations. The Transboundary bar shows the overall mean for all the sites as a metric for the transboundary level overall.

FISH TROPHIC GROUPS

Overall, across the transboundary sites, Herbivores were the most dominant trophic group, with a mean biomass of 151.6 ± 53.6 kg/ha and density of 1384.9 ± 343.4 fish/ha (Figure 8). While herbivore presence is ecologically important for controlling algal growth and facilitating coral recovery (Mumby et al., 2007), the high densities coupled with relatively low biomass indicate that herbivore populations are composed primarily of smaller individuals. Larger-bodied herbivores, particularly large scaridae, are functionally far more effective as bioeroders and macroalgal grazers, and the scarcity of these individuals limits the overall ecological impact of herbivory across the TBCA despite high herbivore counts (Bellwood et al., 2004; Green & Bellwood, 2009). Pisci-omnivores were also notably abundant, with a mean density of 631.40 ± 286.7 fish/ha and biomass of 98.6 ± 48.9 kg/ha. In contrast, Detritivores, Planktivores, and Corallivores had mean biomass values below 20 kg/ha.

In Kenya, of the sites surveyed, herbivores and pisci-omnivores were the dominant trophic groups with biomasses of 174 kg/ha and 128.9 kg/ha and densities of 1779.1 fish/ha and 980.8 fish/ha, respectively. Vanga recorded the highest herbivore dominance, with a mean biomass of 447.9 ± 130.8 kg/ha and 3810

± 494.3 fish/ha. Notably, Invertivores were recorded the highest in Kisite Marine Reserve with biomass at 27.3 ± 5.3 kg/ha and 182 ± 72 fish/ha, consistent with the prey availability expected within a formal reserve (Samoilys et al., 2019).

In Tanga, of the sites surveyed, herbivores were also the most dominant group, with a mean biomass of 146.1 ± 51.3 kg/ha and density of 925 ± 250.6 fish/ha. Dundulika site recorded the highest herbivore overall biomass, with 400.4 ± 191.9 kg/ha and 1210 ± 457.9 fish/ha. Chundo also had high herbivore abundance at 232.2 ± 31.2 kg/ha and 2240 ± 551.8 fish/ha. Pisci-omnivores had an overall mean biomass of 63.3 ± 42.4 kg/ha and 223 ± 135.5 fish/ha. Minyaani site had the highest biomass for the pisci-omnivore trophic group, with 145.6 ± 118 kg/ha and 620 ± 451.5 fish/ha, suggesting localised persistence of mid-level predators at this site. Similar to the Kwale sites in the Kenya region, the Detritivores, Planktivores, and Corallivores groups were notably low in both biomass and density, reflecting low functional diversity across much of the transboundary area.

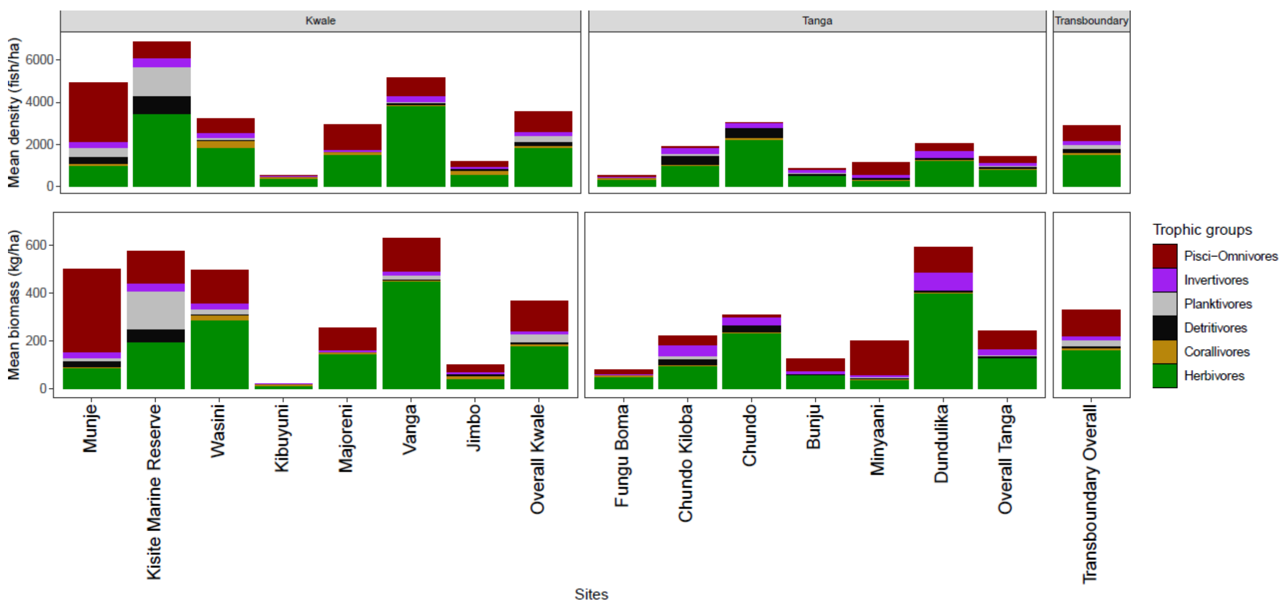

Figure 8. Trophic groups' mean density (fish/ha) and mean biomass (kg/ha) at the surveyed sites in Kwale and Tanga locations. The Transboundary bar shows the overall aggregation for all the sites as a metric for the transboundary level overall.

3.1.2 Discussion

The report provides an overview of the coral reef status across the Kwale-Tanga transboundary area as of early 2025. Results revealed concerning coral reef conditions at the TBCA level, with an average algal cover of 45%, comprising 32% turf algae and 13% macroalgae, more than four times higher than the average hard coral cover (9.8%). A ratio of hard coral to algae cover below 0.83 is considered indicative of a functionally collapsed coral reef under the IUCN Red List of Ecosystems (RLE) Framework (Obura et al., 2021). In comparison, the post-2016 coral bleaching report found an average coral cover exceeding 40%

across the Western Indian Ocean (WIO) region (Obura et al., 2017), our results therefore suggest a 75% decline in coral cover across the TBCA since 2016.

Coral recruitment is critical for resilience and recovery of coral reef ecosystems (Hughes and Tanner, 2000; Dela Cruz and Harrison, 2020). Recruit density above 5 recruits/m² was recorded in Kwale (Kibuyuni, Munje, Wasini) and Tanga (Bunju, Dundulika, and Fungu Boma), reflecting moderate recruitment success across the TBCA (Dela Cruz and Harrison, 2020). Although coral recruitment varies depending on the local context (i.e., species, location, disturbance), studies from the WIO, in areas like Seychelles and Madagascar have reported densities of 5-25 recruits/m² on relatively healthy reefs (Bigot et al., 2011). These findings suggest the potential of these reefs across the TBCA to support coral recruitment and opportunities for natural recovery if favorable environmental and management conditions are maintained.

In Tanga, while the reefs across the northern region are reportedly composed of sandy patches (Wells et al., 2007), our present results show macroalgal cover increased by approximately 10% compared to the 1.5% recorded in 2024 (CORDIO, 2024), indicating a notable shift in benthic composition since the previous assessment. Such a proliferation could be a consequence of a high mortality of hard coral post-2024 coral bleaching event, leaving space for macroalgae to colonise the substrate. This may also reflect intense fishing pressure and the loss of top-down control by key herbivores (Mumby et al., 2007; Hughes et al., 2007). While herbivores such as the Scarinae and Acanthuridae were present in high densities, their low biomass suggested populations being dominated by small-sized individuals rather than large fish. This may limit their overall ecological impact as important excavators and browsers on the reef in regulating macroalgal overgrowth. These patterns highlight the need for targeted conservation and restoration efforts to reduce algal dominance and promote coral recovery across the Kwale-Tanga transboundary region.

In the Kenyan reefs, benthic communities were primarily dominated by turf algae, sand, and macroalgae, collectively accounting for approximately 67.4% of the substrate cover. Hard coral cover varied from very low around 0.5% to moderately about 26%. These observations contrast with the national coral reef assessment (NCRA) findings based on Criterion D which reported the lowest national decline in hard corals (Gudka et al., 2024). The dominance of algae and rubble in Tanga suggests more degraded reefs and lower coral cover compared to some Kenyan sites, indicating potential phase shift from coral to algal dominance. Such trends may signal declining reef resilience and highlight the need for localized management interventions to reduce stressors such as overfishing and sedimentation which can limit coral recovery.

Fish biomass is a key indicator of fishing impacts and productivity on coral reefs (Samoilys et al., 2019). At the transboundary level, dominant reef families like Acanthuridae, Scarinae and Lutjanidae which play critical roles in maintaining reef ecosystem structure and function were, on average, low at 100 kg/ha indicating low productivity and possible fishing pressure. In addition, families such as Epinephelinae, Lethrinidae, and Haemulidae, which are commonly used to understand fishing dynamics (Samoilys et al., 2019), were also low, indicative of links to human activities such as heavy fishing pressure (Obura et al., 2021; McClanahan et al., 2019).

In the Tanga region, the mean biomass averaged 246.4 kg/ha, higher than the 2024 survey (CORDIO, 2024), suggesting some level of recovery. The Dundulika site, a community-managed reserve, recorded the highest biomass, likely benefitting from local protection and acting as a potential source of fish replenishment to neighbouring reefs. In the Kwale region, the overall biomass averaged 373.2 kg/ha, slightly above the 2022 survey findings, which averaged 368.64 kg/ha indicating relative stability in fish populations. Despite the positive observations, the overall transboundary biomass remains below the ecological threshold benchmark of 500 kg/ha, the level considered necessary to maintain ecological integrity and resilience in coral reef ecosystems (MacNeil et al., 2015). This highlights the need to strengthen fisheries management and protection measures to support continued recovery of key reef fish groups.

Fish trophic groups are crucial in coral reef resilience as their interaction helps maintain the health and stability of reef ecosystems (Bellwood et al., 2004). Herbivores,in particular, are critical in controlling algal communities, reducing competition with hard corals and supporting coral recovery and resilience (Mumby et al., 2007; Green & Bellwood, 2009). At the transboundary level, herbivores were among the most dominant trophic groups primarily presented by Scarinae and Acanthuridae families. Acanthuridae, functioning as grazer-detritivores, tend to thrive in areas where benthic food sources have increased due to coral mortality, as the resulting algal growth provides abundant food sources (Samoilys et al., 2018). Their dominance in Kwale and Tanga reefs may reflect the dominant algal food sources in these areas and possible degraded coral habitats. In Tanga, Scarinae families were the most dominant which corroborates with the 2024 survey findings that reported the family dominance relative to others (CORDIO, 2024). The Green Humphead Parrotfish previously observed exclusively in Tanzania (Samoilys et al., 2025) supports earlier observations by McClanahan et al. (2009), of high Scarinae in both fish and unfished reefs in the Tanga. Similarly, in Kwale, Scarinae were also recorded in relatively high densities compared to Tanga. However, the Siganidae were largely absent across most sites and their decline may inhibit overall herbivory function on algal control. Generally, although herbivores were among the most dominant trophic groups, the high densities coupled with relatively low biomass suggest that populations are mainly composed of smaller individuals.While these smaller fish continue to contribute to grazing, the scarcity of larger individuals may lower overall grazing efficiency. This highlights the need for continued conservation and fisheries management measures to ensure healthy and sufficient herbivore populations.

At the broader transboundary scale, Piscivorous-omnivores, that include families of Epinephelinae, Lutjanidae, Lethrinidae, and Haemulidae had mean biomass of 128.9 kg/ha. These families are vulnerable to fishing pressure particularly with Epinephelinae populations which have slow growth and low reproductive capacity. Their sensitivity to fishing is reflected in the low abundance recorded across sites, averaging only 10kg/ha. These patterns are consistent with findings from the NCRA assessments and RLE findings, underscoring their continued risk of overexploitation (Obura et al., 2021; Gudka et al., 2024). Higher top-predator abundance at sites like Minyaani in Tanga and Munje in Kenya suggests localized predator persistence that can help control herbivore populations and support trophic balance. However, general decline in the trophic group across the transboundary scale indicates disrupted predator-prey dynamics and reduced ecosystem stability emphasizing need for stronger fisheries regulation and spatial-targeted interventions to replenish these families.

The Kwale-Tanga transboundary reefs highlight ongoing coral decline and increased algal dominance, particularly in Tanga, indicating reef degradation and reduced hard coral cover. Tanga region previously experienced a decline in fish catches due to destructive fishing practices (Verheij et al., 2004). This prompted the establishment of the Tanga Coastal Zone Conservation and Development Programme (TCZCDP) in 1994 (Verheij et al., 2004), leading to increased enforcement against destructive fishing methods, including dynamite, drag nets, and poisons (McClanahan et al., 2009). However,findings from this study suggest that perhaps destructive fishing practices may still be occurring and may need intervention. Despite moderate coral recruitment in both regions, the dominance of smaller herbivorous fish and low populations of key piscivores such as groupers suggest limited grazing pressure and heavy fishing impacts, which may hinder reef recovery. To promote resilience and restore ecosystem balance, targeted interventions such as strengthened fisheries management, active coral restoration, and community-led conservation are essential for controlling algal overgrowth, supporting herbivore and piscivore populations, and ensuring the long-term health of these vital coral reef ecosystems.

3.1.3 Conclusion

In conclusion, the 2025 survey shows a decline in hard coral cover across the transboundary seascape, accompanied by increased algal dominance. Hard corals and algae compete for space (Chadwick and Morrow, 2011), which can lead to phase shifts from coral-dominated to algae-dominated reef systems. Such phase shifts have been widely documented and are often associated with reduced reef resilience and altered fish communities (Ainsworth et al., 2015; Barott et al., 2012). However, these shifts may be reversible through effective management interventions aimed at controlling competing benthic groups. These interventions include active coral restoration efforts and enhanced management measures to reduce overfishing, which helps maintain herbivorous fish populations critical for controlling algal growth (Mumby et al., 2007; Ainsworth et al., 2015). Furthermore, community-led conservation initiatives, coupled with ongoing monitoring and research, are essential for developing adaptive management strategies that promote hard coral recovery. The implementation of these measures is vital to ensure the long-term resilience and ecological health of these reef ecosystems.

3.2 Mangroves

3.2.1 Results and Discussion

3.2.1.1 Desktop Review

Biodiversity Status of the proposed TBCA

Biodiversity studies within the proposed Kenya-Tanzania Transboundary Conservation Area (TBCA) have been uneven in scope, taxa coverage, and spatial distribution, with research largely fragmented. In Kenya, efforts have concentrated on Gazi Bay, covering benthic organisms, macrofauna, fish (Teleostei), birds, fungi, mangroves, and microbes. This breadth presents Gazi as a biodiversity study hotspot but also highlights a disproportionate focus, leaving other key mangrove areas understudied. For instance, Vanga has mainly been assessed for fish despite its productive mangrove fisheries, while Shimoni studies have been restricted to plants, offering little faunal or microbial insight. Table 3 below provides a summary of the relevant literature on biodiversity accessed during this study.

Table 3. Summary of biodiversity surveys conducted in mangrove forest formations within the proposed Kenya-Tanzania TBCA.

Site	Taxa surveyed	Source	Link	Country
Vanga	Fish (*Teleostei*)	Peer Reviewed	Wanjiru et al., 2022	Kenya
Pongwe Kidimu	*Archaea, Bacteria, and Eukarya*	Report	Available upon request	Kenya
Shimoni	*Plantae*	Book chapter	Ouko and Manohar, 1998	Kenya
Gazi Bay	*Benthic organisms*	Thesis	Kyalo, 2009	Kenya
Gazi Bay	*Plants*	Peer reviewed	Schrijvers, 1991	Kenya
Gazi Bay	*Macrofauna*	Peer reviewed	Ruwa, 1990	Kenya
General	*Plants (including mangroves)*	Peer reviewed	Martens, 1996	Kenya
Gazi Bay	*Fish (Teleostei)*	Thesis	Wakwabi, 1999	Kenya
Gazi Bay	*Fish (Teleostei)*	Peer reviewed	Nyunja et al., 2009	Kenya
General	*Primates*	Grey	Prosperi et al., 2021	Kenya

Gazi and Mida	*Bacteria*	Peer reviewed	Muwawa et al.,2021	Kenya
Gazi and Mida	*Fungi*	Peer reviewed	Muwawa et al., 2024	Kenya
Gazi Bay	*Fish (Teleostei)*	Grey	Crona and Ronback, 2007	Kenya
Gazi Bay	*Birds*	Peer reviewed	Seys et al., 1995	Kenya
Gazi Bay	*Fish (Teleostei)*	Peer reviewed	Huxham et al. 2004	Kenya
Gazi Bay	*Fish (Teleostei)*	Peer reviewed	Kimani et al., 1996	Kenya
Gazi Bay	*Plant (Mangroves)*	Peer reviewed	Neukermans et al., 2008	Kenya
TBCA	*IUCN*	Technical paper	Parks, 2017	Kenya, Tanzania
Across board	*Fish , Corals, Seagrass*	Peer reviewed	Spalding et al., 2015	

No published studies were found describing biodiversity in mangrove patches within the TBCA with a focus on Tanzania. Generally, mangroves provide critical nursery grounds for fish, crustaceans, and molluscs, as well as feeding and roosting areas for migratory and resident bird species. Adjacent communities rely on these ecosystems for fishing, mangrove pole harvesting, seaweed farming, beekeeping, eco-tourism, and small-scale mariculture activities, making the mangroves vital for both ecological and socio-economic sustainability (Bosire et al., 2008).

Available information on Health of the Mangrove Forests of the TBCA

Forest Structure

According to literature accessed during this review, the TBCA has all the nine mangrove tree species of the WIO region, dominated by *Rhizophora mucronata* and *Ceriops tagal,* which account for about 70% of the forest cover. These mangroves display a zonation pattern typical of Eastern Africa, with *Sonnertia alba, R. mucronata,* and giant *Avicennia marina* on the seaward zone, *R. mucronata, Bruguiera gymnorrhiza, C. tagal* in the mid-zone, and dwarf *A. marina, Lumnitzera racemosa, and Xylocarpus granatum* landward (Lang'at and Kairo, 2008). Studies from the Shirazi-Funzi complex in Kenya reported six species dominated by *R. mucronata, C. tagal,* and *A. marina*, (Lang'at, 2008). Vanga, adjacent to Shirazi-Funzi, is similarly dominated by *R. mucronata* and *C. tagal*, which make up 81% of the forest (VAJIKI, 2019-2023). The Pongwe-Kidimu participatory forest management plan (2022-2026) shows a similar species composition with seven dominant mangrove species namely *A. marina, C. tagal, R. mucronata, B. gymnorrhiza, S. alba, X. granatum, and L. racemosa.*

In Mkinga District, particularly Moa village, *R. mucronata, C. tagal,* and *S. alba* dominate, while *B. gymnorrhiza, Heritiera littoralis, L. racemosa,* and *X. granatum* occurs less frequently (Kairo, 2010).

Mangroves in Moa have a mean tree height of 6.32 ± 0.18 m, mean DBH of 7.61 ± 0.20 cm, and a stand density of about 1,500 stems/ha (Kairo, 2010). Omar et al. (2019) documented four species (*R. mucronata, C. tagal, B. gymnorrhiza,* and *A. marina*) in Boma and Mahandakini, with variable densities across sites. Additional species such as *X. granatum, Xylocarpus moluccensis, S. alba,* and *Pemphis acidula* were also recorded. The basal area ranged between 25.78 m^2/ha in Boma and 18.01 m^2/ha in Mahandakini, with *R. mucronata* exhibiting the highest importance value in both sites (Omar et al., 2019). According to Alavaisha and Mangora (2016), small estuarine mangroves in Geza had a stand density of 1,740 stems ha^{-1} and basal area of 17.2 m^2 ha^{-1}, while Mtimbwani recorded 2,334 stems ha^{-1} and a basal area of 30.3 m^2 ha^{-1} values (Table 4).

Table 4. Structural attributes of mangroves in the Kenya-Tanzania TBCA.

Site	Tree species encountered	Overall structural attributes	Source
Shirazi-Funzi	6 species	-Overall stand density: 1573 to 1839 stems/ha -Mean height: 6.0 to 7.4 m -Mean BA:7.7 to 30.3 m^2/ha	Technical report (Lang'at, 2008)
Vanga	Dominated by *R.mucronata and C.tagal*	Data not available	Management plan (VAJIKI-PFMP 2019-2023)
Pongwe-Kidimu	7 species	Data not available	Management plan (Pongwe-Kidimu PFMP 2022-2026)
Moa	Dominated by *R. mucronata, C. tagal,* and *S. alba*	-Mean tree height: 6.32 ± 0.18 m (height range 2.0 m - 13.0 m) -Mean stem DBH:7.61 ± 0.20 cm	Consultancy report (Kairo, 2010)
Boma	4 tree species	-BA: 25.78 m^2 ha^{-1} -Density: varying across species (1092 - 3717 trees per/ha)	WIOMSA Symposium proceedings (Omar et al., 2019)
Mahandakini / Jasini		-BA: 18.01 m^2 ha^{-1} -Density: Varying across species 51- 204 trees/ha	
Geza	5 species	-BA: 17.21 m^2 ha^{-1} -Density: 1740 stems/ha	Peer-reviewed article (Alavaisha and Mangora, 2016)

Mtimbwani	5 species	-BA: 30.27 m^2 ha^{-1} -Density: 2334 stems/ha	Peer-reviewed article (Alavaisha and Mangora, 2016)

Documented Mangrove Forest Biomass in the TBCA

Global and regional studies show that mangrove ecosystems are major carbon reservoirs, with soil organic carbon forming the dominant pool. Donato et al. (2011) reported mean global total ecosystem carbon stocks of 1,023 Mg C ha^{-1}, with soils contributing 50-70% of the total. Studies from Kenya align with this finding, though with relatively lower values. Kairo et al. (2021) reported an average total ecosystem carbon of 560 Mg C ha^{-1} in the mangroves of Lamu, with soil organic carbon accounting for approximately 70% of the total. The Rufiji Delta falls in between, with approximately 160 Mg C ha^{-1}, of which 61.6% is soil carbon (Lupembe and Munishi, 2019). Table 5 gives a summary of documented carbon stocks within the TBCA, demonstrating values comparable to those recorded elsewhere (Omar et al., 2019; Njana et al., 2018).

Table 5. Estimates of mangrove ecosystem carbon and pool contributions in Kenya and Tanzania.

Site	**Total Ecosystem Carbon (Mg C ha^{-1})**	**Soil Organic Carbon (%)**	**Above-ground biomass (%)**	**Below-ground biomass (%)**	**Source (citation)**
Gazi & Vanga, Kenya	370-600 Mg C ha^{-1}	Dominant pool (>50)	Minor	Minor	Peer-reviewed article (Gress et al., 2016)
Boma, Tanzania	282.94 Mg C ha^{-1}	42.46	36.99	20.54	WIOMSA proceedings (Omar et al., 2019)
Mahandakini, Tanzania	386.49 Mg C ha^{-1}	70.30	19.07	10.62	WIOMSA proceedings (Omar et al., 2019)
Geza, Tanzania	414.6 Mg C ha^{-1}	>65	<20	<15	Peer-review article (Alavaisha and Mangora, 2016)

Degradation trends, drivers and threats

The mangrove cover within the proposed TBCA has undergone marked structural changes between 1986 and 2016 (Mungai et al., 2019). In 1986, dense mangrove stands dominated the landscape, covering 92% (13,812 ha), while sparse mangroves accounted for only 8% (1,203 ha). By 2016, this balance had shifted; dense mangroves declined to 69% (8,216 ha), whereas sparse mangroves expanded to 31% (3,690 ha). The trend over the 30 years reveals a steady degradation of mangrove density. Dense mangroves decreased at an average rate of 187 ha per year, translating to an annual decline of ~1.4%. In contrast, sparse mangroves increased by 83 ha per year, equivalent to ~6.9% annual growth. This suggests progressive reduction and fragmentation of mangrove forests rather than outright loss of cover.

Drivers of degradation in the TBCA

Mangrove degradation in the proposed TBCA can be attributed to various drivers which together reduce resilience, compromise biodiversity, and diminish the ecosystem services on which coastal communities depend.

Poor agricultural practices: unsustainable farming methods upstream, such as over-cultivation, deforestation, and a lack of soil conservation, accelerating soil erosion and sedimentation in rivers. The transboundary Umba River traversing between Kenya and Tanzania thus not only delivers freshwater to the mangroves especially those of Vanga, but also loads of nutrients and terrigenous sediments. While important nutrient inflows come from this source, increased erosion through poor land-use practices in the river catchments can lead to smothering of downstream ecosystems (Kimeli et al., 2022) thus affecting growth and may result in death of mangroves (Okello et al., 2014; Okello et al., 2019).

Population pressure: The Kenya-Tanzania border region is a densely populated coastal region with communities relying heavily on mangroves and related marine ecosystems for their livelihoods, exerting undue pressure on through increased demand for land, food, and forest products (Alongi, 2002; Kairo et al., 2017). In villages such as Vanga, Jimbo, and Kiwegu in Kenya, and Tanga in Tanzania, have heightened demand for mangrove wood and wood products with many rural households in Tanga depending directly on coastal and marine resources for subsistence (Yusuf et al., 2015) and a further loss experienced due to associated increased land-based pollution from highly populated settlements as shown in Plate 1 (FAO, 2007; Giri et al., 2011).

Plate 1. Pollution from nearby human settlements in the mangrove forests in Vanga.

Poverty: According to the Kenya Poverty Report (2021), Kwale County has a poverty headcount rate of 55.1%, reflecting significant economic challenges. Vanga specifically records a poverty index of 0.25% with a 90% dependency ratio which is the highest in Kwale county. This is attributed to the high unemployment rate, which is estimated at 30% of the population (Kenya National Bureau of Statistics (Obiene et al., 2023). Tanga has a poverty headcount rate of 38% (https://dataafrica.io/profile/tanga-tza), with districts like Mkinga recording extreme poverty among people despite its unique location that connects Kenya and Tanzania mainland through highway and marine transportation via Tanga, Mombasa, and Zanzibar ports which could have made it a highly developed region (Yusuf et al., 2015). This generally gives a reflection on high reliance on natural resources thus compromising resilience.

Overlapping governance system: Kenya and Tanzania hold shared responsibility over the management and conservation of the proposed Transboundary Conservation Area (TBCA) . While each country has its own policies and legal frameworks guiding ecosystem management, the transboundary nature of the TBCA presents challenges that require well-coordinated governance, joint planning, and harmonised enforcement (Horigue et al ., 2025). The absence of a centralised or collaborative management structure increases the risk of unsustainable activities such as illegal logging, overharvesting of mangroves, and cross-border timber trade occurring undetected. In addition, weak enforcement in shared waters allows destructive fishing practices and pollution from land-based activities to spill over national boundaries. Collectively, these governance gaps exacerbate mangrove degradation and compromise the sustainability of the ecosystems and livelihoods within the Kenya–Tanzania transboundary region.

Climate change and its impacts

Climate change impacts have intensified the pressures facing mangrove forests, exacerbating their degradation. Key stressors include sea-level rise, increased sedimentation, drought and consequent hypersalinisation, flooding, and coastal erosion. These extreme events are projected to become more frequent and severe, further threatening the stability and resilience of mangrove ecosystems. For instance, the 1998 El Niño event caused large-scale dieback in several mangrove areas along the Kenyan coast due to the substantial influx of sediments carried by heavy rainfall and eroding coastal catchments (Fortnam et al., 2021). In Vanga, the El Niño events of 1997–1998 and 2016 led to flooding along the banks of the Umba River, which flows into the Indian Ocean, resulting in significant destruction of adjacent mangrove stands.

3.2.1.2 Field Findings

Verification of management areas boundaries

The results in this section are based on information provided by CFA officials and verified by Kenya Forest Service (KFS). According to officials from the VAJIKI and POKICOFA, the boundaries between the VAJIKI and POKICOFA management blocks are naturally defined by river tributaries, which serve as clear and practical markers separating the respective blocks. The VAJIKI mangrove block extends from the River Umba tributary at the Kenya-Tanzania border to the River Mwena, where it adjoins the Pongwe-Kidimu mangrove forest block. The Pongwe-Kidimu block continues from the River Mwena estuary in the south to the River Ramisi estuary in the north, where it borders the RACOFA block (Table 6).

Table 6. Description of situation and coverage of the community forest associations mangrove areas in kenya.

CFA	Situation	Area
VAJIKI CFA block	latitude 4°40′0″S and longitude 39°13′0″E, stretching from the Umba River estuary to the mangroves around Kiwengu village.	3,061 ha of mangrove forests.
POKICOFA block	latitude 4°38′0″S and longitude 39°23′0″E. From the Mwena River estuary in the south near Majoreni to the Ramisi River estuary in the north	2,865 ha of mangroves
RACOFA CFA (previously called MWABBOFU)	Situated at a latitude of 4°38′0″S and a longitude of 39°23′0″E.	approximately 2,300 ha

Mangrove uses and status as perceived by the local community

Key Informant Interviews revealed that the communities across the study areas recognise mangroves as a vital resource for both livelihoods and ecosystem services. In Wasini, the communities are widely involved in eco-tourism activities as the main source of income. The presence of a board walk running through the rugged dead coral remains and into the mangroves attracts both local and foreign tourists in the area which boosts the local economy. Additionally, it was mentioned that the mangrove forests act as breeding and nursery grounds for fish, crabs, oysters, and other marine species, while also supporting beekeeping for the production of honey. The mangroves of Wasini are home to a range of species, including crabs (Kaa/Zobe), juvenile and mature fish such as rock cod (*Lotella rhacina*) and Tembo (*Lutjanus monostigma*), pearl oyster (*Pinctada margaritifera*), which thrives in rocky areas, as well as species locally referred to as Tondo (*Terebralia palustris*) and Kome (*Chicoreus ramosus*).

Communities in Vanga, Jimbo, and Kiwegu primarily rely on mangrove products for energy and wood for firewood, poles (Plate 2) and timber. Additionally, mangroves were historically used for boat building, dye, and chalk production and contribute to community income through carbon credit projects in Jimbo-Jasini, which have also reduced direct harvesting. Communities also highlight ecological benefits such as shoreline protection, especially during storms, and the role of mangroves as habitats for diverse species, including Red snapper (*Lutjanus argentimaculatus*), Dome (*Sepia spp*), and paramamba (*Pomadasys maculatus*).

Plate 2. House showing the use of poles from mangroves for construction.

In Tanzania it was mentioned that communities rely on mangrove ecosystems for fisheries, construction materials, fuelwood, and eco-tourism, while they also hold cultural and spiritual significance. Fisheries, construction and fuelwood were mentioned across all the sites. Mangroves were also appreciated for their spiritual values particularly in Moa village.

Species composition varied across sites within the proposed TBCA. A total of eight true mangrove tree species namely *A. marina*, *B. gymnorhiza*, *R. mucronata*, *C. tagal*, *H. littoralis*, *L. racemosa*, *S. alba*, and *X. granatum* were found, as well as *Pemphis acidula* (generally considered a mangrove associate) which grows on calcareous substrates within the tidal flats. Table 7 below shows the distribution of mangrove tree species across the sites sampled. Shimoni had the least tree species diversity occupying a fringing mangrove area against a backdrop of an eroding coastline, while Kibuyuni recorded the highest diversity. Of the eight true mangrove tree species encountered, *C. tagal* and *R. mucronata* had the highest frequency of occurrence, being found in five of the six sites sampled in Kenya, and all the four sites in Tanzania (Table 7). *Lumnitzera racemosa* and *H. litorallis* were the least dominant species being encountered in only one site each.

Table 7. Species composition of study sites in Kenya and Tanzania.

Tree Species	**Kenya**							**Tanzania**			
	Jimbo	**Vanga**	**Majoreni**	**Kibuyuni**	**Shimoni**	**Wasini**	**Munje**	**Vuo**	**Boma**	**Moa**	**Jasini**
A. marina	+	+	+	-	-	-	+	+	-	+	-
B. gymnorhiza	+	+	-	+	-	+	+	+	+	+	+
C. tagal	+	+	+	+	-	+	+	+	+	+	+
R. mucronata	+	+	+	+	-	+	+	+	+	+	+
S. alba	+	+	+	-	+	-		+	-	-	-
H. littoralis	-	-	-	+	-	-		-	-	-	-
X. granatum	-	+	-	-	-	-	-	-	-	-	+
L. racemosa	-	-	-	+	-	-	+	-	-	-	-
*P. acidula**	+	-	-	+	-	-	-	-	-	-	-

**P. acidula* is considered a mangrove associate though this tree species also occupies the intertidal areas

On the Kenyan side, Majoreni recorded the highest stem density while Kibuyuni recorded the least Table 8). Despite single species composition, Shimoni recorded high mean diameter at breast height and considerable stem densities. Vanga had the tallest trees as demonstrated by the mean canopy height while Boma, Vuo and Shimoni had trees with the largest girths.

Table 8: Structural attributes of the Kenya-Tanzania TBCA.

Country	Site	Stem density	Mean DBH±SE (cm)	Mean Canopy ht±SE (m)	Basal Area (m^2/ha)	Total BGB (t/ha)	Total AGB (t/ha)
Kenya	Jimbo	2155.6	5.9±0.4	4.0±0.2	11.0		
	Vanga	1587.5	19.9±1.5	8.6±0.5	27.3	4	
	Majoreni	2250	13.9±0.9	3.2±0.1	67.7	32.3	
	Kibuyuni	709.1	15.7±1.3	8.2±0.7	17.8		
	Shimoni	950.2	21.9±2.4	8.3±0.6	71.0		
	Wasini	2480	16.6±1.2	6.9±0.3	43.9		
	Munje	766.7	10.7±0.9	3.6±0.2	11 .0		
Tanzania	Vuo	238.9	20.1±0.5	6.5±0.3	9.8	43.95	93.5
	Boma	931.3	26.8±0.6	8.2±0.4	20.5	84.89	180.63
	Moa	327.0	14.0±0.4	5,9±0.8	26.9	50.83	108.15
	Jasini	1396.5	19.9±0.4	6.2±0.7	58.7	56.04	119.23

Utilization classes and stem quality

Mangroves were categorized into diameter size classes to evaluate utilization patterns across the study sites, with local names assigned to each class. In Kenya, these classes include; fito, pau, mazio, boriti, nguzo, and vigingi with diameter ranges of 2.5–6.0 cm, 6.1–9.0 cm, 9.1–13 cm, 13.1–20.0 cm, 20.1–35.0 cm, and >35.0 cm respectively (Okello et al., 2022). Mangroves of Tanzania were categorised into six utilisation classes (Table 9).

Table 9. Densities of the various utilization classes across the study sites (values in parenthesis are proportions).

Country	Site	Fito	Pau	Mazio	Boriti	Nguzo	Banaa	Mbao
Kenya	Jimbo	900 (41.8)	666.7 (30.9)	411.1 (19.1)	44.4 (2.1)	44.4 (2.1)	77.8 (3.6)	11.1 (0.5)
	Vanga	50 (8.5)	56.3 (9.6)	56.3 (9.6)	81.3 (13.8)	81.3 (13.8)	181.25 (30.9)	81.3 (13.8)
	Majoreni	280 (12.4)	590 (26.2)	400 (17.8)	300 (13.3)	180 (8.0)	320 (14.2)	180 (8.0)
	Kibuyuni	18.2 (2.6)	72.7 (10.3)	163.6 (23.1)	18.2 (2.6)	181.8 (25.6)	254.5 (35.9)	0
	Shimoni	0	0	0	200 (12.5)	500 (31.3)	700 (43.8)	200 (12.5)
	Wasini	160 (10.8)	160 (10.8)	240 (16.2)	80 (5.4)	280 (18.9)	480 (32.4)	80 (5.4)
	Munje	75.0 (9.8)	183.3 (23.9)	183.3 (23.9)	166.7 (21.7)	91.7 (12.0)	33.3 (4.3)	33.3 (4.3)
Tanzania		< 5cm	5-9.9	10-14.9	15-19.9	20-24.9	>25	
	Vuo	14.1 (0.2)	382.0 (6.1)	1655.2 (26.5)	1655.2 (26.5)	976.2 (15.6)	1556.2 (24.9)	
	Boma	12.7 (0.1)	292.8 (2.9)	1731.6 (17.4)	2521.0 (25.4)	1362.4 (13.7)	4010.7 (40.4)	
	Moa	50.9 (0.6)	3616.0 (43.2)	2100.8 (25.2)	967.7 (11.6)	713.0 (8.6)	878.5 (10.6)	
	Jasini	0	1438.8 (15.3)	2279.1 (24.3)	1846.2 (19.6)	1642.5 (17.5)	2190.0 (23.3)	

Trees classified as Nguzo were the most widely distributed across all size classes, dominated by *C.tagal* and *R. mucronata*, followed by *B. gymnorhiza* and *A. marina*. Next were Vigingi, primarily composed of *R.*

mucronata, with decreasing proportions of *C. tagal*, *B. gymnorhiza*, and *A. marina*. Mazio followed, dominated by *C. tagal*, then *R. mucronata*, *A. marina*, and least *B. gymnorhiza*. Pau followed, largely consisting of *C. tagal*, *A. marina*, *B. gymnorhiza*, and least *X. granatum*. Mbao followed closely, mostly *R. mucronata*, followed by *B. gymnorhiza*, *C. tagal*, and least *A. marina*. Boriti were majorly *C. tagal*, followed by *R. mucronata*, *B. gymnorhiza*, and least *A. marina*. The least represented group was Fito, primarily composed of *A. marina*, followed by *C. tagal* and lastly, *R. mucronata* .

In terms of quality (usability of the stems in construction), Shimoni and Kibuyuni had the highest composition of form 3 stems, which cannot be used for construction (Table 10). Wasini, which of all the sites appeared less disturbed, had the highest density of trees which could be used for construction with some form of modification (Form 2), and those for direct construction use (Form 1). In Tanzania, Vuo recorded the highest proportion of low quality stems, while Moa had more Form 1 stems (Table 10).

Table 10. Densities of the various stem qualities across the study sites (values in parenthesis are proportions).

Country	Site	Form 1 - Suitable for direct construction use	Form 2 - Usable for construction with modification	Form 3 - Unsuitable for construction
Kenya	Jimbo	433.3 (8.8)	1377.8 (28.1)	3100 (63.1)
	Vanga	25.0 (1.73)	537.5 (37.2)	881.25 (61.0)
	Majoreni	640 (14.2)	1900 (42)	1980 (43.8)
	Kibuyuni	36.4 (1.8)	327.3 (16.4)	1636.4 (81.8)
	Shimoni	0	200 (4.3)	4500 (95.7)
	Wasini	540 (20.3)	1400 (52.6)	720 (27.1)
	Munje	158.3 (9.1)	483.3 (27.8)	1100 (63.2)
Tanzania	Vuo	158.3 (20.6)	241.6 (31.5)	366.6 (47.8)
	Boma	300 (15)	950 (47.5)	750 (37.5)
	Moa	445.5 (27.1)	754.5 (45)	445.4 (27.1)
	Jasini			

Natural Regeneration

Varying levels of natural regeneration was witnessed in the sites surveyed during the study with Majoreni recording the highest counts of saplings per hectare dominated by young Seedlings of less than 40 cm in height- RCI, and those between 40 cm and 150 cm- RCII (Table 10). Notably, a section at Mwakifukua-Vanga had high densities of *A. marina*, pointing towards possibilities of future recovery (Plate 3) of the lightning stricken area (though this might take a long time).

Plate 3. Avicennia marina natural regeneration under the canopy of mature mother trees in one of the sites sampled in Vanga.

Shimoni had almost no natural regeneration particularly due to the exposure of the sites to direct wave action. Similarly, Wasini recorded low counts (Table 11), but this was attributed to the relative pristine nature of the mangroves and closed canopies limiting extensive recruitment of saplings.

Table 11. Densities of juveniles across all three classes (values in parenthesis are proportions).

Country	Site	Counts/Ha			
		RCI	**RCII**	**RCIII**	**Total**
Kenya	Jimbo	618 (21.1)	945.5 (32.2)	1369.7 (46.7)	2,933
	Vanga	971.4 (18.2)	2723.8 (51.1)	1638.1 (30.7)	5,333.3
	Majoreni	5636.4 (47.6)	3927.3 (33.2)	2266.7 (19.2)	11,830.3
	Kibuyuni	88.9 (12.9)	200 (29.0)	400 (58.1)	688.9
	Shimoni	100 (100)	0	0	100

	Wasini	400 (22.2)	800 (44.4)	600 (33.3)	1,800
	Munje	1800 (28.3)	3775 (59.4)	775 (12.2)	6,350
Tanzania	Vuo	1000 (17.5)	2700 (47.4)	2000 (35.1)	5,700
	Boma				
	Moa	3400 (27.4)	3000 (24.2)	6000 (48.4)	12,400
	Jasini	5000 (48.5)	3500 (34.0)	1800 (14.5)	10,300

Degradation status

Key informant interviews revealed a range of natural and human-induced threats to mangrove ecosystems across the study sites. In Vanga, degraded areas were identified as Mwakifukua, Kikatasini, Umba (eneo la Bububu), Mkadini, Ngoa, Kifunga Usubi, and Mwagugu Island, with illegal logging and shoreline erosion noted as the main threats. Natural disturbances, specifically lightning strikes, led to extensive tree mortality at Mwakifukua in 2020 leading to massive death of large mature *A. marina* trees (Plate 4). While some of the trees showed signs of regeneration from the remains of live bark close to the butt region, most of the trees dried completely. The area has since not fully recovered but some natural regeneration was witnessed.

Plate 4. A mangrove patch in Mwakifukua- Vanga, where lightning resulted in the death of mangrove trees.

While some parts of the forest were showing significant natural regeneration of *A. marina*, most of the area (as seen from Plate 4) has remained bare with dead standing trees succumbing and falling over, further damaging young recruits.

The mangroves of Jimbo-Jasini, particularly at Bazo (an abandoned salt mining site), face threats from coastal erosion. In addition, populations of *X. granatum* has declined significantly due to illegal logging for timber, leaving only a few remnants standing. Historically, mangroves were harvested for firewood and timber, but current restrictions and participation in carbon credit initiatives have nevertheless reduced direct cutting.

In Kibuyuni, mangrove degradation has been largely attributed to bait harvesting at sites such as Ngomani and Kijiweni. Although this practice has now been restricted, new threats are emerging, particularly the proposed LPG pipeline project. The community anticipates that mangrove clearance may be required to accommodate the development. Illegal logging for boat construction, grazing by goats, and bait harvesting were identified as key threats to the mangroves of Wasini, with Nyuma ya Maji cited as a degraded area.

Jafuo and Vunguvunguni were identified as degraded areas in Majoreni. Sedimentation, charcoal burning, bait harvesting, and illegal logging were reported as key threats to the mangroves of Jafuo. Oil spills and plastic waste, frequently washed into mangrove areas, add further stress and hinder natural regeneration. In Vunguvunguni, similar concerns were noted, with illegal logging and plastic pollution identified as major threats.

In Munje, mangrove degradation was reported across several areas, including Rukungwi, Mwanagapi, and Kwa Makata. In Rukungwi, logging for charcoal burning was reported, with most stumps observed from *C. tagal*, which is commonly harvested for firewood and charcoal. Livestock browsing on species such as *C. tagal*, *A. marina*, and *L. racemosa*, particularly by cattle and goats, was also noted to disrupt sapling recruitment. Footpaths crossing through the mangroves have further added to the disturbance in the area impeding natural regeneration due to the compacted ground. In Mwanagapi, logging has primarily been carried out for construction purposes, whereas in Kwa Makata, logging was historically linked to pole extraction for lime production in the 1980s, with the poles being transported to Magadia.

Tree health

The proportion of defective (including dead standing) trees varied across sites. Shimoni recorded 100% defective trees from the sampled pool while the other sites recorded less than 30% occurrence probability. Across the sites, pest infestation was identified as the most prevalent of all the recorded cases of defects (Figure 9). Except for Jimbo, Kibuyuni and Wasini, pest infestation and dieback constituted the largest proportion (>60%) of defective trees in the sites surveyed. In most cases, pest and epiphyte infestation both resulted in poor tree health with affected branches and stems also displaying dieback.

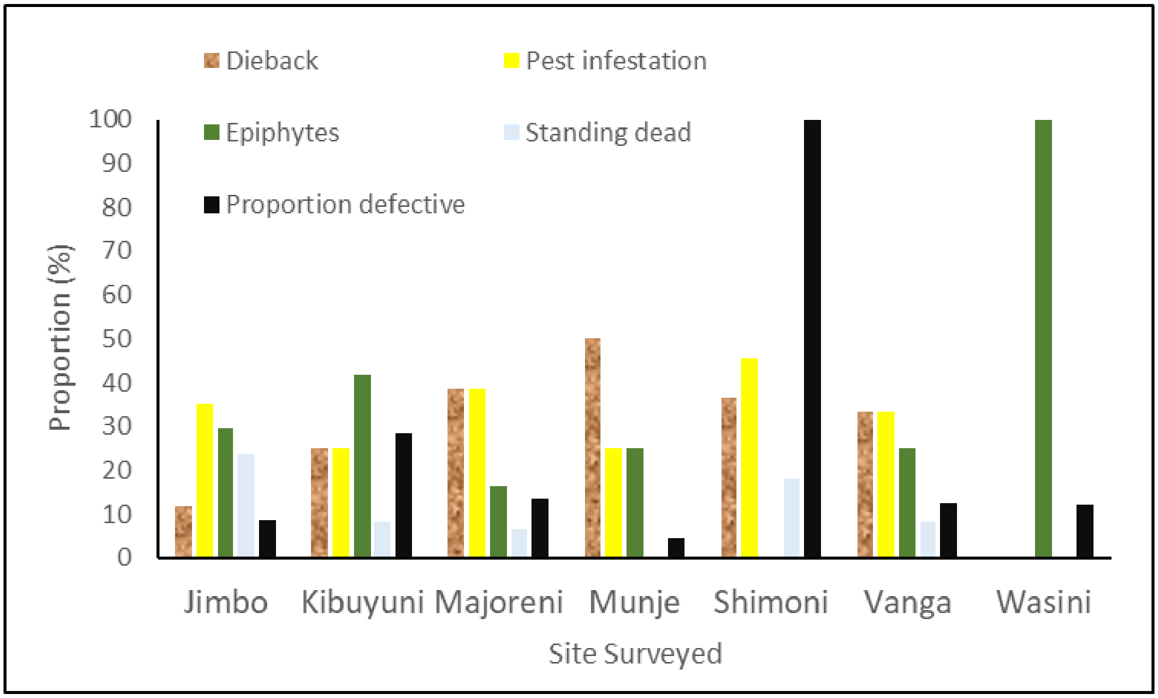

Figure 9. Proportion of trees with various forms of defects across the sites surveyed

Munje recorded less than 5% chance of encountering a defective tree, but with the largest proportion of diebacks. These were majorly linked to cattle browsing and epiphyte invasion. Similarly, Majoreni and Vanga also had a considerable proportion of trees with dieback. Kibuyuni displayed a mixed species band over a very small stretch, with mature, relatively old trees, as also seen in Wasini. In both cases, trees had epiphytes with no or minimal dieback. Moderate epiphyte presence was observed in Munje and Vanga, while Majoreni had the lowest occurrence. Jimbo recorded the highest proportion of dead trees, followed by Shimoni, while both Vanga and Kibuyuni had the least proportions (see Figure 9).

3.2.1.3 Results synthesis

This survey was conducted as a baseline study of the mangrove ecosystems in the Kwale-Tanga region (Shimoni-Vanga in Kenya and the Tanga seascape in Tanzania) to generate ecological data that would inform transboundary conservation, sustainable management, and policy for marine and coastal resources. With the proposal to have the area declared as a Ramsar site, this survey forms part of a larger study in providing data towards demonstrating both local and global significance of the wetland. Moreover, from the desktop review, it was established that there are very few studies on biodiversity of the mangroves in Kenya and none in the Tanzanian area of the Transboundary Conservation Area (TBCA). Further, the records appeared skewed toward fish and plants in Kenyan sites, with major ecological groups such as insects, reptiles, mammals, and diverse microbial lineages underrepresented. Addressing these gaps is critical for establishing a comprehensive biodiversity baseline to guide TBCA management and conservation.

Mangroves are sensitive ecosystems particularly due to their situation at the interphase between land and sea. They are vulnerable to environmental dynamics such as alterations in fresh water flow, pollution both land and seaborne, as well as sea level rise which may lead to fluctuations in salinity levels, smothering of breathing roots and sometimes loss of habitat. Narrow fringing mangrove patches of mangroves of Shimoni could be considered highly vulnerable but very important as they form patchy protective barriers along the shores preventing erosion. The fact that the area is composed of a single species exacerbates the vulnerability as single species can easily be wiped out in case of a species-specific infestation. The results show that of all the trees sampled, none was free of defects.

Similarly, Kibuyuni is a relatively small patch against an eroding shoreline (Plate 5). The area also recorded high species diversity including the mangrove associate *P. acidula*. Protecting these mangrove areas would be important in ensuring sustained provision of the ecosystem services.

Plate 5. Narrow fringe of S. alba in Shimoni, Kenya; A lone S. alba mangrove tree standing against an eroded shoreline in Kibuyuni, Kenya.

Literature also revealed low-income levels coupled up with high rates of unemployment and dependency ratios for the communities along the coastal strip of the TBCA. As a result, residents' resort to unsustainable practices like illegal logging of mangroves as a source of income to sustain their households. Moreover, this creates overdependence and pressure on the mangrove forests, leading to overharvesting for their daily subsistence. Continued extraction of mangrove wood products is likely to result in continued forest degradation if no intervention is taken. Sustainable management of these resources with a view to balance community needs with conservation goals is essential in improving resilience of the mangrove ecosystem in the area.

Other site-specific recommendations

The mangrove ecosystem in Moa faced several threats, including habitat degradation due to fuelwood collection, illegal cutting, and disturbance of endangered species such as *X. granatum*, encroachment for settlement, seaweed farming, salt mining, and clearance of vegetation for pathway creation. To combat these, strict protected area regulations should be implemented. Additionally, community awareness programs should be implemented to enhance local understanding of mangrove conservation and to promote sustainable livelihood options such as ecotourism and sustainable aquaculture. The establishment of buffer zones is also recommended to reduce anthropogenic impacts on the mangrove ecosystem.

Similar threats were observed in Vuo, including overharvesting, seaweed farming, clearance of mangrove areas for salt mining, and cattle grazing. To address these challenges, the establishment of community-led mangrove monitoring programs is recommended, alongside the implementation of mangrove reforestation initiatives. In addition, pollution-control measures should be implemented to minimize environmental contamination, while environmental education campaigns should be conducted to raise community awareness on the significance of conserving and protecting the mangrove ecosystem.

Mangroves in Jasini were affected by various threats including deforestation for salt mining, illegal harvesting of poles, clearance to create a pathway for canals, cutting of branches during propagule harvesting, and overharvesting of *R. mucronata* and *C. tagal*. To mitigate these threats, community-based conservation initiatives should be strengthened and supported. Furthermore, the promotion of alternative livelihood opportunities is essential to reduce dependence on mangrove resources. Mangrove restoration programs should also be initiated to rehabilitate degraded areas, accompanied by enhanced enforcement and monitoring to ensure compliance with conservation regulations.

On the other hand, Boma experienced habitat degradation due to cutting of *R. mucronata* and *B. gymnorhiza*, as well as salt mining. In response, sustainable harvesting guidelines should be implemented to prevent overharvesting, while mangrove restoration using native species should be done as well. Additionally, community training on sustainable use of mangrove resources should be provided to sensitise local communities and promote conservation. Enforcement of coastal protection measures will also contribute significantly to the preservation of mangrove ecosystems.

Beyond their ecological and livelihood functions, the mangrove forests of the Kwale-Tanga TBCA represent a substantial blue carbon asset. The documented carbon stocks across the TBCA ranges from 282 Mg C ha^{-1} to 600 Mg C ha^{-1}, with soil organic carbon comprising 42-70% of total ecosystem carbon across sites (Table 5). Given the extent of mangroves in Kwale county (~8,354 ha), the region represents a significant carbon credit reservoir. Community carbon credit initiatives already active in Jimbo-Jasini demonstrate the viability of blue carbon financing in the study area, which could simultaneously incentivise mangrove conservation, generate community income, and reduce poverty-driven resource extraction.

3.3 Seagrass

3.3.1 Results and Discussion

3.3.1.1 Overview of seagrass cover

Mean seagrass cover varied across the surveyed sites, with generally high values recorded (Figure 10). The highest cover was observed at Jibweni Bazo and Ngomani, both exceeding 90%. Mliani and Wasini Tengefu also exhibited relatively high cover, with values above 85%. In contrast, Chenga chenga and Kukwiri had the lowest mean cover, both slightly below 70%. Intermediate values were observed at Fungu Goma**,** Mpunguti ya chini**,** Mpunguti ya juu, and Mwarembo, ranging between 73% and 83%.

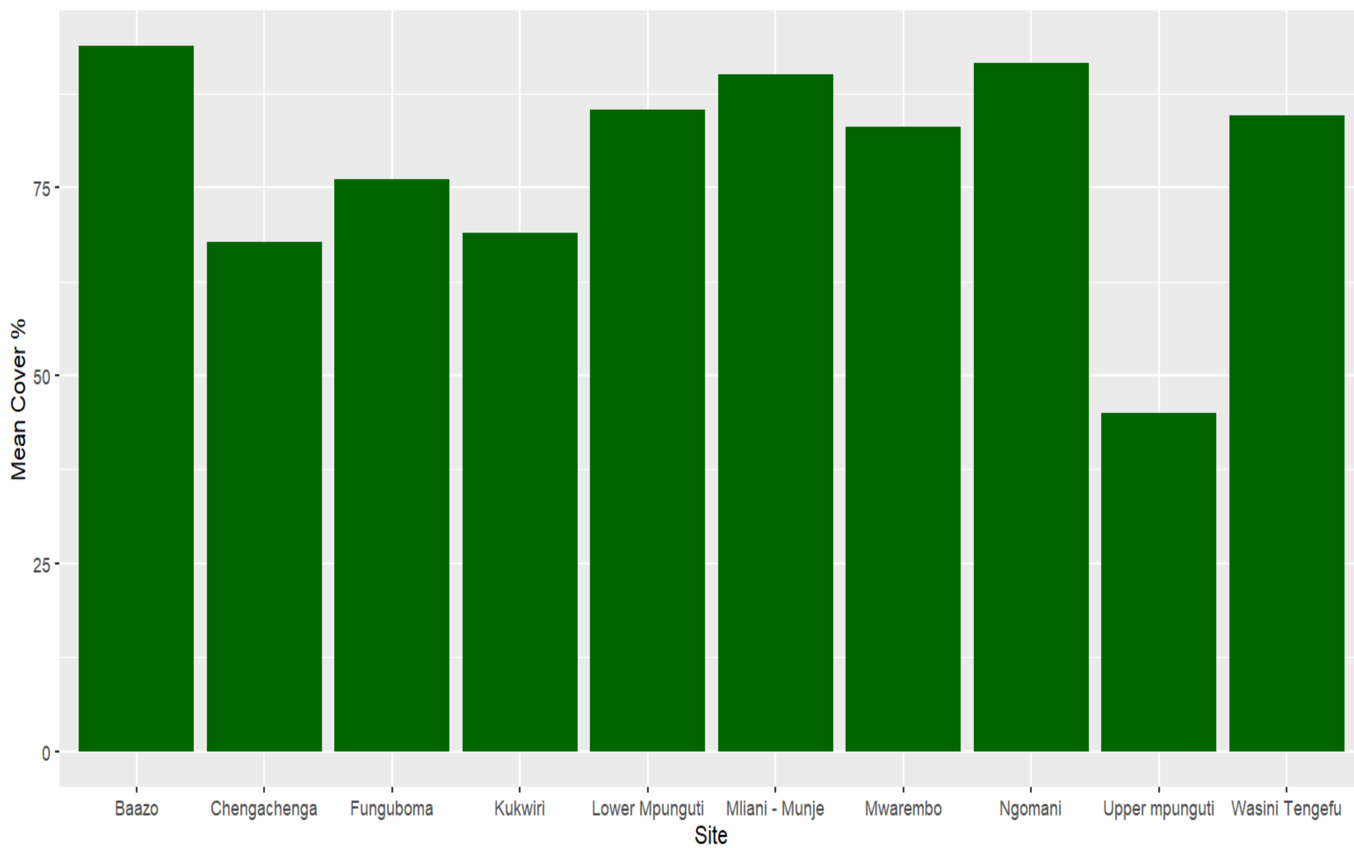

Figure 10. Mean percentage seagrass cover at all surveyed sites.

A total of 8 species were encountered during the survey, namely: *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halodule uninervis, Halophila ovalis, Syringodium isoetifolium, Thalassia hemprichii, and Thalassodendron ciliatum*. *H. ovalis* however showed very low cover. Relative abundance of seagrass species varied considerably among sites (Figure 11).

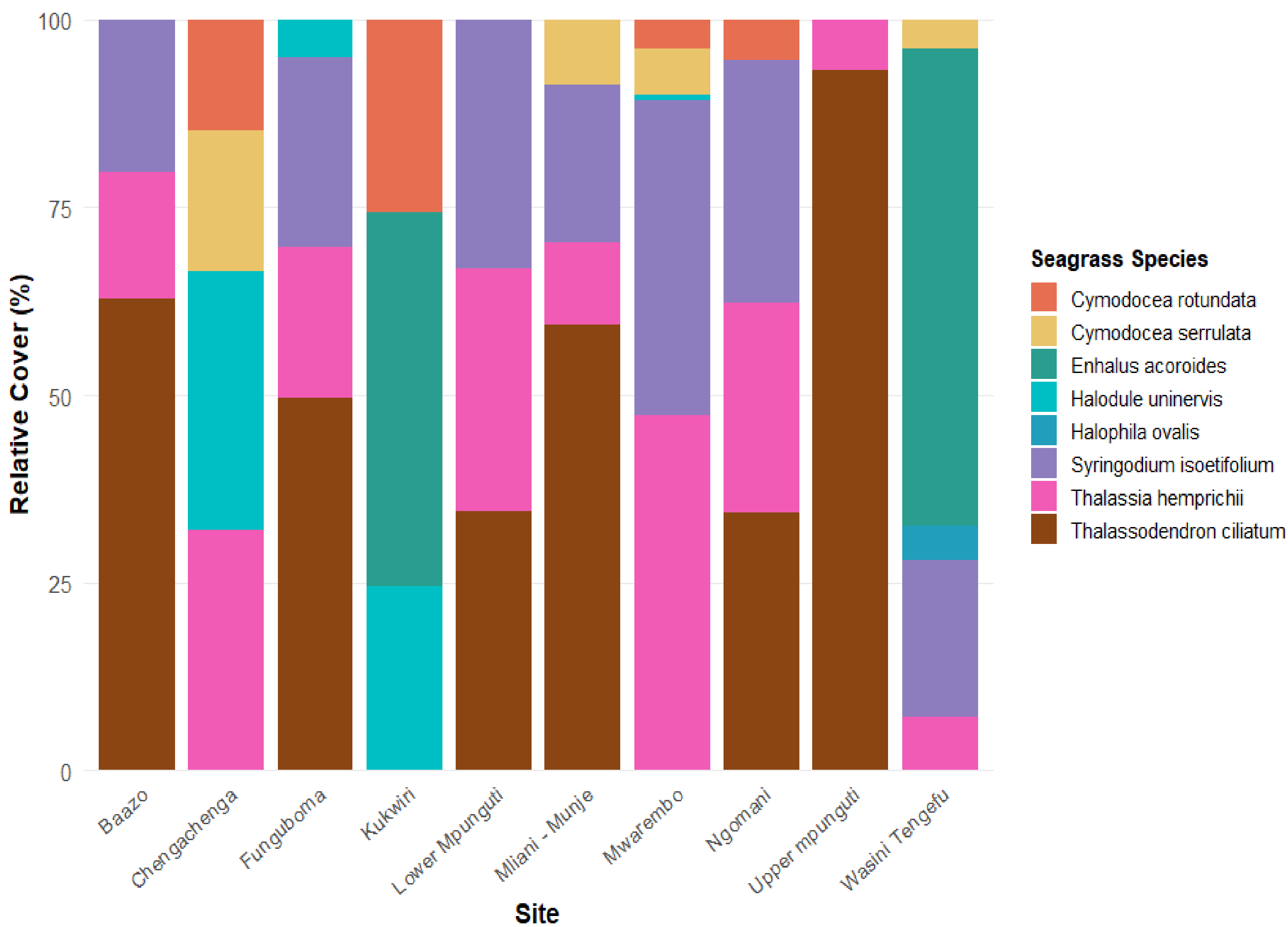

Figure 11. Seagrass species composition relative cover at the surveyed sites.

Chenga chenga hosted a diverse mix, dominated by *Halodule uninervis* and *Syringodium isoetifolium*, with notable contributions from *Thalassia hemprichii*, *Cymodocea serrulata*, and *Cymodocea rotundata*. Kukwiri was strongly dominated by *Enhalus acoroides*, with smaller proportions of *Halodule uninervis* and *Cymodocea serrulata*. *Fungu Boma, Jibweni Bazo, Mliani, Mpunguti ya chini, and Mpunguti ya juu* were dominated by *Thalassodendron ciliatum*, which accounted for more than half of relative cover at each of these sites. Mwarembo exhibited a mixed assemblage with *Thalassia hemprichii*, *Thalassodendron* *ciliatum*, and *Syringodium isoetifolium* as co-dominants. Ngomeni also showed high cover of *Thalassodendron ciliatum*, alongside *Thalassia hemprichii* and *Syringodium isoetifolium*. Wasini Tengefu was distinct, being dominated by *Enhalus acoroides* and *Syringodium isoetifolium*, with low cover of *Thalassia hemprichii*.

HABITAT CHARACTERISTICS

The surveyed sites showed different meadow structures which correlated with protection status and wave exposure levels and seagrass density based on the Braun Blanquet score (Table 12). The study sites occupied shallow subtidal waters but each location had different wave exposure levels and dominant seagrass species. The Marine Protected Areas (MPA) Mpunguti ya juu and Mpunguti ya chini maintained dense and long-lasting seagrass meadows which consisted mainly of *Thalassodendron ciliatum* and *Thalassia hemprichii*. The meadows at Mpunguti were dense but Mpunguti ya chini showed very dense meadows seagrass patches with *Thalassodendron ciliatum* co-occurring with *Syringodium isoetifolium*, and *Thalassia hemprichii*. The meadow condition at Locally Managed Marine Areas (LMMAs) showed wide-ranging differences between locations. The meadows at Bazo consisted of dominant *Thalassodendron ciliatum* with occasional *T. hemprichii* and *S. isoetifolium* species. The meadow at Mwarembo consisted mainly of *T. hemprichii* with *S. isoetifolium* and low seagrass cover for *Cymodocea serrulata* and *C. rotundata*. The meadow at Wasini Tengefu featured a diverse plant community which included *Halophila ovalis*, *Enhalus acoroides, S. isoetifolium, T. hemprichii* and *C. serrulata*. The meadows at Fungu Goma were dense with T. ciliatum forming the main species group alongside T. hemprichii and S. isoetifolium. The sites without protection showed different levels of habitat conditions. The meadow at Ngomani maintained dense and diverse community of *T. ciliatum*, *S. isoetifolium, T. hemprichii* and *C. rotundata*. The meadow at Chenga chenga consisted mainly of dense *T. hemprichii* and *Halodule uninervis* with lower cover of *C. serrulata* and *C. rotundata*. Dense meadows of *Enhalus acoroides* dominated Kukwiri while *C. rotundata* and *H. uninervis* co-occurred in this sheltered lagoon environment. The exposed location of Mliani supported very dense meadows where *T. ciliatum* formed the main component with lower cover of *T. hemprichii* and *S. isoetifolium* and *C. serrulata*.

Table 12. Habitat condition of the surveyed sites.

Site	Protection status	Wave exposure	Water depth	Cover	Seagrass assemblages	Dominant species type	Dominant meadow form
Mpunguti ya juu	MPA	Exposed	Shallow subtidal		***Thalassodendron ciliatum***	Persistent	Enduring
Mpunguti ya chini	MPA	Exposed	Shallow subtidal		***Thalassia hemprichii***	Persistent	Enduring
					Syringodium isoetifolium		
					Thalassodendron ciliatum		
Bazo	LMMA	Exposed	Shallow subtidal		***Thalassodendron ciliatum***	Persistent	Enduring
					Thalassia hemprichii		
					Syringodium isoetifolium		
Mwarembo	No Protection	Sheltered	Shallow subtidal		***Thalassia hemprichii***	Persistent	Enduring
					Syringodium isoetifolium		
					Cymodocea serrulata		
					Cymodocea rotundata		
Chenga chenga	No Protection	Exposed	Shallow subtidal		***Thalassia hemprichii***	Persistent	Enduring
					Cymodocea serrulata		
					Cymodocea rotundata		
					Halodule uninervis		

Key
Very dense
Dense
Medium density
Sparse
Very sparse
No seagrass

Kukwiri	No Protection	Sheltered	Shallow subtidal		***Enhalus acoroides***	Persistent	Enduring
					Cymodocea rotundata		
					Halodule uninervis		
Wasini Tengefu	LMMA	Sheltered	Shallow subtidal		*Halophila ovalis*	Persistent	Enduring
					Enhalus acoroides		
					Syringodium isoetifolium		
					Thalassia hemprichii		
					Cymodocea serrulata		
Ngomani	No Protection	Sheltered	Shallow subtidal		***Thalassodendron ciliatum***	Persistent	Enduring
					Syringodium isoetifolium		
					Thalassia hemprichii		
					Cymodocea rotundata		
Mliani	No Protection	Exposed	Shallow subtidal		***Thalassodendron ciliatum***	Persistent	Enduring
					Thalassia hemprichii		
					Syringodium isoetifolium		

Fungu Goma	LMMA	Exposed	Shallow subtidal		*Cymodocea serrulata*	Persistent	Enduring
					Thalassia hemprichii		
					Thalassodendron ciliatum		
					Thalassia hemprichii		
					Syringodium isoetifolium		
					Halodule uninervis		

The majority of sites maintain stable seagrass cover at high levels which indicates good meadow health that can support associated biodiversity and provide essential ecosystem functions including habitat protection and nursery areas. The low cover at Kukwiri and Chenga chenga may indicate possible human activities that include coastal development, sedimentation and fishing practices. The generally high seagrass cover across most sites (>75%) suggests that seagrass meadows remain an important and dominant habitat type in this region.

This further suggests that these sites provide favorable conditions for meadow stability and expansion. Such high cover is often associated with well-established meadows dominated by climax species that form dense and persistent beds, capable of stabilizing sediments and resisting disturbance. These sites are therefore likely to play an important role in providing ecosystem services such as carbon storage, sediment retention, and nursery habitat for fish and invertebrates. Therefore, these meadows still provide substantial ecological functions but may be more sensitive to additional stressors such as eutrophication, sedimentation, or climate-driven impacts. The low seagrass cover, at Chenga chenga and Kukwiri, suggests a degree of meadow fragmentation or degradation. Such meadows may have lower resilience to disturbance and provide fewer ecosystem services compared to high-cover sites.

SHOOT DENSITY

Shoot density showed marked spatial differences, with the highest mean values recorded at Ngomani (1050 shoots m^{-2}) and Jibweni Bazo (950 shoots m^{-2}) (Figure 12). Intermediate shoot densities were observed at Mliani, Mwarembo, and Wasini Tengefu (ranging between 700 - 850 shoots m^{-2}), while Chenga chenga, Fungu Boma, Kukwiri, and Mpunguti ya chini recorded lower densities. The lowest shoot density was found at Mpunguti ya juu (300 shoots m^{-2}).

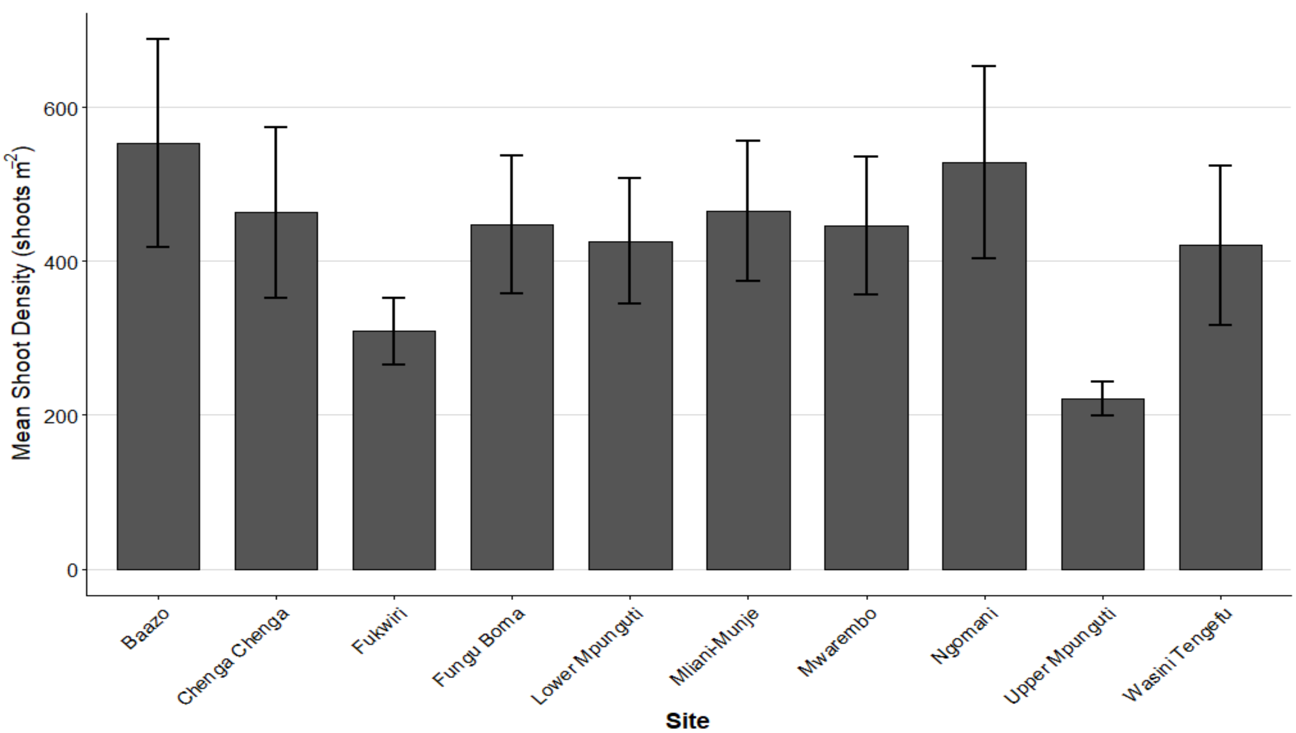

Figure 12. Mean shoot density of seagrass per site.

The survey showed spatial differences in shoot densities in the surveyed areas. The shoot densities at Ngomani and Jibweni Bazo sites indicate productive seagrass meadows. However, high seagrass shoot densities may not necessarily reflect higher productivity, as this may be driven by dominance of fast-growing colonizing species rather than more stable climax species, which typically exhibit lower shoot densities but contribute to longer-term ecosystem persistence and stability. This supports the low seagrass density at Mpunguti ya juu that was dominated by the climax species *T. ciliatum*. The majority of sites show moderate seagrass density levels which indicate stable but vulnerable meadows to environmental disturbances. The high variability within each site at Ngomani, Mwarembo and Wasini Tengefu indicates that meadow structures vary across small areas. This may be attributed to differences in habitat conditions that may be as a result of localized disturbances triggering fast colonizing species with high shoots densities in other areas.

Canopy height

The sites displayed wide variations in mean canopy height measurements ranging from 11.1 cm to 35.3 cm (Figure 13). The highest canopy was reported at Wasini Tengefu (35cm) and Mliani (32cm). Moderate canopy heights were recorded at Bazo, Chenga chenga, Kukwiri, Mpunguti ya juu and Fungu Boma ranging between 15–20 cm. Canopy heights for Mwarembo and Ngomani were approximately 14cm with the shortest canopies at Mpunguti ya chini at approximately 11cm.

Notably, sites with high shoot density did not necessarily correspond to taller canopies. For example, Ngomani exhibited the highest shoot density but only moderate canopy height. This indicates that variability in seagrass structural attributes across sites, likely reflects differences in species composition, environmental conditions, or disturbance regimes.

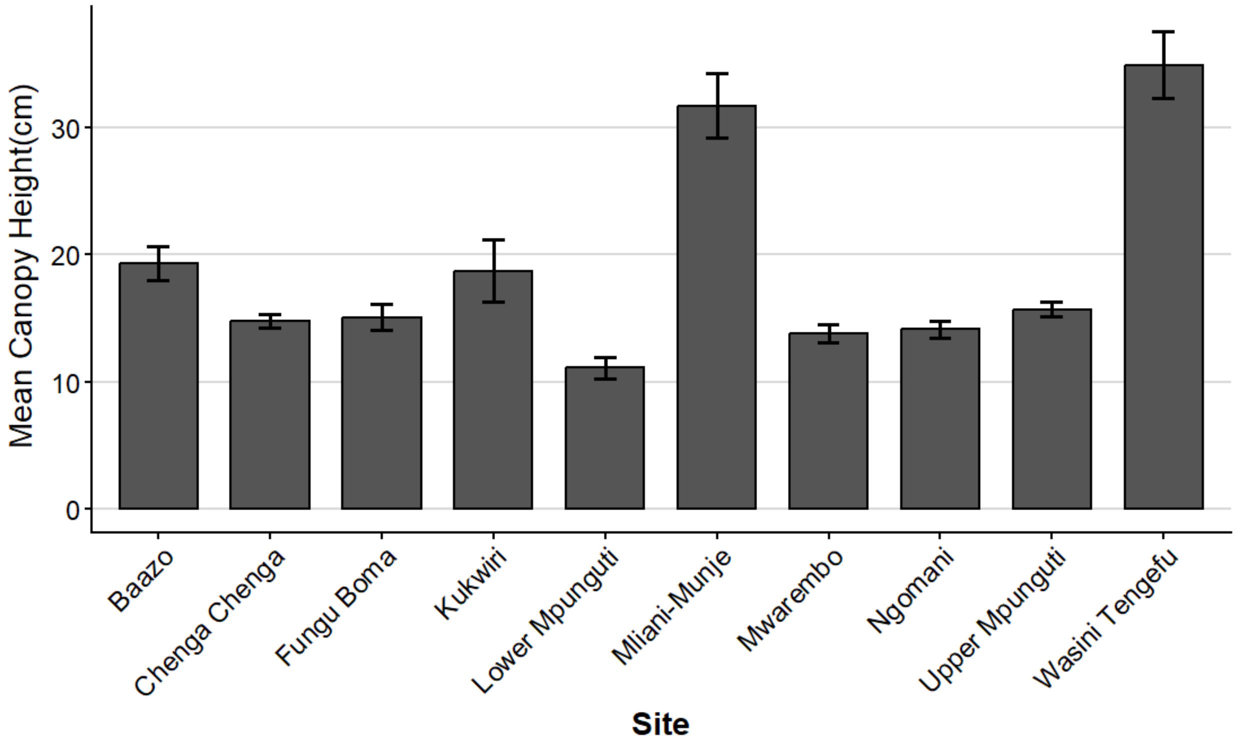

Figure 13. Mean canopy height of seagrass per site.

Wasini Tengefu and Mliani exhibited the tallest canopies that may indicate the dominance of species such as *Enhalus acoroides* or *Thalassodendron ciliatum*, which are known for their vertical growth form. These sites may therefore contribute disproportionately to ecosystem services such as carbon storage, sediment stabilization, and provision of habitat for associated fauna, even if shoot densities are lower.

3.3.1.2 Fish Abundance

A total of 2119 individuals belonging to 30 families and 96 species were encountered during the survey. Mean fish abundance at the surveyed sites varied between 21 and 106 individuals 250 m^2 transect with Chenga chenga and Ngomani recording the highest and lowest densities, respectively (Figure 14). Fish abundance also varied between locations and protected status. The highest fish densities were found in Fungu Boma (LMMA), Mpunguti ya chini (MPA), Mpunguti ya juu (MPA) and Wasini Tengefu, respectively. Sites with no protection showed lower densities below 50 individuals m^{-2} with the lowest at Ngomani with 21 individuals m^{-2}.

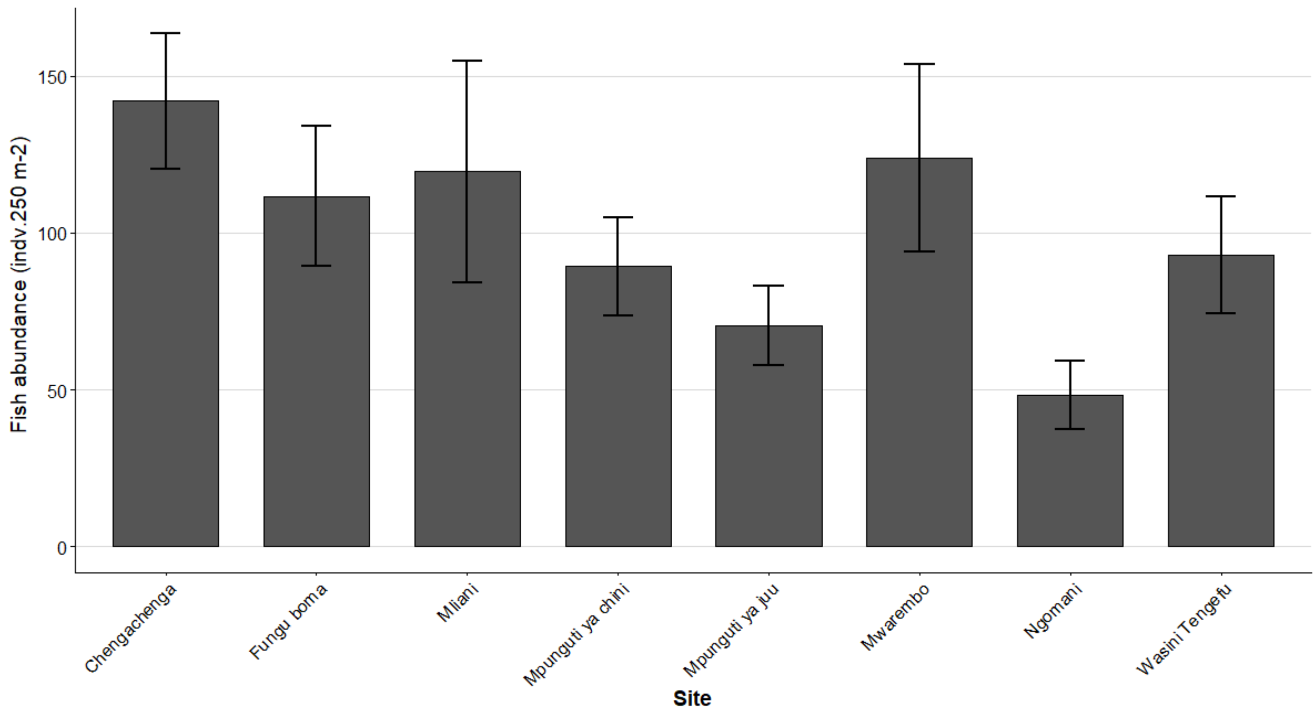

Figure 14. Mean fish densities at the surveyed sites.

Overall, species richness ranged from 5 species in Mwarembo to 16 species in Mpunguti ya chini. All the protected areas exhibited higher species richness possibly because the sites have better habitat quality, due to their protection. The most common species encountered in all sites included *Leptoscarus vaigiensis, Lethrinus harak, Scarus ghobban,* and *Siganus sutor* (Figure 15).

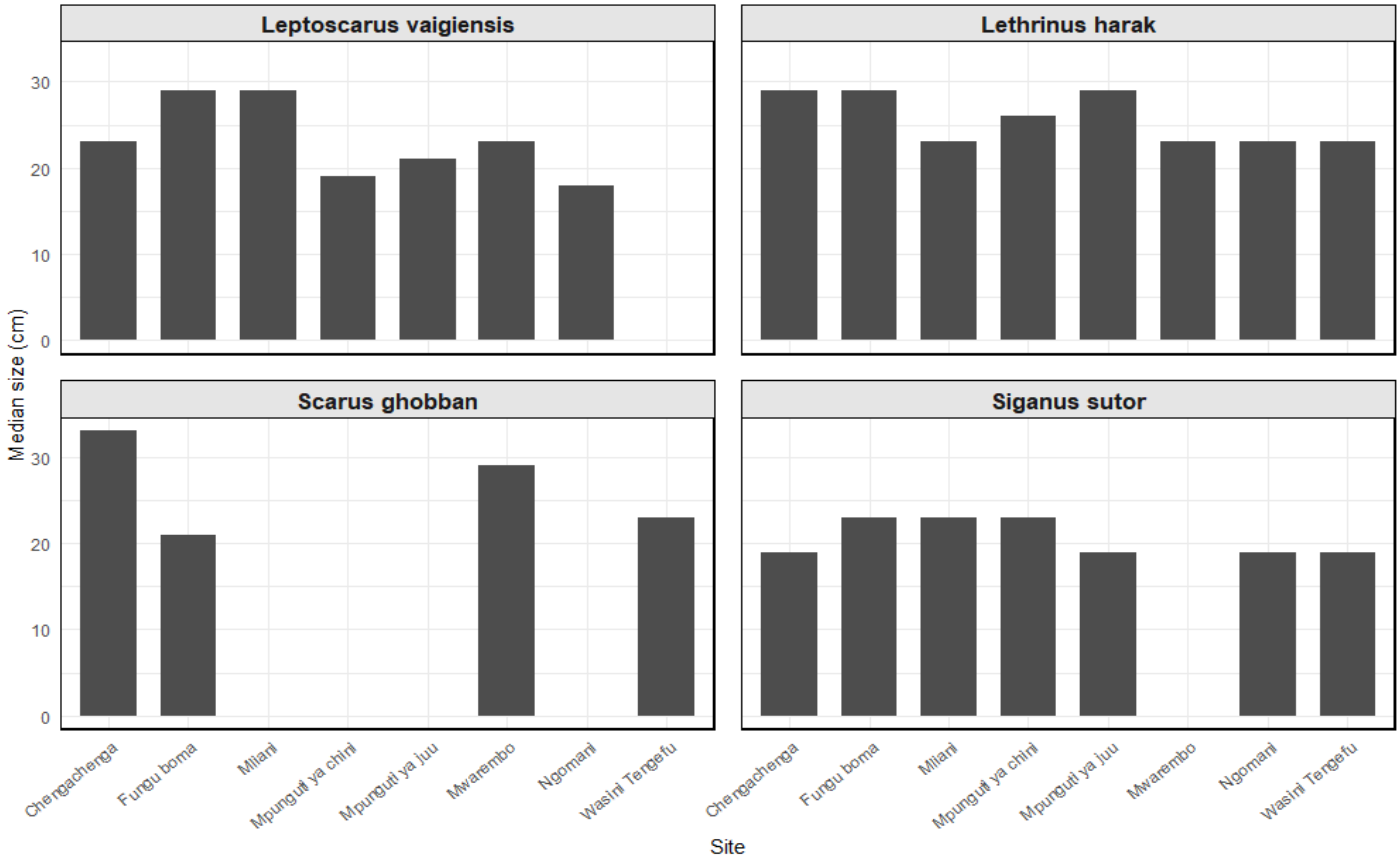

Figure 15. Median size of the four most encountered fish species encountered during the survey.

Fish size-frequency analysis revealed a strong dominance of individuals within the mid-size ranges (Figure 16). The highest frequency occurred in the 17–21 cm size class, followed by the 22–26 cm size class. The 12–16 cm and 27–31 cm size classes were moderately represented, while the smallest size class (6–11 cm) contributed less than 20 individuals. Larger size classes were rare, with only a few individuals recorded in the 32–36 cm and 41–46 cm categories.

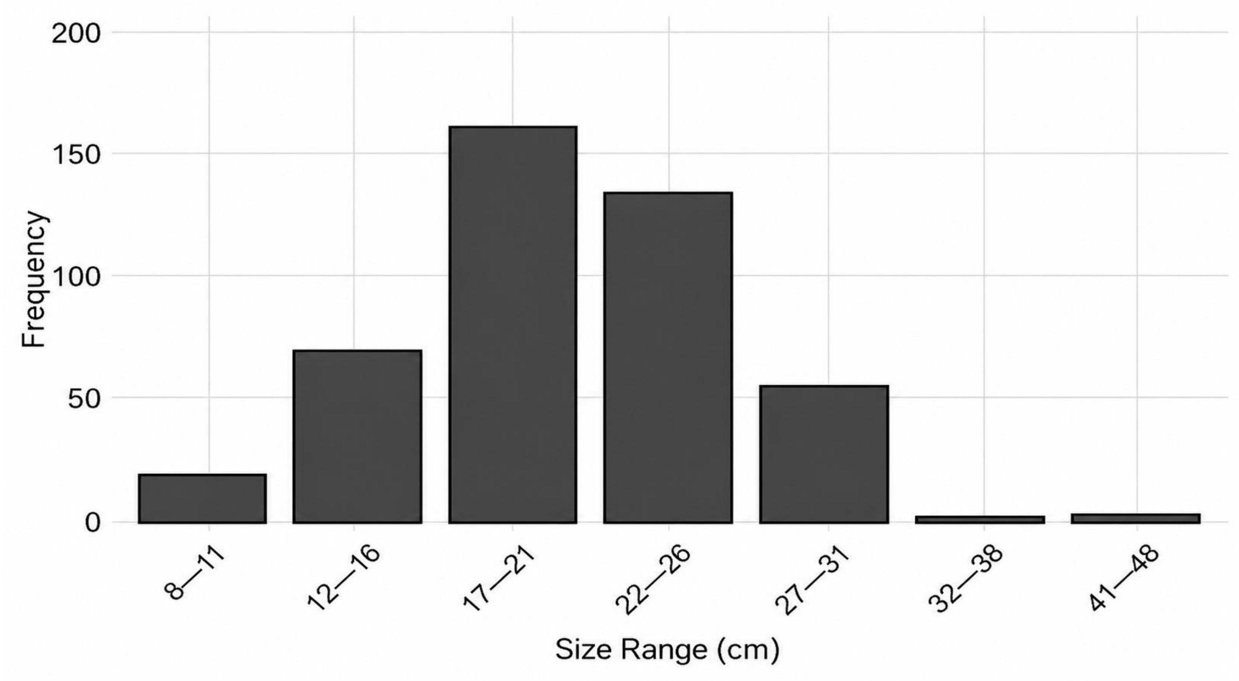

Figure 16. Size-frequency distribution of total fish abundance per site (transects were pooled per site).

The size distribution shows a distinct bias toward fish of medium size while showing minimal numbers of large fish. The population shows signs of overfishing because fishing practices tend to eliminate larger fish from the population. The abundance of fish in intermediate size classes indicates successful recruitment and growth into sub adult stages. The low numbers of large fish indicate impacts on population reproduction and long-term sustainability.

The herbivores together with generalist carnivores dominated these sites because seagrass and surrounding areas experience strong grazing pressure from key species which maintain ecosystem operations. The low numbers of piscivores throughout all sites indicate that fishing activities may have depleted top predators through selective removal of larger predatory species. The fish abundance at Chenga chenga, Fungu Boma and Mpunguti ya chini and Wasini Tengefu sites remains high while their herbivore and generalist carnivore populations stay balanced which suggests these areas need protection or decreased fishing activities. The fish populations at Ngomani and Mwarembo were low which may be attributed to deteriorated or fishing activities that may have reached extreme levels. The persistent absence of piscivores along with minimal planktivore numbers indicates that trophic structure has become less complex which weakens ecosystem stability and changes natural processes including predation and nutrient cycling.

The sites show generalist carnivores play a major role but their numbers exceed piscivores indicating a shift toward mid-trophic levels instead of apex predator populations.

Fish biomass

Mean fish biomass ranged from 2.4 to 31.4 kg/250 m^{-2} (Figure 17). The highest biomass was recorded at Chenga chenga, followed by Fungu Boma and Wasini Tengefu. Intermediate biomass occurred at Mpunguti ya chini and Mpunguti ya juu. The lowest biomass was observed at Mliani, Mwarembo, and especially Ngomani, which recorded the lowest overall mean biomass.

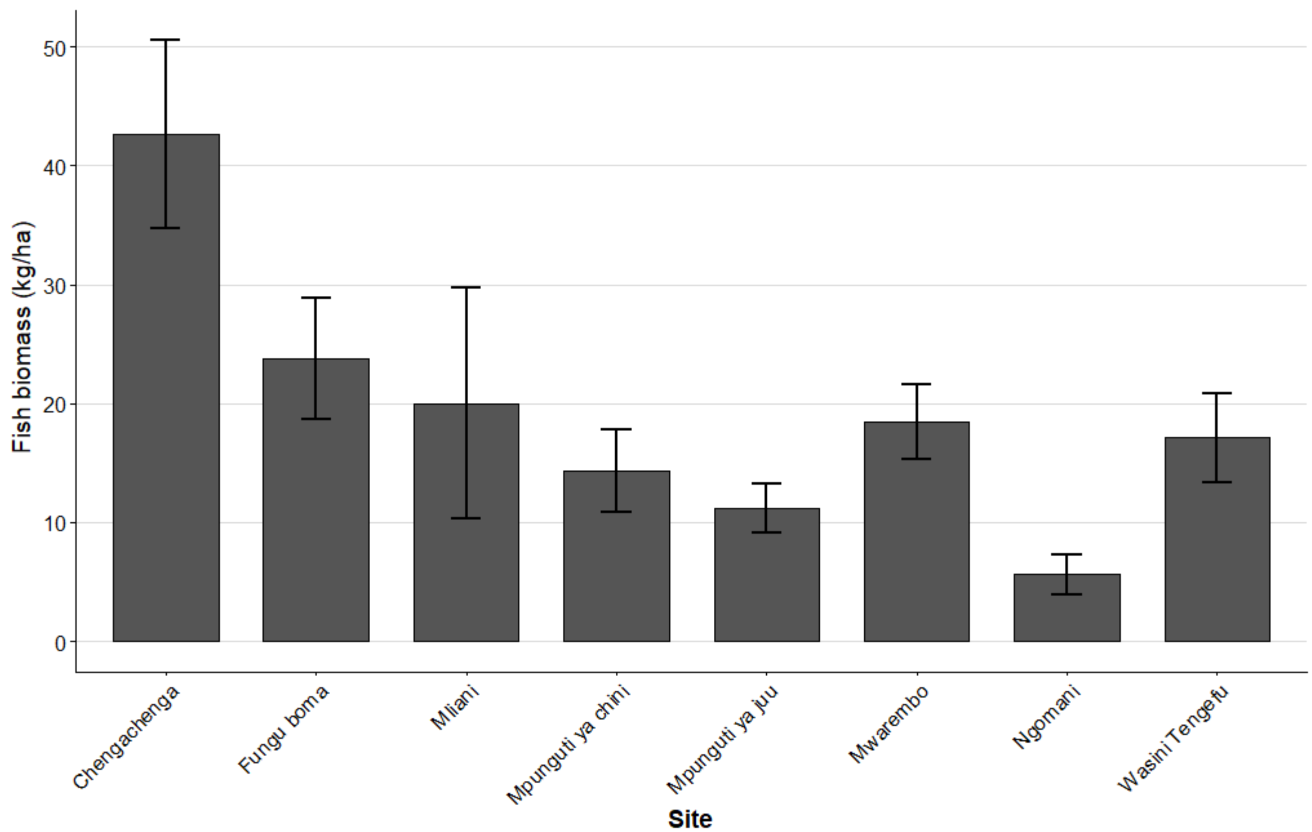

Figure 17. Mean fish biomass at the surveyed sites.

MEAN FISH BIOMASS OF INDICATOR SPECIES

Most of the sites showed high biomass levels of herbivores (rabbitfishes and parrotfishes) (Table 13). The seagrass meadows at Mpunguti ya chini and Fungu Boma supported the highest rabbitfish biomass levels of 124.26 kg/ha and 171.18 kg/ha, respectively which demonstrates the crucial role of MPAs and LMMAs in supporting these herbivores. However, parrotfish biomass peaked at Chenga chenga (189.58 kg/ha), followed by Wasini LMMA (109.70 kg/ha), indicating that certain unprotected sites also sustain substantial herbivore populations. Emperors were particularly abundant at Chenga chenga (156.98 kg/ha), while snapper biomass was highest at Fungu Boma (41.83 kg/ha) and Chenga chenga (39.52 kg/ha). Goatfish biomass reached its maximum at Mwarembo (75.39 kg/ha), a site without formal protection, suggesting strong nursery and feeding functions of seagrass habitats even in fished areas. Wrasses and Triggerfishes showed patchy biomass patterns. Wrasses were broadly present across sites, with the greatest biomass at Fungu Boma (29.31 kg/ha) and Mpunguti ya juu (24.13 kg/ha). Triggerfishes were restricted, occurring primarily at Mpunguti ya juu (15.65 kg/ha), but were largely absent elsewhere, indicating sensitivity to fishing pressure. Large predators were rare, with groupers recorded only at Mliani (4.38 kg/ha) and Fungu Boma (10.07 kg/ha), and barracudas at Mliani (15.13 kg/ha) and Fungu Boma (1.49 kg/ha). Their low biomass across all sites reflects a general depletion of top predators within the study area. Seahorses and pipefishes were not detected in the surveys, which may reflect either their naturally low biomass or limitations of the sampling methods.

Table 13. Fish biomass of indicator fish groups.

Country	Site	Status	Fish Biomass (kg/ha)									
			Wrasse *Indicator species*	**Trigger fish** *Indicator Species*	**Rabbit fish** *Seagrass associate*	**Parrot fish** *Seagrass associate*	**Emperor** *Seagrass associate*	**Snapper** *Seagrass associate*	**Goat fish** *Seagrass associate*	**Grouper** *Large predator*	**Baraccuda** *Large predator*	**Sea horse and pipefish**
Kenya	Mpunguti ya juu	MPA	24.13	15.65	19.19	40.31	11.12	5.29	18.41			
	Mpunguti ya chini	MPA	21.63	5.38	124.26	34.88	11.45	11.74	17.50			
	Mwarembo	No protection				71.97	16.33		75.39			
	Chenga chenga	No protection	2.14		38.50	189.58	156.98	39.52	12.97			
	Ngomani	No protection	4.61		28.52	16.70	7.17					
	Mliani	No protection	5.37		91.45	30.35	7.17		4.75	4.38	15.13	
	Wasini Tengefu	LMMA	10.42		43.34	109.70	16.70	16.66	5.02			
Tanzania	Fungu Boma	LMMA	29.31		171.18	60.29	9.84	41.83	23.47	10.07	1.49	

The survey results show that fish biomass distribution varies between protected areas and unprotected sites and between different management systems which proves the value of seagrass-reef ecosystems and demonstrates how protection affects fish population diversity. The majority of fish biomass at most sites consisted of rabbitfishes and parrotfishes. The high productivity of seagrass meadows supports grazing fish communities which explains the dominance of these two groups at most sites. The high rabbitfish numbers in protected areas Mpunguti ya chini and Fungu Boma demonstrate that protection measures boost herbivore numbers but the high parrotfish biomass at Chenga chenga proves that local environmental conditions support herbivore populations without formal protection. The ongoing presence of herbivorous fish populations remains essential for ecosystem operation because these species control algae growth and preserve both seagrass and coral ecosystems. The biomass of emperors, snappers and goatfishes appeared irregular throughout the study area but was higher in unprotected sites such as Chenga chenga and Mwarembo than in MPAs. The seagrass meadows function as nurseries and feeding grounds for mid-level carnivores which continue to thrive under fishing pressure. The higher snapper biomass Fungu Boma LMMA indicates that these protected areas protect nursery habitats while decreasing fishing-related mortality rates. These fish groups maintain essential ecological value because they link herbivores to apex predators in the food chain. The protected areas of Fungu Boma and Mpunguti ya juu contained higher wrasse biomass levels which indicates that fishing activities have been reduced in these areas. The limited distribution of triggerfishes at Mpunguti ya juu confirms their vulnerability to fishing activities. The observed indicator family patterns prove their effectiveness for detecting fishing effects and assessing management success. Groupers and barracudas remained scarce throughout all sites with only minimal biomass found at Mliani and Fungu Boma. The widespread absence of large predators indicates that fishing activities may have caused significant damage to these seagrass ecosystems.

The absence of piscivores at all sites demonstrates a predator community that has been depleted through extensive fishing activities over time. The sites show generalist carnivores play a major role but their numbers exceed piscivores which indicates a shift toward mid-trophic levels instead of apex predator populations. The fish populations at Ngomani and Mwarembo sites contain many individuals but their total biomass remains low because small species dominate and large fish are scarce. The findings support previous evidence which shows that size reduction has occurred and ecological operations have decreased.

3.3.1.3 Macroinvertebrates

The highest abundances were recorded at Mwarembo and Mliani, followed by Fungu Boma and Wasini Tengefu (Figure 18). Moderate values were observed at Mpunguti ya chini and Mpunguti ya juu and very low abundances at Ngomani. No macroinvertebrates were observed at Chenga chenga and Kukwiri.

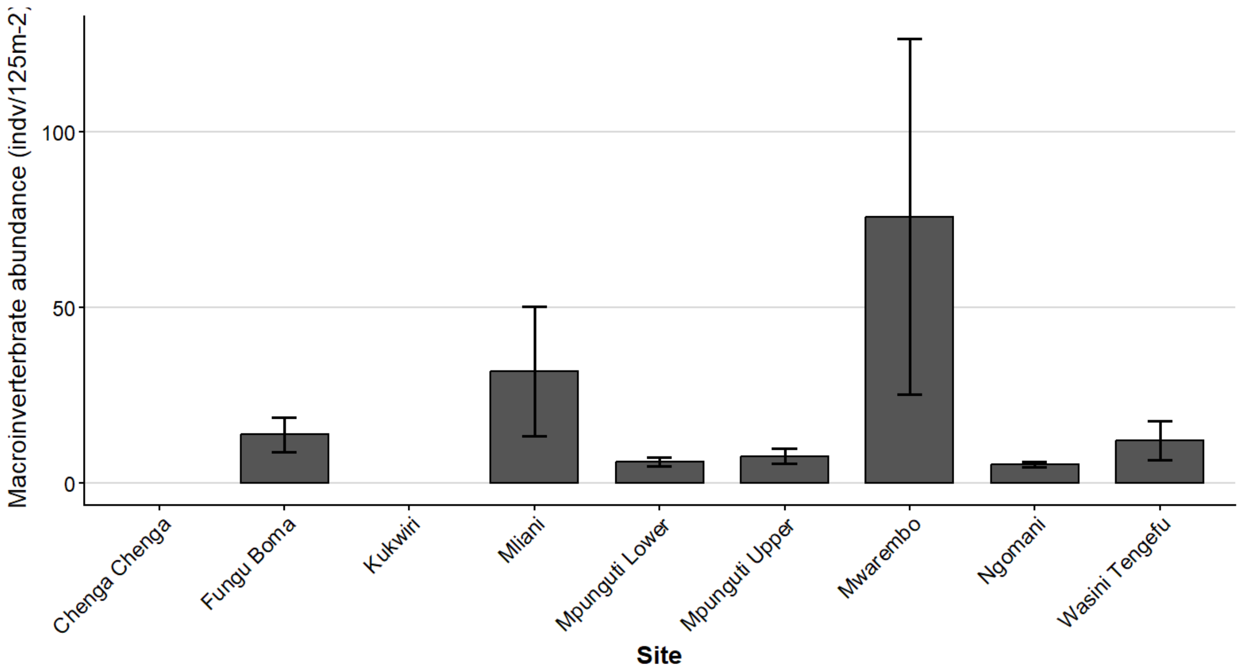

Figure 18. Macroinvertebrates abundance at the surveyed sites.

Macroinvertebrate indicators showed distinct patterns across management regimes and sites (Table 14). Sea cucumbers (bioturbators) were most abundant in the MPAs of Mpunguti ya juu and Mpunguti ya chini, with an exceptionally high density recorded at Mliani, a non-protected site. In contrast, few individuals were reported at Fungu Boma and Mwarembo, and absent from most other sites. Collector sea urchins, indicative of overgrazing pressure, were most numerous at the LMMAs of Wasini Tengefu and Fungu Boma, with low abundance at Ngomani, while they were absent from all other sites, including the MPAs. However, this abundance was still very low at approximately <1 individual m^{-2}. These patterns suggest that these sites generally maintain balanced macroinvertebrate communities with functional sediment turnover and without signs of urchin outbreaks. Non-protected sites exhibited unusually high sea cucumber densities especially at Mliani, highlighting the patchy nature of pressures on seagrass macroinvertebrate assemblages.

Table 14. Abundance of macroinvertebrate indicators.

Country	Site	Status	Abundance (Individuals/125m^{-2})	
			Sea cucumbers (bioturbators)	**Collector sea urchin** (Overgrazing)
Kenya	Mpunguti ya juu	MPA	16.5	
	Mpunguti ya chini	MPA	16	
	Mwarembo	No protection	4	
	Chenga chenga	No protection		
	Kukwiri			
	Ngomani	No protection		5
	Mliani	No protection	69	
	Wasini Tengefu	LMMA		23
Tanzania	Fungu Boma	LMMA	2	28

3.3.2 Conclusion

The surveyed sites exhibited seagrass ecosystems which serve as essential biodiversity habitats while supporting fishery production. For instance, the protected areas of Mpunguti ya juu and Mpunguti ya chini maintain continuous dense meadows of *Thalassodendron ciliatum* and *Thalassia hemprichii*. These habitats support large amounts of rabbitfishes and parrotfishes which demonstrate their importance for maintaining ecosystem stability and resilience. The Fungu Boma LMMA demonstrates the value of community-based management, sustaining relatively high fish biomass and robust herbivore populations.

The unprotected area of Chenga chenga supports substantial parrotfish biomass indicating its conservation value even though it lacks official protection status. In contrast, Kukwiri shows signs of human activities because its meadows exist in a degraded condition with low coverage which may require interventions such as elimination of the degrading factors or restoration.

The protection measures show positive results but multiple ongoing threats continue to affect the area. The non-protected zones show signs of fishing pressure together with damaged habitats and irregular distributions of macroinvertebrates. The evidence of overfishing becomes apparent through the observation of smaller sized fish and missing top predator populations. The survey shows that unprotected seagrass ecosystems remain at risk because fishing activities may have led to smaller fish body sizes and eliminated top predator populations. However, these sites may also lack historical data for tracking long-term changes since monitoring is mostly focused in protected areas. Further monitoring may be necessary, particularly at Kukwiri, to determine the causes of decline and potential recovery prospects. Conservation in this transboundary area needs immediate improvement to promote sustainable use of marine and coastal resources in the Kwale-Tanga region.

3.3.2.1 Recommendations

- The protection of essential seagrass habitats requires expanding both MPAs and LMMAs to cover more space for safeguarding vital feeding and nursery areas of important species.
- Fisheries management needs to establish rules which prevent excessive fishing of large predatory and herbivorous fish populations to achieve ecological stability and ecosystem stability.
- The restoration of degraded seagrass areas requires immediate attention through habitat conservation programs which should combine local community involvement for sustainable results.
- The implementation of monitoring programs should track seagrass health, macroinvertebrates and fish biomass to support evidence-based adaptive management decisions.
- The conservation program needs to increase local community participation through fisher involvement while teaching people about seagrass ecosystems' dual ecological and economic worth.
- The protection of seagrass habitats requires solutions to tackle pollution sources and physical disturbances which continue to harm these ecosystems in unprotected areas.

4. Integrated Conclusion and Recommendations

4.1 Conclusion

The Kwale–Tanga transboundary seascape comprises a continuum of interconnected ecosystems; coral reefs, seagrass meadows, and mangrove forests; that together sustain biodiversity, fisheries, and coastal livelihoods. Results from the three ecological assessments demonstrate both ecological significance and increasing vulnerability of these habitats, reflecting the cumulative impacts of unsustainable resource use, coastal development, and land-based pressures.

Coral reefs across the transboundary seascape show a reduced live coral cover and increasing algal dominance in areas exposed to fishing pressure and sedimentation. Seagrass meadows remain relatively extensive and productive, supporting critical nursery habitats for fish and invertebrates, though localized degradation is evident in unprotected sites. Mangrove forests show structural degradation and fragmentation, with a shift from dense to more open stands, especially in sites with single-species dominance or exposure to erosion.

Despite these pressures, the persistence of functional herbivore populations, persistence of dense seagrass meadows, and relatively intact mangrove stands within managed areas such as Marine Protected Areas (MPAs) and Locally Managed Marine Areas (LMMAs), demonstrates the ecological benefits of protection and community-led management. The assessments reaffirm the strong ecological connectivity between the three ecosystems; healthy mangroves stabilize sediments and filter runoff, maintaining water quality for seagrass meadows, which in turn buffer reefs from sedimentation and support reef fish recruitment. The resilience of one ecosystem directly influences the recovery potential of the others, underlining the importance of managing them as a linked seascape rather than as isolated habitats.

Safeguarding the ecological integrity of this transboundary seascape will require concerted efforts to strengthen fisheries management, restore degraded coral and seagrass habitats, and enhance mangrove protection. Continued cross-border collaboration between Kenya and Tanzania, anchored in scientific monitoring and community participation, will be essential to supporting ecosystem resilience, sustaining fisheries productivity, and advancing the shared vision of the Kwale–Tanga region as a healthy and well-managed coastal and marine landscape.

4.2 Management and Policy Recommendations

Effective conservation of the Kwale–Tanga Transboundary Conservation Area (TBCA) requires an Ecosystem-Based Management (EBM) approach that recognizes coral reefs, seagrass beds, and mangroves as interconnected systems of a single ecological continuum. Conservation efforts should adopt a holistic, cross-ecosystem framework that sustains ecosystem functions, biodiversity, and livelihoods dependent on them.

Strengthening Management and Enforcement

Enforcement should address the disparity in ecology between managed and open-access areas. The assessments show that coral reefs in Kisite-Mpunguti (National Reserve) and Wasini Tengefu (LMMA) maintain higher live coral cover and fish biomass than open-access coral reefs, where algal proliferation, low herbivore biomass and sedimentation are high. Similarly, dense seagrass meadows and intact mangrove stands are most stable in managed zones, while unprotected sites show signs of degradation and canopy loss.

Priority actions include:

- Expanding LMMA designation to currently open-access areas to bring coral reefs, seagrass meadows, and adjacent mangroves under collective management. This may include Jimbo and Majoreni (Kenya), and Moa (Chundo Kilobo and Chundo), Bunju, and Jasini (Tanzania).
- Consolidate no-take and restricted-use zones across Kisite-Mpunguti and Wasini (Kenya) and Dundulika (Tanzania), ensuring representation of coral reefs, seagrass meadows, and mangroves where applicable.
- Formalizing proposed LMMAs at Jimbo and Vanga (Kenya), where community interest already exists, to protect seagrass nurseries and nearby coral reefs.
- Increasing patrol frequency and compliance monitoring in Wasini and Dundulika and expanding patrol coverage into mangrove creeks and shallow seagrass zones.
- Integrating mangrove and seagrass protection into marine patrol plans, recognizing their essential roles in water quality, sediment trapping, and fisheries productivity.

To enable these actions, enforcement capacity must be strengthened through:

- Training of community scouts and LMMA enforcement teams in surveillance, reporting, ecological monitoring, and conflict resolution.
- Provision of patrol equipment, including boats, fuel, safety gear, GPS units, and communication systems.
- Clear governance and decision-making structures within community groups to ensure transparency and accountability.
- Coordinated enforcement mechanisms between national agencies (KWS, MPRU), county authorities, and community groups to ensure consistent regulations, harmonized patrol schedules, and shared information across the transboundary seascape.

Improve Fisheries Management

Fisheries management should focus on enhancing regulation of fishing gears and effort, promoting sustainable fishing practices, and protecting key nursery habitats within both LMMAs and MPAs. These measures will reduce overexploitation and safeguard the ecological functions that sustain fish populations.

Priority actions include:

- Enforce existing legal restrictions on destructive gears (beach seines, ring nets), coupled with gear-exchange schemes to maintain livelihoods while reducing pressure.
- Implementing temporary or rotational, negotiated closures, gear limits, or gear-exchange programmes on degraded reefs such as Ngomani, Kiromo, Kukwiri, and Mwarembo (Kenya) Bunju, Minyani, Moa (Chundo and Chundo Kiloba) and Fungu Boma (Tanzania), coupled with seagrass fisheries management and mangrove restoration in adjacent catchments to reduce sedimentation.
- Applying gear limits and gear-exchange schemes in degraded areas (Chenga chenga, Kukwiri, and Bazo in Kenya) to reduce shallow-drag gear impacts.
- Strengthening fisheries management and enforcement within the Mpunguti Reserve (Kenya) to support herbivore and predator population recovery and improve coral reef and seagrass condition.
- Strengthening mangrove-based fisheries management in high juvenile density areas such as Majoreni, Jasini, and Vanga in Kenya, and Moa in Tanzania.
- Using LMMA bylaws and awareness programmes to reduce fishing of key herbivores (parrotfish, surgeonfish, rabbitfish).

Transboundary Collaboration and Data Sharing

Collaboration between KWS and MPRU should be formalized to support shared monitoring, coordinated patrols, and aligned management across the TBCA.

Priority actions include:

- Standardising ecosystem monitoring and data sharing, adopting joint survey protocols for coral reefs, seagrass, and mangroves, supported by a shared TBCA data platform and annual ecosystem health reports.
- Coordinating enforcement and spatial management through joint KWS-MPRU patrols, harmonised zoning across ecological linkages, and a unified response plan for bleaching events, sediment pulses, or destructive fishing incursions.
- Formalising a TBCA governance framework (KWS-MPRU-BMUs) and holding structured community exchanges between Wasini and Dundulika BMUs, and other locally managed sites to share best practices in enforcement, monitoring, and management.

Community Empowerment and Co-Management

The assessments show that ecological condition is associated with community-based management. LMMAs such as Wasini and community reserves like Dundulika support higher herbivore biomass and more stable benthic structure, whereas most open-access areas, such as Jimbo in Kenya, and Chundo, Chundo Kiloba, Bunju, and Minyani in Tanzania, exhibit the greatest degradation.

Priority actions include:

- Strengthening BMUs, CFAs, and community scouts through training in governance, ecological monitoring, and data interpretation, and provide basic equipment to support long-term tracking of coral reef, seagrass, and mangrove health.
- Supporting communities in Vanga and Jimbo to formalise proposed LMMAs and establish community-led management teams for priority mangrove, seagrass, and coral sites, drawing lessons from successful co-managed areas such as Wasini and Dundulika.
- Promoting livelihood diversification, such as eco-tourism, and delivering targeted awareness programmes that highlight mangrove-seagrass-coral reef connectivity, helping reduce dependence on fishing and strengthen local stewardship.

Habitat Restoration and Connectivity

Restoration efforts should focus on areas where ecosystems are degraded and where ecological connectivity between mangroves, seagrasses, and coral reefs can support recovery. Restoration alone is insufficient; it must be implemented only alongside effective fisheries management, enforcement, and strengthened governance.

Priority actions include:

- Mangroves: Prioritise replanting and shoreline stabilisation in Shimoni, Kibuyuni, and Vuo, where canopy thinning and coastal erosion are evident. Use native species such as *Rhizophora mucronata*, *Ceriops tagal*, and *Sonneratia alba*. Given their position landward of shallow seagrass and coral reefs, restored mangroves are expected to reduce sediment inputs and support improved water quality.
- Seagrass: Focus on reducing sedimentation from adjacent mangrove catchments and managing the use of destructive gears (e.g. beach seine nets, ring nets).
- Coral reefs: Support the recovery of highly degraded coral reefs, particularly in Tanzania (Bunju, Minyani West, Chundo Kiloba, and Fungu Boma) using artificial structures and substrate stabilisation to improve coral settlement and survival. These efforts should be community-managed and implemented only after reducing fishing pressure and improving herbivore biomass.

This networked approach ensures that restored and protected mangroves reduce sediment inflow and nutrient loading, healthy seagrasses trap sediments, improve water clarity, and stabilise soft substrates, and resilient coral reefs support fish recruitment, shoreline protection, and provide key ecosystem services.

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6. Appendices

6.1 Appendix A

Table A. Eleven families surveyed for abundance, biomass, and their 12 trophic groups and functional characteristics for the coral reef surveys. All taxa were recorded at the species level (not all species are listed here). Those split by body size are species that change their diet with size

Functional Group	Notes on feeding habits and selection of species	Group/family	English name or species
Piscivores	Top level predators, exert top-down control on lower trophic levels of fish, are vulnerable to overfishing therefore good indicators of the level of fishing on a reef.	Serranidae Lutjanidae	All groupers *Aprion viriscens* *Lutjanus bohar*
Omnivores (omnivorous carnivores)	Second-level predators with highly mixed diets including small fish, invertebrates and dead animals. Their abundance a good indicator of fishing pressure	Haemulidae Lethrinidae Lutjanidae	All sweetlip All emperor All snapper except *Aprion viriscens* & *Lutjanus bohar*
Corallivores	Obligate and facultative corallivores are a secondary indicator of coral community health.	Chaetodontidae	8 Butterflyfish: *C. bennetti, C. lineolatus, C. melannotus, C. meyeri, C. ornatissimus, C. trifascialis, C. trifasciatus, C. zanzibarensis*

Invertivores	Feed on coral competitors such as soft corals and sponges, their abundance may be a secondary indicator of stability of these groups and of a phase shift. Also prey on small invertebrates in the benthos.	Pomacanthidae	Angelfish. All species except *Centropyge* spp. which are grazer-detrivores
		Balistidae	Benthic triggerfish (e.g. *Sufflamen* spp.)
		Chaetodontidae	Non-corallivore Butterflyfish: all other Chaetodontids except *H. zoster* and *H. diphreutes,* which are planktivores
Planktivores	Reside on reefs but feed in the water column. Their presence/absence may be related to water column conditions, suitable habitat for shelter or reef features such as passes	Chaetodontidae	*Hemitaurichthys zoster, Heniochus* spp.
		Balistidae	Triggerfish in the water column eg. *Melichthys* spp., *Odonus niger*
		Acanthuridae	*A. mata, A. nubilus, A. thompsoni, Paracanthurus hepatus*
			All large *Naso* (>20cm TL, 16cm for *N. hexacanthus*), except *N. unicornis, N. elegans, N. tuberosus,* which are Browsers
		Caesionidae	All Fusiliers

Detritivores	Feed on organic matter, including diatoms in sediment and reef surfaces, high abundances are poorly understood, may play an important role in reef repair or be linked to eutrophication	Acanthuridae	*Ctenochaetus spp.*
Grazer-detritivores	Feed on algal turf and sediment to extract detritus, microbes and diatoms; may limit the growth of macroalgae	Acanthuridae Pomacanthidae	*A. blochii, A. dussumieri, A. leucocheilus,* *A. nigricauda, A. xanthopterus, A. tennenti* *Centropyge* spp.
Herbivores	Feed on endolithic and epilithic algae, substratum and macro-algae. Exert control on coral-algal dynamics, implicated in determining phase shifts from coral to algal dominance e.g., in response to mass coral mortality		
Large excavators	Take a few, large, deep bites, and remove calcareous substratum; play a large role in bioerosion	Scarinae	*Chlorurus spp. >35cm,* e.g. *C. strongylocephalos* *Cetoscarus ocellatus* *{Bolbometapon muricatum}*
Small excavators	Remove algae and substrate; play a smaller role in bioerosion	Scarinae	*Chlorurus spp. <36cm*
Scrapers	Remove algae, sediment and detritus by closely cropping or scraping the substrate		*Scarus spp., Hipposcarus spp.*

Browsers	Feed on large macro-algae	Scarinae	*Calotomus* spp. *Leptoscarus* spp.
		Acanthuridae	*Naso elegans, N. tuberosus, N. unicornis,* other *Naso spp.* <21cm (<16cm for *N. hecacanthus*)
		Ephippidae	Batfish – *Platax* spp.
		Kyphosidae	Rudder fish – *Kyphosus* spp.
Grazers	Graze epilithic algal turfs, including red algae; likely to limit the growth of macroalgae	Acanthuridae	*Zebrasoma* spp. *A. nigrofuscus,* other *Acanthurus spp.* e.g, *A. lineatus*
		Siganidae	*Siganus* spp

6.2 Appendix B

Table B. Surveyed sites, dates, and coordinates of the coral reef surveys.

Survey Date	Country	Location	Site	Station	Latitude	Longitude	Reef type	Management level
22/01/2025	Kenya	Munje	Mliani	Mliani_01	-4.54551	39.48526	Fore reef	Open
22/01/2025	Kenya			Mliani_02	-4.55005	39.48344	Fore reef	Open
23/01/2025	Kenya	Kisite Marine Reserve	Upper Mpunguti Inner	Upper_Mpunguti_01	-4.70137	39.40589	Fore reef	National Reserve
23/01/2025	Kenya		Lower Mpunguti Inner	Lower_Mpunguti_02	-4.68506	39.39695	Fore reef	National Reserve
24/01/2025	Kenya	Kibuyuni	Nyuma ya Mwamba Mkuu	Nyuma_Mw.mkuu_01	-4.69287	39.32709	Reef flat	Open access
24/01/2025	Kenya		Ngomani	Ngomani_02	-4.64545	39.32241	Reef flat	Open access
25/01/2025	Kenya	Wasini	Wasini Tengefu	Wasini_Tengefu_01	-4.655	39.36403	Fore reef	Community LMMA
26/01/2025	Kenya	Jimbo	Midjira East	Midjira	-4.72616	39.30555	Fore reef	Open access
26/01/2025	Kenya		Bazo Jibweni	Bazo	-4.63632	39.44065	Fore reef	Proposed LMMA
27/01/2025	Kenya	Vanga	Chenga chenga	Chenga_chenga	-4.67569	39.26802	Fore reef	Open access
27/01/2025	Kenya		Mwarembo	Marembo	-4.66068	39.2484	Fore reef	Proposed LMMA
28/01/2025	Kenya	Majoreni	Kukwiri	Kukwiri	-4.66093	39.29963	Fore reef	Open access
28/01/2025	Kenya		Kiromo	Kiromo	-4.63706	39.3032	Fore reef	Open access
13/03/2025	Tanzania	Tanga	Fungu Boma	Fungu boma_02	-4.89512	39.20576	Fore reef	Open access
13/03/2025	Tanzania	Tanga		Fungu boma_03	-4.89952	39.2035	Fore reef	Open access
18/03/2025	Tanzania	Moa Mkinga	Chundo Kiloba	Chundo_NE	-4.88786	39.29709	Fore reef	Open access

18/03/2025	Tanzania	Moa Mkinga	Chundo	Chundo_inner	-4.89931	39.28624	Reef flat	Open access
19/03/2025	Tanzania	Jasini	Minyani West	Minyaani_west	-4.71391	39.23763	Fore reef	Open access
19/03/2025	Tanzania	Moa Mkinga	Bunju South	Bunju_South	-4.76355	39.26973	Fore reef	Open access
20/03/2025	Tanzania	Tanga	Dundulika	Mkadini	-4.84325	39.21769	Fore reef	Community reserve

6.3 Appendix C

Table C. Data collectors, affiliations, and their role for the coral reef surveys.

Name	Organization	Role
Aboud Swaleh	CORDIO East Africa	Team leader and Kwale benthic surveys - Coral recruits data collection
Juma Mwanaisha	REEFolution	Kwale benthic surveys - Coral recruit data collection
Karan Diana	CORDIO East Africa	Kwale fish surveys - Second observer
Karisa Juliet	KMFRI	Kwale benthic surveys - Coral adult size-class data collection
Moejes Karin	CORDIO East Africa	Kwale and Tanga benthic surveys - photoquadrat data collection
Pagu Julius	MPRU/WCS	Tanga fish surveys - Second observer, fish diversity data collection
Rambahiniarison Joshua	CORDIO East Africa	Tanga fish surveys - Lead observer, fish abundance and long swim data collection
Samoilys Melita	CORDIO East Africa	Kwale fish surveys - Scientific and technical oversight
Singo Amos	MPRU	Tanga benthic surveys - Coral recruits and adult size-class data collection
Thouless Clare	CORDIO East Africa	Kwale fish surveys - Lead observer fish abundance
Zamu Masoud	KMFRI	Kwale benthic surveys - Laying of the transect, and safety diver

6.4 Appendix D

Table D. Relative abundance (%) of most abundant fish species at each site surveyed for the seagrass surveys.

Site	Species	Common name	Proportional abundance (%)
Mpunguti ya juu	*Chlorurus sordidus*	Bullethead parrotfish	18.64
	Dascyllus trimaculatus	Three spot dascyllus	13.90
	Acanthurus nigrofuscus	Dusky surgeonfish	9.49
	Siganus sutor	Shoemaker spinefoot	6.10
	Parupeneus macronemus	Long–barbel goatfish	5.76
	Thalassoma hardwicke	Sixbar wrasse	5.76
	Thalassoma hebraicum	Goldbar wrasse	5.76
	Cheilinus chlorourus	Floral wrasse	4.41
	Cheilio inermis	Cigar wrasse	4.07
	Parupeneus barberinus	Dash–and–dot goatfish	4.07
	Acanthurus gahhm	Black surgeonfish	3.73
	Sargocentron diadema	Crown squirrelfish	3.05
	Chrysiptera annulata	Footballer demoiselle	2.71
	Chaetodon lunula	Racoon butterflyfish	1.69
	Thalassoma lunare	crescent wrasse	1.69
	Caesio xanthonota	Yellowtop fusilier	1.36
	Coris formosa	Queen coris	1.36
	Lethrinus harak	Blackspot emperor	1.36
	Chaetodon trifasciatus	Redfin butterflyfish	1.02
	Ctenochaetus truncatus	Indian gold ring bristle tooth	1.02

	Leptoscarus vaigiensis	Seagrass parrotfish	1.02
	Lutjanus fulviflamma	Blackspot snapper	1.02
	Scolopsis ghanam	Arabian monocle bream	1.02
Mpunguti ya chini	*Siganus sutor*	Shoemaker spinefoot	36.44
	Chlorurus sordidus	Bullethead parrotfish	15.96
	Parupeneus barberinus	Dash–and–dot goatfish	10.37
	Thalassoma hebraicum	Goldbar wrasse	4.26
	Labroides dimidiatus	Bluestreak clean wrasse	3.46
	Halichores scapularis	Zigzag wrasse	2.93
	Parupeneus macronemus	Long–barbel goatfish	2.93
	Chaetodon lunula	Racoon butterflyfish	2.13
	Zanclus cornutus	Moorish idol	2.13
	Cheilio inermis	Cigar wrasse	1.86
	Lutjanus gibbus	Humpback snapper	1.86
	Thalassoma lunare	crescent wrasse	1.86
	Dascyllus trimaculatus	Three spot dascyllus	1.60
	Zebrasoma scopas	Brushtail tang	1.60
	Calotomus carolinus	Stareye parrotfish	1.33
	Cheilinus chlorourus	Floral wrasse	1.33
	Lethrinus harak	Blackspot emperor	1.33
	Acanthurus leucosternon	Powderblue surgeonfish	1.06
	Acanthurus tennentii	Doubleband surgeonfish	1.06
	Scolopsis ghanam	Arabian monocle bream	1.06

	Thalassoma trilobatum	Christmas wrasse	1.06
	Ctenochaetus strigosus	Goldring bristletooth	0.80
	Hemigymnus melapterus	Blackedge thicklip wrasse	0.80
	Scarus rubroviolaceus	Redlip parrotfish	0.80
Mwarembo	*Mulloidichthys vanicolensis*	Yellowfin goatfish	44.53
	Apogon cookii	Blackbanded cardinalfish	13.28
	Scarus ghobban	Blue–barred parrotfish	11.72
	Abudefduf sexfasciatus	Scissortail sergeant	10.16
	Leptoscarus vaigiensis	Seagrass parrotfish	8.59
	Lethrinus harak	Blackspot emperor	6.25
	Parupeneus indicus	Indian goatfish	5.47
Chenga chenga	*Lethrinus harak*	Blackspot emperor	16.11
	Abudefduf sexfasciatus	Scissortail sergeant	14.69
	Leptoscarus vaigiensis	Seagrass parrotfish	12.80
	Siganus sutor	Shoemaker spinefoot	12.80
	Scarus rubroviolaceus	Redlip parrotfish	11.37
	Dascyllus trimaculatus	Three spot dascyllus	4.74
	Scarus ghobban	Blue–barred parrotfish	4.74
	Lutjanus fulviflamma	Blackspot snapper	3.79
	Plectorhinchus gaterinus	Blackspotted rubberlip	3.32
	Acanthurus nigricauda	Blackstreak surgeonfish	2.37
	Heniochus monoceros	Masked bannerfish	2.37
	Parupeneus macronemus	Long–barbel goatfish	2.37

	Mulloidichthys vanicolensis	Yellowfin goatfish	1.90
	Amphiprion allardi	Allards anemonefish	1.42
	Heniochus acuminatus	Longfin bannerfish	1.42
	Parupeneus indicus	Indian goatfish	1.42
	Labroides dimidiatus	Bluestreak clean wrasse	0.95
	Naso annulatus	Whitemargin unicornfish	0.95
	Lethrinus nebulosus	Spangled emperor	0.47
Ngomani	*Siganus sutor*	Shoemaker spinefoot	24.39
	Leptoscarus vaigiensis	Seagrass parrotfish	14.63
	Abudefduf sparoides	False eye chromis	12.20
	Lethrinus harak	Blackspot emperor	7.32
	Thalassoma hebraicum	Goldbar wrasse	7.32
	Abudefduf sexfasciatus	Scissortail sergeant	4.88
	Chrysiptera annulata	Footballer demoiselle	4.88
	Grammistes sexlineatus	Sixstripe soapfish	4.88
	Plectorhinchus gaterinus	Blackspotted rubberlip	4.88
	Chaetodon auriga	Threadfin butterflyfish	2.44
	Chaetodon trifasciatus	Redfin butterflyfish	2.44
	Cheilio inermis	Cigar wrasse	2.44
	Halichoeres hortulanus	Checkerboard wrasse	2.44
	Hemigymnus melapterus	Blackedge thicklip wrasse	2.44
	Paracirrhites forsteri	Freckled hawkfish	2.44
Mliani	*Siganus sutor*	Shoemaker spinefoot	32.89

	Taeniamia pallida		24.00
	Acanthurus triostegus	Convict surgeonfish	19.11
	Cheilio inermis	Cigar wrasse	4.00
	Chrysiptera annulata	Footballer demoiselle	4.00
	Sphyraena flavicauda	Yellowtail barracuda	3.11
	Stethojulis strigiventer	Three ribbon wrasse	2.67
	Abudefduf sparoides	False eye chromis	2.22
	Thalassoma hebraicum	Goldbar wrasse	2.22
	Leptoscarus vaigiensis	Seagrass parrotfish	1.78
	Labroides dimidiatus	Bluestreak clean wrasse	1.33
	Lethrinus harak	Blackspot emperor	1.33
	Thalassoma lunare	crescent wrasse	1.33
Fungu boma	*Siganus sutor*	Shoemaker spinefoot	49.37
	Chlorurus sordidus	Bullethead parrotfish	12.82
	Thalassoma hebraicum	Goldbar wrasse	4.62
	Cheilinus chlorourus	Floral wrasse	3.78
	Mulloidichthys vanicolensis	Yellowfin goatfish	3.36
	Lutjanus bohar	Twinspot snapper	2.94
	Macolor niger	Black snapper	2.73
	Chaetodon lunula	Racoon butterflyfish	2.52
	Parupeneus macronemus	Long–barbel goatfish	2.10
	Abudefduf vaigiensis	Indoor pacific surgent	1.89
	Halichoeres hortulanus	Checkerboard wrasse	1.89

Scarus ghobban	Blue–barred parrotfish	1.89
Chaetodon trifasciatus	Redfin butterflyfish	1.26
Labroides dimidiatus	Bluestreak clean wrasse	1.26
Acanthurus tennentii	Doubleband surgeonfish	1.05
Thalassoma hardwicke	Sixbar wrasse	1.05
Thalassoma lunare	crescent wrasse	1.05
Lethrinus mahsena	Sky emperor	0.84
Plectorhinchus gaterinus	Blackspotted rubberlip	0.84
Siganus rivulatus	Marbled spinefoot	0.84
Lethrinus harak	Blackspot emperor	0.63
Pomacanthus semicirculatus	Semicircle angelfish	0.63
Sphyraena flavicauda	Yellowtail barracuda	0.63

On behalf of:

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for the Environment, Climate Action,
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