# Patterns of fish community structure in protected and non-protected marine areas of mainland Tanzania

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## Abstract

Information on the benefits of Marine Protected Areas (MPAs) for the condition of fish stocks is not well documented in Tanzania. Fish landing sites located in Tanga and Mtwara regions were surveyed to assess patterns of fish community structure; particularly fish abundance, species diversity, growth patterns, and maturity stages, based on catches landed at sites with different protection status. Fish abundance in the catch from protected areas was significantly lower than in non-protected areas *($p$=0.002)*. Species diversity was relatively higher in catches from non-protected (H=2.742) compared to protected areas (H=2.232). A high percentage of species (63.24 %) exhibiting negative allometric growth was observed in catches from non-protected areas. Further, a large number of mature fish was observed in catches from protected areas compared to non-protected areas ($p<0.01$). These indices are useful indicators of the performance of MPAs. The observed negative allometric growth and reduced number of mature fishes in non-protected areas suggest that extractive pressure and disturbances from fishing gears have negative impacts on the fish stock. Continued high extraction may induce a decline in general fish size due to the constant selection for large-trait fish specimens, potentially causing evolutionally change in morphological traits. In contrast, the lower abundance and species diversity from the protected areas reflected low catch effort as a result of regulated fishing pressure in MPAs, rather than indicating the actual diversity in the fish stocks in these protected waters. Based on these findings it is recommended that more regulatory strategies are implemented in non-protected waters to allow more time for fish to attain appropriate harvest sizes and to ensure the effective protection of marine resources.

**Keywords:** fish growth, fish maturity, fish diversity, protected area, landing sites

## Introduction

Coral reef fishes contribute significantly to tropical world fisheries (Jiddawi, 1997). While reef-associated fisheries officially make up about 10 % of global marine fishery landings, in some developing countries reef fish can contribute >35 % to national fisheries production (Jiddawi and Ohman, 2002). Fisheries resources are a vital source of food with high protein and omega 3 contents and make valuable economic contributions to the local communities involved in fishery activities, especially along the Tanzania coastline and its numerous islands (Jiddawi and Ohman, 2002; Tobey and Torell, 2006). About 95 % of fisheries in Tanzania are artisanal using traditional boats and gears such as dhows, outrigger canoes, nets, movable traps and fixed traps (Jiddawi and Ohman, 2002). The legal fishing gears which are encouraged to be use are indicated in the Fisheries Act no 22 of 2003 where the use of destructive methods is prohibited in both protected and non-protected areas. Fish caught in Tanzanian coastal waters are primarily traded in domestic markets, but the demand is increasing due to the increase in the human population (Kawarazuka *et al.*, 2017).

In Tanzania coral reef fishes form the basis of small-scale subsistence fisheries, often representing the

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major income for many coastal communities (Tobey and Torell, 2006). Reef fisheries are amongst the most important fisheries on the Tanzania mainland and provide a substantial part of the livelihood of coastal communities. However, reefs are highly subjected to human disturbances such as fishing (Muhando and Mohammed, 2002) undermining their sustainability and productivity potential. The impacts on coral reefs affect fish communities (Wagner, 2004) with considerable cascades on the economies of local coastal human populations. Reef fishes are highly targeted for consumption, and this pressure has secondary effects on the value of fish stocks (Rajasuriya *et al.,* 1998) by impacting on fish growth, maturation and fertilization (Wilson *et al*, 2006).

The contribution of the fisheries sector to economic development cannot be understated. The marine fishery industry contributes significant economic earnings to the gross domestic product (GDP) of several countries and a growing business worldwide (Sarpong, 2015). Lack of appropriate management practices have led to excessive fishing pressure and remarkable habitat degradation, among other environmental problems potentially undermining the economic viability of this sector. For example, the lucrative nature of the fishery business has, in most parts of the world, lead to over exploitation of the fishes (Mvula, 2009). Overfishing may cause the decline of fish stocks and increase risk of extinction of some fish species (Crowder *et al.*, 2008). These management and conservation challenges have led to many countries implementing control measures by delineating areas of marine waters where fishing activities are regulated. These areas, termed as Marine Protected Areas (MPAs), provide refuges and breeding havens for fish species and play an important role in replenishing otherwise depleted fisheries in areas affected by overfishing (Klein *et al.,* 2010). MPAs are viewed as important conservation areas similar to their terrestrial counterparts, yet they are under increasing pressure due to the increasing demand for fish protein from a rapidly growing human population worldwide (Kuboja, 2013).

MPAs in Tanzania were developed in the 1970s where several marine sites were established as marine reserves (Machumu and Yakupitiyage, 2013). The United Republic of Tanzania has improved the protection of marine resources by creating marine parks and marine reserve laws that allow the establishment of Marine Protected Areas (URT, 1994). Following these efforts, MPAs have contributed to an improvement in fish communities and increased resilience to anthropogenic disturbances (Alonso *et al.*, 2017). These areas are now recognized to be effective in providing refuges to fish populations (McClanahan and Arthur, 2001).

Ocean zoning provides a means for separating unsustainable human activities from marine resources as well as reducing conflicts among user groups (Crowder *et.al.,* 1994). Zoning aims to harmonize conflicting conservation and livelihood objectives by spatially separating extractive resource use areas from sensitive habitats (Lokina, 2005). Zoning has been useful in protecting critical species, species-rich habitats including sub-tidal areas, mangroves, forest, bird nesting, fish spawning as well as turtle breeding grounds. The existing forms of zoning in the MPAs of Tanzania include core zones, specified use zones and general-use zones (Kuboja, 2013). The levels of protection in these zones include core zones which provide the highest level of protection, also known as no take zones (Hamilton, 2012). Fishing and extractive activities without license are not allowed in MPAs. Other zones such as specified use zones act as buffers around marine parks, while multiple use zones allow fishing by resident fishers using traditional methods. Permitted fishing gears include hand-lines, basket-traps, pullnets (mesh size less than 2.5 mm), shark nets, set-nets (mesh size 2.5 mm-7 mm), while octopus collection and sport fishing is also allowed. These gears and fishing activities are only allowed in general use zone and specified use zone with special permits for residents and non-residents. The general use zones are intended to be used by residents in a sustainable manner, while extractive activities are allowed but only with permission from the park authorities (Kuboja, 2013). These areas also help to preserve coral reefs that provide breeding grounds to many fish species.

Despite these existing measures of protection there is still insufficient information from landing sites that provides a detailed picture on the status of marine resources in Tanzania's marine waters that differ in protection status. This study was conducted to fill this gap and to assess the fish community structure to determine the extent to which marine parks are effective in conserving fishery resources. Specifically, this research aimed at assessing the abundance and diversity of landed reef fishes, their growth patterns and maturity stages.

## Materials and methods

### Study area

Four landing sites in Mtwara and Tanga regions, Tanzania were selected. In each region, two sites were picked from unprotected waters and protected marine parks, respectively. The landing sites of Msimbati and Deep Sea are located within marine parks and the remaining two of Shangani and Moa are outside the marine parks. These areas were chosen based on protection status and ease of access (Sobo, 2004).

Msimbati landing site in Mtwara region is found within Mnazi Bay-Ruvuma Estuary Marine Park (MBREMP) located at 10° 00' 0.0" S, and 40° 00' 0" E. The park is located south of Mtwara town in southern Tanzania, stretching over 45 km of coastline from the headland of Ras Msanga Mkuu to the Ruvuma River that forms the border with Mozambique. The park covers an area of 650 km². The varied ecosystems of the park support a great diversity of marine life including mangrove forests (nursery grounds for many fish and crustacean species), sea grass beds (feeding ground for a number of marine species) and diverse coral reefs with approximately 250 species of hard coral, 400 species of fish, and 100 species of echinoderms (Obura, 2004). Shangani landing site is located at 10° 15' 56.880" S,

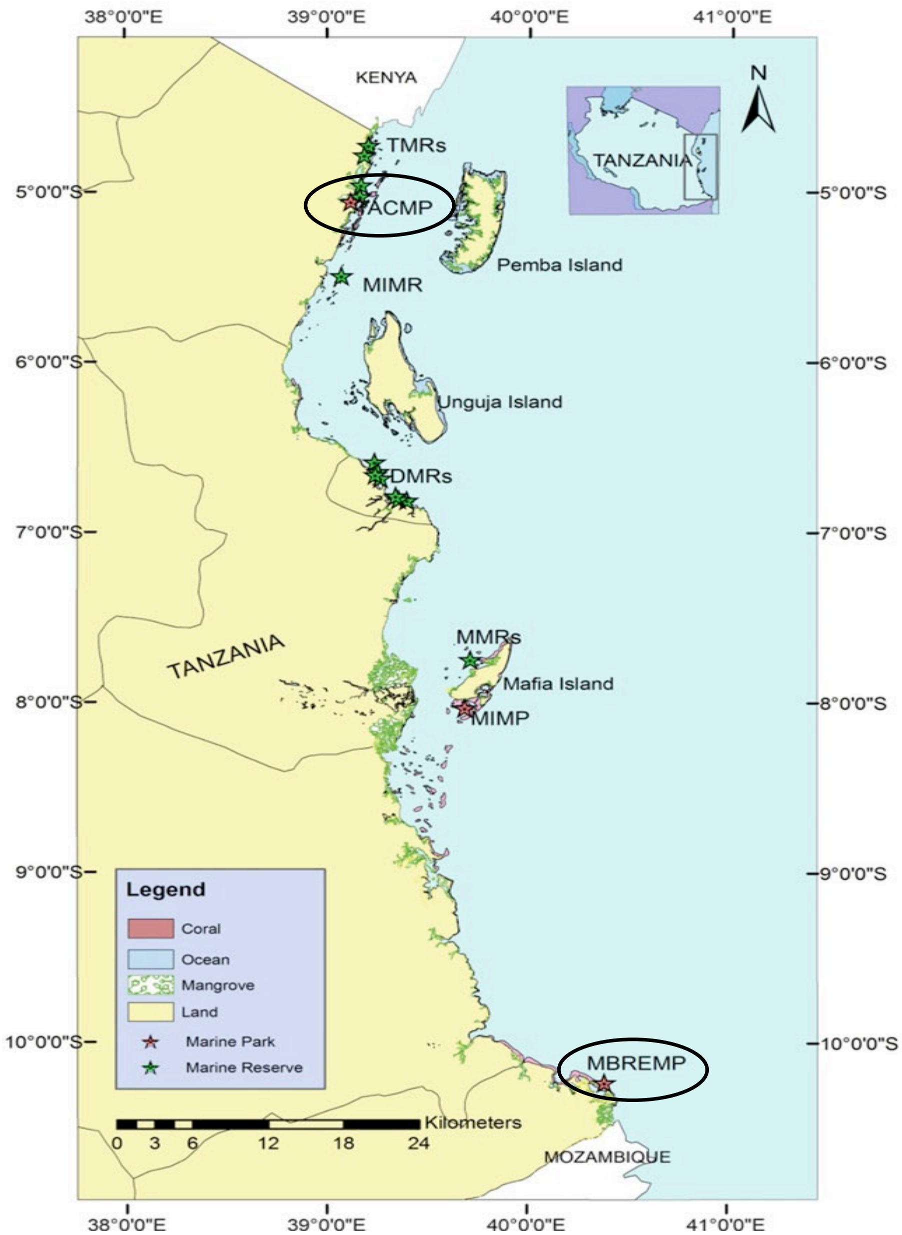


**Figure 1.** Map of Tanzanian coast showing the location of study areas. Source (Mangora *et al.*, 2014).

and 40° 11' 4.560" E in the northern part of Mtwara region. It is one of the largest and busiest landing sites located on the Msanga Mkuu peninsula in Mtwara.

The third site was Deep Sea found within the Tanga Coelacanth Marine (TACMP) Park located at 8° 49′ 60 E and 5° 30′ 0″ S. The park extends for 100 km along the coastline from north of Pangani River estuary to Mafuriko village north of Tanga City. The park covers an area of about 552 $km^2$ of which 85 $km^2$ is terrestrial and 467 $km^2$ aquatic. The uniqueness of the park includes the occurrence and high rates of incidental catches of the CITES - listed and iconic Coelacanth, *Latimeria chalumnae*. TACMP is also home to other endangered species like dugongs, sea turtles, and migratory water- birds (Harrison, 2010).

The Moa unprotected landing site is located at 4°77′ 0″ S and 39° 15′ 0″ E in Mkinga district in the northern part of Tanga region. Mkinga coastal zone is rich in marine resources that include a variety of fishes, octopus, sea cucumber, spring lobster, prawns, sea crabs and seaweeds. A large part of the Mkinga coastline is covered with mangrove stands of considerable density (Harrison, 2010).

## Data collection

Fish samples were collected for three days per month at landing sites during neap tides. The sampling was conducted during the Northern Monsoon period starting in October 2019 to March 2020, making a total of 18 fishing trips surveyed per site. A fishing vessel that utilized various fishing gears was used as a sampling unit. Soon after the fishing vessel had landed, the fishers were asked from which sites they had fished in order to record the fish samples in appropriate study sites based on protection status. The most encountered gears were traditional such as longlines, short handlines, box traps and pull nets (mesh size larger than 2.5 mm and smaller than 7 mm). Some of the fishing gears were regulated within MPAs; pull nets with mesh size of 2.5 mm and shark nets were only allowed within the general use zone. With the help of an expert in fish identification, the fish were selected and grouped based on their genera for further identification using a field guide (Lieske and Myers, 1994). The fish which were not identified in the field were photographed for further identification in the zoology laboratory at Sokoine University of Agriculture. Further, measurements of length and weight of each individual sampled fish were taken using a measuring board and weighing balance respectively. Fish maturity stages were assessed for a single selected species (*Lethrinus harak)*, which was selected because of its economic value in the local markets and availability across the coastline of Tanzania. The maturity stages were assessed by visual inspection of gonads after ventral dissection of the fish (Balci and Aktop, 2019). The modified five-point maturity scale (Burnett, 1989) based on the external appearance of the gonads was used to classify maturity stage. The features used to stage the gonads included, size, shape, colour, volume, and degree of vascularization and opacity in the ovary.

Length measurement was carried out by measuring and recording the standard length to the nearest centimeter. Weight was determined by measuring and recording the total body weight of the fish to the nearest gram. These data were used for assessing of reef fish size structure.

## Data analysis

The relative abundance of species was calculated and the accumulation curves of abundance data from both protected and unprotected areas were visualized in Microsoft excel 2010. Further, the significant difference in fish abundance between protected and non-protected areas was tested using the Mann-Whitney test. The species diversity was calculated at the site level using the Shannon-Wiener diversity index. The data were then pooled from individual sites to the protected and non-protected site levels so that the assessment of the protection status on fishing grounds could be done.

The growth patterns of fish were calculated using the length-weight relationship through the regression equation $W = aL^b$, where W = weight (g), L = total length (cm), a = constant (intercept) and b = growth exponent (Thulasitha and Sivashanthini, 2012). The frequency of occurrence of growth patterns was plotted on a bar graph to assist with visualization. Furthermore, assessment of the significant difference of the growth patterns between the sites was tested using the student's t-test, after confirming normal distribution in the data using the Kolmogorov-Smirnov test. The Mann-Whitney test was used to compare fish maturity stages between protected and non-protected areas. A graph showing fish maturity stages against the sites was plotted to visualize the variation between the protection statuses. All the statistical analyses were performed in Paleontological Statistics (PAST 4.03).

## Results

### Fish composition and abundance

A total of 1548 fish samples from 50 species were examined. 6030 fish samples were collected from protected and 918 from non-protected areas. In Tanga region a total of 205 individual fish of 11 species, and 521 individual fish of 18 species were sampled from the protected and non-protected area landing sites, respectively. In Mtwara, the protected area and non-protected area landing sites provided a total of 415 fish of 10 species, and 503 fish of 13 species, repectively. Species composition of the catches was variable. The highest abundance within protected areas were *Lethrinus harak* (26.35 %, n=166), followed by *Siganus sutor* (21.43 %, n=135) and *Scarus ghoban* (13.02 %, n=82). Further, in non-protected areas the highest abundant species were *Lethrinus borbonicus* (21.35 %, n=196), followed by *Ctenochaetus striatus* (17.32 %, n=159) and *Scarus niger* (10.46 %, n=96) (Fig. 2). There was a significant difference in abundance of species between protected and non-protected areas (Mann-Whitney test, U=815.5, p=0.002). The accumulation curves for protected and unprotected sites showed increasing patterns indicating more sampling was needed to reach an asymptote (Fig. 3).

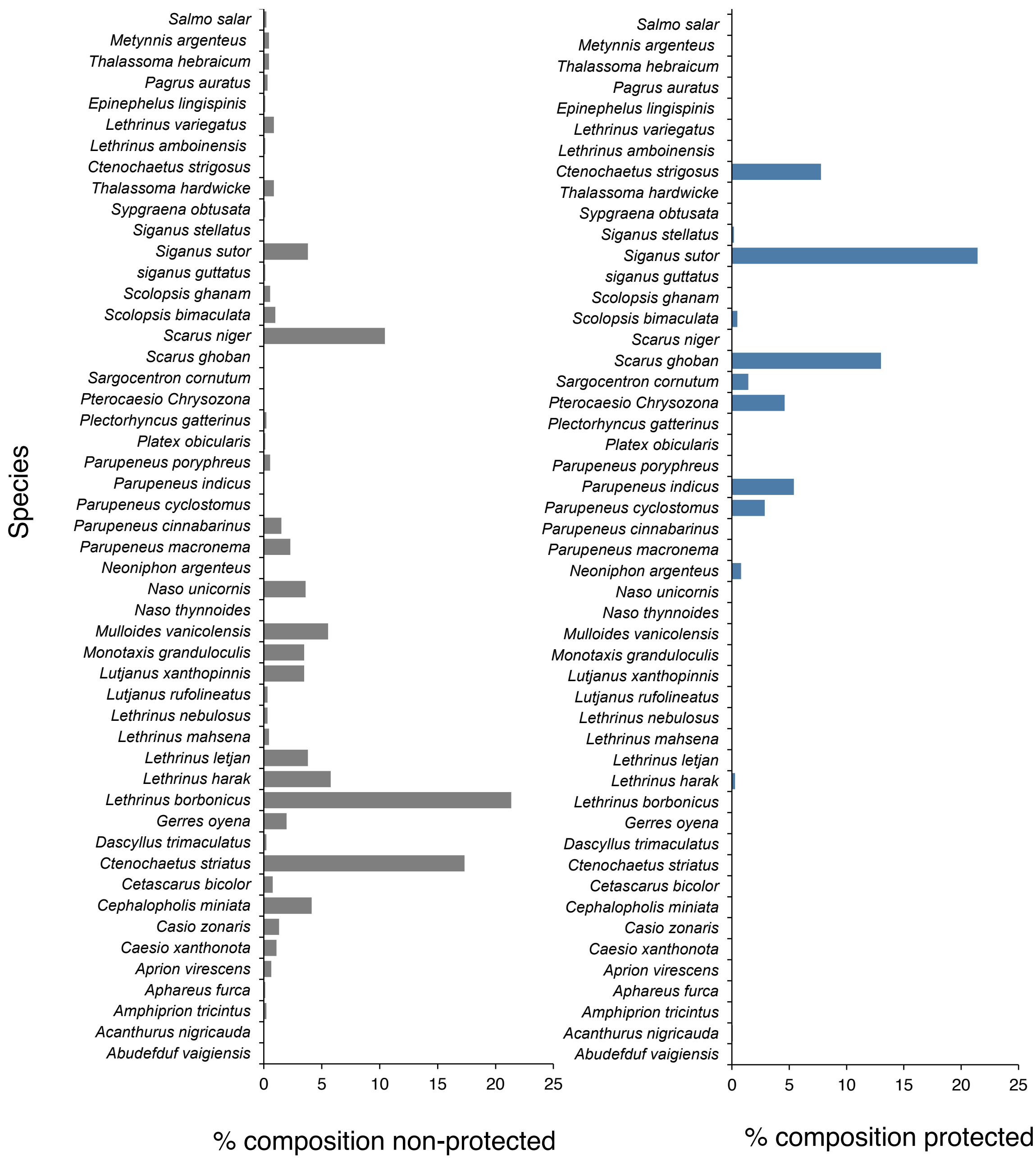


**Figure 2.** Composition and relative abundance of species in protected and non-protected sites.

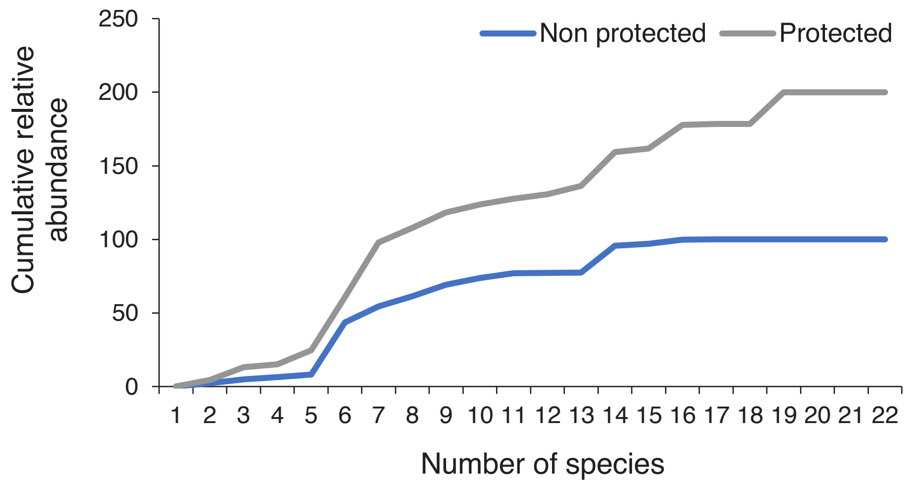


**Figure 3.** Cumulative relative abundance of landed fishes from protected and non-protected sites indicating more abundant catches in the former.

### Fish species diversity

The diversity of landed species varied with protection status. In Mtwara the non-protected area had higher species diversity than the protected area (Fig. 4). A similar pattern was observed in Tanga region. Overall, the catch of fish landed from protected areas had lower species diversity than from non-protected sites.

### Growth patterns and size distribution of landed fish

The growth patterns of collected samples in relation to protection status were analyzed allometrically. The majority (63.24 %) of species sampled exhibited a negative allometric growth form (Fig. 4). The percentage of growth types from fish landed from protected areas were variable: 70.83 % exhibited negative allometric growth; 12.5 % positive allometric growth; and 16.67 % isometric growth. Further, non-protected areas showed varying growth patterns: 56.82 % negative allometric growth; 25 % positive allometric growth; and 18.18 % isometric growth (Fig. 6).

*Siganus sutor* and *Lethrinus harak* were common in catches from both protected and non-protected sites. The mean size of species was higher in fishes landed from protected and lower from non-protected sites (Fig. 5). There was no significant difference in the counts of growth patterns within the protected areas of Tanga and Mtwara ($p > 0.05$).

### Fish maturity status

The sampled fishes were grouped under five maturity stages (Table 1). The fishes had variable maturity stages across the protected and non-protected sites. Individuals in stages II, III, and IV (developing, maturing, and ripe) were dominant across both sites.

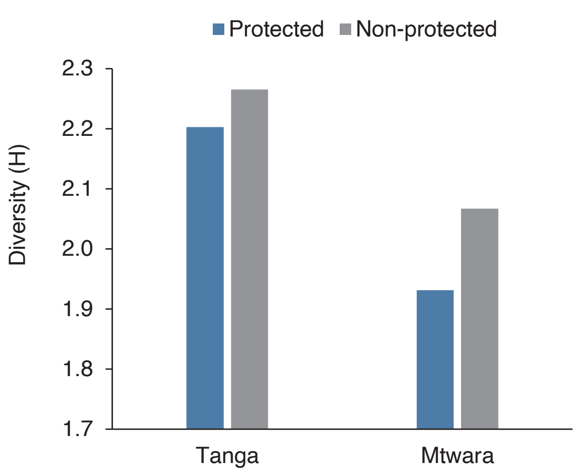


**Figure 4.** Shannon-diversity index of protected and non-protected areas in Mtwara and Tanga regions.

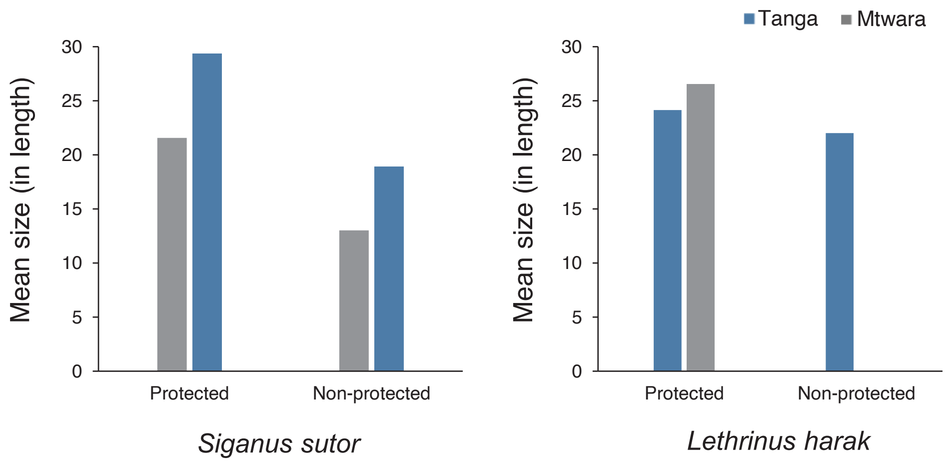


**Figure 5.** Mean size and size structure of *Siganus sutor* and *Lethrinus harak* from Tanga (blue) and Mtwara (grey) regions in protected and non-protected areas.

In Tanga region, 59 specimens of *Lethrinus harak* were examined from the landing site within the protected area (25 males, 35 females), while it was not possible to observe the gonads of specimens from the non-protected landing site as they were gutted at sea. A total of 107 individuals were collected from the Mtwara region landing site within the protected area (42 males. 65 females). In the non-protected landing site 49 individuals collected (28 males, 21 females). There was a significant difference in fish maturity stage (I-V) of females within protected and non-protected areas (Mann-Whitney, $U=0$, $p<0.01$). However, no significant difference was observed in counts of maturity stages of males between the sites (Mann-Whitney, $U = 4$, $p = 0.09$). Further, there was a higher number of females in catches at landing sites from protected areas (59.88 %, n=100) as compared to non-protected areas (40.12 %, n=21) ( ).

## Discussion

This study aimed to assess the patterns of fish community structure in marine protected and non-protected areas of the Tanzania mainland. Significant differences were observed in species abundance, growth patterns, and female maturity stages. No significant differences were observed in the maturity stages of males between protected and non-protected areas. Also, maturity stages showed that there was a higher number of mature specimens from landing sites within protected areas as compared to those from non-protected areas (Fig. 7).

The high diversity and abundance at landing sites within non-protected areas could be influenced by differences in protection status and restrictions existing to regulate fishing. Fishers in marine parks are controlled by the park regulations and they are limited to using gears which are very selective, therefore they obtain small catches compared to the landing

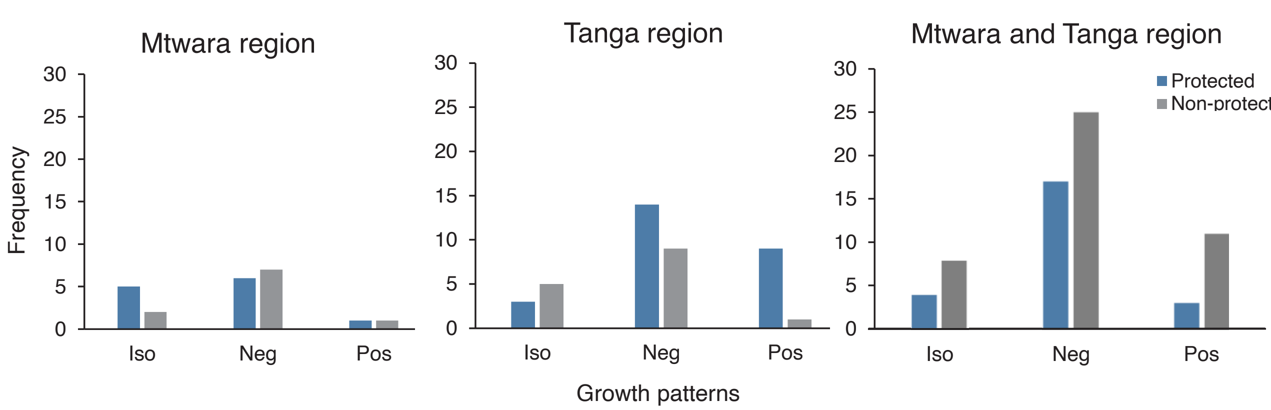


**Figure 6.** Frequency of growth patterns in different regions. Isometric (Iso), Negative allometric (Neg), Positive allometric (Pos).

**Table 1.** Fish maturity stages and their descriptions.

| Maturity stage | Criteria | | Description |
|---|---|---|---|
| | Male | Female | |
| **I (Immature)** |  |  | Males: testes very small and undeveloped; pinkish color<br>Females: ovary small; light pink jelly |
| **II (Developing)** |  |  | Males: testes opaque with lobed or wavy appearance; color variable from red or pink to gray or white; milt may or may not be present in small amounts<br>Females: ovaries opaque and enlarged with blood vessels becoming prominent |
| **III (Maturing)** |  |  | There is a further increase in the weight and volume of the ovaries, which have a deep yellow colour and occupy 2/3 to ¾ of the body cavity. Vascular supply increases and the blood capillaries become conspicuous |
| **IV (Ripe)** |  |  | Male: testes large, milt flows freely from testes<br>Female: The ovaries are further enlarged occupying almost the entire body cavity. They are turgid, deep yellow, the blood supply increases considerably |
| **V (Spent)** |  |  | Males: testes emptying somewhat, still white<br>Females: The ovaries are flaccid, shrunken and sac-like reduced in volume and have a dull colour. The vascular supply is reduced |

sites outside marine parks where there are less restrictions (Tuda, 2018). Various studies have found higher fish diversity in MPAs as compared to non-protected areas (Sarkar *et al.,* 2013; Sweke *et al.,* 2013; Aller *et al.*, 2017). These studies contradict the findings reported here. The difference could be because of the sampling methods used; either collecting or counting fish directly in the fishing area, or from landed catches, as was the case in the present study. Further, the variation observed between the current study and other studies could be influenced by differences in the management of the resources (Sweke *et al.*, 2013). Restrictions on extractive activities within MPAs could limit the size of catches, which determined the sample size. Alternatively, the lower species abundance and diversity from catches within protected areas could be an

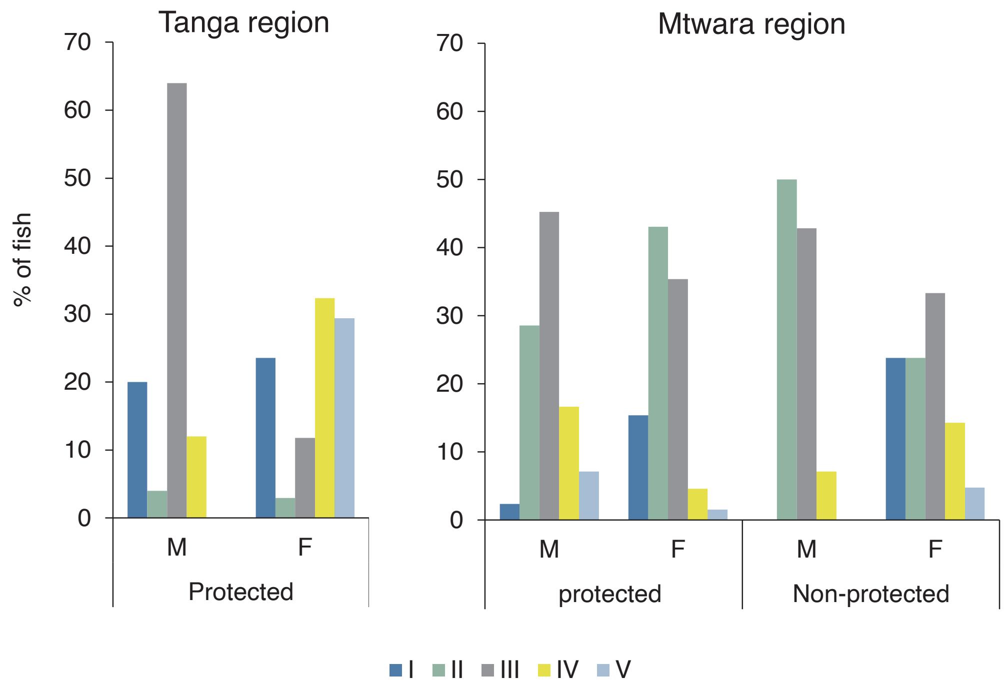


**Figure 7.** Maturity stages of *Lethrinus harak* in protected and non-protected sites from Tanga and Mtwara region. Fish maturity stages: immature (I); developing (II); maturing (III); ripe (IV); and spent (V). Fish sex: Male (M) and Female (F).

indicator of less exploitation and proper management practices which reduces fishing pressure (Silvano *et al.*, 2009; Samoilys *et al.,*2007).

The length and weight relationship helps to provide information on the wellbeing and growth of fish (Jisr *et al.*, 2018). This study indicated that catches at all landing sites, irrespective of their protection status, displayed a majority of reef fishes (63.24 %) exhibiting negative allometric growth. The high percentage of negative allometric growth from non-protected areas could be an indicator of overfishing and unregulated fishing activities (Jisr *et al.,* 2011). The rapid increase in fishing pressure over time on the Tanzanian coast could be the cause of non-proportional fish growth and could be considered as a clear sign of overfishing (Anderson *et al.*, 2008). Unrestricted fishing activities in non-protected marine areas may create disturbances which may interfere with normal proportional fish growth. In negative allometric growth, the fish becomes slender as it increases in length (Mazumder *et al.*, 2016). It is assumed that less disturbance favours healthy fish growth rates, thus the negative allometric growth observed in the majority of species could be influenced by disturbances caused by overfishing. Protected areas provided few individuals with negative allometric growth and their mean sizes were also higher than in non-protected areas.

Size structure is a critical component in maintaining the reproductive stability of fish populations as large individuals tend to produce many and high-quality eggs (Hsieh *et al.*, 2010). Size structure may be altered by several causes including fishing. The presence of large sized fish within protected areas may indicate the effectiveness of fishing regulations. The restrictions within protected areas help to create less disturbed environments for fish growth. Proportional growth is therefore expected to be higher within protected areas. (Magnussen, 2007). Experiences from MPAs show that limitations in fishing effort helps the fish stocks to recover, as individuals are able grow and mature in less disturbed environments (Hoof and Klaan, 2017).

Determination of sex and maturation provides an understanding of the reproductive biology of a species. The high percentage (78.57 %) of mature females from landing sites within protected areas may indicate limited fishing pressure which allows fish to mature in less disturbed areas (Wells *et al.*, 2012). Most species of fish mature when they reach 65-80 % of their maximum size (Beverton and Holt, 1959). The average length at maturity for *Lethrinus harak* is 21.5 cm in males and 22.5 cm in females (Badr *et al.,* 2019). The high number of mature females within protected areas is likely to be linked to their larger average sizes.

The restriction on type of gears within protected areas may greatly influence the sizes of female fishes in catches.

A higher female to male sex ratio increases fertilization success and productivity (Maskill *et al.,* 2017). The high percentage of mature females from catches within protected areas may indicate healthier productivity in the fish community, while the lower number of mature fish in non-protected areas suggests unregulated fishing pressure may lead to lower productivity.

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## References

Aller D, Rathke S, Laird D, Cruse R, Hatfield J (2017). Impacts of fresh and aged biochars on plant available water and water use efficiency. Geoderma 307: 114-121

Alonso E, Jiddawi S, Eklof S (2017) Marine protected areas increase temporal stability of community structure, but not density or diversity, of tropical seagrass fish communities. Plos One 12: 1-23

Anderson N, Hsieh H, Sandin A, Hewitt R, Hollowed A, Beddington J, Sugihara G (2008) Why fishing magnifies fluctuations in fish abundance. Nature 452*:* 835-839

Badr , Adam E, Sheikheldin M, Mohammed S (2019) Reproductive biology of the Thumbprint Emperor, *Lethrinus harak* (Forsskal 1775) using histological ultra-structural characteristic in gonads along Sudanese coastal waters. Biology, Agriculture and Healthcare 9: 65-87

Balci A, Aktop Y (2019) Histological assessment of seasonal gonad maturation of red mullet (*Mullus barbatus* L, 1758) in Antalya Bay of Mediterranean in Turkey. Applied Animal Research 47: 63-71f

Beverton H, Holt J (1959) A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. John Willey and Sons, London. 180 pp

Burnett J (1989) Finfish maturity sampling and classification schemes used during Northeast Fisheries Center bottom trawl surveys, 1963-1989. US Department of Commerce 76. Northeast Fisheries Center. pp 1-14

Crowder B, Crouse T, Heppell S, Martin H (1994) Predicting the impact of turtle excluder devices on loggerhead sea turtle populations. Ecological Applications 4: 437-445

Hamilton M (2012) Perceptions of fishermen towards marine protected areas in Cambodia and the Philippines. Bioscience Horizons: The International Journal of Student Research 5: 1-24

Harrison J (2010) Entrenching livelihoods enhancement and diversification into Marine Protected Area management planning in Tanga, Tanzania. International Union for Conservation of Nature, Nairobi. 95 pp

Hsieh H, Yamauchi A, Nakazawa T, Wang F (2010) Fishing effects on age and spatial structures undermine population stability of fishes. Aquatic Sciences 72: 165-178

Jiddawi N (1997) The reef dependent fisheries of Zanzibar. In: Proceedings of the national conference on coral reefs. Coral reefs: values, threats and solutions. Zanzibar, Tanzania. pp 12-24

Jiddawi S, Ohman C (2002) Marine fisheries in Tanzania. Ambio 31: 518-527

Jisr N, Younes G, Sukhn C, El-Dakdouki H (2018) Length-weight relationships and relative condition factor of fish inhabiting the marine area of the eastern Mediterranean City. The Egyptian Journal of Aquatic Research 44: 299-305

Kawarazuka N, Locke C, McDougall C, Kantor P, Morgan M (2017) Bringing analysis of gender and social–ecological resilience together in small-scale fisheries research: Challenges and opportunities. Ambio 46: 201-213

Klein J, Steinback C, Watts M, Scholz J, Possingham P (2010) Spatial marine zoning for fisheries and conservation. Frontiers in Ecology and the Environment 8: 349-353

Kuboja N (2013) Policies and legal frameworks for Marine Protected Areas governance in Tanzania mainland: Their potential and limitations for achieving conservation and livelihood goals. United Nations-Nippon Foundation of Japan Fellowship Program, Japan. 107 pp

Lieske E, Myers R (1994) Coral reef fishes: Caribbean, Indian Ocean, and Pacific Ocean including the Red Sea. Princeton University Press. 400 pp

Machumu E, Yakupitiyage A (2013) Effectiveness of Marine Protected Areas in managing the drivers of ecosystem change: A case of Mnazi Bay Marine Park. Ambio 43: 369-380

Magnussen E (2007) Inter population comparison of growth patterns of 14 fish species on Faroe Bank: Are all fishes on the bank fast-growing? Journal of Fish Biology 71: 453-475

Mangora M, Shalli S, Msangameno J (2014) Livelihoods of coastal communities in Mnazi Bay-Ruvuma Estuary Marine Park Tanzania. University of Dar es Salaam, Tanzania. 271 pp

Maskill C, Miller R, Halvorson J, Treanor B, Fraser W, Webb H (2017) Role of sex ratio and density on fertilization success of intensively cultured endangered Woundfin. Journal of Fish and Wildlife Management 8: 249-254

Mazumder K, Das K, Bakar Y, Ghaffar A (2016) Effects of temperature and diet on length-weight relationship and condition factor of the juvenile Malabar blood snapper (*Lutjanus malabaricus* Bloch & Schneider, 1801). Journal of Zhejiang University-Science 17: 580-590

McClanahan R, Arthur R (2001) The effect of marine reserves and habitat on populations of East African coral reef fishes. Ecological Applications: 559-569

Muhando A, Mohammed M (2002) Coral reef benthos and fisheries in Tanzania before and after the 1998 coral bleaching and mortality event. Western Indian Ocean Journal of Marine Science 1: 43-52

Mvula T (2009) Factors influencing choice of fishing location in Namkumba peninsula: A case of study of gillnet and chilimira fisheries. University of Malawi. 94 pp

Obura D (2004) Biodiversity surveys of the coral reefs of the Mnazi Bay-Ruvuma Estuary Marine Park Tanzania. International Union for Conservation of Nature, Nairobi. 77 pp

Rajasuriya A, Ohman C, Johnstone W (1998) Coral and sandstone reef habitats in north-western Sri Lanka, patterns in the distribution of coral communities. Hydrobiologia 362: 31-43

Samoilys A, Martin-Smith M, Giles G, Cabrera B, Anticamara A, Brunio O, Vincent C (2007) Effectiveness of five small Philippines coral reef reserves for fish populations depends on site-specific factors, particularly enforcement history. Biological Conservation 136: 584 – 601

Sarkar U, Kumar Pathak A, Kumar Tyagi L, Mohan Srivastava S, Prakash Singh S, Kumar Dubey V (2013) Biodiversity of freshwater fish of a protected river in India: comparison with unprotected habitat. Revista de Biologia Tropical: 161-172

Sarpong B (2015) The economic and social contribution of fisheries to gross domestic product and rural development. Food and Agriculture Organization, Ghana. 53 pp

Silvano A, Ramires M, Zuanon J (2009) Effects of fisheries management on fish communities in the floodplain lakes of a Brazilian Amazonian Reserve. Ecology of Freshwater Fish: 156-166

Sobo S (2004) Strengthening of artisanal fisheries data collection and management in Tanzania. Fisheries Training Programme. The United Nations University, Iceland. 44 pp

Sweke, A, Assam M, Matsuishi T, Chande I (2013) Fish diversity and abundance of Lake Tanganyika: Comparison between protected area (Mahale Mountains National Park) and unprotected areas. International Journal of Biodiversity: 516-522

Sweke A, Assam M, Chande I, Mbonde S, Mosha M, Mtui A (2016) Comparing the performance of protected and unprotected areas in conserving freshwater fish abundance and biodiversity in Lake Tanganyika, Tanzania. International Journal of Ecology: 1-7

Thulasitha S, Sivashanthini K (2012) Growth pattern and length-weight relationship of *Scomberoides lysan* (Pisces: Carangidae) from the northern waters of Sri Lanka. Journal of Fisheries and Aquatic Science 7: 57-64

Tobey J, Torell E (2006) Coastal poverty and MPA management in mainland Tanzania and Zanzibar. Ocean and Coastal Management: 834-854

Tuda M, (2018). Assessing the state and impacts of the artisanal reef fisheries and their management implications in Kenyan south coast. University of Bremen. 198pp

URT (United Republic of Tanzania) (1994) The marine parks and reserves act. Ministry of Natural Resources and Tourism, Dar es Salaam. 388 pp

Wagner M (2004) Coral reefs and their management in Tanzania. Western Indian Ocean Journal of Marine Science 3: 227-243

Wells S, Burgess N, Ngusaru A (2007) Towards the 2012 marine protected area targets in Eastern Africa. Ocean and Coastal Management 50: 67-83

Wilson M, Longley K, Muon S, Rodgers M, Murray C (2006) Examining the contributions of perceived psychological need satisfaction to well-being in exercise. Journal of Applied Biobehavioral Research: 243-264