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ABCDs of Triggerfish in Pemba and Misali Island: Abundance, Biodiversity, Behaviour, Cultural Significance and Distribution

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SIT Study Abroad

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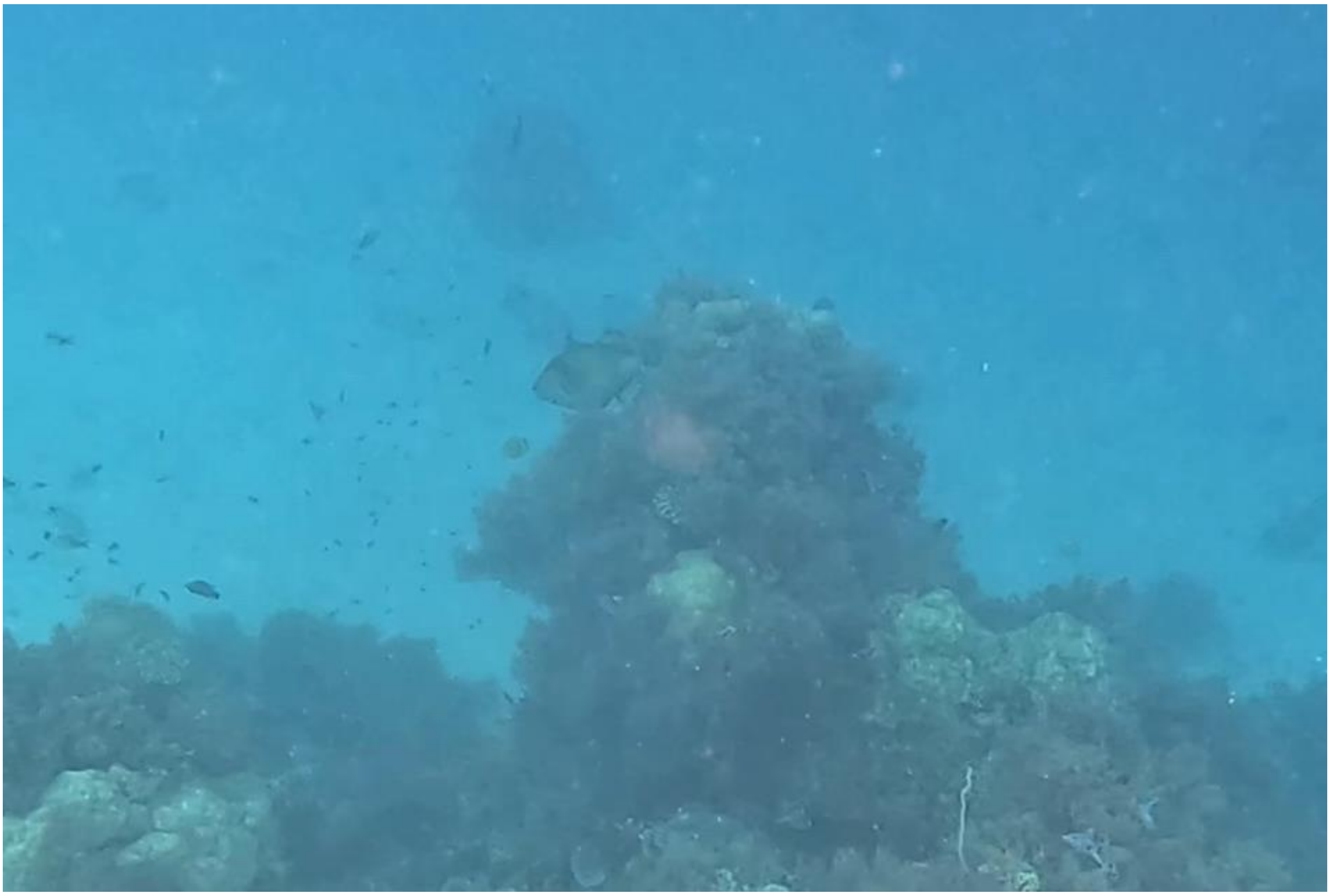

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Ad Majorem Dei Gloriam, for the greater glory of God.

ABSTRACT

This study takes a socioecological approach to understanding triggerfish (Balistidae) in Pemba Island, using Misali Island reefs as a sample ecological site. Two reef sites on Misali Island and three of four districts in Pemba were observed during the study. The abundance of *Balistipus undulatus* at one of two study sites is close to the maximum carrying capacity of the reef. Overall observed biodiversity was low. Behavioural trends point to distinct species specific defence strategies and species aggression taking different forms. Triggerfishes cultural significance was primarily as a food fish, though it is not highly sought after. With polarised responses for both catch and as a food, the fishery pressure on them was assessed to be moderate. Balistidae abundance, especially *B. undulatus* could be a good reef health and fishery monitoring metric. This study samples triggerfish ecology, finding interactions and samples which produce a holistic idea of triggerfish in Pemba.

DHAHANIA

Utafiti huu mdogo ulitumia mbinu za sosiologia kuwafahamu Samaki aina ya Kikande (Balistidae) katika kisiwa cha Pemba, katika miamba ya kisiwa cha Misali kama eneo la kiikologia katika kukusanya. Maeneo mawili ya miamba katika kisiwa cha Misali na Pamoja na Wilaya nne katika kisiwa cha Pemba yaliwezwa kuchunguzwa katika utafiti huu. Wigi wa jamii ya Samaki aina "*Balistipus undulatus*" katika moja ya maeneo mawili ya utafiti huu karibu na uwezo wa kubeba katika mwamba Kwa ujumla bioanuawai ilikuwa chini. Tabia tofauti katika spishii za aina tofauti zikuwa ni kujihami na kuchokza. Kikande katika utamaduni ni muhimu kimsingi kwa ajili ya chakula, kwa kiasi kikubwa haitafutwi. Wanavuliwa kwa kwa ajili ya chakula, uvuvi wake sio mkubwa bali ni wastani. Wingi wa Balistidae, (*B. undulatus*) Unamaanisha mwamba huo ni wenye afya na mazingia bora ya baharini na kipimo cha uvuvi. Sapli za utafiti wa kikande, ulionyesha maingiliano na sampuli za ujumla, wa Samaki wa aina ya kikande katika kisiwa cha Pemba.

Introduction

Triggerfish (Swahili, henceforth italicized: *kande*) are a vibrant reef fish from the family Balistidae. Known for their balistiform swimming pattern where their side fins are used to propel their body through the water to their territorial nature which has led to diving injury mishaps when they use their sharp teeth. Balistidae are a diverse family of fish that span from coral reefs to open pelagic waters distributed across the Indian, Atlantic and Pacific Oceans. Currently comprising 37 species, they occupy different ecological niches, with different colourations, diets and behaviours.

This study takes a socioecological approach to understanding triggerfishes in the Western Indian Ocean, specifically in the Pemba Island region and on Misali Islands coral reefs. Specifically, what are triggerfish in the socio-ecological context in Pemba? Combining natural science and social science data, this study gains insight to both triggerfishes in their natural habitat and human interactions with them. By linking scientific knowledge with the triggerfishes roles in coastal communities, the study addresses current knowledge gaps in abundance, biodiversity, distribution and behaviour that links current and historical community interactions with them. This multifaceted study expands knowledge on triggerfishes' natural biology and ecology, and how humans interact with them.

Documenting and understanding marine species in tandem with linking them to human interactions with it is important in broadening our academic understandings of all things marine and cultural, as it looking at species in a cross-disciplinary perspective. It allows academia to extend knowledge past disciplinary lines and instead look at subjects more holistically. In addition, marine topics in coastal Eastern Africa are salient – there are many gaps in academic understandings ecologically and culturally. This study takes on a specific triggerfish shaped gap.

Background

This study was conducted in the Pemba Island region, documenting human-triggerfish relationships in Pemba and specifically ecological analysis from Misali Island, an island within the Pemba Island region. All research occurred between 8th April to 3rd May 2023, during the long rainy season (*masika)* and spanned across Ramadan and Eid. These are seasonal and religious occurrences that resulted in changes in weather and human behaviour.

Location

Pemba Island is located within the Zanzibar Island Archipelago, off mainland Tanzania in East Africa. It is the bigger of the two main islands in the Archipelago (the other being Unguja Island) and is relatively less developed; especially in terms of economy, infrastructure and tourism. It has a population of 543,441 people (Tanzania National Bureau of Statistics 2022), with much of its population in rural settlement dependent on the natural environment for subsistence. Pemba Island is divided into four main administrative districts; Mkoani, Chake Chake, Wete and Michewani (refer to Figure 1).Located along the tropics, Pemba Island is a biodiversity hotspot for both marine and terrestrial organisms. Its unique positionality allows its communities access to both extremely fertile land and diverse types of fishing grounds

Pemban communities have access to deeper water fishing to the east, where the deep Pemba Channel allows catch of bigger pelagic fishes, while the islands and islets host many coral reefs where reef fish communities thrive. These different marine ecosystems provide an essential subsistence source for communities.

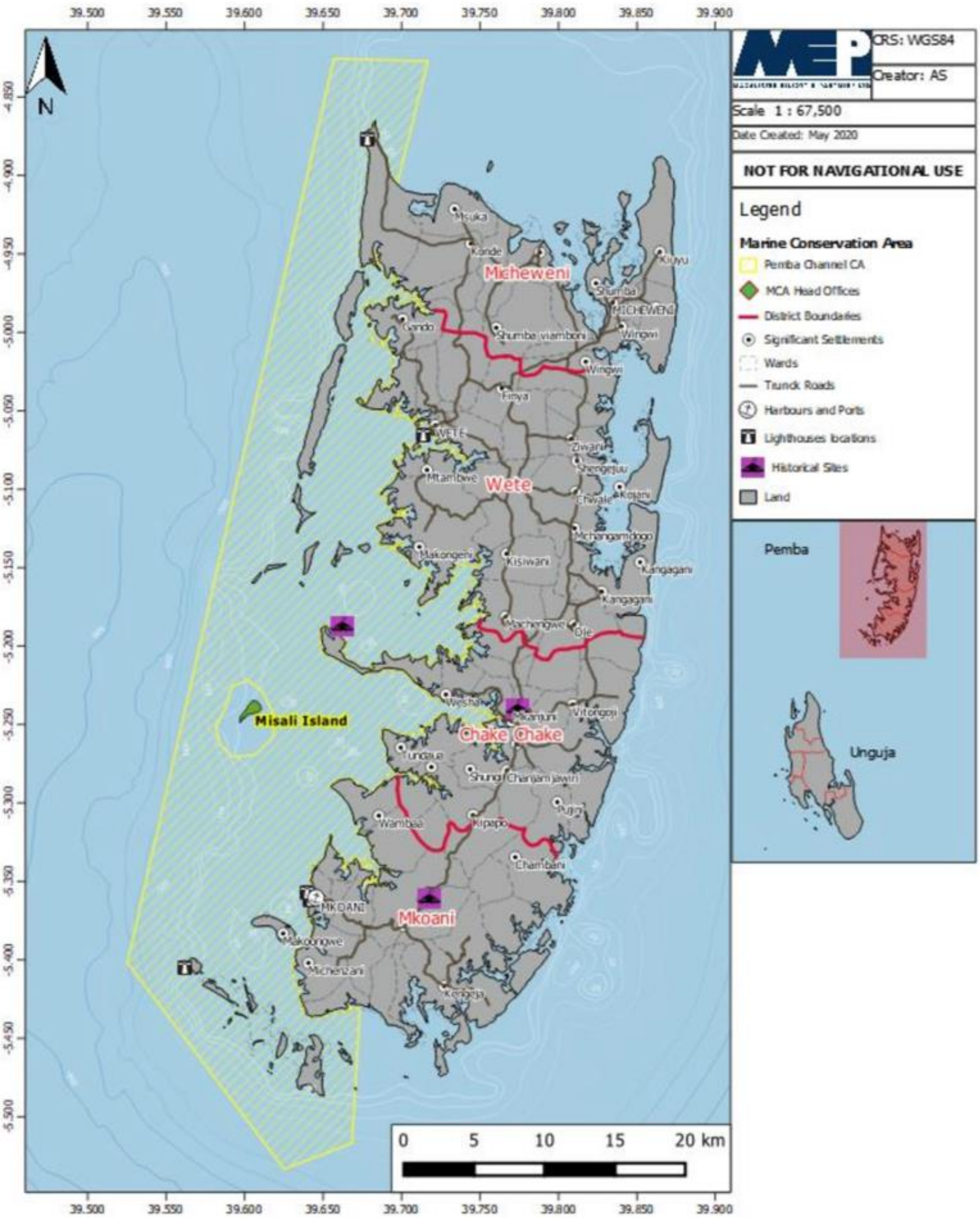

Figure 1: Map of Pemba area with administrative districts and PECCA boundary demarcated (Richmond 2022:7)

The fish network through Pemban communities moves fish from the ocean and through many different people and sites before arriving on a plate. Fishermen catch their fish from the ocean, before transporting it on their vessels to the nearest port. Though sometimes ports are a formal landing point, often landing sites consist of at most a cement structure with tables and a weight hook. Often, landing sites are an open beach face where auctioneers gather with fishmongers and fish sellers awaiting the arrival of fish. There can be anywhere between 30 to 70 people present at the landing site, with varying energy and aggressive levels. From the vessel, fishermen hand over their fish, porters and middlemen sometimes help to bring them to auction or else they carry their catch to an auctioneer who then hawks the fish off. The fish is sold, cleaned and transported to its next stop, usually by the nuyer. Most buyers at the landing sites were buying these fish to bring them somewhere else to sell, at Tumbe and Banderini several fishmongers told me they were going to Chake. In a semi-structured interview with the Head of Fishermen of Wete, he told me that people go to Banderini to sell at "Chake Chake, Konde, up to Mkoani and Micheweni" (2 May 2023). Often the next stop is a stall, either on the roadside or in a market. Customers come to the stall to buy fish, these are usually for the home or for a food business. The fish then gets cooked and consumed.

The equipment used at each stage also varies widely. Traditional fishing techniques include using hand lines (*mshipi*), nets (*nyavu*) and traps (*dema*). Cleaning and gutting the fishes typically are done with hand knives or sharp shells, washing the fish with whatever water source is most readily available. Banana leaf baskets and buckets are used to transport the fish, while at the markets wood chopping boards and newspaper are the equipment of choice. The physical spaces through which these fish move through range widely, and the extensive network of people and exchanges that take place create different socioeconomic and socioecological dynamics. These were all observed during study observations and supported by interviewees.

In personal communications with a Fisheries Statistics Officer who had been involved in the Pemban fisheries ministries since 1995, the state level monitoring system was explained (Key informant, 27 April 2023). The Fisheries ministry monitored sample predetermined landing sites for a select 18 species. Monitored landing sites are available in Appendix B. A beach recorder would pick a certain species, recording its weight and price; repeated twice a week. This would be compiled and sent to her by the district fisheries officer. Each of the four districts had one district officer and three beach recorders. However, due to funding issues full staffing was rare, many beach recorders had retired and a gap in data was left in their place.

She described Micheweni as the most productive fishery district, as there were the greatest number of fishermen and vessels, and the fishermen "go far to fish", thus bringing in bigger and more fish. However, she pointed out that Micheweni only had 1 recorder, thus on paper it would not look like the most productive region. She told me that Chake mostly fishes sardines (*daga*), and that Wete and Mkoani would look the most productive on paper because they had more recorders.

In terms of species' economic importance, she pointed out kingfish (*changu*) would average 7000Tsh per kilogram, whereas sting rays (*taa*) and sharks (*papa*) would average 2000 to 5000Tsh per kilogram. When asked if size was the deciding factor in price, she pointed out the difference between big species like shark versus tuna or tuna-like species (*joddari/sehewa*); people much preferred tuna and tuna-like species and this was reflected in the prices of these fish.

Misali Island is a 0.9km/sq island located 8am west from Chake Chake, Pemba Island. It is known to be one of the last two historically well-protected reefs in the Zanzibar

Archipelago that have managed to maintain relatively high levels of diversity and abundance. This makes it an appropriate choice for a baseline study of triggerfish abundance, biodiversity, behaviour and distribution. Its proximity to main Pemba Island also allowed researchers accessibility to study triggerfish significance to Pemban communities.

Misali Island is well known to Pemban fishing communities in its vicinity for it abundant reefs, which have been attributed to many factors, such as its long-term protection and unique oceanographic features that insulate it from the more devastating effects of climate change. With the 500m deep Pemba Channel to the west and Pemba Island to the east, reefs are insulated by the cold East African Current that flows through the channel. This current brings in substantial amounts of upwelling, keeping the reefs cool and allowing for circulation of nutrients from deeper water to higher in the water column. Misali's reef, itself, follows the shape of the island, with wide shallow areas of less than 5.5m both to its east and west (Richmond and Mohammed 2001). Slopes off of the east side are gradual with a maximum depth of 20-30m while slopes off of the west side drop 500m within 500m off the reef crest (Richmond and Mohammed 2001).

Two sites were chosen on Misali Island for the study, Baobab Beach Reef and Turtle Beach Reef. Baobab Beach Reef (East site) is shallower, with a shallower reef top and reef slope that ends in sandy bottom within 15m in a width of 7m from the surface. In the middle of the transect, the slope curves and the substrate changes from reef slope, to a majority sandy slope with coral outcrops (sandy reef slope) to a completely sandy substrate at the curvature point of the reef. As the curvature lessens, there is a small stretch of sandy reef slope before a full reef slope dominates the remaining transect area. Turtle Beach Reef (West site) is deeper, with the reef top and crest starting around 6-8m from the surface, with a more gradual reef slope which extends beyond visible range from the surface over the reef crest.

The West site had an extremely high live coral coverage, with branching, boulder, brain and table corals present. The East site had more dead corals, with a medium to high live coral coverage. The types of coral present were similar, however certain areas in the transect had more soft coral cover, while the sandy curved section had 10% coral cover at the edges and 0% coral cover in the middle.

A severe bleaching event in 1997-1998 on Misali's reef resulted in a huge change in coral diversity and cover (Jones et al. 2019). This may have shifted triggerfish species composition, distribution and abundance, though specific data is unavailable. Misali's reefs have been protected since 1998 but have undergone somewhat tumultuous management. From a collective community management with the aid of the Non-Governmental Organisation, CARE, the once small Misali Island Marine Conservation Area (MIMCA) was expanded to 1000km squared in 2006 by the Zanzibar government. The new area encompasses the large swath of marine area west of Pemba Island and is now known as Pemba Channel Conservation Area (PECCA), under government management.

Around Misali Island, the west side off of Turtle Beach consists of an undemarcated non-extraction zone, while the rest of the coast allows fishing and extraction of marine resources under certain guidelines. Figure 2 in the Appendices reflects the non-extraction zone. Misali Island has no permanent inhabitants nor infrastructure except the ranger station. Regulars on the island only include the rangers, ephemeral fishermen, and less than a hundred tourists on an annual basis.

Since expanding the protected area, the number of rangers have remained the same and funding has dried up significantly. This has resulted in inadequate patrols in the larger area and on Misali's reefs. Recently, ownership of Misali Island has been sold by the Zanzibar government to a private company, with the current anticipation that a tourist establishment (hotel) will be developed on the island. Thus, studies contributing to recording current environmental status is crucial for creating baseline data for environmental evaluations to hold the development accountable for protecting existing biodiversity.

Triggerfish

Attempting to understand these specific, different facets of triggerfish are salient at this juncture for a variety of reasons. Firstly, triggerfish species' distributions on reefs, behaviours and abundances are poorly understood. Marine organisms and ecosystems are difficult to study due to the difficulties associated with conducting research underwater. As such, academic resources on behaviours, distributions and abundances of triggerfishes are relatively few and tend to be outdated, despite their global diversity and distribution – spanning 37 species in the Indian, Atlantic and Pacific Oceans (Matsuura 2015). Balistidae can be found in shallow reefs to open water columns, with huge range between species colourations, diets, behaviours and geographical spreads. Complete species and family specific information is scarce and last updated a decade ago, likely due to the high barrier to entry in studying marine organisms. Unlike other reef fish, Balistidae have extremely different species taking up different niches in the reef ecosystem, with diet, reproductive strategy and habitat preference varying widely across species.

In the 2017 survey at Misali, the following species were recorded: *Balistapus undulatus* (Orange-striped Triggerfish), *Sufflamen chrysopterum* (Half-moon/Flagtail Triggerfish), *Balistoides viridescens* (Titan Triggerfish), *Sufflamen bursa* (Scythe Triggerfish) and, *Rhinecanthus assasi* (Arabian Triggerfish) (Jones 2017). In 2001, other triggerfish species have been documented in the reef such as *Sufflamen albicadatus* (Bluethroat Triggerfish) and *Rhinecanthus aculeatus* (Picasso Triggerfish) (Richmond and Mohammed 2001). Generally, studies on Misali have documented the presence of Balistadae primarily in the extraction zones of the reef (Jones et. al. 2019, Daniels et. al. 2003). These species are thought to prefer reef slopes with depths of 50m (Matsuura 2015). Distribution studies separating data from extraction zones and non-extraction zones will also contribute to understanding this discrepancy. General observations suggest that bigger fish are harvested, thus an anthropogenic pressure has changed the species composition across zones. This does not explain why triggerfish – which tend to be larger reef fish, would therefore be present in the extraction zones.

Behavioural studies include many different aspects including but not limited to feeding behaviours, aggregation and reproduction strategies. In terms of diet, triggerfish species diet range from plankton and algae to invertivores including predation of sea urchins, small crustaceans and molluscs. The presence of certain species can therefore be used as a good indicator for the presence of their prey species. *B. viridescens* and *B. undulatus* in particular are known to eat sea urchins, an overabundance of which is associated with overfishing and or eutrophication (Mclanahan 2000). A consistent, balanced number of individuals would indicate a healthy reef. Triggerfishes have also been documented causing feeding aggregation on the reef, with other species following them and consuming discards (mit Drückerfischen & Moosleitner 2010). Species that have displayed these tendencies include *B.undulatus, B. viridescens* and *S. chrysopterum* (mit Drückerfischen & Moosleitner 2010). Schooling behaviour is commonly observed in *Odonus niger*, the Red-toothed Triggerfish, however, most other triggerfishes are mainly solitary.

Another common behaviour triggerfish are known to display is aggression, especially males that are guarding nests on sandy sea floors located at the bottom of reef slopes. Both *B. undulatus* and *B. viridescens* are known to display these behaviours, going as far as to bite divers which have strayed too close. Territorial behaviours in other species of triggerfish are not as well documented. Defence strategies for small to medium species include darting into the crevices of reefs, thought to be associated with predator avoidance. Triggerfish aggression is closely linked to their reproductive strategies. Parents guard their nests, chasing conspecifics and other fishes away (Fricke 1980). Most species make raised nests in sandy bottoms, guarding it and adhering their eggs to the sandy substrate (Fricke 1980).

There is a lack of academic understanding and documentation of triggerfish significance in human culture. It is thought that triggerfishes in the Zanzibar Archipelago have been fished out due to their larger size and meatiness as a food fish, however this has not been substantiated before. According to Richmond and Mohammed (2001), triggerfish are commonly caught using hand lines.

Methodology

The methodology section details ecological methods employed on Misali Island and social science methods employed throughout the Pemba region in that order.

Ecological Methods

All underwater data was collected on reefs off of Misali Island between 10th to 21st April 2023. Transects using the Underwater Visual Census (UVC) method were conducted to determine abundance, behaviour, diversity and distribution. In addition, longer behavioural observations were conducted along the West transect site to supplement behavioural data. Researcher visited 2 specific stretches of reef, indicated on the map. All transects were swum in the same sequence, west to east for the East transect and south to north for the West transect. For safety, West transects were conducted with the aid of a boat. In total, 12 swims were conducted. 6 independent transects and 1 independent behavioural observation was done, with the remaining 5 swims being combined transects with select longer behavioural observations recorded.

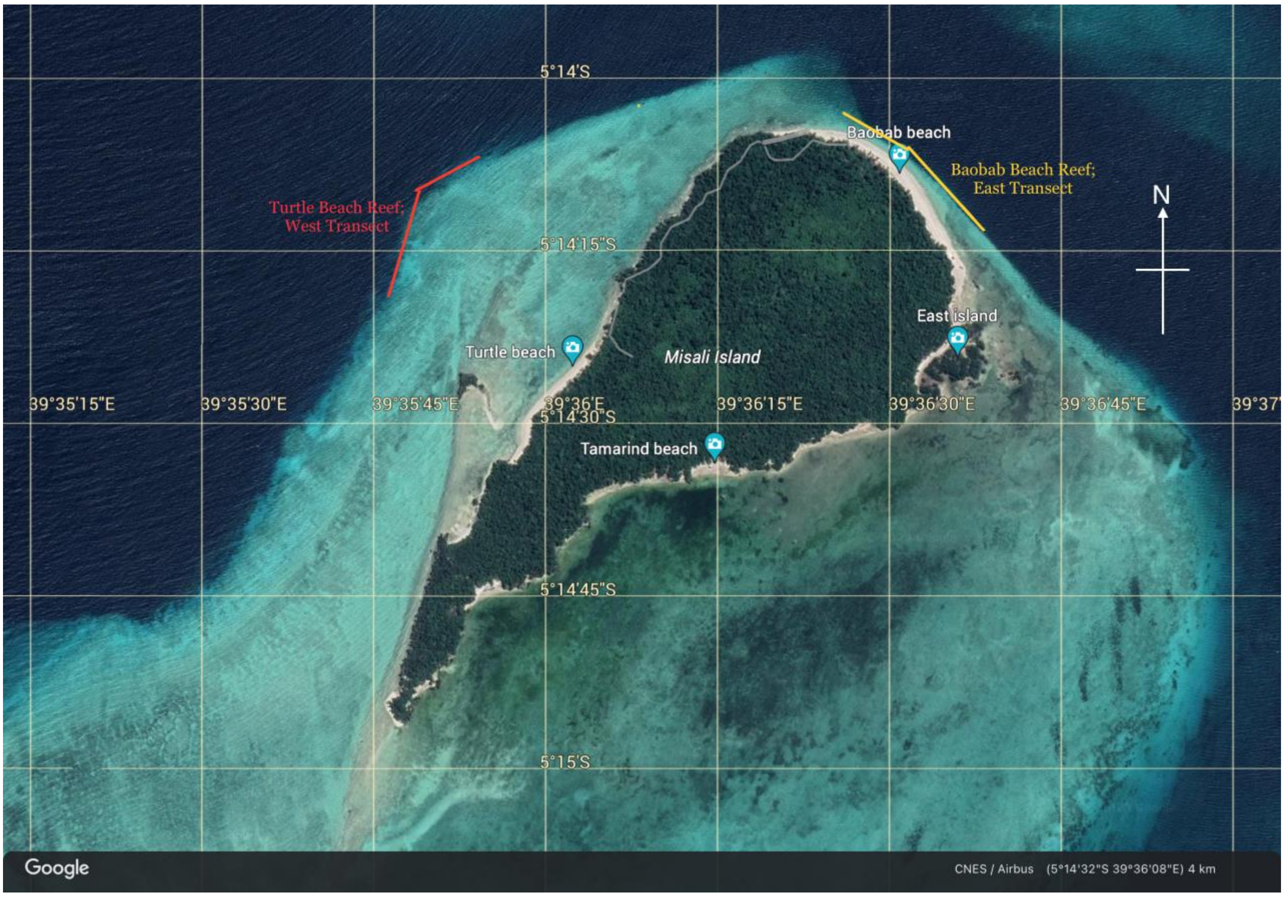

Figure 2: Map of Misali with transect locations marked (Google Earth, accessed 5 May 2023).

A Dolphin Underwater dive book and a pencil was used to record transect and behavioural data, along with an analogue wristwatch for timings. In each transect, species, estimated size, depth, position on reef, time of observation and behaviour at time of observation was recorded. For the additional longer behavioural observations, species, depth, estimated size, estimated distance from fish, time and behaviours were recorded. A GoPro Hero 11 was brought in an underwater case to record unusual behaviours on video. A measuring dive stick was brought to aid the researcher in estimating size in centimetres more accurately. Each swim was done with a buddy for water safety, while wearing a full wetsuit. Diving below the surface was generally avoided to avoid scaring triggerfishes. During behavioural observations, diving would not be done to allow subjects to continue their activities undisturbed by human influence.

Data collected was analysed in Microsoft Excel. Using Google Maps and recorded GPS coordinates, an estimation of transect length was found. Density used definite separate observation of individuals by using only the highest number of individuals per species in one observation per location. Abundance of triggerfish in Misali Island was measured by calculating density of species per metre in the respective transect locations. The Shannon-Weiner Index (H') and the Simpson's Index (*l*) were calculated to determine Balistidae

$$H' = -\sum_{i=1}^{R} p_i \ln p_i \qquad \ell = \frac{\sum_{i=1}^{R} n_i(n_i - 1)}{N(N-1)}$$

biodiversity. Both indices were used to differentiate between biodiversity accounting for rare species and species dominance. Additionally, both definite separate observations of individuals as well as all observations of individuals were used. This was to account for different weightages that rare species had on the index. Behavioural data was processed by categorising behaviour non-exclusively and analysing trends in species, duration and location of these behaviours.

<u>Social Science Methods</u>

To determine human uses and interactions with triggerfish in Pemba Island region, 2 different methodology was used. First, certain fish markets were identified based on accessibility and size. These were then visited and observed for 1 to 2 hours, depending on the size and activity. Observations were made of the processes involved with the processing and sale of fishes at these sites, specifically the people, fish, money and environment involved in the process. Secondly, structured interviews were conducted with different stakeholders involved in the fisheries sector. Interviews focused on determining; 1. the scope and role of the interviewee in the fisheries industry, 2. the knowledge the interviewee had of triggerfishes through their work and personal lives. A one hour long semi-structured interview was also conducted with a statistics fisheries officer. Sample interview questions are provided in Appendix A.

Results

The following sections address ecological and social results separately. Ecological results first go over overall observations before moving through results on abundance, distribution, biodiversity and behaviour.

Ecological Results

A total of 11 transects were done, 7 on the Baobab Beach Reef East (henceforth; East site) and 4 on the Turtle Beach Reef West (henceforth; West site). There was a total of 143 triggerfish observed through the 656 minutes spent in the field. On average, 13 individuals were recorded per transect, with each transect averaging 54minutes and 40 seconds. Transects were conducted in mid and low tides for safety reasons. Brightness was maximised by going out during the best weather conditions for visibility, however due to the rainy season this was not always possible. Refer to Appendix C for an overview of transects.

The three main species that were observed were *B. undulatus, S. chrysopterum* and *B. viridescens,* in order of the greatest number of sightings. Overall abundance was found to be relatively high, with higher abundance of Balistidae found on the East site. Distribution data showed differences across species and sites, with certain species preferring certain habitats while others preferred a certain depth. Biodiversity results showed variation because of the different evenness of species in East versus West versus Overall. Overall, generally low Balistidae diversity was observed. There were two sets of behavioural results: one for initial observed behaviour and one for longer behavioural observations. The majority of initial observed behaviour was of individuals swimming or hiding. Majority of interaction behaviours were by immature *B. undulatus* individuals. Of the longer behavioural observations, movement was also the primary observed behaviour, followed by feeding, then hiding. In terms of aggression, very different levels and forms were observed across species.

Abundance

Generally, all results found higher *B. undulatus* concentration in the East site compared to the West site. Overall, Balistidae density was 5.74 individuals per 100m length of transect. All calculations used individuals per 100m length of transect, and assuming the observed transect width was minimally 5m, all these data are comparable to individuals per 500m squared. Overall Balistidae density was 6.25 in the East and 5.24. The density by species found the following; *B. undulatus* was 4.25 East versus 3.57 West, *B. viridescens* had densities of 0.5 East versus 0.24 West, and *S. chrysopterum* had 0.75 East versus 0.48 West. The mean observed Balistidae size was 14.87cm. The mean observed size of *B. undulatus* was 14.91cm in the East and 13.37cm in the West, difference of 1.54cm; while the ratio of mature (more than 10cm) to immature individuals (10 cm and under) was 2.68:1 for West and 2.45:1 for East, 0.23 difference. Refer to Appendix D for full data.

Distribution on reefs

Habitat preferences were categorised based on location due to the variation of the substrate and habitat distribution in the sites. As mentioned in the Background section, East and West sites differed in depth and bathymetry – East had a shallow reef top and slope with a sandy bottom within 15m depth and 7m from crest to bottom. It also had a sandy slope in the middle of the transect. West was deeper, with reef top and crest around 6-8m and a gradual reef slope beyond visible range.

In the West site, *B. undulatus* was found with a relatively equal spread across reef slope and crest, with slight preference for the reef top. In the East site, *B. undulatus* was primarily observed on the reef slope. *S. chrysopterum* was usually observed at the same place in the East transect, along the sandy reef slope before the sandy curve. *B. viridescens* was usually observed in the last third of the transect, at the bottom of the reef slope over sandy bottoms or in the open water column. All sightings of *B. viridescens* ranged between 10 to 15m in depth, while *B. undulatus* sightings ranged between 3 to 12m. *S. chrysopterum* were all observed within 3 to 8m. Refer to Appendix E for raw data and summaries.

Biodiversity

Using the Shannon-Wiener's Index and the Simpson's Index, diversity was calculated for the respective locations for both maximum number of independent observations per site and for all observations of all species. This allows for comparison of diversity with and without the weightage of species that were only sighted once, and thus for species dominance. There was great discrepancy found between the two calculation methods; thus Table 1 is included.

Table 1. Balistidae diversity by location.

Location	**ShannonWiener (max. obs. per site)**	**Simpsons (max. obs. per site)**	**ShannonWiener (all obs.)**	**Simpsons (all obs.)**
East	0.973	0.477	0.604	0.702
West	0.930	0.485	0.590	0.711
Overall	1.060	0.704	0.640	0.724

The observed dominant species was *B. undulatus* comprising 66.67% of observations, *S. chrysopterum* being 11.11%, and *B. viridescens* 6.67%, with 15.55% comprising other species.

Behaviour

During transects, initial behaviour of observed individuals was recorded. A total of 136 individuals' behaviours were recorded.

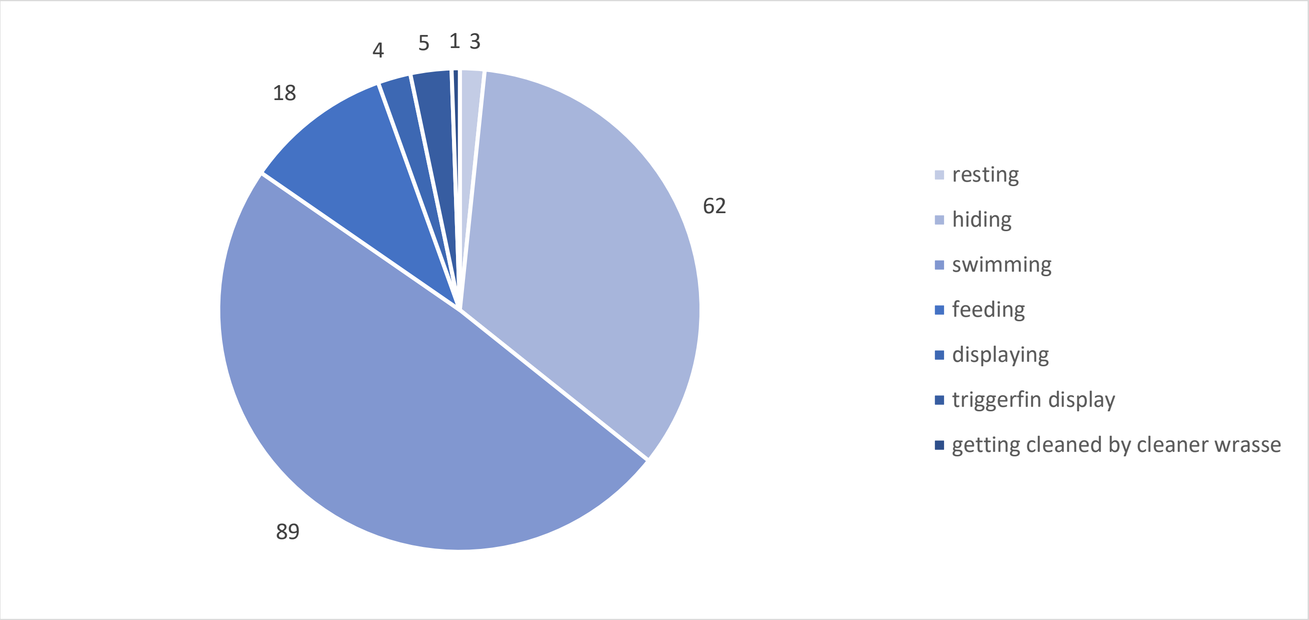

Figure 1. Initial behavioural observations of Balistidae

This data was analysed by categorising behaviour into Active/Passive; 114 active behaviours and 21 passive behaviours. A total of 27 individuals were observed interacting, of which 4 were *O. niger* schooling and the remaining 23 interaction were *B. undulatus*. Of the 23, 14 were conspecific interactions, including 4 pairs of chasing/being chased, and a pair of a mature and immature individual feeding on the same urchin. The remaining observations comprised of 5 interspecies interactions such as being cleaned by wrasse (2 counts) and chasing or being chased by other reef fish, and 6 aggregation behaviours. All but one of aggregation behaviours were by juvenile or immature individuals.

Feeding, aggressive/defensive behaviour and displaying were also analysed. 18 observations of feeding were recorded, 9 of *B. undulatus*, 7 of *S. chrysopterum* and 2 of *B. viridescens*. *S. chrysopterum* was usually observed biting at logs or sand, while *B. undulatus* was usually observed biting at corals or urchins. *B. viridescens* was usually observed biting coral.

Behaviours that included chasing or triggerfin displays at another individual were considered aggressive, defensive behaviours included hiding, circling an area or being chased by another individual. A total of 12 aggressive behaviours were identified, 10 by *B. undulatus* and 2 by *S. chrysopterum.* The former was mainly observed chasing, while the latter was mainly observed displaying its triggerfin. 48 defensive behaviours were identified, of which 46 were by *B. undulatus* and the remaining 2 were by *S. chrysopterum.* Most comprised of swimming into corals or rocks to hide or being chased. Display behaviours were observed thrice by *S. chrysopterum* at the same location, a display of its side fins fluttering as it swam while rotating on its base fin. The display of triggerfin was recorded 5 times; 3 by *B. undulatus*, once each by *S. chrysopterum* and the unidentified triggerfish species.

Twenty-nine longer behavioural observations were made of *B. undulatus, B. viridescens* and *S. chrysopterum,* ranging between 1 to 10 minutes in duration. 105 minutes of observations were recorded. These were made opportunistically during select timed swims or transects, and when Balistidae individuals did not swim away, hide or when visibility of subject was lost. An overview of longer behavioural observations can be found in Appendix F.

The most common behaviour by occurrence of behaviour observed was movement, where the individual was moving from point to point. After, the next most common behaviour observed was feeding followed by hiding. Notably, the only species observed displaying (rotating and fin fluttering) was *S. chrysopterum*, and this was observed thrice for a total of 4.75 minutes. The same behaviour was also observed during non-behavioural observations of *S. chrsyopterum* at the same location on 3 other occasions. The most common behaviour by length of time observed was movement (52.43 minutes), followed by feeding (30.49 minutes) then hiding (19.23 minutes). All of 3 species were observed in these behaviours. *S. chrsyopterum* was not observed resting, but the only one observed displaying.

It was the most often and totalled the longest time displaying its triggerfin. *S. chrysopterum's* most observed behaviour was feeding (10.75 minutes), followed by movement (6 minutes), then display.

Using a ratio to compare minutes spent hiding versus minutes spent on aggressive behaviours (categorised as aggression or triggerfin display); *B. undulatus* had a ratio of 18.23:4.98, *B. viridescens* 0.5:1 and *S. chrysopterum* 0.5:3.25.

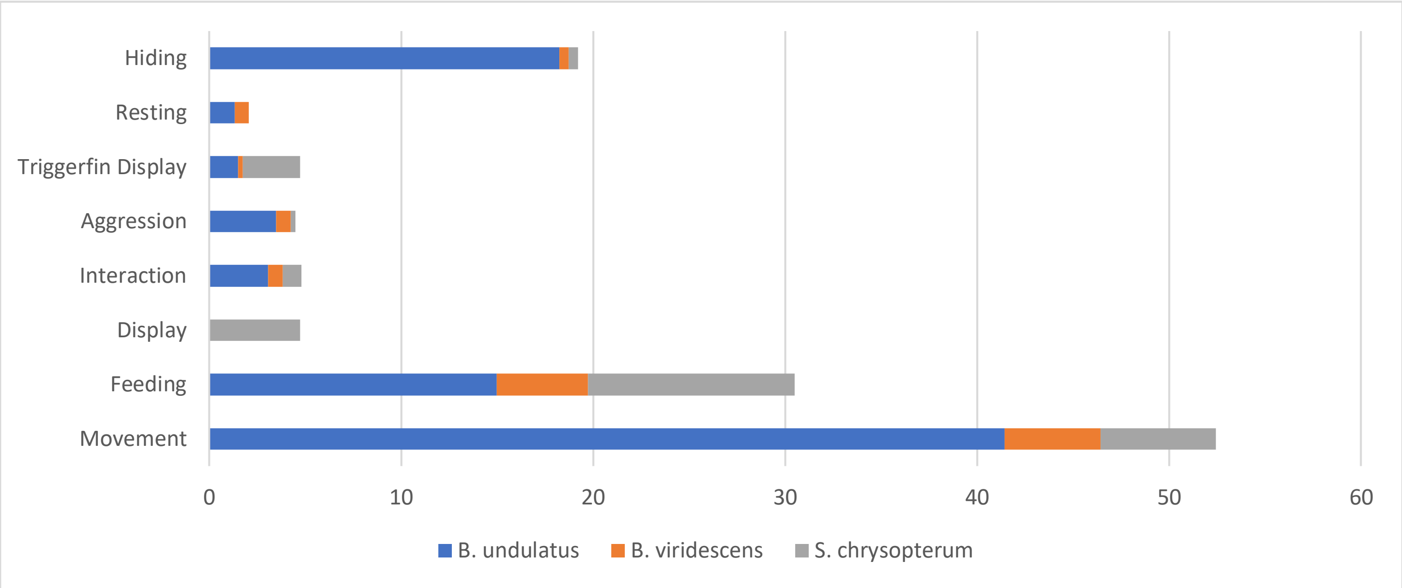

Figure 2: Balistidae behaviours by duration of observation (minutes).

During the longer behavioural observations, 11 out of 14 interspecific interactions by *B. undulatus* were aggressive; either of chasing or triggerfin display. The subject of aggression was not size specific, there were multiple counts of aggression of individuals that were bigger or of a school of fish.

Social Science Results

Observations took place on the 8th, 29th, 30th of April and 1st, 2nd at Mkumbuu landing site, Tumbe landing site, Banderini landing site and a small local fish market in Wete. The observations identified the key participants involved in the movement of fish through Pemba. Figure

Observations

The landing sites that were visited were Mkumbuu (Chake Chake District), Tumbe (Micheweni District) and Banderini (Wete District). Each observation consisted of 2-5 structured or semi-structured interview and 1-2 hours of observation of activities occurring at the site. Notes on people, activity, fish and exchanges were noted.

The types of fish observed at the landing sites varied greatly. Mkumbuu generally had strings of reef fishes, squids, needlefish and octopus. Tumbe mainly had buckets of smaller fish, rabbitfishes and catfishes. Banderini had strings of reef fish, buckets of *uma*, squids, small catfish and small parrotfishes. During auctions, there were no triggerfish observed. However, because some people knew I was looking out for triggerfish, as and when smaller triggerfish where brought in I was brought to see them.

At Mkumbuu, there were 2 small individuals while at Tumbe there was 1 larger individual. There were none observed at Banderini. A small local market in Wete was also observed for a total of one and a half hours, however no triggerfish were observed,

Interviews

A total of 15 structured and semi-structured interviews were conducted with fishermen (12), fish porters (1), auctioneers (1) and fishmongers (3). These interviews took place at Mkumbuu landing site, Misali Island, Tumbe landing site, a local market in Wete and Bandarini landing site between 8th April to 2nd May 2023. All interviews were conducted in Swahili. A translator was only present at Mkumbuu and for a portion in Misali.

All interviewees were male, between the ages of 15 to 67 years of age. Fishermen interviewed had been fishing for between 1 to 40 years. The auctioneer was also the Chairperson of Fishermen in Wete, and his interview was semi-structured with a focus on understanding Banderini's role in the fisheries industry. Fishmongers interviewed all worked in the Wete District, and were between 38 to 65 (est.) years old with 7 to 30 years of work experience.

The fishermen used a range of equipment; these included hand lines (6), ring nets (1), nets (4), drag nets (1), dema traps (4) and spear fishing (1). The boats they used included canoes *mtumbui* (4) with between 2 to 20 people on board, outrigger canoes *galawa* (2) with 3 people on board, or dhow boats *mashua* (2) with 6 people on board. The majority of interviewees fished everyday (8), others reported fishing 21 out of 30 days or every day except Friday. Friday is a holy day dedicated to praying in Islamic culture. The timing of fishing varied depending on the type of fish the fishermen caught, 5 interviews reported fishing in the morning between 6am to 11am, 4 interviewees reported fishing during the night. A fisherman explained that those using dema traps only went out in the day. The places fishermen go to fish varied; those interviewed in the same geographical location tended to visit the same areas.

All fishermen have caught triggerfish before. The interviewees were shown picture of triggerfishes that were prepared and asked to point out species that they had caught. The most commonly caught species was *B. viridescens* and *B. undulatus*. Several interviewees told me the Swahili names for the various species, but this varied based on interview locations. Between locations, fishermen's estimation of the size of *B. undulatus, S. chrysopterum, S. bursa* and *R. assasi* did not vary much. They responded that it was between hand to half their forearm sizes depending on the species. The estimated size of *B. viridescens* varied more, at Mkumbuu, Tumbe and Misali tended to range between 0.5 to 1m. At Banderini, the reported size was 1 to 1.3m.

The reported frequency of catch varied. 3 interviewees stated that they caught triggerfish (usually between one to five smaller ones) everyday, with bigger ones and *B.*

viridescens coming in once a month. 2 interviewees stated that they were usually caught once every 2 to 3 days. Many fishermen added caveats to their reported frequency or instead answered that the location of fishing, weather and method of fishing caused frequency of triggerfish catch to vary greatly.

Initially, the interview included asking the fishermen who triggerfish usually sold to. However, this proved unhelpful as fishermen would answer “to the market” or to the people. The interview was then modified to ask where the fish were typically sold. Most responses cited the landing site or to anyone who wanted to buy them.

The range of prices of triggerfish was relatively consistent. Big ones (*B. viridescens*) sell for between 15000 to 50000Tsh, depending on season, district and size. Seasonality, both weather and cultural seasons change demand for fish and thus their price. Smaller triggerfish typically sell for between 2000 to 15000Tsh, depending on size. Of these, *B. undulatus* typically sells for 10000 to 15000Tsh because of their bigger size.

According to the interviewees, triggerfish are mostly a food fish (though the desirability of it range depending on who you ask). Several respondents cited that it was good in soups. Other uses include using it as a selling fish for economic gain, and the skin is sometimes used as ornamental or a skin exfoliant. The skin is usually removed before selling by the fishermen. During the study period, fishermen I had interviewed previously brought a skinned *B. undulatus* along with 2 smaller triggerfishes. The skinned individual was still breathing and continued to do for 3 to 4 hours after it was brought to me.

The interviews ended with a question on the intentionality of catch, and this question yielded the most variety in terms of answer. For quantification, these responses were divided into 3 categories: wanted to catch, neutral and by-catch. 3 respondents wanted to catch them, 2 were neutral and 3 were by-catches.

The interview with the fish porter, the fishmongers and the auctioneer were mainly from people living and working at Wete, with the exception of the fish porter who was interviewed at Mkumbuu.

All three fishmongers interviewed bought their fish from Banderini (1 was interviewed there, the other 2 were interviewed in Wete, at the market which was a 30 minute walk away). All of them visit Banderini on a daily basis to buy fish. Certain fishmongers tended to prefer bigger fish, while others tended to sell smaller fishes. All three responded that their role included, cleaning, cutting and selling the fish at the market they worked at. 2 of the three interviewees did not buy or sell triggerfish; they attributed this to their personal dislike or perceived that customers disliked triggerfishes. The one fishmonger that did sell triggerfish agreed with other price estimations, 15000Tsh for small ones and 25000Tsh for bigger ones. His estimations of prices agreed with the estimations that fishermen had given.

The interview with the Head of Fishermen in the Wete district was intending to contextualize Banderini in the larger Pemban fish networks. Additionally, he was an ex-fisherman who currently also worked as an auctioneer. He estimated that 700 people visited Banderini on a daily basis. When asked about the scale of purchase, he said that there was a fish that had sold for 1 700 000 Tsh at Banderini. When asked about what types of fish people typically liked, he responded that Pembans eat fish, so “wote!”, meaning all. He then listed, “kure, changu, pono, ngoro, joddari, sehewa, pwesa, ngesi”. He estimated that they would usually cost between 20000 to 25000Tsh for big ones, and 5000 to 12000Tsh for smaller ones. Personally, he likes to eat them with cassava.

The interview with the fisheries officer intended to establish her role in the fisheries department, establish an understanding of the monitoring processes and data collection done and to document her understanding of the fisheries industry as a government official. At the time of the interview she was 51 years old.

When asked about triggerfish, she explained that triggerfishes were not one of the selected species for recording because it was not as common or as desired as the others. Thus, it would be categorised under the Others category on their recording spreadsheets (*Wengineo*). Other species included in this category were crabs (*kaa*) and bivalves (*kombe*). During the interview, she said that triggerfish were almost endangered. When asked how she knew this despite the lack of data collected on it, she said that the fishermen had noticed that triggerfish catches were consistently decreasing overtime, and that during her own site visits before switching departments fishermen themselves would point this out to her. I asked if she noticed the same trend with other predator species such as sharks and rays, but she replied that there were many of those species, but that fishermen had less desire to catch them because of their low economic value.

Discussion

The discussion section will treat ecological and social factors separately first, before drawing them together to offer a comprehensive socio-ecological perspective on the results.

Ecological

The ecological discussion will first comment on overall Balistidae trends, before going through species by species trends.

Balistidae abundance on Misali Island was assessed by comparing the overall density and the density of each species along each transect site. There was a consistent 1 to 2 times difference in species density between East and West, indicating a greater overall abundance at the East location. This agrees with previously done surveys which indicated that Balistidae were more abundant in extraction zones (East) compared to non-extraction zones (West) (Jones et al 2019, Daniels et al 2003). Because of the continuation of this trend through time, it is possible that triggerfishes have a more established, larger population on the East.

The overall Balistidae biodiversity levels at transect sites was relatively low. Comparing the results of all the diversity indices, all methods of calculation find that West site had slightly higher diversity than East. In addition, seven individuals of two different species (one unidentified, the other being *O. niger*) were included in the diversity calculations. Due to the time, visibility and knowledge limitations, the margin for human error in this calculation is high. It does however, support that *B. undulatus* is the dominant species found in these communities.

Balistidae preference for reef habitats of depths between one to 50m as found by Matsuura was generally supported, however further discussion will be offered species by species (2015). Behavioural results showed that Balistidae is a generally very active fish, spending up to 50% of observed time swimming. Though it varied species by species, the general trend of activity aligns with many other mobile reef fishes and especially reinforces the hypothesis that they are protecting a territory which they monitor by patrolling it. Analysis of aggression between species differentiated certain species in terms of territory protection strategies, pointing to either to species or site specific strategies. Diet also ranged from species to species, thus generalising diet is unhelpful in understanding Balistidae ecology.

B. undulatus

B. undulatus was the most observed species by far. It was seen in the highest numbers on both sites, though data suggests a healthier population in the East. Density metrics suggest that the East site is close to maximum carrying capacity for this species, while analysis of depth suggest it is the most adaptable species observed. In addition, the ratios and sizes of individuals uphold historical trends. Generally, *B. undulatus* showed a strong preference for reef habitats across transects within a 9m range. This would suggest that *B. undulatus* may be more adaptable to a range of depths compared to the other species. Behavioural analysis suggest that *B. undualatus* is an anomaly in terms of defensive versus aggressive levels. All these factors could be attributed to higher predation and sexual selection pressures because of their abundance.

According to McClanahan, the estimated maximum carrying capacity of a reef is more than 5 *B. undulatus* individuals/500m squared. With an estimated underwater visual census width of a minimum of 5m, the calculated density metrics of 4.25 East and 3.57 West can be compared to more than 5 (2000). This suggests that the East site reefs have close to the maximum carrying capacity of *B. undulatus* individuals, an indication that protection of reefs has resulted in healthy populations of reef fishes and predator species like *B. undulatus.*

In comparing density matrices between East and West sites, we find a 0.23 difference in ratio of mature to immature individuals and 1.54cm difference in mean size. Assuming that the ideal reproduction rate is a direct replacement rate of 1:1, these metrics suggest more mature and larger individuals present on the East reef with a healthier reproduction rate. This upholds historically recorded distribution of Balistidae on Misali reed (Jones 2019, Daniels 2003).

Strong sexual dimorphism has been observed in *B. undulatus,* and females reproduce from as small as 8.4cm, and finish their eggs by 17cm in length (Matsuura 1976, Longenecker 2017). These factors would suggest that sexual selection pressure in *B. undulatus* would therefore be higher in larger populations. Comparing East and West density metrics, the higher density in the East and the higher mean size could be a result of a higher sexual selection pressure.

Behavioural observations found that *B. undulatus* spent 3.7 times more minutes on defensive behaviour than aggressive behaviour. Linking this to their abundance, this could be due to a higher predatory pressure (both natural and anthropogenic). Observations of feeding found their diet to be generalist; they were observed biting at coral, urchins, sand and a log. Interestingly, one observation was of a much larger individual and a smaller individual feeding on an urchin together. It is possible these were mates, as the larger individual chased another large *B. undualatus* individual away during that observation. It is worth noting that *B. undulatus* was observed being cleaned by cleaner wrasse on multiple occasions, indicating a possible symbiotic relationship. This was the only non-aggressive interaction with another species observed during the study.

B. viridescens

B. viridescens was observed most at a specific area in the East site and spent twice the time observed on aggressive rather than defensive behaviours. These support the hypothesis that this species protects a certain territory aggressively. Depth analysis suggest that they generally prefer deeper water and sandy bottoms below the reef slope. Observations found an instance of a possible feeding aggregation.

B. viridescens was only observed along the last third of the East transect site. They were observed in deeper waters, within a 5m range of 10m with a preference for sandy substrates near reefs. This, combined with their observed tendency towards aggression supports the hypothesis that the observed individuals were protecting a certain territory, which included the bottom of the reef slope on the East site. It is possible that their territory extends well beyond the reef slope and further into the blue, where deeper sandy bottom habitat lies. Without scuba diving, it would not be possible to ascertain the real size of their territory.

According to Matsuura, *B. viridescens* can occupy ranges from 1m to 50m in depth. While this data does not dispute this range, it is certainly much narrower. The research instead suggests that while it is possible that while *B. viridescens* can inhibit this wide a range, its habitat preference of sandy bottoms near reefs is the key determining factor in its depth range.

S. chrysopterum

S. chrysopterum was also observed displaying, aggressing and feeding at a specific location along the East transect. These possibly indicate a specific territory that observed species were protecting. This species had the shallower depth range, of three to eight metres, with a preference for a specific habitat located in the middle of the East transect site.

The preferred habitat of *S. chrysopterum* was majority sandy substrate with 10% coral outcrops. They were observed displaying, hiding and feeding in this area, with only one individual observed swimming into the reef slope. This indicates a strong preference for this habitat on the East site, however *S. chrysopterum* was observed on the West site along the reef top. Thus, this species may have specific preferences but high adaptability.

Seven out of eleven instances of shorter observation was of feeding, in sand or biting at logs. This species was observed feeding the most out of the three. It is unclear whether an abundance of food or seasonality or simply species specific behaviour is the cause.

They were the only species observed displaying, a movement where the fins were fluttering and it rotated on its bottom fin. It is unclear whether this individual (which was observed at the same location doing the same behaviour) was displaying for mating purposes or other reasons. It is also possible that this swimming pattern is to dislodge parasites from its fine, however the proliferation of cleaner wrasse would make this unlikely, it it needed to be cleaned it could easily be cleaned.

In terms of aggressive behaviour, it was rarely observed chasing, instead it displayed its triggerfin regularly. It spent 6.5 times more minutes on aggression as opposed to defence, indicating extremely high aggression in behaviour. Due to its smaller size, using its triggerfin could therefore be a method to enlarge its body size and intimidate others. The specific sightings at the same reef suggest that this area was part of its territory, therefore the study can conclude that *S. chrysopterum* is therefore the most likely of the observed species to use their triggerfin as an aggression technique in protecting territory.

Social Science

Social science data had two main objectives, establishing the triggerfishes role in Pemban fishing communities and gaining a baseline understanding of the communities knowledge of their distribution and size in Pemba fishing areas. Interviews and market observations generally found that triggerfish are not unanimously seen as a food fish in Pemban communities. Responses varied in terms of desired-ness, as a food it had deterring factors inhibiting community acceptance. Generally, fishermen were knowledgeable of their sizes and reefs where they could be found. Larger trends in decline were not immediately apparent during field work, but were identified by the fisheries officer.

Interviewees all knew what triggerfish were, but the reaction to them varied. Fishermen knew to be wary of the teeth and knew their tough skin needed to be removed to make them edible, the fishmongers did not particularly care for it. The overall sentiment was that the fish was edible, but no one’s first choice. For the fish, this is always good news, however it makes monitoring their populations even more salient. A (sudden) decline of triggerfishes would therefore be a very good indicator of impending fisheries collapse.

The communities understanding of biodiversity and abundance was also relatively comprehensive. Although difficult to quantify in interviews, many interviewees could correctly estimate sizes of species and distribution on a reef. This indicates frequency of interaction between themselves and triggerfishes. Additionally, many of them caught triggerfishes on a regular basis in the reefs they visited, indicating a healthy enough population on these reefs to sustain harvesting.

Throughout the study, caught triggerfishes were brought to me (both during observations on field, or during normal day-to-day activities on Misali Island). The biodiversity of caught triggerfishes were much higher than the five species initially expected (recorded by Jones 2017).

In conversation with rangers and dive masters on Misali Island, I was told that many varieties of triggerfishes were found in Pemba region, but that certain reefs (usually only accessible by diving) and certain places had different types and sizes. This agreed with many other fishermen’s perspectives, thus observed biodiversity should only be taken as representative of sites surveyed.

In the interview with the fisheries officer, she called triggerfish “endangered”. When I asked further, she explained that many fishermen complained that they were seen and caught much less regularly, and the sizes of catch had declined significantly in the years she had been working (close to thirty years). This was substantiated by other interviewees who agreed to a certain extent, although many had not indicated noticing changes.

Additionally, the fact that only triggerfish were perceived to be declining, but not other predator species like sharks and rays is a good indicator a anthropogenic pressure. Further research in the wider area both ecological and social in nature would be able to substantiate this. Either way, this broader perspective suggests that while triggerfishes are still present, they could be suffering from population decline due to anthropogenic fishing pressures.

The recorded uses of triggerfish as food, an exfoliant or as furniture coverings does indicate the multiplicities of possibility that other coastal communities would have for use of triggerfishes. Without any other cultural studies on triggerfishes in the region, it is difficult to ascertain if this is the case even within coastal East Africa. In order to better understand their broader cultural significance in Swahili culture, further study would be necessary.

Socio-Ecological

In one particular interview, the interviewee had attributed the decline in triggerfish catches to a behavioural change in the triggerfishes. He hypothesized that they were more able to avoid being caught by using their triggerfins to lodge themselves firmly into rocks and crevices. He attributed this to a reaction to spear fishing. Fishing methods have many impacts, and defensive fish behaviours as observed especially of *B. undulatus.*

Healthy numbers of Balistidae (especially in terms of density of *B, undulatus*) could be indicative of a well-protected reef. As mentioned, Balistidae are not a household desire; they are eaten opportunistically or by select people. In addition, because of their size and placing in trophic terms, they thrive on healthy reefs. Thus their abundance should be attributed to the maintenance of healthy fishery stock on Misali's reef. Historically protected reefs are known to have spillover effects in surrounding areas. This could be one such example of spillover protection. Alternatively, because of the non-extraction zone on the other side of the island, fishermen may be less inclined to fish in Misali generally, possibly generating spillover protection.

This positions Balistidae, especially those higher in the trophic chain and predator of urchins to be a good environmental monitoring metric. Healthy numbers of high abundance and persistence through time suggest healthy reef stocks. Species like *B. undulatus* are therefore unique ecological and social indicators of moderate fishing pressure and a healthy ecosystem. Sudden decline in populations would be indicative of impending fishery stock collapse, while sudden abundance could be due to eutrophication and thus an overabundance of their prey, urchins.

Conclusion

This study offers a snapshot overview of triggerfishes in Pemba Island region; using Misali Island reefs as a sample ecological site and sampling Pemban communities for the social perspective. Their high abundance indicates a healthy historical population on Misali Island, especially on the East sites reef. Size data suggest higher sexual selection on the East site. Low biodiversity in Balistidae were observed, however indices indicate a clear dominant species, *B. undulatus.* There are clear observations that support that behaviour is both site and species specific, especially in terms of aggression and territory defence. Triggerfishes are a general food fish, however they are not a commonly desired species making demand for them moderate. Therefore, it is possible to use Balistidae, especially urchin predator species like *B. undulatus* as reef health and fishery stock monitoring metric.

This study is the first of its kind in the Zanzibar Archipelago; both in its focus on Balistidae as well as its socioecological approach. The contribution of the study to the understanding not just ecologically to marine organisms but also their significance in human communities ties two important aspects together. In addition, work done in coastal Eastern African communities create mediums for these ecologies and perspectives to be shared. In the age of globalisation, development and climate change, establishing baseline understandings of existing relationships across disciplines in areas with a dearth of research should continue to be a priority.

Recommendations

This study takes a socioecological approach to an organism in order to create a holistic understanding of this organism. By continuing to conduct multi-disciplinary studies, ecological and biological elements can be married into sociocultural elements. I recommend that other organisms, especially marine organisms, be studied in the manner in order to provide clear links between humans and environment. Environmental studies at its core has the capacity to sit at the intersection of human and non-human. Studies continuing to link these are important to reimagining our relationships with everything around us.

I would also recommend that this information be used by the upcoming development on Misali Island. Understanding the ecology of the reef pre-development allows the company to access their impacts on the marine environment during development and operations. As a part of a marine conservation area and in the era of climate change, protecting existing biodiversity should be a key focus for the company.

As mentioned, triggerfish (especially *B. undulatus*) has the potential to be both an ecological and social metric for measuring reef health and as a fisheries stock index. CHICOP has previously used them to survey and compare reef health, similar studies across Pemban reefs could be beneficial for establishing health levels of reef and informing gap where conservation and protection is needed.

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Appendix A

Sample interview questions for fishermen

Questions: General fishery

1. How long have you been fishing?
   Ulivua kwa muda gani?

2. What equipment do you usually use to fish? Handline, gill nets, dema traps or something else?
   Kila kawaida vifaa gani unatumia kwa kuvulia? Mshipi, jarife, dema au chochote?

3. What type of boat do you use?
   Unatumia aina gani ya boti ya uvuvi?

4. When in the year do you usually fish? What time of day?
   Kila kawaida umevua lini?
   Unavua samaki muda gani (miongo gani)? Muda gani (asubuhi, mchana, usiku)?

5. Where do you normally fish? (have a map, ask for a general area)
   Kila kawaida ulivua wapi? Unaweza onesha kwa ramani tafadhali.

6. Have you caught triggerfish before? (show pictures)
   Ulikamata kande kabla ya?

Triggerfish (kikande)

1. Which kinds do you normally catch? How big are they?
   Kila kawaida, kande ya aina nini? Wana ukubwa gani?

2. How often do you catch them? Has this changed over time? If yes, why do you think it has changed?
   Ulikamata kande kwa muda gani? Wanabadilika kwa muda? Ikiwa ndio, unawfikiri kwa nini wamebadilika?

3. To whom do you sell them? Usually, for how much?
   Nani anauza kande? Kwa kawaida, ni kiasi gani?

4. What are they usually for? Food, ornamental, bait or something else?
   Ni kwa matumizi gani? Chakula, mapambo, chambo au kwa nini?

5. Are they a type of fish that you try/intend to catch or are they by-catch?
   Ulitaka kuvua kande? Au ulibahatisha?

Appendix B

List of landing sites used for collection of fisheries data in Pemba.

District	Landing Sites	Notes
Wete	Wete Pani Fundo Kivumonemtamwe	Only 2 recorders.
Michewani	Tumbe Shumba Msuka	Only 1 recorder.
Chake	Wesha Kichuani Ndaagoni	Only 1 recorder, Ndaagoni has not had a recorder since 7 years ago.
Mkoani	Ngazini Nisofini Muambe	Has recorders at every site.

Appendix C

Overview of transects conducted on Misali Island sites.

Transect	Date	Location	Tide	Time (mins)	Vis	Weather	BU	BV	SC	Others	Total no. of Obs
1	10/4/23	West	Mid	25	8 to5	Bright, cloudier at the end	6	0	0	4 ON	10
2	10/4/23	East	Mid	46	10 to 3	Bright	11	0	1	0	12
3	11/4/23	West	Low	49	10	Bright	5	0	0	0	5
4	12/4/23	West	Low	50	10	Bright	11	1	2	0	14
5	13/4/23	West	Low	49	8 to 10	Bright	15	0	0	0	13
6	14/4/23	East	Low (neap)	104	7 to 3	Overcast	10	1	1	0	12
7	15/4/23	East	Mid	54	5	Overcast	10	0	3	0	13
8	16/4/23	East	Mid	55	4	Overcast, drizzling	17	0	2	0	19
9	18/4/23	East	Low	60	5 to 2	Bright, became overcast	11	0	2	0	13
10	20/4/23	East	Low (spring)	64	2 to 5	Bright	9	0	2	0	11
11	21/4/23	East	Low	60	8 to 2	Bright	16	2	0	*3 unidentified species	21
Total				**616**			**121**	**4**	**13**	**7**	**143**

Appendix D

Balistidae abundance by location, species and size.

Location	Overall Balistidae Density per m2	B. u Density per m2	B. v Density per m2	S. c Density per m2	Balitidae mean size (cm)	B. u mean size (cm)	Mature Indivs B.u. (=> 10cm)	Immature Indivs B.u. (<10cm)
West	6.25	4.25	0.5	0.75		14.91	59	22
East	5.24	3.57	0.24	0.48		13.37	27	11
Overall	5.73	3.9	0.37	0.61	14.87	14.06		

Appendix E

Balistidae habitat preference by location and species.

Location	Habitat	BU	BV	SC	Others	Total
Baobab Beach Reef (East)	Reef Slope	67	2	2	3	74
	Reef Crest	2	0	0		2
	Reef Top	8	0	0		8
	Sandy Reef Slope	1	0	9		10
	Sandy Bottom	0	1	0		1
subtotal		78	3	11	3	95
Turtle Beach Reef (West)	Reef Slope	10	0	0		10
	Reef Crest	10	0	1		11
	Reef Top	18	0	1	4	23
	Open Water Column	0	1	0		1
subtotal		38	1	2	4	45

Overall Balistidae habitat preference by species.

Habitat	BU	BV	SC	Others	Total
Reef Slope	77	2	2	3	**84**
Reef Crest	12	0	1		**13**
Reef Top	26	0	1	4	**31**
Sandy Reef Slope	1	0	9	0	**10**
Sandy Bottom	0	1	0	0	**1**
Open Water Column	0	1	0	0	**1**

Appendix F

Longer behavioural observation overview.

	No. of Obs.	**Mean Obs. length (min)**	**Max Obs. length**	**Min Obs. length**	**Total (min)**
B. undulatus	22	3.09	6	1	68
B. viridescens	3	4.67	9	1	14
S. chrysopterum	4	5.75	10	4	23
Overall	29	0	10	1	105