PATTERNS OF FISH COMMUNITY STRUCTURE IN PROTECTED AND NON-PROTECTED MARINE AREAS IN TANZANIA MAINLAND

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN WILDLIFE MANAGEMENT AND CONSERVATION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA

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ABSTRACT

Over the years Marine Protected Areas (MPA) have excelled in protecting marine biodiversity contrary to other less protected areas. However, information on the performance of protection on the condition of fish stocks is less well documented in Tanzania. The survey was done on fish landing sites located in Tanga and Mtwara regions to assess patterns of fish community structure particularly on the fish abundance, species diversity, growth patterns, and maturity stages based on catches landed from sites differing in protection status. The fish abundance 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) than in protected areas (H=2.232). High percentage of species (63.24%) exhibiting negative allometric growths were observed in catches landed from non-protected areas. Further, large number of matured 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 in fishes and low fish maturity in the non-protected area strongly suggest the role of high or uncontrolled extractive pressure and disturbances caused by the fishing gears on the fish stock. Continued high extraction may induce a decline in general fish size due to constantly selecting for large trait fish stock, potentially causing evolutionally change in morphological traits. In contrast the lower abundance and species diversity from the protected area is reflective of low catch effort, a common strategy of regulating fishing pressure in MPA rather than indicating the actual diversity in the fish stocks in these protected waters. Based on these findings more regulatory strategies of fishing in the open waters are recommended to allow for more time for the fish to attain the appropriate size and to ensure the effective protection of marine resources.

DECLARATION

I Fausta Salema do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my original work done within the period of registration and that it has neither been nor being currently submitted in any other institution.

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My utmost gratitude to South West Indian Ocean Fisheries Governance **(SWIOFish)** for funding my research, my parents for their support and encouragement throughout my study period, I also wish to thank my classmates and friends who have given me their time and experience, their contributions are highly appreciated.

DEDICATION

I dedicate my dissertation to God, my family and friends. A special feeling of gratitude to my loving parents, Gaspar Salema and Magreth Mselewa whose words of encouragement and support pushed me to this stage. My young brother and sister Ewald and Angelica who are my motivation for working hard.

I also dedicate this work to my classmates who have encouraged and supported me throughout the process, am deeply grateful for everything they have done.

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LIST OF ABBREVIATION AND SYMBOLS

CBD	Convention of Biological Diversity
GDP	Gross Domestic Product
MBREMP	Mnazi Bay Ruvuma Estuary Marine Park
MIMP	Mafia Island Marine Park
MPAs	Marine Protected Areas
MPRU	Marine Park Reserve Unit
TACMP	Tanga Coelacanth Marine Park
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

Fisheries resources are a vital source of food and make valuable economic contributions to the local communities involved in fishery activities especially along the Tanzania coastline and its numerous islands. About 95% of fisheries in Tanzania are artisans using traditional gears and boats such as dhows, outriggers canoes, nets, movable traps and fixed traps. Fish caught in Tanzanian coastal waters are primarily traded at domestic markets, but the demand is increasing due to the increase in the human population (Kawarazuka *et al*., 2017).

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 is one of the growing business worldwide (Sarpong, 2015). Lack of appropriate management practices have led to excessive fishing pressure and remarkable habitat degradation among other environmental problems.

The lucrative nature of the fishery business has, in most parts of the world lead to over exploitation of the fishes (Larsen and Mvula, 2009). Overfishing and the associated negative impacts cause the decline of fishery stock and fish species and increased risk for extinction some of fish species (Crowder *et al.*, 2008). These management and conservation challenges have led many countries to put up control measures by delineating areas of marine waters out of fishing activities. These areas termed as Marine Protected Areas (MPAs) provide refuge and breeding haven for fish species and replenish depleted areas by acting as the main source recruits.

MPAs are viewed as important conservation areas similar to their terrestrial counterparts, but yet they remain under increasing pressure due to increasing demand for fish protein from a rapidly growing human population worldwide (Kuboja, 2013). Marine Protected Areas in Tanzania were developed in the 1970s with several sites 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 reserves laws that allow the establishment of Marine Protected Areas (URT, 1994).

Following these efforts, Marine Protected Areas have shown great improvement in fish communities and increased resilience to anthropogenic disturbances (Aller *et al.*, 2017). These areas are now recognized to be effective in providing refuge to fish populations (Mclanahan, 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, 2006). Zoning has bee useful in protecting critical species, species-rich habitats including sub-tidal areas, mangroves, forest, birds nesting, fish spawning as well as turtle-breeding grounds. Further, the existing forms of zoning in Marine Protected Areas of Tanzania include core zones, specified use zones and general-use zones (Kuboja, 2013). The levels of protection includes among others (Hamilton, 2012),. the core zones which provides highest level of protection are also known as no take zones. In these zones fishing and extractive activities without license are not allowed. Other zones such as specified use zones act as buffer to marine parks and in multiple use areas fishing is permitted to resident fishers with traditional methods of fishing.. The general use zones is intended to be used by residents sustainably, extractive activities are allowed but only with permission from the park (Kuboja, 2013). These areas also help to preserve coral reefs that provide breeding ground to many fish species.

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). In Tanzania coral reef fishes form the basis of small-scale subsistence fisheries, often representing the major income for many coastal communities. Reef fisheries are amongst the most important fisheries in Tanzania mainland and provide substantial part of the livelihood of coastal communities. However reefs are highly subjected to human disturbances such as fishing (Muhando and Mohammed, 2002) undermining the sustainability and productivity potentia. 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, thus the pressure associated in coral reefs have secondary effects on value of fish stocks (Rajasuriya *et al.,* 1998). The pressure in reef areas threatens fish growth, maturation and fertilization.

1.1 Problem statement and justification

MPAs were established to overcome fishing pressure, overharvesting of fish stocks and degradation of ecological habitats (Mbije *et al.*, 2010). These areas are considered to be the sites of high species diversity and biodiversity protection, (Lokina, 2006). Various studies have assessed the performance of Marine Protected Areas in Tanzania through visual census by directly observing the sites where fish inhabits (Aller *et al.,* 2017, Sweke *at al.,* 2016). Although, these studies provide useful information on how the protection schemes influence marine biodiversity, assessments of actual fish biodiversity landed from these protected areas are still few. Such studies could provide a direct measure of biodiversity and help to detect any potential leakage due to weakness in law enforcement of these Marine Protected Areas in Tanzania.

The current study assessed fish catch from landing sites within protected and non-protected areas. The findings from this study will provide information to guide fishery management. The findings will also be essential for understanding the performance of Marine Protected Areas. Furthermore, results will inform decision-makers on the appropriate level of protection to be instituted when establishing MPAs in order to meet specified management goals.

1.2 Objectives of the study

1.2.1 Main objective

To evaluate the performance of Marine Protected Areas in Tanzania mainland

1.2.2 Specific objectives

i. To assess diversity and abundance based on the fish landed from protected areas and non-protected areas.
ii. To determine the growth patterns of fish from protected and non-protected areas
iii. To examine maturity stages of fish landed from protected and non-protected areas

These data will provide a glance on the community structure of fish across the target marine fishing ground. For the purpose of this study, the community structure is confined into fish diversity, growth patterns and maturity stages.

1.3 Research questions

i. Is there any difference in diversity and abundance of landed fish between protected and non-protected areas?
ii. Are the growth patterns of fish differ between protected and non-protected areas?
iii. Do the maturity stages of fish differ between protected and non-protected areas?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Marine protected areas

The convention of biological diversity (CBD) in 2004 defined marine and coastal protected areas as "an area within or adjacent to the marine environment, together with its overlying waters and associated flora, fauna, and historical and cultural features, which has been reserved by legislation or other effective means, including custom, with the effect that its marine and/or coastal biodiversity enjoys a higher level of protection than its surroundings". These areas are designated purposely for conservation of biodiversity and cultural heritage (Gjerde, 2007).

Marine park reserve unit (MPRU) of mainland Tanzania has three marine parks; Mafia Island Marine Park (MIMP), Mnazi Bay, Ruvuma Estuary Marine Park (MBREMP) and Tanga Coelacanth Marine Park (TACMP) (URT,2018). There are also areas designated as marine reserves which are mostly located on the eastern side of the coast, under the custody of Dar es Salaam marine reserves system management. Other reserves are in Mafia and Tanga that are currently under the custody of MIMP and TACMP (URT, 2018). Together these Marine Protected Areas provides means for managing coastal and marine resources as well as providing sustainable development (Akwilapo, 2007). These sites help to reduce detrimental effects in fish populations caused by overfishing (Hamilton, 2012). Lester and Halpern (2008) showed that density of organisms within Marine Protected Areas is greater than the density in non-protected areas. MPAs have been effective in managing the resources due to presence of regulations and management procedures (Machumu and Yakupitiyage, 2013). Majority of communities surrounding

MPAs (TACMP, MBREMP and MIMP) are aware of the regulations and comply with them. These regulations have a big impact on fishers' access to marine resources (Mwaipopo, 2008).

2.2 Influence of coral reefs on the fish community

Coral reefs are the major fishing grounds and tourist attractions in Tanzania, that contribute positively to the economy and ecosystem functions (Wagner, 2007). The reefs provide resources for many coastal communities for example building materials (Yahya, 2011). Coral reef fisheries yield at least 6 million metric catches in the world annually (Mcclanahan, 2014). There is high abundance, biomass and diversity of fish are in reef sites than in non-reef sites (Vincent *et al*., 2011). This is because coral reefs act as their nursery and breeding grounds, thus any change in the coral reefs will alter the fish community (Yahya, 2011).

Coral reefs have been observed to be the most vulnerable ecosystems (Guldberg, 1999). Many coral reefs have changed due to a significant increase in human disturbances and natural stressors (Harborne *et al.,* 2016). Substantial destructive impacts from dynamite fishing have been observed in coral reef communities (Wagner, 2007). Marine Protected Areas have been developed worldwide to protect the coral reef communities from human pressure (Vincent *et al*., 2011). In Tanzania, there are fringing and patch reefs along two thirds (600 km) of the narrow continental shelf. These reefs face great damage from sediments runoff from agriculture and coastal development. Until recently, there was little capacity for marine research and management in the region (Salm *et al*., 1998). Thus coral reef monitoring require more research to ensure their successful management (Muhando, 2009).

2.3 Fish growth patterns

The length and weight relationship help to provide information on the well-being and growth of fish (Jisr *et al.*, 2018). Estimation of the length and weight relationship helps to compare growth patterns in the management of fisheries (Moutopoulos and Stergiou, 2002, Okgerman, 2005). The length-weight relationship has been determined by the formula $W = a L^b$ Where, W = weight (g), L = total length (centimeters), a = constant (intercept) and b = growth exponent (Thulasitha and Sivashanthini, 2012). The parameter b is applied to assess whether the fish growth is allometric or isometric. The ideal growth exponent is when b value equals three and is termed as isometric growth. In this growth the fish retain their body size and shape and remain unchanged over the lifetime. On the other hand if the b value is less than three the fish become more slender as it increases length. This growth type is termed as negative allometric and if the value of b is greater than three, the growth type is termed as positive allometric where the fish becomes heavier as it increases in length (Blackwell *et al.*, 2000).

Growth types are influenced by habitat conditions, (Mazumder *et al.*, 2016). Marine Protected Areas provide favorable habitat conditions which favor the growth of fish to exhibit positive allometric growth (Cooney *et al.*, 2020). According to Karachle and Stergiou (2011), there is a strong relationship between growth type and habitat types. Differences in growth patterns in fish species might be attributed to variations in habitat conditions (Dewiyant *et al.*, 2020). Further fish exploitation may also influence the growth of fish by reducing the population abundance and altering density of species (Saborido and Kjesbu, 2012). Areas which are heavily exploited, the excessive removal may lead to poor fish growth.

2.4 Fish maturity stages

Maturation refers to the process of becoming sexually matured and capable of reproduction (Domínguez *at al.,* 2017). Gonad maturation in fish is important in monitoring changes in biological characteristics of fish (Williams, 2007) because the process of maturation is mainly influenced by the environment (Thorpe *et al.*, 1998). Maturity in fish is assessed based on the ripeness of gonads. There are various stages profiled by authors in assessing maturity in fish (Burnett, 1989). In this study modified five-point (I-V) maturity scale was used.

As is for growth patterns fish maturation is also influenced by various factors such as food,, Taranger *et al.* (2010) reported that growth is the key factor for initiation of reproductive development. Under favorable conditions with plenty of food, the growth of fish is rapid and mature very fast (Policansky, 1983). Most species of fish mature when they reach 65-80% of their maximum size (Beverton and Holt, 1959). The proportion of mature individuals increase with age and size. Maturation and growth differ among males and females due to variations in physiological adaptations in both sexes (Domínguez *et al.,* 2017). Dynamics in maturation can may affect reproduction success and stability of the population (Cooper *et al.*, 2013).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the study area

This study was conducted in four landing sites in Mtwara and Tanga regions. The two landing sites (Msimbati and Deep Sea) are within marine parks and the remaining two (Shangani and Moa) outside the parks.

Msimbati landing site in Mtwara region is found within the Mnazi Bay Ruvuma Estuary Marine Park (MBREMP) located (-10° 00' 0.0" S and 40° 00' 0" E). The Park is located south of Mtwara town in southern Tanzania, stretching over the last 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 (650km²). 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 constitute this diverse marine ecosystem (Obura, 2004). TFunrther Shangani located at -10° 15' 56.880" S and 40° 11' 4.560" E in the northern part of Mtwara region. It is one of the largest and busiest landing sites located within Msanga Mkuu peninsula in Mtwara.

The third site was Deep sea landing site found within the Tanga Coelacanth Marine (TACMP) Park is 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 km² of which 85 km² are terrestrial and

467 km² are aquatic. The uniqueness of the park includes: 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 dugong, sea turtles, and migratory water- birds (Harrison, 2010).

The Moa unprotected landing sites is located at 4°77′ 0'' S, 39°15′ 0'' E in Mkinga district on the northern side of Tanga region was used. 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 Mkinga coastal line is covered with mangrove stands of considerable density (Harrison, 2010). The selection criteria for sampling sites are based on protection and the accessibility of the areas (Sobo, 2004).

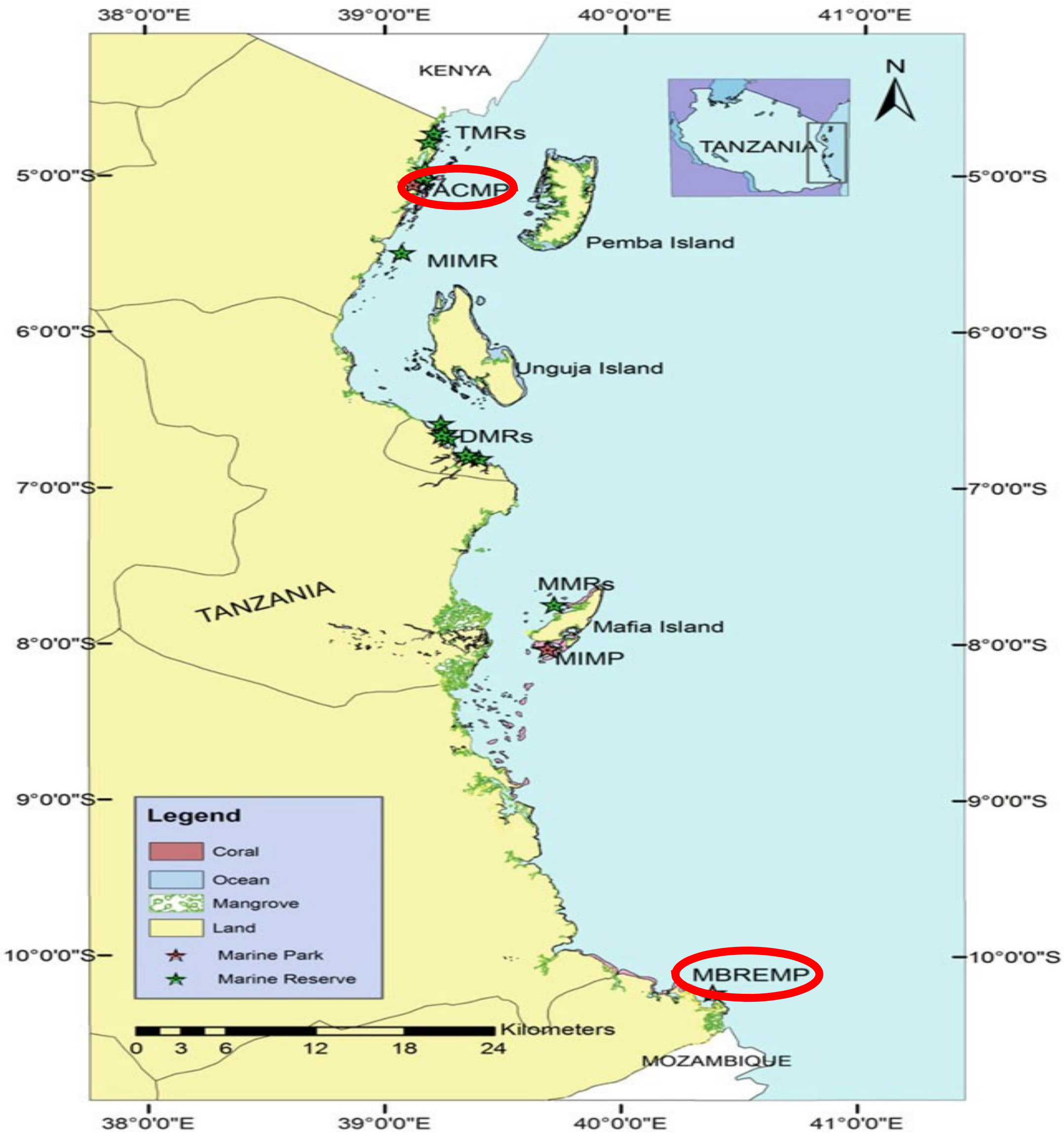


Figure 1: Map showing the location of study sites, red circles show the location of marine parks (Source Mangora *et al.*, 2014)

3.2 Study assumptions and limitations

The following assumptions were made

i. Marine Protected Areas are governed by similar Acts and Policy therefore the management practices within sites are similar.

ii. The marine ecology of the study sites are similar.

The following were the study limitations

i. Data were collected on landing sites and not within the ocean.
ii. Data were collected from fishermen using different fishing gears.
iii. Environmental variables were not collected due to limited time and fund.

3.3 Sampling procedure and data collection

Fish samples were collected for three days per month on landing sites during neap tides. The sampling was conducted during Northern Monsoon period starting October 2019 to February 2020 making a total of 18 fishing trips surveyed per site. A fishing vessel involving 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 hand lines box traps and pull nets (mesh size larger than 2.5 and smaller than 7). Some of the fishing gears were regulated within MPAs, pull nets with mesh size of 2.5 and shark nets were only allowed within 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 book (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 weights of each individual sampled fish were taken using measuring board and weighing balance respectively. Fish maturity stages were assessed on a single selected species (*Lethrinus harak)*, based on the species economic value in the local markets and availability across the coastline of Tanzania. The maturity stages were assessed by visual inspection of gonads after dissecting the fish on its ventral part (Balci and Aktop, 2019). Care was taken not to destroy the gonads. The modified five-point maturity scale (Burnett, 1989) based on the external appearance was used to classify the maturity stage of the gonads. The features used to stage the gonads included, size, shape, and color, volume, and degree of vascularization and opacity in the ovary.

3.4 Statistical analysis

All the statistical analyses were performed in Paleontological Statistics (PAST 4.03). 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 levels so that comparison of the protection status of fishing grounds can 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 growth patterns was plotted on a bar graph to aid visualization. Furthermore, the assessment of the significant difference of the growth patterns between the sites was tested using student's t-test, after confirming normal distribution in the data using Kolmogorov-Smirnov test.

Also Mann-Whitney test was used to compare fish maturity stages between protected and non-protected marine areas. A graph showing fish maturity stages against the sites was plotted to visualize the variation between the protection statuses.

CHAPTER FOUR

4.0 RESULTS

4.1 Abundance and diversity of landed fish

A total of 1548 fishes were examined from 50 species, six hundred and thirty samples were collected from protected and 918 from non-protected areas. In Tanga region, the protected landing sites had a total of 205 individuals sampled from 11 species. In contrast the non-protected landing site had 521 individuals sampled from 18 species. At Mtwara the protected landing site had a total of 415 sampled from 10 species, while the non-protected landing site had a total of 503 individuals sampled from 13 species. Species composition of the catches were variable.

The highest abundance (Figure 2) within protected areas were from; *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 highest abundant fish were, *Lethrinus borbonicus* (21.35% n=196), followed by *Ctenochaetus striatus* (17.32% n=159) and *Scarus niger* (10.46% n=96). There was a significant difference in abundance of species between protected and non-protected areas (Mann-Whitney test, U=815.5 p=0.002).

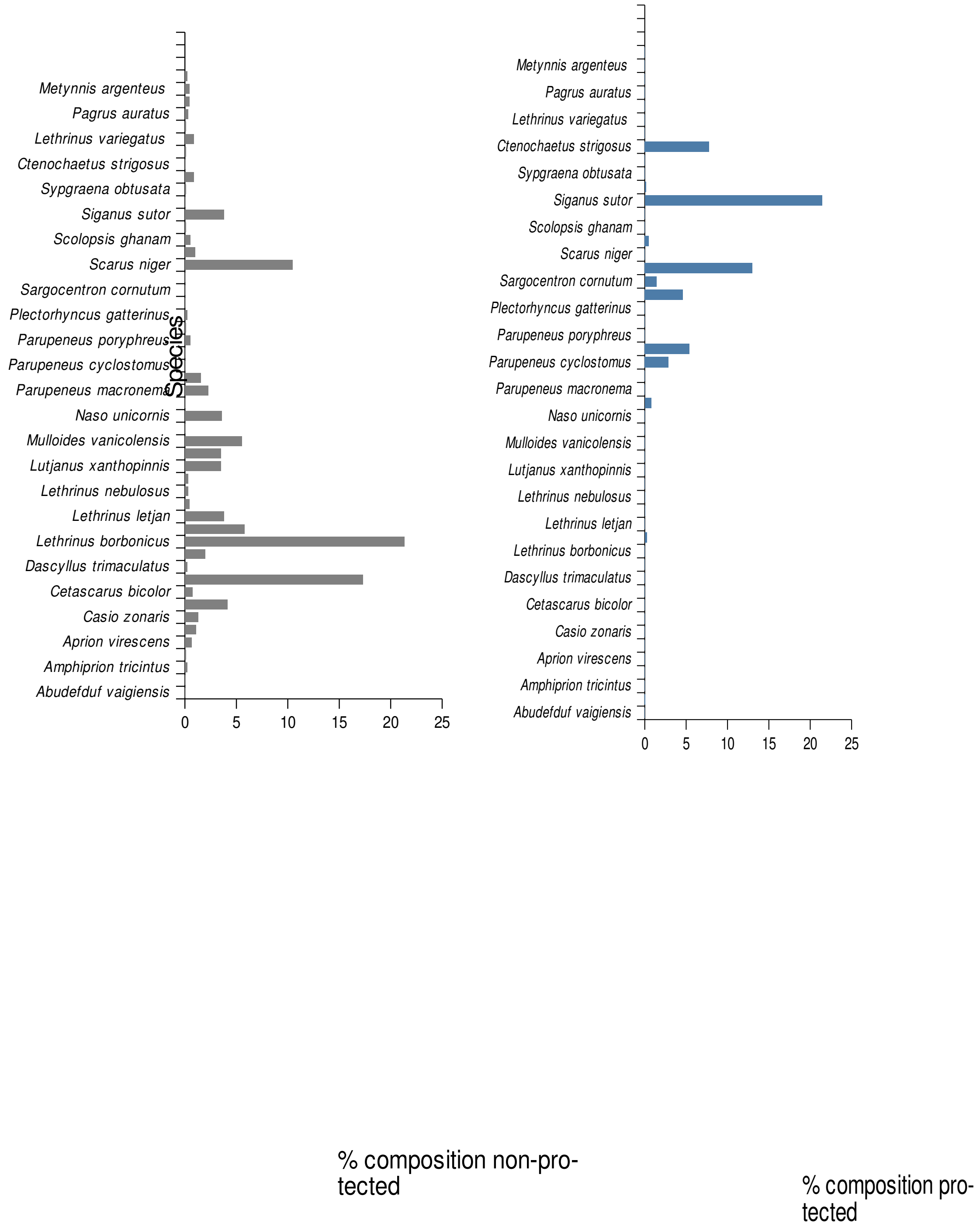


Figure 2: Composition and relative abundance of species in protected and non-protected sites.

The diversity of landed species varied with protection status. In Mtwara the landing site the non-protected area had high species diversity than the protected one (Figure 3). A similar pattern is observed in Tanga region Overall, fish landed from protected areas had lower species diversity than from non-protected sites

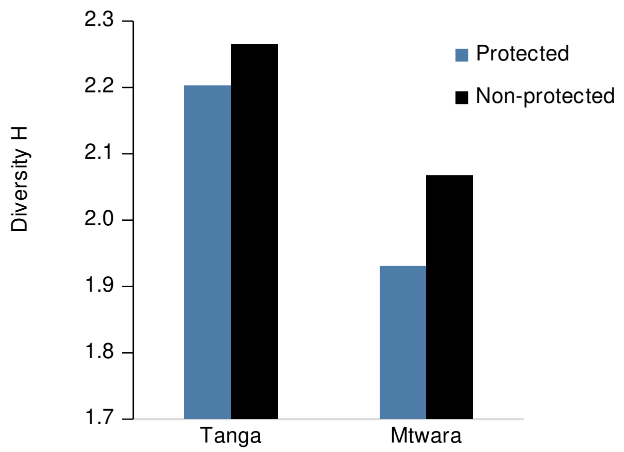


Figure 3: Shannon-diversity index of protected and non-protected areas in Mtwara and Tanga region

4.2 Growth patterns of landed fish

The growth patterns of collected samples in relation to protection status were analyzed allometrically. The majority (63.24%) species sampled exhibited a negative allometric growth form (Figure 4). The percentage of growth types of fish landed from protected areas are 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. There was no significant differences in the counts' growth patterns within protected areas of Tanga and Mtwara region ($p=0.795$).

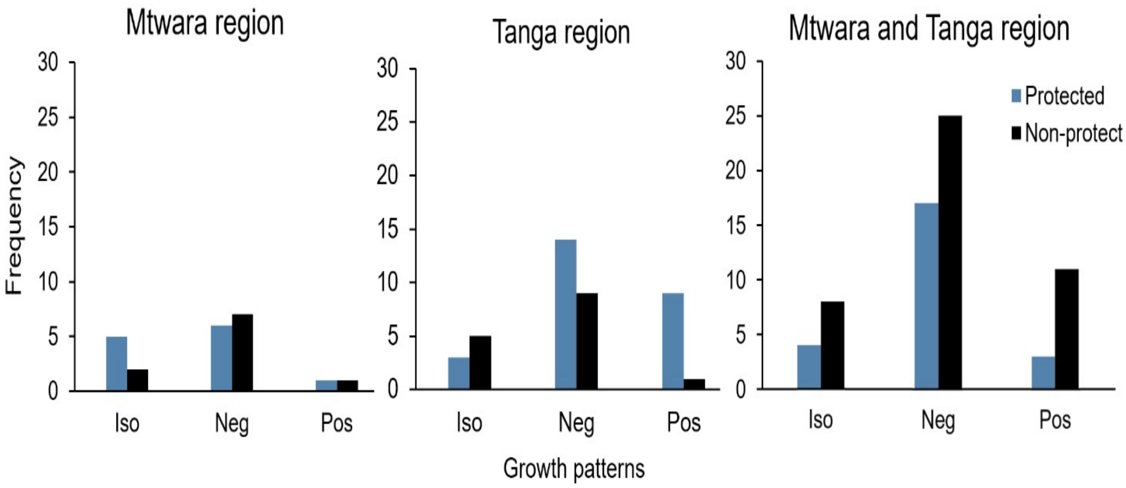
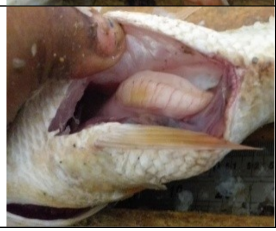

Mtwara region
Tanga region
Mtwara and Tanga region
Frequency
30
25
20
15
10
5
0
Iso
Neg
Pos
Growth patterns
Protected
Non-protect

Figure 4: Frequency (%) of growth patterns in different regions. Isometric (Iso), Negative allometric (Neg), Positive allometric (Pos) (p=0.795).

4.3 Maturity status

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

Table 1: Fish maturity stages and their descriptions

Maturity stage	Criteria		Description
	Male	Female	
I (Immature)			**Males:** testes very small and undeveloped; pinkish color **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 mayor may not be present in small amounts **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 **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 **Females:** The ovaries are flaccid, shrinked and sac-like reduced in volume and have a dull colour. The vascular supply is reduced

In Tanga region, the landing site within the protected area had a total of 59*Lethrinus harak* . Among them 25 were males and 35 were females. Further, in non-protected landing sites none were collected since the fish arrived with their gut contents removed at the ocean. In the Mtwara region the landing site within the protected area had a total of 107 individuals collected, 42 were males and 65 were females. In non-protected landing site, there was 49 individuals collected, 28 were males and 21 females. Generally, there was a significant difference in fish maturity stages (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 male sex between the sites (Mann-Whitney, U=4, p=0.09). Further, there was a high female population size on landing sites within protected (59.88%, n=100) and lower in non-protected areas (40.12% n=21) waters (Fig. 5).

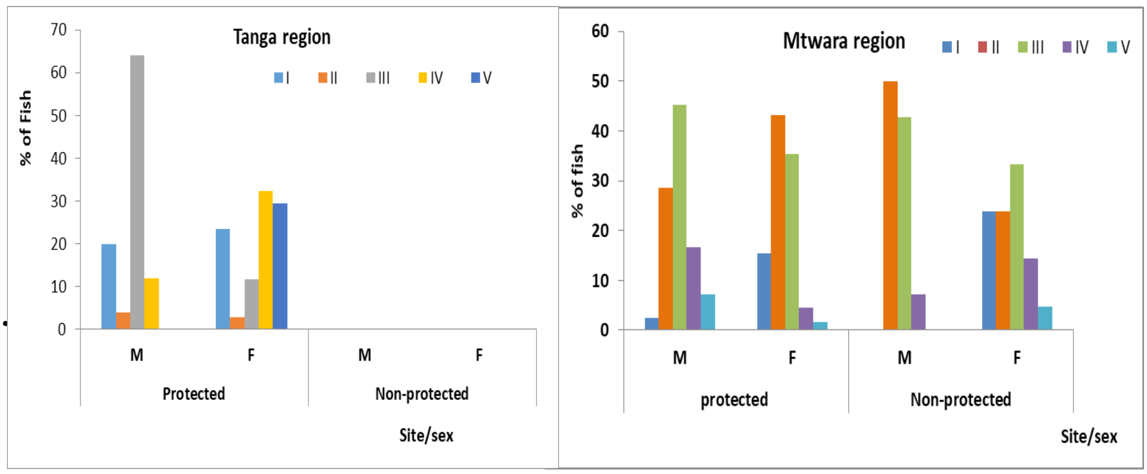


Figure 5: Maturity stages of Lethrinus harak in protected and non-protected sites from Tanga and Mtwara. Fish maturity stages: immature (I); developing (II); maturing (III); ripe (IV) and spent (V). Fish sex: Male (M) and Female (F)

CHAPTER FIVE

5.0 DISCUSSION

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 are limited to using gears which are very selective; therefore obtain small catches compared to the landing sites outside marine parks where there are less restrictions (Katikiro, 2018). Various studies have indicated the higher fish diversity in Marine Protected Areas than non-protected areas (Sarkar *et al.,* 2013, Sweke *et al.,* 2013 and Aller *et al.,* 2017). These studies contradict with the findings reported in this study from other landing sites. The difference could be due to different research approach used where by these studies collected data from fishing zones while in the current study data were collected on the shore. Further, the variation observed in the current study and other studies could be due to by differences in the management of the resources (Sweke *et al*., 2013). Restrictions on extractive activities within Marine Protected Areas could limit the number of catches, which determined the sample size. Inadequacy of conservation efforts in many tropical protected areas can also be a factor for low diversity, this reveal deficiencies in management practices (Oberosler *et al*., 2020) The lower species abundance and diversity within protected areas could also be an 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 wellbeing and growth of fish (Goñi *et al.,* 2018). The study indicates that both landing sites irrespective of their protection status have majority of reef fishes exhibiting negative allometric growth. However, the high percentage of negative allometric growth within non-protected areas could be an indicator of overfishing and unregulated fishing activities (Goñi *et al.*, 2011). The rapid increase in catches on landing sites and non-proportional fish growths could be a clear evidence of overfishing (Hoof and Klaan, 2017). Unrestricted fishing activities in non-protected marine areas may create disturbances which may interfere with the 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 favors fish growth rate, thus negative allometric growth observed in the majority of species could be influenced by overfishing. Protected areas had few numbers of species exhibiting negative allometric growth. This may be linked to fishing regulations. The restrictions within protected areas help to create less disturbed environments for fish growth. Thus proportional growth is expected to be higher within protected areas. A significantly lower number of negative allometric growth in protected areas may indicate reduced disturbances which may influence proportional fish growth (Magnussen, 2007). Experiences with MPAs show that limitations of fishing efforts helps the fish stocks to recover. Thus restrictions within protected areas may have helped the fish to 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 stock. The high percentage of matured females observed on the landing sites within protected areas may indicate limited fishing pressure on fishing grounds 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 centimeters in Females (Badr *et al.,* 2019), which may considerably increase under such favourable environment. The high number of mature females within protected areas could be linked to their large sizes. MPAs regulate the type of gears (gill nets), which enables catching large legally sized fish (Sweke *at al.*, 2016). Due to restriction on type of gears and frequent patrols conducted by park management, only large-sized fish were caught, which in this study was dominated by females.

Furthermore, the higher female to male sex ratio increases the fertilization success and productivity (Maskill *et al.,* 2017). The high percent of matured females within protected areas may indicate healthier productivity in the fish community. While the lower number of matured fish in non-protected areas could detail unregulated fishing pressure and a lower rate of productivity.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

Based on the study findings on the patterns of fish communities in protected and non-protected marine areas the following conclusions were made. The lower fish abundance, diversity and the high number of matured females observed on landing sites within protected areas may indicate minimum extraction activities. This could imply that MPAs played a great role in controlling people's behavior towards the extraction of marine resources. The amounts of catches on landing sites correspond with the efforts applied by fishermen. However having low abundance and diversity on landing sites in protected areas may also indicate the deficiencies in management practices taken by park management. Therefore sufficient enforcements such as frequent patrols within the parks is recommended to ensure the fishermen adhere to the regulations.

The high percentage of negative allometric growth observed within non-protected areas could be influenced by disturbances from unregulated fishing pressure. Unregulated fishing pressure may interfere with the growth and maturation of fish in non-protected areas. This may lead to a higher number of species growing non-proportionally. Thus more regulatory strategies of fishing in the open waters to allow for more time for the fish to attain the appropriate size and to ensure the effective protection of marine resources. Further studies with controlled and relevant environmental indicators are recommended to determine to what extent MPAs management activities contributes in protection of fish communities.

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