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Fall 2016

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A comparative study between the Ushongo Village Reef and the Fungu Zinga Reef over time

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SIT Tanzania Fall 2016

Acknowledgements

To Kerstin at Kasa Divers, without whom our study project would have truly been impossible. You were an amazing mentor and friend during our month in Ushongo, and your work with Friends of Maziwe as the sole driving force of conservation efforts in Ushongo is inspiring.

To Oscar, for his tireless efforts, patience and good humor, without which this program wouldn't have been possible.

We'd like to thank Felicity, Mama Juni, Simba and all the other SIT staff who worked tirelessly to make sure that everything was running smoothly.

Thank you to all the other students on the program—for never letting us go a day in Tanzania without laughing hysterically. You all are the most unexpected and wonderful family I could have hoped for these four and a half months in Tanzania. There it is and here I am.

Thank you to Uhoro and Rajabu for taking us out to Fungu Zinga many early mornings and prodding us along with our Kiswahili.

And to the beautiful reef: for being not only the breathtaking foundation of an invaluable marine ecosystem, but a resource deeply entrenched in the livelihoods and presence of Ushongo. You were worth every jellyfish sting, sunburn and long day. The reef has showed me (who had never snorkeled a day in my life before this study), to not fear the unknown, because the unknown can be incredible. We cannot imagine spending a month anywhere else.

And to our friends and family back home, for your unconditional support and encouragement.

To Corinne, for always believing in us when the tide was high but we were holdin' on—and for being perpetually salty, sandy and pruney with me for a month.

And truly, thank you Della. Thank you for being my partner in crime, the dafu to my nazi, and always steering this project right. Thank you for putting up with my nonsense, knowing when the storm clouds are just a bit too close, and keeping us in one piece. You put the smile on my face and I could not have asked for a better friend to be flopping around in the water with, in long sleeve shirts and bucket hats, every day.

Abstract

The world's oceans are becoming increasing acidic due to global climate change, posing a threat to marine ecosystems, including coral carbonate systems. Environmental threats are exacerbated by human development stressors as well: growing populations, dependency on marine resources, and unsustainable practices invaluable marine ecosystems at risk. Tanzania's coral reef system extends for 3580 km^2 (Muhando *et al.* 2008) near the Tanga region, serving over half a million people who are highly dependent on fishing and other marine resources as their livelihoods (Samoilys *et. al.* 2008). With Tanzania's population rapidly growing, the unsustainable pressure on coral reefs for sustenance and livelihood will only get worse. East African reefs have shown good recovery since the 1998 bleaching event, but progress is slowing due to destructive fishing practices (Muthiga *et al.*2008). This study compares coral and fish health between two reefs along Tanzania's coast, Ushongo Village Reef (UVR) and Fungu Zinga Reef (FZR). It was hypothesized that FZR would be healthier than UVR due to its natural protection with distance from human populations and the presence of a sand bar. There is a trend in past studies of improving reef health and increased understanding of conservation among fishermen (Henderson *et al.* 2014; Azoff and Mecham *et al.* 2014: Houlihan *et al.* 2010). UVR and FZR were found to have statistically significant differences between fish abundance, number of species, number of coral genera and percentage of live coral coverage ($p = 0.0227, 0.000024, 0.0374; 0.0432$). FZR was found to be the healthier reef, while both reefs are improving in overall health.

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Background

Coral reefs are home to an expansive underwater ecosystem. They hold over 25% of the ocean's diversity while covering less than 1% of the ocean's floor (Coral Reef Alliance *et al.* 2014). As one of the most diverse ecosystems in the world, their value is exponential. Coral reefs are threatened heavily by ocean acidification and other changes brought about by global warming. Ocean acidification or the decreased pH levels in the ocean, have been caused by the increasing levels of greenhouse gas emissions, mainly CO_2. Reef-building corals, one carbonate system, have seen to be drastically effected by decreases in ocean pH (Kleypas *et al.* 2006).

Reef-building corals or hard corals are made up of calcium carbonate and rebuild through a natural calcification process. Decreased pH levels dissolve this calcium carbonate and break down this natural rebuilding process (Kleypas *et al.* 2006). With that, ocean acidification can lead to coral bleaching, killing off sections of and many times entire reef systems. Coral gives life to a reef system and without it, the ecosystem falls apart. Additionally, other keystone species like mollusks and even crustaceans, are killed by decreasing pH levels. Along with warming ocean temperatures and other changing factors within ocean chemistry due to climate change, ocean acidification can prove to be even more detrimental to marine ecosystems (Rodolfo-Metalpa *et al.* 2010). As human development continues to release large quantities of CO2 into the atmosphere, ocean acidification shall continue to prove a problem (Kleypas *et al.* 2013).

While coral reefs are an invaluable ecosystem, facilitating a perfect oasis of high biodiversity, the meaning of the reef on Tanzania's coast bares a deeper importance as well. Over a quarter of the world's small scale fishermen harvest from coral reefs, an estimated six million people (Coral Reef Alliance *et al.* 2014). On the Tanga coast, the coral reef system extends for 3580 km2 (Muhando 2008), serving over half a million people who are highly dependent on fishing and other marine resources as their livelihoods. The WWF has recognized Tanga's numerous islands, adorned by fringing reefs, lush seagrass beds, mangroves and extensive biodiversity as an eco-regionally important seascape within WWF's East African Marine Ecoregion (EAME) (Samoilys *et. al.* 2008).

According to the 2013 World Bank census, Tanzania's population was at 49.25 million, and steadily growing, estimated to be 51.04 million as of 2016. A rapidly increasing population and, as it would appear, a population that is reliant on a single resource has been detrimental to the health of reef ecosystems. A rising population exerts pressure on marine resources and increasing demand for food. This breeds a desperation for more efficiently obtaining food or higher yields of economic gain, and therefore Tanzania was introduced to dynamite fishing, poisoning and drag net fishing. Initially documented in 1960's in Tanzania, dynamite fishing uses commercial dynamite or homemade bombs, to blow up an area of reef in order to kill all of the fish with one blast (Lewis, 1996). The blast provides easy collection for the fishermen; while destroying the coral, the blast stuns the fish and bursts their swimming bladders. This produces an instantaneous loss in buoyancy, and the fish float to the surface. When coral is blasted, there is no chance of natural rejuvenation; the dynamite destroys the calcium carbonate coral skeletons (Muthiga *et al.* 2008). This leaves vast expanses of once thriving marine habitat resembling coral graveyards.

Despite laws banning dynamite fishing, the challenge of eradicating these practices comes from the combination of weak infrastructure, widespread poverty and disparity in power dynamics that Tanzania is currently facing. With weak infrastructure, Tanzania's government officials are lack the ability to properly enforce dynamite fishing laws. There is insufficient funding to patrol large stretches of coast, combined with an incredibly low occurrence of consequences and follow through from the criminal justice system. Additionally, when someone reports suspected dynamite fishing, by the time law enforcement comes around, it is very commonplace for the suspect in question to have already gotten the heads up, and have had time to prepare for the police's arrival. "I've been on the beach doing yoga and I've heard blast after blast," said the Capricorn Beach Cottages owner, whose lodge borders the Kigombe beach, "Sometimes you can even see it in the water. I've complained to the Coelacanth Marine Park many times, but they just don't seem to care."

When it is widely known that there is minimal threat of retribution for dynamite fishing, little enforcement and patrolling, and a high yield of economic gain, this poses an opportunity that many find impossible to refuse (Erler, personal communication).

Often these fishermen are being paid and acting by proxy of people who are of higher socioeconomic status, because dynamite fishing is a lucrative business. Keeping the power dynamics in mind, it is incredibly difficult for people living below the poverty line to say no to a lump sum of money and dynamite provided by whomever is hiring them (Erler, personal communication). With the added reality that the overwhelming majority of people in coastal communities are documented as living at or below the national poverty line, it is easy to see how dynamite fishing has become an epidemic along the coastline. An exemplification that these drastic measures are a product of desperation and poverty is that fishermen are "not even deterred by the personal physical consequences that include loss of limbs, blindness, deafness, death" (Samoilys *et al.* 2008).

Beyond being detrimental to the coral reef and the ecosystem it provides, an unfortunate consequence of dynamite fishing is fishermen using safe and legal fishing practices are forced to go further offshore to fish in deeper waters. Traditional shallower areas previously used for fishing are now unproductive because of dynamite fishing. Other destructive fishing practices prevalent in Tanzania include drag net fishing and poisoning. Drag net fishing involves pulling a fishing net behind the boat, which results in damage to the coral. Drag net fishing can break the coral or damage the soft coral tissue, leaving the polyps susceptible to infection (Fay, 1992). Though less common, fishing through poisoning is known to happen; fishermen will use pesticides or chemicals to kill the fish, and which can be very harmful to human health as well.

Nearby villages such as Kigombe, where five blasts can be heard before breakfast (Erler, personal communication), the consequences of dynamite fishing are now obvious with the lack of fish in that area. The link between biodiversity and poverty alleviation is one that various NGOs have been attempting to educate coastal communities on in the Tanga region. The sustainable use of biodiversity has significant links to human wellbeing and poverty reduction; when reef health is maintained, species density and richness is sustained, providing livelihood stability and food security for the long term. "Reduction of poverty through sustainable livelihood development, which in turn helps people from destructive practices, maintain biodiversity and improve conservation strategies is a pressing theme…" (Ireland *et. al*) (Harrison 2005). Organizations such as USAID and SEEGAD have been attempting to diversify the economy in Tanga region using seaweed farming, milkfish pond farming, crab fattening in mangroves. By diversifying the economy's reliance on marine resources, there can be higher levels of biodiversity and livelihood development. However, many of these programs in recent years have been discontinued due to lack of funding, and waning motivation from the locals involved.

The Tanga Coastal Zone Conservation and Development Program (TCZCDP), started in 1994 to oversee coastal zone and fisheries management. This program was created by

International Union for the Conversation of Nature (IUCN), supported by foreign aid. Though initially TCZCDP was a government program but in the 1990's the Local Government Reform Programme (LGRB) shifted the responsibility to the districts Muhzea, Pangani, and Tanga City. Though the local governments have promised to uphold resource management and "ecological integrity" (Wells, 2007), many aspects of TCZCDP's mission has weakened in practice.

The local governments do not patrol as they have promised (Erler, personal communication), which is where the non-profit Friends of Maziwe comes in. It is a conservation organization that utilizes community-based and NGO patrolling of the marine park, Maziwe, and the surrounding areas for dynamite fishing as well as enforcing park fees and running a turtle conservation program.

This study specifically focuses on a comparison of the health of two reef in along Tanzania's eastern coast, Ushongo Village Reef (UVR) and Fungu Zinga (FZR), using fish species and diversity as indicators of reef health to compare to studies done in 2010 and 2014 as well as between each other. This is combined with fisherman interviews on their practices to obtain a holistic perspective of the reef. The fisherman and population of Ushongo's perspective is essential to truly understanding the Ushongo Village Reef. It is an invaluable ecosystem not only for marine life but one that is deeply entrenched in the development, livelihood and presence of the Ushongo population. The reef is the backbone of the village's food security and livelihood to the 360 individuals living here (Tobias, personal communication). The high level of dependence on the ocean—and therefore the Ushongo Village Reef and Fungu Zinga Reef—is an exacerbating factor of stress placed on the biodiversity and therefore health of the reef.

Study Site Description

This study was conducted from Ushongo Village located outside of Pangani in the Tanga region, along Tanzania's eastern coast with the Indian Ocean. For this study two reefs, the Ushongo Village Reef and the Fungu Zinga Reef, were observed from November 6th until November 25th, 2016.

The Ushongo Village Reef is located directly off of the shore from Ushongo Village. Ushongo village is classified as an open reef and thus is freely fished. As a gap reef there are multiple sections forming the overall reef system. Part of the reef stems directly from shore out, while another section is located approximately 200m from shore, and a last section approximately 800m from shore. The dark outline in **Figure 1.** shows the relative area of the reef system. As the overall health of the entire reef system was being studied, plots were taken from throughout many separate sections. During this study, this reef was regularly fished on a small scale level. Fishermen were seen spear fishing, line fishing, and sometimes using nets. During low tide, near the full moon, many locals would walk out onto the reef to catch fish, octopus, and crustaceans as the reef would poke out from the water.

Figure 1. A Google Earth screenshot showing the Ushongo Village Reef.

Figure 2. A Google Earth screenshot showing the Fungu Zinga Reef.

Fungu Zinga Reef, also known as the Sand Island, is located approximately 6kms from Ushongo Village. Fungu Zinga is a sand island with a surrounding coral reef. In **Figure 2.** the sand bar, the lighter green blotch, can clearly be seen in relationship to Ushongo Village. Fungu Zinga is also classified as an open reef allowing it to be freely fished while the sand bar near the reef and distance from the village provides natural protection. Within this reef system, many fishermen were seen. They mainly used nets and swam with spears here. On a few occasions nets would be set very close to the study plots while the fishermen on the ngalawa used to get to the reef commonly line fished while waiting for plots to be finished. There is an additional third reef in the area, Maziwe, which is a national marine reserve and thus a protected free. Seen in **Figure 2.** to the left of Fungu Zinga, Maziwe is situated at the northern end of the Zanibar Channel, 10 kilometers from Ushongo and also develops a sand bar during low tide. Absolutely no fishing is allowed on this reef due to its history as a turtle nesting site. Maziwe is monitored daily to enforce the fishing restrictions through the Friends of Maziwe project.

The Fungu Zinga, Maziwe, and Ushongo Village reef attracts capital through tourism, which in turn funds the conservation efforts here such as Friends of Maziwe, which work in tandem with Kasa Divers. Kerstin Erler is the driving force behind Kasa Divers and Friends of Maziwe, the voice of conservation efforts in the Tanga region while also leading educational scuba diving and snorkeling expeditions.

Methods

Fish and coral populations were studied as indicators of the overall marine ecosystems health. A kayak was used to study the nearby Ushongo Village reef while two fishermen were hired to sail out to the Fungu Zinga Reef in a ngalawa, the local sailboats. When studying the Ushongo Village Reef, tide tables from the Tanga and Dar regions were referenced in order to find times where there would be ample water coverage over the reef. Fish were counted and identified by species (Richmond, 1997; Debelius, 2002; Gerald, 2005). Coral was observed by genera while the % of coverage, total, live, and dead, were estimated. Additionally, echinoderms, mollusks, and other commercially desirable marine species were observed to help better develop an understanding to their presence within both reef systems.

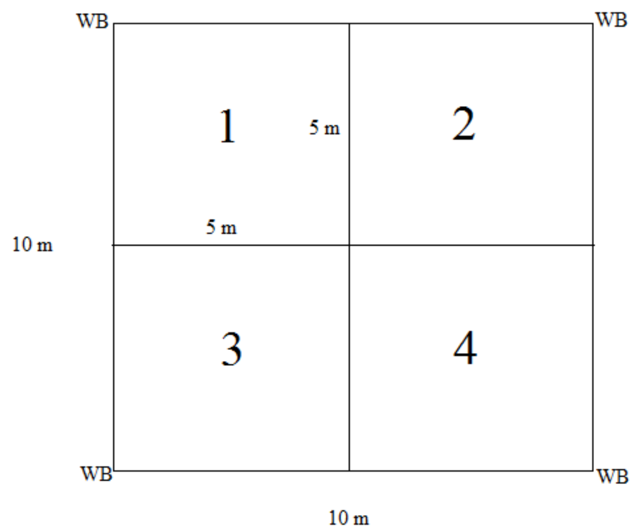

Figure 3. Pictorial representation of apparatus used to measure 100m^2 plots. The lines represent string while WB stands for water bottle. Each point where the lines meet represents where the rope was tied together.

Once in the water and on the reef, a 10m x 10m plot was set on the ocean floor. Each 100m^2 plot was broken up into 4, 5m x 5m, quadrants. These plots were made using string and water bottles filled with sand like the pictorial representation in **Figure 3.**. Four 10m long lengths of rope were tied off to water bottles in order to create the 10m x 10m square. Two additional 10m lengths of rope were tied between each set of parallel sides in order to create the 4, 5m x 5m quadrants. Non-random plots were chosen by simply ensuring it was part of the reef system and that it had not yet been studied. Meta-data was recorded for the chosen location then the counting began. Each quadrant was counted separately. For the fish populations, one individual started at the center of the plot then took an initial survey to count the fish swimming within that quadrant. After, the plot perimeter was observed with continual diving down to look for fish hiding within the bottom or coral. Finally, the student studying that plot swam throughout the entire quadrant in order to find any additional fish hiding within the reef. The relative location of each fish/school observed was noted in attempts to prevent double counting.

After quadrant one was completed, one moved onto quadrant two, three, and four. All results were recorded on sand treated slates using pencils. These slates were made by laminating identification sheets then rubbing the lamination with sand (sandpaper). During this project, a second individual followed the same process counting echinoderms, mollusks, and coral starting in quadrant two. After the first observation window, one moved on to quadrant three, four, and one. In addition, this individual estimated the total coral coverage within the $100m^2$ plot. From the total, the percentage of live coral coverage as well as dead/damaged coral coverage was also noted.

24 plots were observed between November 7th and 25th 2016. 13 plots were observed at the Ushongo Village Reef from the 7th until the 18th while 10 were observed at the Fungu Zinga reef between the 19th and the 25th. The results were then compared between the two reefs as well as to two past studies, one from 2010 and one from 2014.

For the interviews with Ushongo's fishermen, a group interview was conducted with thirteen individuals and one translator. The fishermen were briefed on what was happening, asked to sign the consent form, then asked the set of questions prepared (See appendix G). Once finished, the fishermen were compensated slightly for their time.

Additionally, Kerstin Erler, the head diver at and owner of Kasa Divers was casually interviewed to seek her view of the changing reef systems in the Ushongo area as she has been present and diving in these systems for the past ten years.

Materials

- 65+ feet of rope
- Snorkels and fins
- Four water bottles filled with sand
- A kayak
- Fish guides
- Laminated recording slates
- Sandpaper (sand & a konga)
- Pencils
- Pencil sharpener
- Tape
- Small pieces of twine
- A translator for the two days of interviews
- Chartered boat to the FZR
- Tide tables
- Google Earth
- Marine species and coral ID books (Richmond, 1997; Debelius, 2002; Gerald, 2005)

Results

Coral Results

Throughout November of 2016, a total of 2,300m^2 were observed across both reefs, 1,300m^2 on UVR and an additional 1,000m^2 on FZR.

Coral coverage, live and dead/damaged, as well as species of coral were observed. UVR had an average coral coverage of 62.92% with 47.04% being alive and 15.04% being dead or damaged, **Figure 4**. FZR had an average coral coverage of 75.5%, 66.40% alive and 9.10% dead or damaged. The 2010 study found a 44.71% average coral coverage at UVR, 28.17% alive and 16.54% dead or damaged, **Figure 5** (Houlihan, 2010). The 2014 study found a 45.10% coral coverage at UVR, 29.96% alive and 15.14% dead or damaged (Azoff and Mecham 2014). Additionally, an average of 9.7 genera of coral with 15.31 species were observed in each plot at UVR. FZR saw an average of 14.4 genera and 21.22 species per plot. Within the UVR system, 37 genera were observed while 42 were observed throughout FZR. Between FZR and UVR there was a statistically significant difference between % live coral coverage and # of genera ($p = 0.0432, 0.0374$). Although, there was no statistically significant difference between dead/damaged coral coverage between FZR and UVR ($p = 0.345$).

	% Total Coverage	% Live coverage	%Dead or Damaged Coverage	# Genera	# Species
UVR	62.92	47.04	15.04	9.7	15.31
FZR	75.50	66.40	9.10	14.4	21.22

Figure 4. Summary of the total, live, and dead/damaged coral coverage as well as coral genera present between the Ushongo Village reef and the Fungu Zinga reef in 2016. All of these values are listed as an average per 100m^2 plot.

UVR	% Total Coverage	% Live coverage	%Dead or Damaged Coverage	# Genera (average per plot)
2010	44.71	28.17	16.54	8
2014	45.10	29.96	15.14	10
2016	62.92	47.04	15.04	9.7

Figure 5. Summary of the total, live, and dead/damaged coral coverage on the Ushongo Village Reef and the average number of coral genera present on the Ushongo Village Reef plots in 2010, 2014, 2016 (Houlihan, 2010; Azoff and Mecham, 2014).

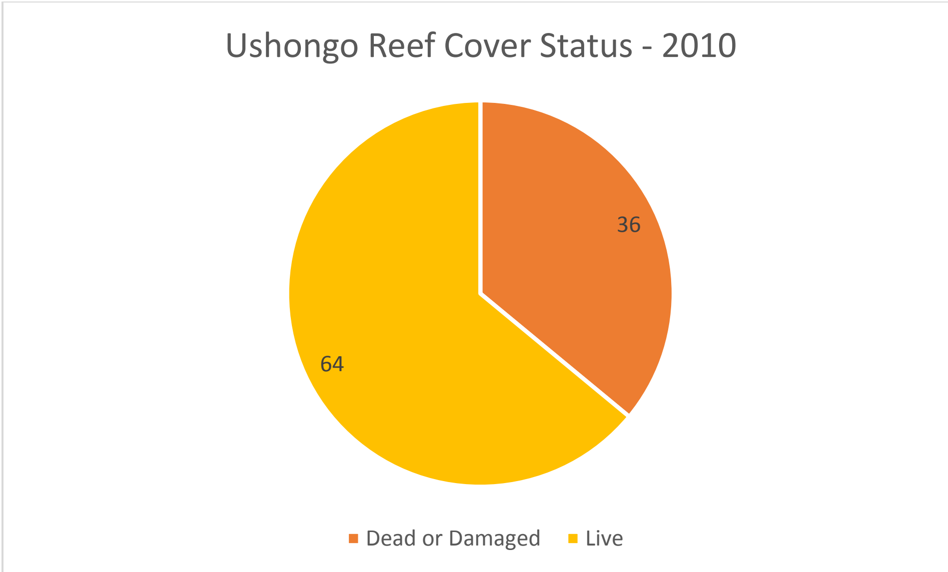

Figure 6. The percentage of live vs. dead or damaged coral coverage from the Ushongo Village Reef in November of 2010 (Houlihan 2010).

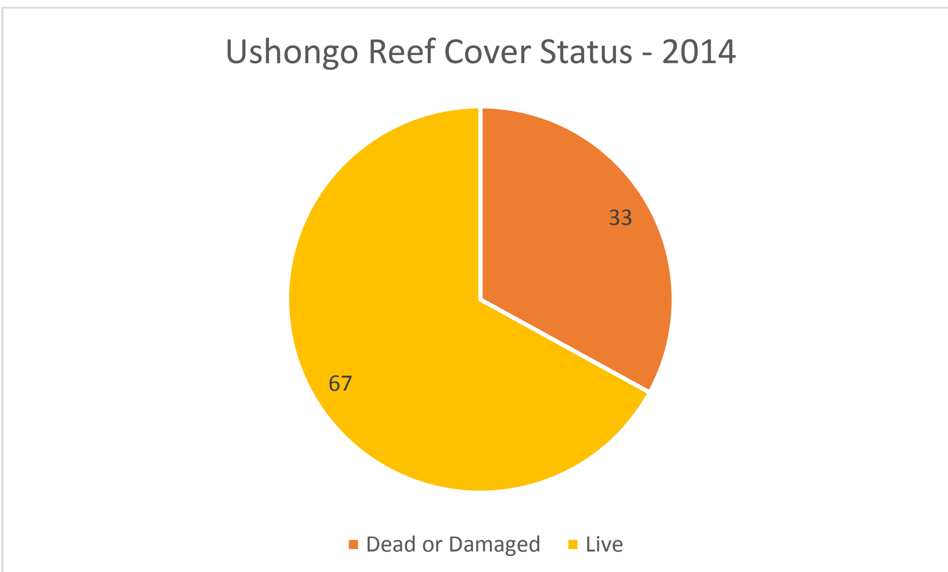

Figure 7. The percentage of live vs. dead or damaged coral coverage from the Ushongo Village Reef in April of 2014 (Azoff and Mecham 2014)

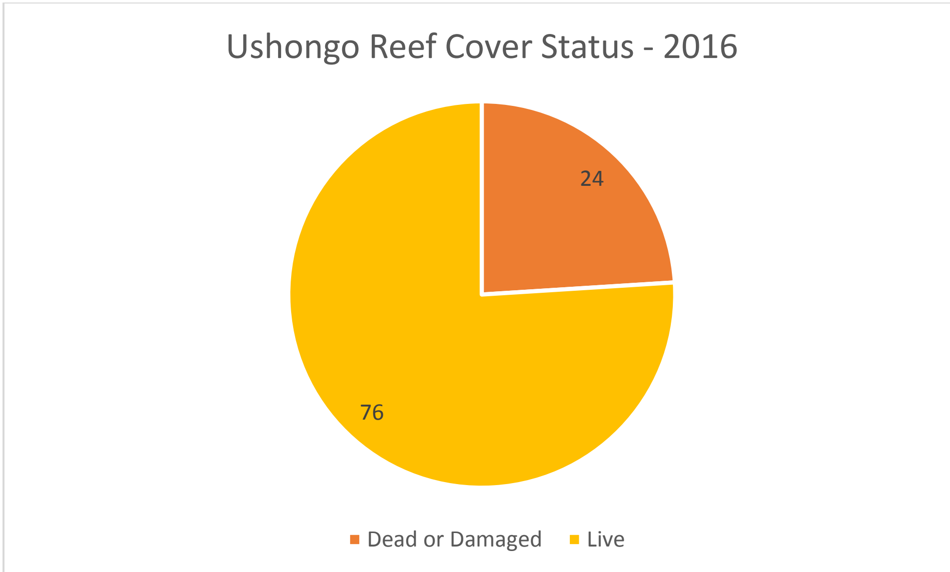

Figure 8. The percentage of live vs. dead or damaged coral coverage from the Ushongo Village Reef in November of 2016.

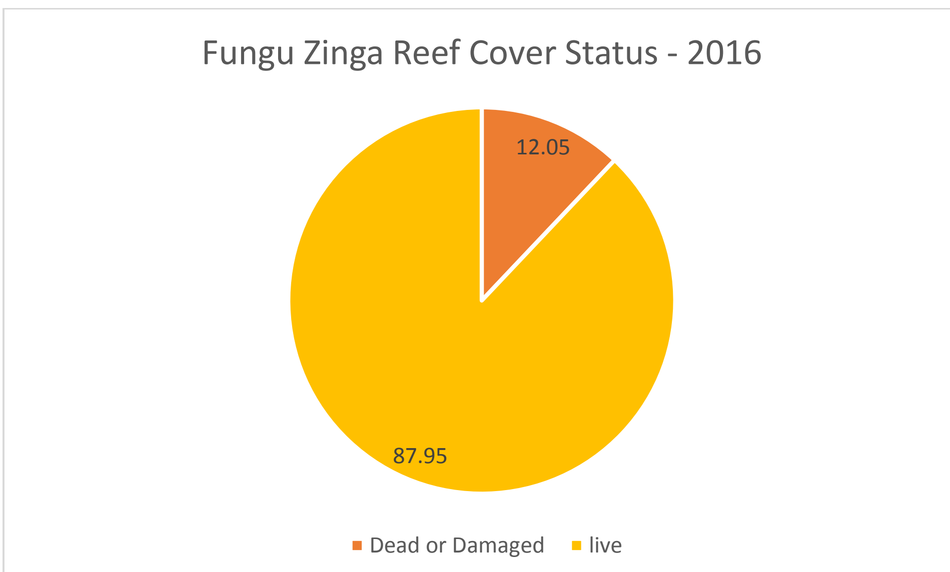

Figure 9. The percentage of live vs. dead or damaged coral coverage from the Fungu Zinga Reef in November of 2016.

Fish Results

Across the 13 100m^2 plots on studied in 2016 on UVR, a total of 3,072 individuals were observed with an average density (100m^2) of 236.31, **Figure 10**. In the 10 100m^2 plots studied in

2016 on FZR, 5,161 individuals were observed with an average density ($100m^2$) of 460.9. 131 total species were observed on UVR while 159 were seen on FZR. Species richness included all species with more than 10 individuals counted. UVR had 45 species with more than 10 individuals while FZR had 55. A Simpson's Index of Diversity of 0.889 was found for UVR in 2016 and of 0.922 for FZR. In 2014 a Simpson's Index of Diversity was found of 0.684 for UVR and 0.922 for FZR (Henderson SIT). There was a statistically significant difference between the species abundance on UVR and FZR ($p = .0000239$). There was a statistically significant difference between the abundance of individuals between UVR and FZR ($p = 0.0227$). There was not a statistically significant difference between the indices of diversity between UVR and FZR ($p = 0.549$).

There was not a significant or strong regression seen between any of the coral and fish data. When comparing abundance, number of species, and indices of diversity all with % coral coverage (live, dead, and total) as well as number of coral species and genera, no significant correlations were found ($R^2<0.28$).

Reef	Ushongo Village Reef		Fungu Zinga Reef	
	2014	**2016**	**2014**	**2016**
Total Individual	2838	3072	2403	5161
Total Species	64	131	132	159
Density ($100m^2$)	189.2	236.31	160.2	460.9
Species Richness (>10 Individuals)	28	45	33	55
Simpson's Index of Diversity	0.684	0.889	0.922	0.922

Figure 10. The total number of individual fish, fish species, fish density ($100m^2$), species richness (>10 individuals), and Simpson's Index of Diversity for Ushongo Village Reef and Fungu Zinga Reef based on data collected November 2014 (Henderson 2014) and November 2016 with this study.

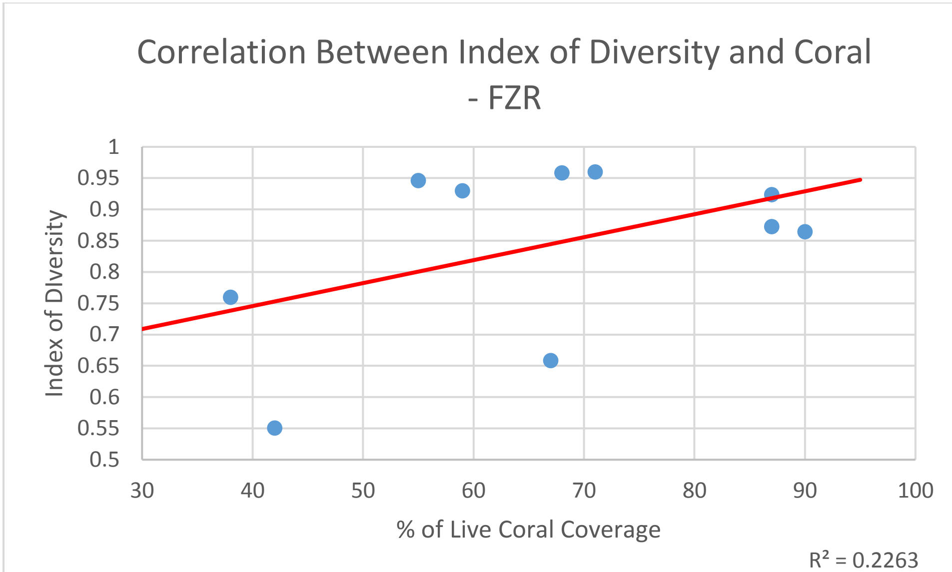

Figure 11. A regression between the index of diversity and the % of live coral coverage for FZR.

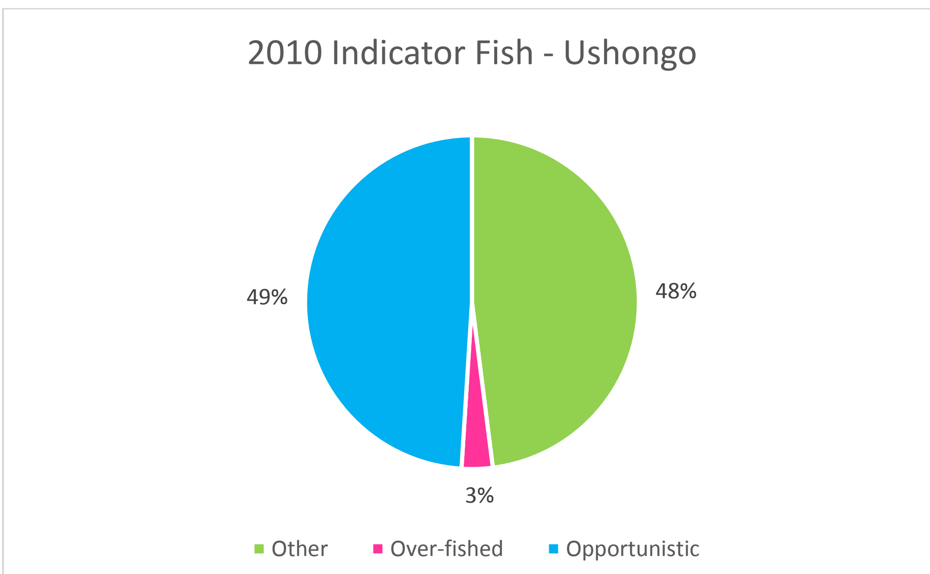

Figure 12. The percentages of individuals within over-fished, opportunistic, and all other species categories on the Ushongo Village reef in 2010. Overfished species included; parrotfish, surgeonfish, grouper, and triggerfish. Opportunistic species included; chromis, damsels, and wrasse. These fish categories were defined by the 2014 and 2010 studies (Houlihan 2010).

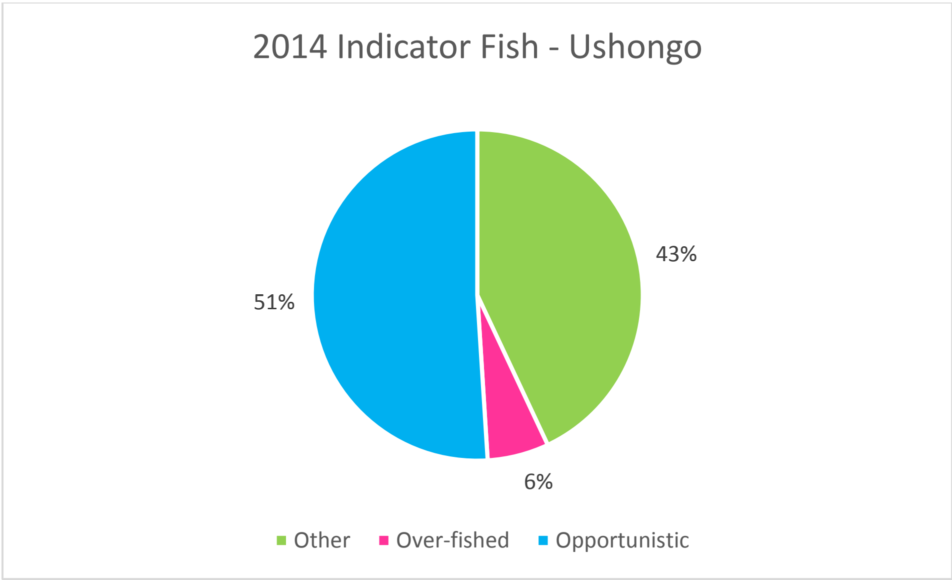

Figure 13. The percentages of individuals within over-fished, opportunistic, and all other species categories on the Ushongo Village Reef in 2014. Overfished species included; parrotfish, surgeonfish, grouper, and triggerfish. Opportunistic species included; chromis, damsels, and wrasse (Mecham and Azoff 2014).

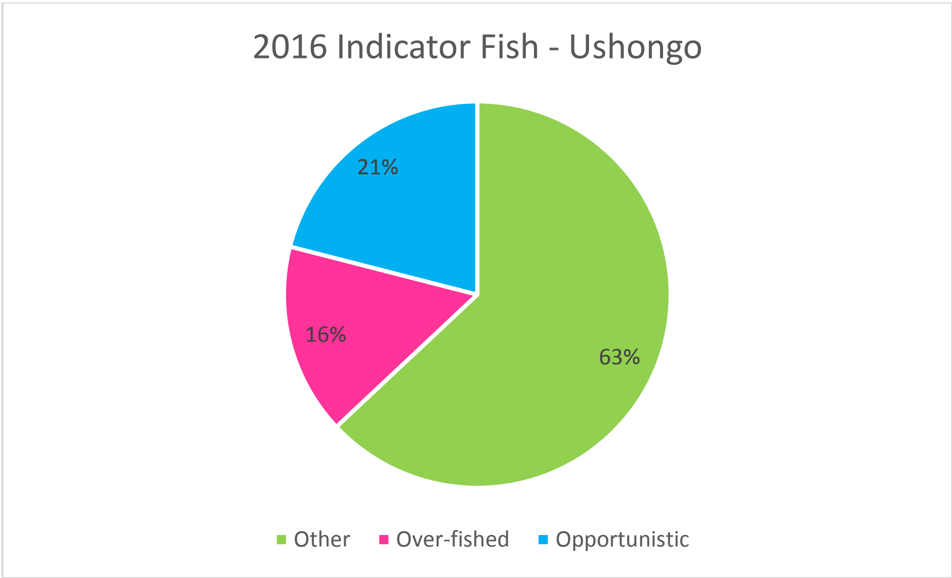

Figure 14. The percentages of individuals within over-fished, opportunistic, and all other species categories on the Ushongo Village Reef in 2016. Overfished species included; parrotfish, surgeonfish, grouper, and triggerfish. Opportunistic species included; chromis, damsels, and wrasse.

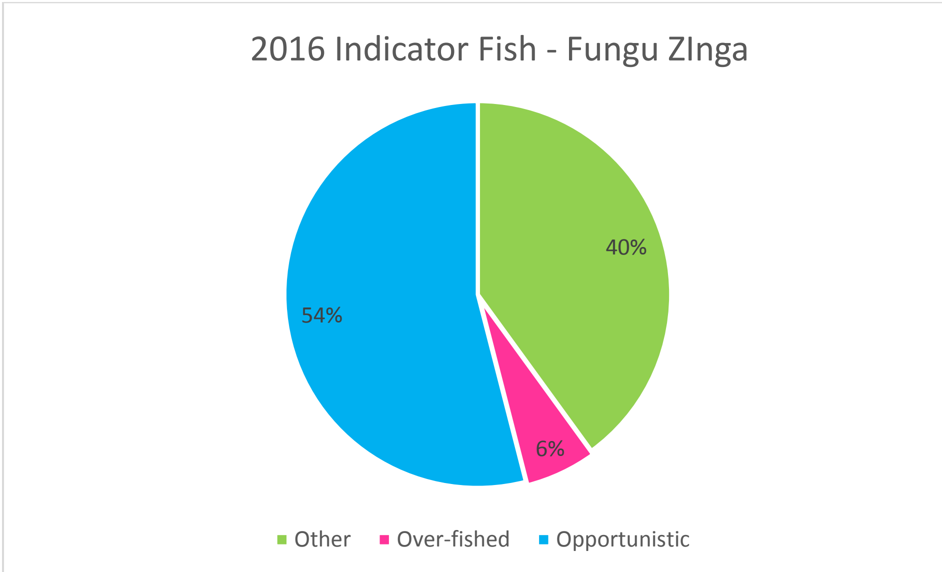

Figure 15. The percentages of individuals within over-fished, opportunistic, and all other species categories on the Fungu Zinga Reef in 2016. Overfished species included; parrotfish, surgeonfish, grouper, and triggerfish. Opportunistic species included; chromis, damsels, and wrasse.

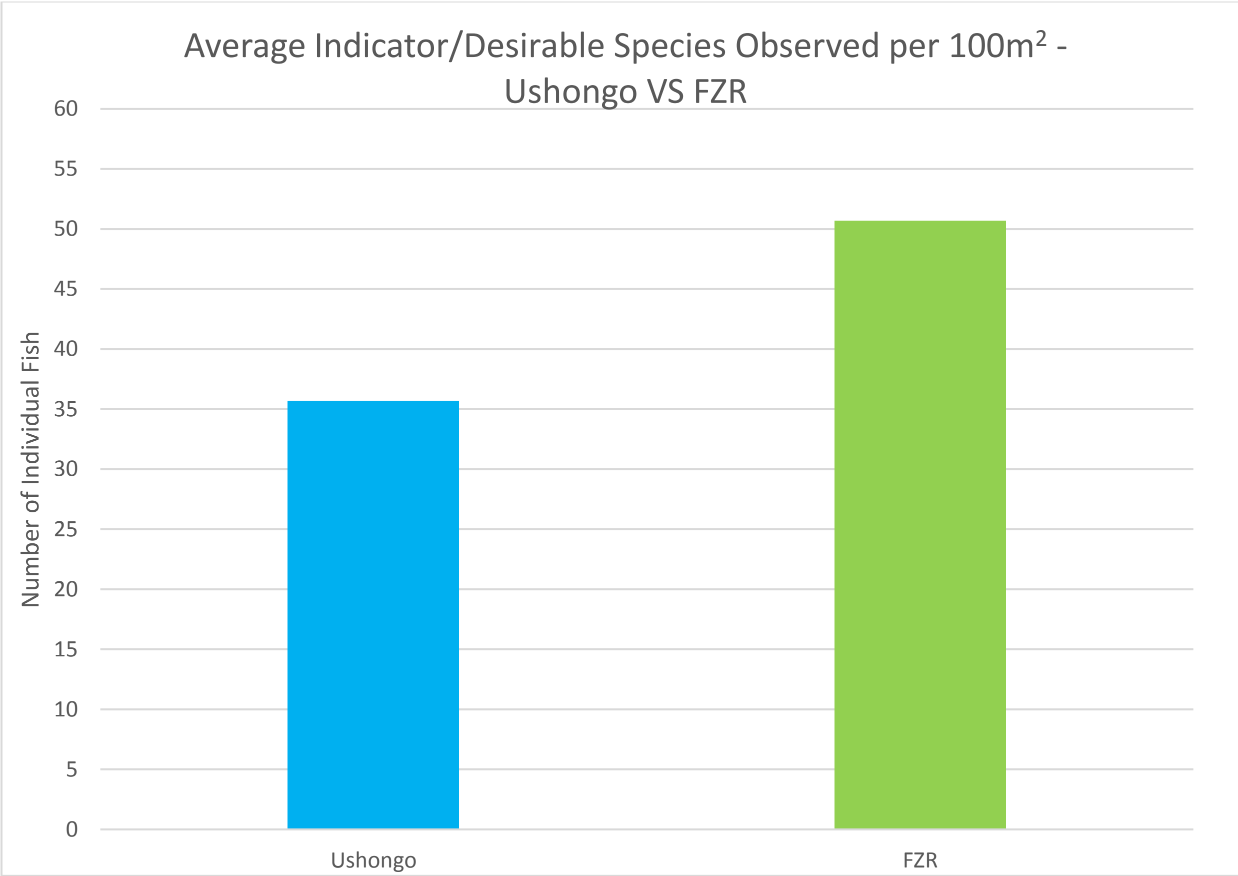

Figure 16. The average number of individual fish observed per $100m^2$ plot that are commercially desirable and indicator species compared between the Ushongo Village and the Fungu Zinga Reefs. Commercially desirable and indicator species for this study include; grouper, snapper, triggerfish, surgeonfish, rabbitfish, barracuda, angelfish, and butterflyfish.

Coral Discussion

By the completion of data collection in November 2016, a total of 2,300m^2 were observed across both reefs, 1,300m^2 on UVR and 1,000m^2 on FZR. A plethora of live and dead/damaged coral coverage was observed, with a wide variation of species. By analyzing the data, it can be deduced that FZR there was more average coral coverage on FZR than UVR. This implies that, because of the higher average coral coverage, FZR is overall a healthier reef than UVR. FZR had a stronger average coral coverage of 75.5% with 66.40% alive coverage and 9.10% dead or damaged coverage. In comparison, UVR had a lesser coral coverage average of 62.92% with 47.04% alive coverage and 15.04% dead or damaged coverage. Though the contrast in the percentages of dead/damaged coral coverage for FZR and UVR can be noted—from our results and was observed during data collection--there was no statistically significant difference between the percentages, with a p value of 0.345. To compare the UVR coral coverage with previous studies, the 2010 Henderson study found a 44.71% average coral coverage at UVR, 28.17% alive coverage and 16.54% dead/damaged coverage. The 2014 Mecham, Azoff study found a 44.71% average coral coverage on UVR, with 29.96% alive coral coverage and 15.14% dead/damaged coral coverage.

We originally hypothesized that FZR would be healthier than UVR, quantified in terms of fish diversity, species and coral health. Additionally, it was hypothesized that both UVR and FZR would be getting healthier over time, since this is what the 2014 Mecham, Azoff study's data suggested. Our first hypothesis was proven correct; using number of genera as an indicator of health, there was an average of 9.7 for coral genera per plot at UVR, and an average of 14.4 coral genera at FZR. FZR had more genera of coral per plot than UVR, and had more species present. An average of 15.31 species per plot were observed in UVR, and 21.22 species per plot observed at FZR. Though the difference in number of species between study locations is not significantly significant difference, it is important to note this data in order to understand the overall health of both reefs.

In total, UVR had 37 genera of coral observed, and FZR had 42 genera of coral observed throughout our entire data collection. Again, while this difference is not enough to have a p value less than .05 to make it statistically significant, it should be noted that this adds overall to the information regarding health of the two reefs.

Comparing the genus amounts on UVR from the 2010 Henderson study and the 2014 Mecham, Azoff study (Appendix A), a clear trend of increasing coral genera can be found. In 2010, 24 coral genus were observed. In 2014, 30 coral genus were observed. In 2016, 37 coral genus were observed. It can be inferred from this trend of increasing coral genus observed that UVR is flourishing and becoming healthier, with a wider variety of biodiversity in corals. However, it is important to point out that this could be due to one of two biases: without the raw data of the 2010 Henderson study and 2014 Mecham, Azoff study, it is impossible to know the exact location of their plots. Therefore, perhaps if we had gone exactly to the plots of coral from 2010 and 2014, we would have observed the same amount and genera of coral. Secondly, a large bias is lack of expertise; in the 2010, 2014 and 2016 study were all conducted by undergraduate students with little experience identifying coral. It is possible that there is error in each year's coral identification, skewing the comparison between the three data compilations.

Additionally, coral coverage status of UVR can be compared from all three studies conducted. In 2010, coral coverage status included an estimation of 36% dead/damaged, and 64% live coral, **Figure 6**. In 2014, coral coverage status had an estimated 33% dead/damaged coral, and 67% live coral, **Figure 7.** Our 2016 data concluded that there was an estimated coral coverage status of 24% damage and 76% live coral on UVR, **Figure 8**. The observance of dead/damaged coral has decreased from an initial 36% to 33% to 24% in the course of six years. While the same biases as detailed before can be applied to this statistic, it is heartening to see data that would suggest that the reef is getting healthier. It is also pertinent to assert that this statistic does not mean as much about dead/damaged coral than it does about live coral; the data implies that there is new coral regenerating over the dead/damaged coral. This would increase the live coral coverage percentages, while decreasing the percentages of dead/damaged coral.

On a more informal note, it was apparent from observation without data collection that FZR is healthier than UVR. The coral is vibrant and makes you go, "Ah, so that's what that genus is supposed to look like!", as if it has been plucked straight from the textbook. Additionally, the water is clear with absolutely no turbidity, making coral far easier to identify and observe, and adding to the broader scale of the health of FZR. Keeping in mind our formal coral data collection, calculations in comparison to previous studies' coral coverage, and informal observations, it can be concluded that Fungu Zinga Reef is healthier than Ushongo Village Reef in terms of coral.

Fish Discussion

The differences seen between FZR and Ushongo were not only statistically significant but clear to the naked eye. While there was not a statistically significant difference between the calculated indices of diversity at both sites, the averages were slightly different. Ushongo had an average index of diversity of 0.889 compared to FZR's 0.922, **Figure 10.**. This lack of statistically significant difference could be due to the variance found within each sample across the 10-13 plots. These differences likely across plots arose as different plot sections were sampled; some in sandy sections of the reef, some on the edges of the reef, and some in more central sections of the reef. On the other hand, there was a significant difference between abundance of fish as well as number of species per plot from Ushongo and FZR ($p = 0.0227$, 0.0000200). There was a density of 460.9 fish per $100m^2$ on FZR compared to Ushongo's 236.3. Within the FZR system there were an additional 28 species observed and a greater species richness by 10. Within this greater number of species, there was a larger number of indicator species/commercially desirable species. These results led to the general conclusion that the FZR was indeed healthier. Looking to **Figure 16.**, there was an average of 51 commercially desirable/indicator species individuals per $100m^2$ plot at FZR while an average of 36 individuals within the Ushongo system. Commercially desirable and indicator species fish included; grouper, snapper, rabbitfish, triggerfish, surgeonfish, barracuda, parrotfish, angelfish and butterflyfish. Some of these species, for example the grouper, are indicators of health due to their place on the top of the food chain. As top predicators on the reef, their presence indicators a healthy reef. Others, like snapper, are very desirable for sale by the fishing industry. Last, butterflyfish, parrotfish, and the coral itself, thus the presence of these fish indicates the coral is in healthy condition. Across the past 6 years, it also appears that the presences of some of these commercially desirable fish is growing. In **Figure 12, 13,** and **14**, the ratio percentage of the number of "overfished" fish on the Ushongo reef rose from 3% in 2010 to 16% in 2016. This would help show how the populations of overfished fish are rebounding with new fish regulations and restrictions. Not only were differences in numbers, but also fish both differences in appearance between the two reefs. On FZR, a great deal of substantially larger schools were witnessed and the fish seen there were on average bigger in size than those seen on UVR.

The striking difference between UVR and FZR lies within the distance they both sit from shore and human populations. As the likely cause for the greater health of the FZR system, distance from or access by humans becomes the main protecting factors for a reef system. FZR sits over 8kms from Ushongo Village. The sand island further protects the reef from impending damage. It is also important to note that tourists visit this sand island for snorkeling and relaxing. While the Ushongo reef never acts as a true tourist attraction, the incentive to protect the health of FZR over UVR increases.

Comparing to the study conducted two years ago (Henderson 2014), the index of diversity for Ushongo has risen from 0.622 to 0.889 while the index of diversity at FZR has sat at 0.922. Across these two years, it appears the number of species as well as individuals has risen on both reefs. While it could be true that the Ushongo reef system has been improving in health, these increases are most likely due to differences in methodology. It is valuable to note that there still was substantial cross-over in species observed within both studies (Appendix E, F). This would help confirm some consistency with methodology and identification between both studies.

There were no significant or strong correlations found between any of the coral and fish data. When comparing abundance, number of species, and indices of diversity for fish all with % coral coverage (live, dead, and total) as well as number of coral species and genera some very weak positive and some very weak negative correlations were found. This could be due to the limitation in time and thus data points for this study. While a total of 2,300m^2 of coral reef area was able to be studied, that only accounted for 23 total data points. Looking to **Figure 11.,** the largest of the positive correlations can be seen between the indices of diversity and the % live coral coverage on FZR (R^2 = 0.226). This result makes sense, as it would be predicted that as healthy coral coverage increases, the diversity/health of the fish also increases. When more correlations were run, the opposite was actually experienced. On FZR there was a negative, while too weak to be at all significant, correlations between abundance of fish and species with % live coral coverage were found (R^2 = 0.0792, 0.141). These correlations could be due to errors in counting when on more covered areas of the reef as a great deal of fish could hide in the coral and not be counted. Also, changes in time of day and specific kind of coral could potentially change the number of fish that came in went within each plot.

Fishermen Interviews Discussion

The answers obtained through the focus group with the fisherman were convoluted by the language barrier, despite the presence of a translator, but it is still important to try to analyze the answers we received (Appendix G). The fishermen said that most use drag nets for fishing and spear fishing for octopus. Some of the men volunteered that they use hooks for fishing, which was observed when on the boat with the fishermen on the way to Fungu Zinga. The method involves using squid or small fish as bait, using traditional hooks and lines. These answers are unsurprising; dynamite fishing is not common in Ushongo, and even if it was, no fisherman would readily admit to it.

It is also not a shock that drag net fishing is popular here. Drag net fishing can flatten and damage the coral as its towed behind the boat, and this type of damage was very often observed on the Ushongo Village Reef in the plots. When asked about fishing policies and regulations in Ushongo, the answers became more conflicting and vague. One is not allowed to do “diving with a gas bottle,” which we can interpret as referring to using scuba gear to fish. The fishermen also explained that one is not allowed to use nets with tiny holes, because this catches the smaller fish and results in a large and unnecessary bycatch. Though some of the fishermen would refer to “government regulations” in passing later in the discussion, they were insistent that they are allowed to bring in as much fish as they catch. The fish coming through the market are not regulated or weighed; “they trust that you are catching the right fish.” This would imply that there are “wrong fish”, therefore regulations what is allowed to be fished and not. However, a definite answer for our question was never fully answered. It was offered that a license to fish from the government is required, and the government can take it away as a consequence.

When asked about how they've seen the reef change in the past few years, it seemed they thought we were asking about the different seasons’ effect on the kinds of fish seen on the reef. One man explained through the translator, “The reef can change up to two or three times a year.” He went on to say that the village reef is getting healthier and stronger. Four years back, there were less fish than there are now. Another fisherman said that the reef changes according to the weather; if the sea is rough, it can change the reef. The other answers received for that question indicated that overfishing has changed the reef, while another fisherman said that too many taxes had changed the reef. There used to be more fish in the past than there are now, but he still thinks the reef is getting healthier.

The taxes comment struck a chord in the conversation, prompting the comments: “Nowadays it's not easy like before”—due to government regulations, President Magufuli’s enforcement of policies that have always been there, but never followed. The other fishermen agreed that because of government regulations and patrols, there is less fishing than there was before. There are many new laws with the new government, and before they used to be able to fish over 100 kilograms. Once again, this contradicts the previous statements that there are no maximum weight regulations, just an honor system in place. However, these comments provide a window into the psyche of the typical Ushongo fisherman: the people here are deeply critical of the new president Magufuli, because he is now pushing the enforcement of policies that have actually always been in place. Concurrently, he is now enforcing the fishermen of Ushongo to pay taxes, something virtually unheard of in the past presidency. “It used to be the Wild West out here,” Kerstin has said when explaining the animosity among the fishermen with the political change affecting their fishing. “People could get away with anything and no one would come.”

There is a sense of injustice about the new implementation of old policies and taxes, which is tainting perceptions of their livelihood and how things used to be compared to now. No human can be perfectly pragmatic; perhaps the reef was no healthier in the past than it is today, but their reticent feelings of political bitterness is clouding the perspectives of how things used to be on the reef, so it makes sense that some fishermen would say fishing used to be better. When asked if they think their fishing influences reef health, the answer was that fishing on the reef does not cause any problems for the reef, and the reef allows them to fish more than they otherwise would be able to do. This answer suggests that there is the connection that the presence of the reef provides a habitat for the fish and therefore the presence of the reef is profitable for the fishermen. But there is a lack of understanding that the fishermen in turn can harm the reef by their presence, method, and overfishing.

he fishermen said that the most commercially desirable fish are tuna, *pundaje* (goatfish), blue fish, grouper, *chazanda*, *bora*. It is not a coincidence that most commercially desirable fish and large predators are largely absent from our plots on UVR and Fungu Zinga. Large predators are a strong indicator of reef health, regulating fish populations naturally. Instead, the large predators are missing from the reef and instead the fish populations on UVR and Fungu Zinga are being curbed by overfishing (Erler, personal communication). Though there couldn't be a consensus drawn between the fishermen for if the reef was getting healthier or not, they agreed that the Maziwe reef is very healthy. “At Maziwe, there are three things that depend on each other: water, fish and stones [coral].”

Only at this point in the conversation was there a deeper understanding of the coral reef ecosystem beyond the water’s edge. The fishermen agreed that the water, the marine life and the coral all depend on each other for their existence. It was therefore baffling why the same deductions couldn’t be used for the Ushongo Village Reef by the fishermen. I hypothesize that this could be because Maziwe conservation efforts are prominent in the village—thanks to Kerstin’s efforts—so the fishermen have been exposed to education about the importance of the Maziwe reef’s ecosystem. The language barrier has most likely caused a disconnect between the commonality of the Maziwe reef and UVR.

Limitations and Recommendations

The main limitation with this study was a lack of expertise. Even with continual studying and preparation for learning different fish species, there was no way we could become experts in the short ISP window. Especially with species like damsels or parrotfish, the differences between species are minuscule. Combating this limitation, we utilized the guidebooks, Kerstin's expertise and the internet, though we did push ourselves to memorize fish for immediate identification. This allowed for an accurate index of diversity while maintaining the proper number of individuals and species observed.

When sampling both reefs, solely shallow sections were available to be studied as no diving was conducted. This restricted the observational area to shallow depths commonly housing a different array of marine life.

The coral coverage numbers were also estimated. There is a great deal of error associated with estimation and when comparing these numbers to past studies, it is difficult to ensure there was even a similar methodology or process used.

It is important to note that this study did attempt to identify coral down to a species level in order represent the greater diversity of coral observed on FZR. Many species are only distinguishable through microscopic observations or by individuals with years of expertise, and the coral was compared to other studies and across both reefs on a genera level.

Due to miscommunication with our translator, it seemed we were not getting the full picture at times during the interview. Many of our questions were not received as we intended them; we inferred this because occasionally the fishermen and our translator offered completely irrelevant responses to the proposed question. A great example of this: "How have you seen the reef change over the years?" "It is changing because of taxes".

As our interviews were conducted as one large focal group, it was difficult to seek the individual opinions of each fisherman. Furthermore, on multiple occasions the fishermen seemingly contradicted themselves from previous statements or from what we observed them doing on a daily basis. For future studies, it would be recommended to thoroughly walk through the study questions in advance with one's translator as well as ensure they have a high comprehension in both English and Kiswahili. Additionally, confirming your translator understands the purpose of your study is very important; this was a point of miscommunication several times in our interviews.

Further studies could look into dynamite fishing across the different regions in Tanzania. In some areas, like Kigombe, the explosions are rampant while Ushongo is home to far fewer cases of dynamite fishing. It would also be interesting to look at the health of different reefs along Tanzania's coast that have not been as extensively studied.

It would also be interesting to study the fishermen exclusively; fishing might as well be Ushongo's second religion. Perhaps by conducting a case study on a single fisherman or honing in on the actions of the fishermen and how their daily lives have been affected by the recent enforcement of regulations by President Magufuli.

Conclusion

From November 6th to November 25th, comparative data collection took place on Fungu Zinga Reef and Ushongo Village Reef, using fish diversity and species as well as coral abundance as indicators of health. Analyzing the data collected with the 2010 Henderson study and 2014 Mecham, Azoff study, it can be concluded that FZR is healthier than UVR. There was a significant difference found between % live coral coverage, abundance of fish as well as number of species per plot from Ushongo to FZR. Within this greater number of species, there was also larger number of indicator species/commercially desirable species.

This could be attributed to the geographical protection of FZR compared to UVR; FZR is protected by physical distance from the village, and the sand bar that fringes the reef. In comparison, UVR is a mere couple hundred meters from shore, making it highly accessible to the village and exposed to human waste and pollution from human development being so close. Furthermore, FZR is respected as a tourist attraction while few visitors are even aware of the presence of UVR. These results led to the general conclusion that the FZR was indeed healthier.

Concerning the second hypothesis, that both reefs would be improving in health, results were compared to the data of the 2010 Houlihan study and the 2014 Mecham, Azoff study. It was found that over the course of the three studies, over a time period of six years, the health of the reef concerning total coral coverage, percentages of live and dead coral, abundance and variety of genus of coral, fish diversity and fish species have generally increased.

As the dangers of global warming grow, it is important to continue to study and monitor our marine systems. While these two reefs are doing relatively well and have been rebounding since years of damage in the past, coral reefs are in no way safe. Dynamite fishing is still a large threat across the coast of East Africa. With Tanzania's rapidly growing population, the unsustainable pressure on coral reefs is only predicted to get worse.

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Appendix

Appendix A

Coral Genera Observed in the Ushongo Reef 2010, 2014, 2016

2010	2014	2016
1. *Acanthastrea* 2. *Acropora* 3. *Alvepora* 4. *Echinophyllia* 5. *Echnopora* 6. *Favia* 7. *Fungia* 8. *Galaxea* 9. *Gardineroseris* 10. *Halomitra* 11. *Hydnophora* 12. *Lobophytum* 13. *Montastrea* 14. *Montipora* 15. *Mycedium* 16. *Pavona* 17. *Pectinia* 18. *Platygyra* 19. *Pocillopora* 20. *Porites* 21. *Psammocora* 22. *Sarcophyton* 23. *Sinularia* 24. *Stylophora*	1. *Acanthastrea* 2. *Acropora* 3. *Alvepora* 4. *Anthelia* 5. *Antipathes* 6. *Coscinarea* 7. *Diploastrea* 8. *Echnopora* 9. *Favia* 10. *Favites* 11. *Fungia* 12. *Galaxea* 13. *Gardineroseris* 14. *Hydnophora* 15. *Lobophytum* 16. *Merulina* 17. *Montastrea* 18. *Montipora* 19. *Oulophyllia* 20. *Oxypora* 21. *Paschyseris* 22. *Pavona* 23. *Pectinia* 24. *Platygyra* 25. *Plerogyra* 26. *Pocillopora* 27. *Porites* 28. *Psammocora* 29. *Sinularia* 30. *Stylophora*	1. *Acanthastrea* 2. *Acropora* 3. *Alveopora* 4. *Anacropora* 5. *Anthelia* 6. *Coscinaraea* 7. *Cyphastrea* 8. *Diploastrea* 9. *Echinopora* 10. *Faviaa* 11. *Favites* 12. *Fungia* 13. *Gardineroseris* 14. *Goniastrea* 15. *Halomitra* 16. *Hydnophora* 17. *Leptoria* 18. *Leptoseris* 19. *Lobophyllia* 20. *Lobophytum* 21. *Merulina* 22. *Montastrea* 23. *Oulophyllia* 24. *Oxypora* 25. *Pachyseris* 26. *Pavona* 27. *Pectinia* 28. *Platygyra* 29. *Pocillopora* 30. *Polyphyllia* 31. *Porites* 32. *Rumphella* 33. *Sarcophyton* 34. *Sinularia* 35. *Symphyllia* 36. *Tubipora* 37. *Xenia*

Appendix B

Coral Genera Observed in the Ushongo and Fungu Zinga Reefs - 2016

Ushongo Village Reef	Fungu Zinga Reef
1. *Acanthastrea*	1. *Acropora*
2. *Acropora*	2. *Actinodendron*
3. *Alveopora*	3. *Alveopora*
4. *Anacropora*	4. *Anacropora*
5. *Anthelia*	5. *Caulastrea*
6. *Coscinaraea*	6. *Coelogorgia*
7. *Cyphastrea*	7. *Coscinaraea*
8. *Diploastrea*	8. *Ctenactis*
9. *Echinopora*	9. *Dendronephthya*
10. *Faviaa*	10. *Euphyllia*
11. *Favites*	11. *Favia*
12. *Fungia*	12. *Favites*
13. *Gardineroseris*	13. *Fungia*
14. *Goniastrea*	14. *Gardineroseris*
15. *Halomitra*	15. *Goniastrea*
16. *Hydnophora*	16. *Goniopora*
17. *Leptoria*	17. *Heliofungia*
18. *Leptoseris*	18. *Heliopora*
19. *Lobophyllia*	19. *Herpolitha*
20. *Lobophytum*	20. *Hydnophora*
21. *Merulina*	21. *Lemnalia*
22. *Montastrea*	22. *Leptastrea*
23. *Oulophyllia*	23. *Leptoria*
24. *Oxypora*	24. *Leptoseris*
25. *Pachyseris*	25. *Lobophyllia*
26. *Pavona*	26. *Lobophytum*
27. *Pectinia*	27. *Merulina*
28. *Platygyra*	28. *Millepora*
29. *Pocillopora*	29. *Montastrea*
30. *Polyphyllia*	30. *Montipora*
31. *Porites*	31. *Oxypora*
32. *Rumphella*	32. *Pavona*
33. *Sarcophyton*	33. *Pectinia*
34. *Sinularia*	34. *Platygyra*
35. *Symphyllia*	35. *Pocillopora*
36. *Tubipora*	36. *Porites*
37. *Xenia*	37. *Sarcophyton*
	38. *Seriatopora*
	39. *Stylophora*

	40. Symphyllia *41. Turbinaria* *42. Xenia*

Appendix C

Daily Observed Fish – Ushongo Village Reef

Date	Total Species	Total Individuals
11/7/16	15	332
11/8/16	13	50
11/8/16	30	216
11/9/16	13	91
11/9/16	20	373
11/10/16	11	79
11/11/16	39	296
11/13/16	12	89
11/16/16	36	245
11/16/16	34	416
11/17/16	35	205
11/18/16	50	467
11/18/16	28	213

Appendix D

Daily Observed Fish – Fungu Zinga Reef

Date	Total Species	Total Individuals
11/20/16	62	475
11/21/16	50	514

11/21/16	38	312
11/22/16	39	191
11/22/16	51	298
11/23/16	56	1106
11/23/16	40	330
11/24/16	64	411
11/25/16	63	451
11/25/16	50	1073

Appendix E

Fish Species Observed Ushongo Village Reef – 2016

Common Name	**Latin Name**	7
Banded Sergent	*Abudefduf septemfasciatus*	105
Scissortail Sergent	*Abudefduf sexfasciatus*	51
False Eye Sergent	*Abudefduf sparoides*	93
Indo-Pacific Sergent	*Abudefduf vaigiensis*	67
Orange Socket Surgeon	*Acanthurus auranticavus*	3
Palelipped Surgeonfish	*Acanthurus grammoptilus*	1
Powder-blue Surgeonfish	*Acanthurus leucosternon*	1
Striped Surgeonfish	*Acanthurus lineatus*	8
Brown Surgeonfish	*Acanthurus nigrofuscus*	1
Covenant Surgeon	*Acanthurus triostegus*	2
Yellowmasked Surgeonfish	*Acanthurus xanthopterus*	4
Twinspot Hawkfish	*Amblycirrhitus bimacula*	13
Skunk Anemonefish	*Amphiprion akallopisos*	2
Two-bar Anemonefish	*Amphiprion allardi*	14
Striped Cardinalfish	*Apogon angustatus*	15
False/minic cleaner	*Aspidontus taeniatus tractus*	1
Axilspot Hogfish	*Bodianus axillaris*	2
Saddleback Hogfish	*Bodianus bilunulatus*	250
Lunar Fusilier	*Caesio lunaris*	3
Black-Saddled Toby	*Canthigaster valentini*	1
Brown Dwarf Anglefish	*Centropyge multispinis*	1
Peacock Grouper	*Cephalopholis argus*	17

Threadfin Butterflyfish	*Chaetodon auriga*	8
Saddleback Butterfly	*Chaetodon falcula*	9
Indian Teardrop Butterfly	*Chaetodon interruptus*	2
Klein's Butterflyfish	*Chaetodon kleinii*	8
Raccon Butterflyfish	*Chaetodon lunula*	8
Black-Backed Butterfly	*Chaetodon melannotus*	5
Chevrond Butterflyfish	*Chaetodon trifascialis*	61
Redfin Butterfly	*Chaetodon trifasciatus*	28
Vagabound Butterfly	*Chaetodon vagabundus*	1
Zanzibar Butterflyfish	*Chaetodon zanzibarensis*	51
Floral Wrasse	*Cheilinus chlorourus*	2
Cigar Wrasse	*Cheilio inermis*	32
Bullethead Parrotfish	*Chlorurus sordidus*	12
Two Tone Chromis/Indian half-and-half Chromis	*Chromis dimidata*	2
Scaley Chromis	*Chromis lepidolepis*	6
Ternate Chromis	*Chromis ternatensis*	8
Bluegreen Chromis	*Chromis viridis*	21
Twospot Demoiselle	*Chrysiptera biocellata*	41
Gray Demoiselle	*Chrysiptera glauca*	17
One Spot Demoiselle	*Chrysiptera unimaculata*	2
Pixy Hawkfish	*Cirrhitichthys oxycephalus*	1
Twospot Bristletooth Surgeonfish (Juvenile)	*Ctenochaetus binotatus*	106
Lined Bristletooth	*Ctenochaetus striatus*	65
Humbug Dascullus/Zebra Humbug	*Dascyllus aruanus*	17
Indian Dascyllus	*Dascyllus carneus*	10
Domino Humbug/3 Spot Dascyllus	*Dascyllus trimaculatus*	1
Greasy Grouper	*Epinephelus tauvina*	10
Splenderspine Mojarra	*Eucinostomus jonesii*	41
Bird wrasse	*Gomphosus varius*	6
Twotone Wrasse	*halassoma amblycephalum*	15
Checkerboard Wrasse	*Halichoeres hortulanus*	12
Dusky Wrasse	*Halichoeres marginatus*	13
Greenback Wrasse	*Halichoeres nigrescens*	2
Blackeye Thicklip Wrasse	*Hemigymnus melapterus*	7
Longfin Bannerfish	*Heniochus acuminatus*	3
Masked Bannerfish	*Heniochus monoceros*	45
Common Cleaner Wrasse	*Labroides dimidiatus*	4
Bluestripe Snapper	*Lutjanus kasmira*	3
Mozambique Fangbenny	*Meiacanthus abditus*	2
Scarlet Soilderfish	*Myripristis pralinia*	8
Black Damsel	*Neoglyphidodon melas*	1
Bloodspot Squirrelfish	*Neoniphon Samara*	936
Yellowtail Demosielle	*Neopomacentrus azysron*	22

Cube Boxfish	*Ostracion cubicus*	1
Yellow Boxfish	*Ostracion cubicus*	4
Longnose Filefish	*Oxymonacanthus longirostris*	8
Mimic Filefish	*Paraluteres prionurus*	2
Speckled Sandperch	*Parapercis hexophtalma*	2
Whitesripe Sandperch	*Parapercis xanthozona*	2
Whitelined Goatfish	*Parupeneus ciliatus*	1
Indian Goatfish	*Parupeneus indicus*	19
Longbarbel Goatfish	*Parupeneus macronema*	1
Sidespot Goatfish	*Parupeneus pleurostigma*	1
Rosy Goatfish	*Parupeneus rubescens*	15
Blackspotted Sweetlips	*Plectorhinchus chaetodonoides*	8
Longfin Perchlet	*Plectranthias longimanus*	61
Dicks Damsel/Black Bar Damsel	*Plectroglyphiddon dickii*	4
Johnston Damsel	*Plectroglyphidodon johnstonianus*	179
Jewel Damsel	*Plectroglyphidodon lacrymatus*	67
Whitebanded Damsel	*Plectroglyphidodon leucozonus*	1
Earspot Anglefish	*Pomacanthus chrysurus*	1
Emperor Angelfish	*Pomacanthus imperator*	8
Semicircle Angelfish	*Pomacanthus semicirculatus*	3
Colombo Damsel	*Pomacentrus proteus*	16
Sulfur Damsel	*Pomacentrus sulfureus*	2
Sixstripe Wrasse	*Pseudocheilinus hexataenia*	3
Smalltail Wrasse	*Pseudojuloides cerasinus*	1
Indian Lionfish	*Pterois miles*	1
Picasso Triggerfish	*Rhinecanthus aculeatus*	4
Redcoat Squrrielfish	*Sargocentron rubrum*	1
Bridled Parrotfish	*Scarus frenatus*	2
Surf Parrotfish	*Scarus rivulatus*	12
Greenlip Parrotfish, maybe?	*Scarus virdifucatus*	34
Dusky Rabbitfish	*Siganus fuscescens*	6
Dusky Rabbitfish	*Siganus fuscescens*	26
Dusky Gregory	*Stegastes nigricans*	1
Bluespotted Stingray	*Taeniura lymma*	14
Goldbar Wrasse	*Thalassom hebraicum*	14
6-Bar Wrasse	*Thalassoma hardwickie*	1
Crescent Wrasse	*Thalassoma lunare*	8
Moon Wrasse	*Thalassoma lunare*	5
Sunset Wrasse	*Thalassoma lutescens*	5
5-Stripe Wrasse	*Thalassoma quinquevittatum*	27
Moorish Idol	*Zanclus canescens*	2
Desjardin's Tang	*Zebrasoma desjardini*	12

Indian Sailfin Tang	*Zebrasoma scopas*	2
Oriental Wrasse		
Unidentified Species		4
Spotted gray/brown groupers, blended to rocks/coral		12
Gray rabbit with dark block chunk in tail, yellow surrounding black chunk		1
Gray Chromis or Damsel with neon blue stripe down belly		1
Grayish snapper, with two white dots near back (red juvi)		1
Huge, silvery, scissortail, lost as swimming away, Snapper		1
Smaller, super blue parrotfish, neon in front of tail		6
Yellowtail demosielle but blue tail instead		5
Little white tail, angelfish lik, jv. tang		35
Goby**Burgundy Partner?		4
Unicorn Fish but black, bignose or black spotted?		20
Clown Coris? Line then front and back		1
Two dot humbug with stripes on bottom, juvenile black snapper		12
Like striped cardinalfish but bigger and only top half striped		1
Clear, one dot goby?		16
Damsel, black with neon blue sport back and neon blue checks/line back/belly		1
Yellow black, blue fin damsel		28
Cardinals?		36
Small brown fish (cardinal?)		1
Grouper, red		2
Biglips		1
Orange, yellow, brown, white (spotted parrotfish juvenile?)		1
Red Parrotfish		
Total Species Observed	**Total Species**	130
	Total Individuals	3092

Appendix F

Fish Species Observed Fungu Zinga Reef - 2016

Common Name	**Latin Name**	**Total Individuals**
Scissortail Sergent	*Abudefduf sexfasciatus*	49
False Eye Sergent	*Abudefduf sparoides*	54
Indo-Pacific Sergent	*Abudefduf vaigiensis*	152
Orange Socket Surgeon	*Acanthurus auranticavus*	22
Palelipped Surgeonfish	*Acanthurus grammoptilus*	5

Powder-blue Surgeonfish	*Acanthurus leucosternon*	1
Brown Surgeonfish	*Acanthurus nigrofuscus*	13
Scribbled Filefish	*Aluterus scriptus*	1
Broom Filefish	*Amonses scopas*	1
Skunk Anemonefish	*Amphiprion akallopisos*	11
Two-bar Anemonefish	*Amphiprion allardi*	6
Blue Spotted Wrasse	*Anampses caeruleopunctatus*	1
Goldie	*Anthias squamipinnis*	3
Striped Cardinalfish	*Apogon angustatus*	23
Ringtailed Cardinalfish	*Apogon aureus*	10
Blackspotted Pufferfish	*Arothron higropunctatus*	1
False/mimic cleaner	*Aspidontus taeniatus tractus*	6
Trumpetfish	*Aulostomus Chinensis*	5
Orangestriped Triggerfish	*Balistapus undulatus*	3
Axilspot Hogfish	*Bodianus axillaris*	9
Blackbelt Hogfish	*Bodianus mesothorax*	1
Leopard Flounder	*Bothus Pantherinus*	2
Lunar Fusilier	*Caesio lunaris*	35
Yellowback Fusilier	*Caesio teres*	5
Yellowback Fusiler	*Caesio xanthonota*	3
Comet	*Calloplesiops altivelis*	1
Raggedtooth Parrotfish	*Calotomus spinidens*	9
Bennett's Toby	*Canthigaster bennetti*	3
Honeycomb Toby	*Canthigaster janthinoplera*	3
Black-Saddled Toby	*Canthigaster valentini*	33
Brown Dwarf Angelfish	*Centropyge multispinis*	58
Peacock Grouper	*Cephalopholis argus*	1
Threadfin Butterflyfish	*Chaetodon auriga*	13
Spotted Butterflyfish	*Chaetodon guttatissimus*	6
Indian Teardrop Butterfly	*Chaetodon interruptus*	2
Raccoon Butterflyfish	*Chaetodon lunula*	12
Chevrond Butterflyfish	*Chaetodon trifascialis*	3
Redfin Butterfly	*Chaetodon trifasciatus*	15
Vagabound Butterfly	*Chaetodon vagabundus*	1
Zanzibar Butterflyfish	*Chaetodon zanzibarensis*	2
Floral Wrasse	*Cheilinus chlorourus*	33
Snooty Wrasse	*Cheilinus oxycephalus*	2
Trippletail Wrasse	*Cheilinus trilobatus*	1
Cigar Wrasse	*Cheilio inermis*	5
Largetooth Cardinalfish	*Cheilodiplerus macrodon*	1
Bullethead Parrotfish	*Chlorurus sordidus*	54
Blue-axil Chromis	*Chromis atripectoralis*	65

Two Tone Chromis/Indian half-and-half Chromis	*Chromis dimidata*	668
Ternate Chromis	*Chromis ternatensis*	765
Bluegreen Chromis	*Chromis viridis*	536
Scaley Chromis	*Chromis lepidolepis*	3
One Spot Demoiselle	*Chrysiptera unimaculata*	9
Exquisite Wrasse	*Cirrhilabrus exquisitus*	1
Pixy Hawkfish	*Cirrhitichthys oxycephalus*	4
Filamentous Blenny	*Cirripectes filamentosus*	2
Red-Streaked Blenny	*Cirripectes sigmaticus*	4
Clown Coris	*Coris aygula*	1
Batu Coris	*Coris batuensis*	6
Spottail Sandwrasse	*Coris caudimacula*	8
Queen Coris	*Coris formosa*	8
Indian Sand Coris	*Coris frerei*	7
Yellowtail Coris	*Coris gaimard*	3
Yellowtail Wrasse	*Coris gaimard*	8
Network Pipefish	*Corythoichthys flavofasciatus*	11
Barred Shrimpgoby	*Cryptocentrus fasciatus*	5
Two-spot Bristle	*Ctenochaetus binotatus*	7
Twospot Bristletooth Surgeonfish (Juvenile)	*Ctenochaetus binotatus*	1
Bluelipped Brtistletooth	*Ctenochaetus cyanocheilus*	3
Lined Bristletooth	*Ctenochaetus striatus*	75
Helmut Gurnard	*Dacthloptena orientalis*	1
Humbug Dascullus/Zebra Humbug	*Dascyllus aruanus*	9
Indian Dascyllus	*Dascyllus carneus*	64
Domino Humbug/3 Spot Dascyllus	*Dascyllus trimaculatus*	97
Foursaddle Grouper	*Epinephelus spilotoceps*	2
Leopard Blenny	*Exallias brevis*	11
Cornetfish	*Fistuloria commersonii*	2
Striped Large-eye Bream	*Gnathodentex aureolineatus*	7
Bird wrasse	*Gomphosus varius*	52
Argus Wrasse	*Halichoeres argus*	11
Checkerboard Wrasse	*Halichoeres hortulanus*	41
Dusky Wrasse	*Halichoeres marginatus*	4
Greenback Wrasse	*Halichoeres nigrescens*	54
Barred Thicklip	*Hemigymnus fasciatus*	10
Bi-color Cleaner Wrasse	*Labroides bicolor*	10
Common Cleaner Wrasse	*Labroides dimidiatus*	69
Blackpatch Emperor	*Lethrinus harak*	3
Twinspot Snapper	*Lutjanus bohar*	2
Black Snapper (Jv.)	*Macolor niger*	2

Mozambique Fangblenny	*Meiacanthus abditus*	23
Bigeye Emperor	*Monotaxis grandoculis*	3
Scarlet Soilderfish	*Myripristis pralinia*	1
Bignose	*Naso vlamingii*	2
Black Damsel	*Neoglyphidodon melas*	16
Blood Spot Squirrelfish	*Neoniphon sammara*	6
Yellowtail Demosielle	*Neopomacentrus azysron*	84
Rockmover Wrasse	*Novaculichthys taeniourus*	9
Black Boxfish	*Ostracion meleagris*	2
Yellow Boxfish	*Ostracion cubicus*	1
Twospot Wrasse	*Oxycheilinus bimaculatus*	2
Longnose Filefish	*Oxymonacanthus longirostris*	14
Palette Surgeonfish	*Paracanthurus hepatus*	1
Freckled Hawkfish	*Paracirrhites forsteri*	13
Mimic Filefish	*Paraluteres prionurus*	2
Speckled Sandperch	*Parapercis hexophtalma*	30
Dot-Dash Goatfish	*Parupeneus barberinus*	3
Indian Goatfish	*Parupeneus indicus*	6
Longbarbel Goatfish	*Parupeneus macronema*	74
Rosy Goatfish	*Parupeneus rubescens*	9
Dusky Sweeper	*Pempheris adusta*	790
Blackbar Filefish	*Pervagor janthinosoma*	3
Twostripe Blenny	*Plagiotremus rhinorhynchos*	5
Blackspotted Sweetlips	*Plectorhinchus chaetodonoides*	2
Dicks Damsel/Blackbar Damsel	*Plectroglyphiddon dickii*	90
Jewel Damsel	*Plectroglyphidodon lacrymatus*	83
Semicircle Anglefish	*Pomacanthus semicirculatus*	2
Blueyellow Damsel	*Pomacentrus caeruleus*	5
Sulfur Damsel	*Pomacentrus sulfureus*	85
Sixstripe Wrasse	*Pseudocheilinus hexataenia*	29
Twotone Dartfish	*Ptereleotris evides*	3
Indian Ocean Lionfish	*Pterois miles*	3
Clearfin Lionfish	*Pterois radiata*	1
Royal Angelfish	*Pygoplites diacanthus*	2
Crown Squirrelfish	*Sargocentron diadema*	2
Bridled Parrotfish	*Scarus frenatus*	4
Blue-Banded Parrotfish	*Scarus ghobban*	1
Greenlip Parrotfish	*Scarus virdifucatus*	2
Yellowstrip Bream	*Scolopsis avratus*	2
Arabian Spinecheek	*Scolopsis ghanam*	5
Dusky Rabbitfish	*Siganus fuscescens*	10
Honeycomb Rabbitfish	*Siganus stellatus*	4
Yellowtail Barracuda	*Sphyraena flavicauda*	58

Bluespotted Stingray	*Taeniura lymma*	1
Goldbar Wrasse	*Thalassom hebraicum*	23
6-Bar Wrasse	*Thalassoma hardwickie*	21
Moon Wrasse	*Thalassoma lunare*	8
Sunset Wrasse	*Thalassoma lutescens*	5
Surge Wrasse	*Thalassoma purpureum*	1
Freckled Goatfish	*Upeneus tragula*	9
Moorish Idol	*Zanclus canescens*	13
Desjardin Tang	*Zebrasoma desjardinii*	1
Brushtail Tang	*Zebrasoma scopas*	45
Indian Sailfin Tang	*Zebrasoma veliferum*	1
Bluestreak Surgeonfish		14
Indian Toby		15

Unidentified Species

Stripe Bream	5
Silver Snapper with dot	4
Black tubelip, white lips	16
Pink face, purple body, yellow tail to belly coris	7
Black thicklip with red lips	5
Spotted gray/brown groupers, blended to rocks/coral	5
Small black wrasse	14
Soft blue/pink parrotfish or wrasse	19
Very small, jv. Wrasse, greenface fades into brownish clear/yellow	4
Tan brown damsel with blue eyelid	1
Parrot, black with white chunk before tail	20
Black wrasse with white spots, small	4
Cardinal fish	76
Gray chromis with neon blue edges	1

Total Species Observed	**Total Species**	158
	Total Individuals	5161

Appendix G

Interview Questions with Fishermen - November 14th, 2016

1. What fishing practices do you use?
2. What are the fishing policies in Ushongo and how are they enforced?
3. How have you seen the reef change over the years?
4. Why do you think there are changes?
5. Do you think your fishing effects the reef?
6. What are the most commercially desirable fish?
7. Do you think the protected reef (Maziwe) is healthier than UVR?

Nuts and Bolts

Getting to Ushongo

It is definitely a long day of travel, but well worth it for sure. You can take the Ratco bus, 20,000tsh, from Arusha to Tanga. It leaves at 7am from the bus station 10 minutes walking from Arusha Backpackers, anyone can direct you the way. This is definitely the nicest bus company for traveling to Tanga. Once in Tanga, you can take a daladala or bus to Pangani. The bus station in Pangani is about a 15 minute walk to the ferry. The ferry supposedly runs until 10pm at night but not sure how legitimate that time is. After crossing river, there will be modes of transportation to Drifter's. Don't pay more than five to seven thousand!

Where to stay

We got stuck in Pangani twice due to bad timing on the morning bus and stayed at Safari Lodge. The place was nice enough but make sure you don't get stuck in the back room in the outer house, number 11, or at least have them show you to a room before you decide to book it. If you need any help in Pangani find Rasta Ally (0712440749). Once in Ushongo we camped at Drifters during prep week for 10,000tsh, then in the dorm rooms for ISP month. The dorm room was surely hot and a bit buggy but it was really nice having our own space to spread out, space for food, and greater security than a tent when the morning storms rolled in. Both options would work and I'm sure you could bargain a cheaper price for camping. Mama Tumai owns the place and can help you out with anything.

Project

This is the most amazing project you could pick to do. While loads of students have studied both of these reefs extensively, it was incredibly rewarding learning how to conduct a marine ecology project. Fungu Zinga is potentially the most beautiful thing we have ever seen. The coral and fish looked exactly like they were supposed to from our guide books, the water was crystal clear blue, and the sand bar made you feel like you belonged in white linins in a Sandals ad. In order to make. In order to get to FZR, we hired two fishermen on a ngalawa to sail us out to the reef. It took anywhere from 1 to 3 hours to sail out depending on winds and around an hour to sail back. We hired Uhoro and Rajabu for 60,000tsh to sail us out for the day. We worked it all out with Uhoro's nephew, Rahim (walk next door of Drifters and ask around for him, his name is in the cement on his doorstep). We rented kayaks and snorkels from Kerstin at Kasa Divers (+255784134056). She is the best. Snorkels basically aren't available in this country, so renting seemed the best option.