March | 11

Dissertation

To investigate if illegal fishing pressures affect juvenile fish populations and their growth, condition and diversity in the Bay of Ranobe, Southwest Madagascar.

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"Submitted in partial fulfillment of the requirements for the Bachelor of Science (Hons) in Aquaculture and Fishery Management"

Abstract:
The control and management of artisanal fisheries can be very difficult, beach seines are seen as damaging and destructive gears adding to the reef system and its components, but the actual effects are not well researched. The investigation found as expected beach seine catches to be highly unselective, catching a high diversity of fish (D-1 = >0.95), though its still unknown how much of the population the caught fish represent (Jennings *et al.,* 1999) and how many reach maturity. Samples from the southern most site Beravy found smaller multispecific lengths, and significantly lower mean lengths of three-ribbon wrasse, African white spot rabbit fish and yellow tail barracuda as well as significantly lower condition factors of African white spot rabbit fish and of three-ribbon wrasse, possibly due to fishing pressure increase (Helman *et al.,* 2009) or altering environmental conditions. No significant difference was seen in CPUe between site or tide level, and no significant difference could be determined in length to weight relationships or growth models produced between sample sites.

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Disclaimer:

All work within this thesis is my own, citations have been given where necessary and referenced displaying background reading thus giving credit to appropriate authors where necessary.

Josh Hillman

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Introduction:

Background

Every ecosystem throughout the world is under growing pressure from a range of biological and anthropogenic factors. Temperature rise, ocean acidification and expanding hypoxic zones in the ocean are the most prominent impacts on marine ecosystem health on a global scale. All are, at least partly, related to the anthropogenic release of carbon dioxide and global climate change (WBGU 2006, Stramma *et al*., 2008, WWF 2009). Changes in ocean temperature lead to shifts in the distribution ranges of many marine species.

Recent results show that the reaction of marine ecosystems towards climate change is often not linear, but may occur in abrupt reorganisations of marine communities (Scheffer and Carpenter, 2003). It is now generally accepted that such regime shifts can transfer a marine ecosystem from one steady state to another as soon as certain thresholds of important key species are transgressed (Steele, 2004). Therefore the survival of key temperate marine species and the intrinsically connected branches of a reef system must be paramount for the preservation of coral reef environments which are relied upon so heavily to support a growing number of people.

Nearly 500 million people directly depend on coral reefs for food and income (Wilkinson 2004, Moberg and Folke 1999), and over a billion rely on reef-related fisheries worldwide (FAO, 2003).

Madagascar is the fourth largest island on the globe (WWF, 2009), the Southwest coast supports the 3rd largest coral reef system in the world called the Toliara Reef complex (WWF, 2008), made up of around 450km of reef (Webster and McMahon, 2002). It's the largest Reef system in the West Indian Ocean. There is an estimated 6000 reef associated species, 752 fish species and 340 coral species (Cooke 2002, McKenna & Allen 2003).

Unfortunately, although these are some of the most diverse systems in the world they are also the most fragile and most at risk from anthropogenic impacts (McClanahan, 2000). As from 1998 a medium to high risk status was given to Madagascar's reefs (Bryant *et al.,* 1998). This is due to a number of factors including global warming, sedimentation and overfishing. Deforestation to produce more farmland for Madagascar's growing population (approx 3% annual increase in pop. growth rate), has caused sedimentation and eutrophication. The huge influx in population (which has increased 5 fold in the last 100 years) has also resulted in a migration increase to coastal areas (WRI 2006, Whittingham *et al*., 2003), further increasing the pressure on the already degrading reef system as competition for the same resources increase (WWF, 2009). In 1998 the global coral bleaching event affected Madagascar's coral systems, this has been appointed as the major cause of reef degradation in the Southwest of the island.

Bay of Ranobe

The area chosen for this research was the Bay of Ranobe (23◦ S, 43◦ E) (see figure 1). It is home to the 32km long barrier reef (3rd largest in the world) as well as patch reef in the interior of the barrier. The area is known widely to have a huge biodiversity of fish life and coral species (Cooke 2002, McKenna & Allen 2003, Webster and McMahon 2002). The Vezo people are the traditional inhabitants of the area and their lifestyle is entirely dependant on the coral reefs and lagoons (WWF, 2008). The system comprises of Mangroves, Seagrass beds, Patch coral, Reef flats, Sand and abistle slopes.

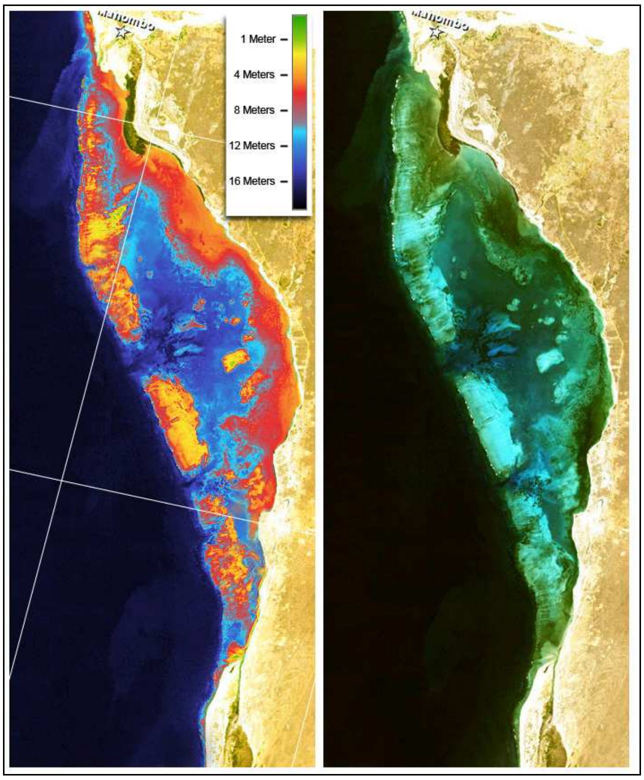

Figure 1 Shows a spectral map of the Bay of Ranobe.

The problems of overfishing and exploitation

Over exploitation in fisheries is defined as: "The rate of exploitation where the resource stock is drawn below the size that, on average, would support the long term maximum potential yield of the fishery" (OECD, 1998). Problems in marine renewable resource management are arising on a worldwide scale, global trends show that the majority of the most important marine stocks in the world are overexploited or depleted (Myers and Worm 2003, Mares 2011). In specific relation to the Bay of Ranobe it's thought that the number of traditional fishermen has increased fivefold in the last 20 years (Gabrié *et al.,* 2000) resulting in significant marine resource over exploitation, added to this it's thought the large urban centre of Toliara is where around 50% of all fishermen operate (Laroche & Rarnananarivo, 1995).

This increase in fishing pressure within the region is due to several factors, as talked about previously Madagascar is experiencing general population increase but to add to that, the agricultural failure, deforestation and drought inland has pushed a migration of Non-Vezo to the coast (WWF, 2009). This new influx of people in coastal regions without traditional knowledge of fishing techniques are thought to contribute largely to not only the over exploitation of limited resources, but increased use of unsustainable and destructive gears such as beach seine activity (McClanahan e*t al*., 2005; Signa *et al*., 2008).

Most of the evidence for 'fisheries impacts on ecosystem structure' comes from systems where biota are important for the structure of the habitat, which has been affected either directly or indirectly (e.g. coral reefs, soft corals and sponges) (Gislason, 2001). Direct damage could consist of gear based damage to the environment by fishing. Indirect damage could be seen as the removal of those species required for maintaining the environment i.e. fishing of herbivorous parrotfish (Scaridae) in a tropical reef system resulted in decreased grazing, and hence increased proliferation of algae on many corals (McManus *et al.,* 2000).

Over exploitation causes shifts in growth rates, age, and size of reproduction in fish populations, which may cause faster growth and earlier maturation compared to unexploited areas (Helfman *et al.,* 2009). This process is known as a 'cascade effect' which penetrates the entire coral reef ecosystem resulting from the changing predator-prey dynamics (McClanahan and Shafir 1990, McManus *et al.,* 2000, Sheffer *et al.,* 2005, Mares 2011). Possibly the most important point relevant to my research is that due to the complex reef system, a shift such as that caused by over exploitation of one group or species can affect the reef system as a whole.

An example of a cascade effect due to fishing pressure is demonstrated by McManus, where the collapse of a Caribbean reef ecosystem was due to the depletion of herbivorous fish, which left sea urchins as the only grazers to control macro algae. When the sea urchins were infected by a disease, brown fleshy algae (non-calcareous macroalgae) rapidly encrusted the coral causing coral-algal phase shift. Phase shifts are further explained by McManus (McManus *et al.,* 2000) Coral communities can recover from algal shifts and become re-dominant

(>50% bottom cover), this is known as “resilience” (Pimm, 1991).

Irreversible change can sometimes result from gradually increasing fishing pressure, though the critical threshold for that change will depend and be affected by the climatic conditions (Sheffer *et al.,* 2005).

Traditional fishing methods and Beach Seines

The Vezo people are the traditional inhabitants of the area and their lifestyle is almost entirely dependant on the coral reefs and lagoons (WWF, 2008). Traditional Vezo fishing methods have been discussed by Gough (Gough *et al.,* 2009*),* a key part of Vezo fishing is the use of a Pirogue or Laka, both are a term used to describe a traditional boat/canoe made from a single hollowed out tree ‘*farafatse*’ (*Givotia madagascariensis)* and used as a platform for fishing and transporting goods or people. Traditional Vezo methods of fishing include types of: spear fishing, line fishing, long lining, gill netting, spear gun, and both open water nets and beach seines. Gleaning of the reef at low tide is also common practice by women and children.

Spear fishing will include the use of one of the various types of different spears: Voloso, Manambaitse, Kijoamanata or Tezo. They are often used during free diving and can target turtles, squid or large fish.

Line fishing will vary according to species with different strengths of line and sizes of hook being applicable to different target species. Line fishing can be stationary from pirogues or while moving acting like a troll. Long lining: known as Palangre is used for targeting larger pelagic fish or sharks.

Spear gun, known as Basim-Pia are used while free-diving often for catching lobster or fish. Net fishing including both gill netting and open water nets are referred to as Mihaza. Nets are deployed individually or in groups, different nets, different methods of deployment according to the depth of the fishing site, the target species, and the local environmental conditions (Gough *et al.,* 2009).

Beach Seine Netting

A beach seine (shown below in figure 2) is referred to as a Tarikake, it's made from Makarakara (mosquito nets largely given to fisherman by aid charities). It's deployed off shore with a team of people on the beach who pull in the net by ropes tied to the sides, whilst a pirogue sorts the net, de-snags it and collects the fish caught in the wings, until the main sock or 'cod end' is pulled up to the beach.

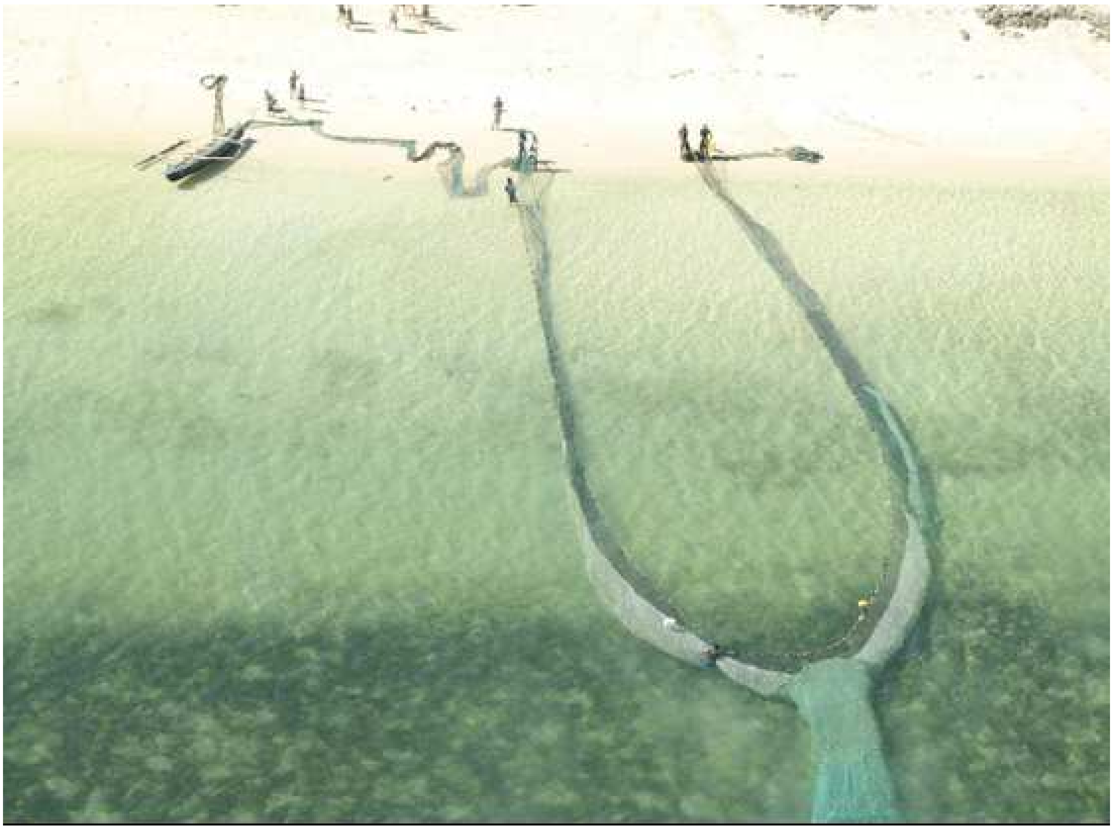

Figure 2 An aerial photo of a beach seine and team.

Beach seines are defined as "long nets averaging 150m and weighted line to hold it down while it is dragged along the seagrass, sand, and coral reef substratum" (Mangi and Roberts, 2006). A seine is created by joining six or more small mesh, (approx 2.5cm) nets, each 25m long and 3-4m deep. In reality it appeared that beach seines varied greatly in quality (holes and tears), materials used and length from 100m long to well over 400m. Coral Stones were used for the weighted line at the base of the net placed at 0.3 m intervals (McClanahan and Mangi, 2004). The use of a small mesh size means a beach seine is relatively indiscriminate of which fish it ensnares (Gough *et al.,* 2009).

The owners and fishers of this gear are according to McClanahan often only people who deal with marketing the catch, or people who aren't full-time fisherman or foreigners (McClanahan *et al*., 1997). It's believed in the Toliara region that the pressure of beach seines is often added to largely by non-Vezo groups, who have migrated to the area and may not have the necessary knowledge of other more skillful fishing methods (WWF, 2009).

The use of destructive gears like beach seines is seen to have a significant relationship to use by poorer people (Cinner, 2009), agreeing with the idea of a poverty trap meaning other options are less available to people in this situation. These fisherman have little interest in long-term sustainability and in practice were fishing partly for home consumption and partly for selling the marketable species caught. The rational choice for them is to continue to use this gear even when it's widely known that this isn't the best long-term option for the fishery (McClanahan, 2005), as it supplies enough food or money, for that day.

Problems associated with Beach Seine Method

Beach seining has been illegal in Madagascar since the 1930's, having said this it is still regularly practiced especially in the heavily fished Toliara region in the Southwest. McClanahan and Mangi (2004) outline the problems with enforcing laws on destructive gears in artisanal fisheries, national governments lacking resources is a key factor, as well as the loosely organized nature and level of poverty of fisherman involved. Poverty and/or decline in yields coupled with lack of enforcement, leaves few alternatives but to the use of destructive gears in hard times (Cinner, 2009).

Elders and ancestors don't approve of the gear therefore it is seen as taboo (McClanahan & Mangi, 2004) Taboo's are explained in detail by Cinner (2007), and relate to traditional things that in this case the Vezo would not do, many have good reason as the problems associated with them are known historically like the use of destructive gears.

Beach seine nets have been thought to be and are referred to as a destructive gear by a range of sources (McClanahan & Mangi 2004, McClanahan *et al*., 2005, Mangi & Roberts 2006, Signa *et al*., 2008, Cinner 2009). Beach seine use can severely degrade the condition of the resource, resulting in lower overall fishery yields (Cinner 2009 & McClanahan & Mangi 2001). This may be due to the weighted bottom causing damage to the substrate and the fact that the catch can consist of (68.4 ± 15.7%) juveniles, significantly more than other gears used (Cinner 2009, Mangi & Roberts 2006). Despite these findings there are remarkably few studies in tropical lagoonal fisheries on the effects of various fishing gear on species diversity, size, trophic level, selectivity or catch composition (McClanahan & Mangi, 2004).

Seagrass Habitat

Habitat characteristics such as coral cover, reef size, reef height, topography of substrate, vegetation cover, flow rate were all found to influence fish abundance (Jennings *et al.,* 1999, Williams 1991). Added to the initial problems mentioned, net dragging is seen to damage fish eggs and the seagrass beds, which are used for substrate for protection as nursery grounds, seen to be crucial for juvenile stages of many tropical reef species development (Nagelkeren *et al.,* 2000). Seagrass beds were found to be important nursery areas for a range of species including *Siganus* canaliculatus (white spotted rabbit fish) and *Lethrinus harak (*black-blotch emperor) (Gell and Whittington, 2002).
There are known to be tight energetic ties between coral reefs, mangroves and seagrass beds within the tropical marine system (Suchanek, 2003). Removing seagrass will cause shifts to lower abundances of micro and macro invertebrates and fish (Suchanek, 2003).

Species Diversity and Gears Selectivity

As proven with seagrass investigations, an ecosystem and its functional features are intricately linked (Mares, 2011*),* therefore consequences of removing one feature may have severe effects. Interactions in the Trophic seascrape are well described by (Moberg and Folke, 1999). The study was carried out within "one of the most dynamically varying marine ecosystems in the world, the West Indian Ocean (WIO) eco-region" (McClanahan 1988, Richmond 1997). The Toliara reef system is known to be very abundant with over 400 fish species and 300 coral species (WWF, 2009), therefore high levels of diversity are expected to be seen in samples.

The measurement of diversity indices within fisheries studies is not only of importance in indication of the natural diversity of the environment, but also a positive indication to the level of selectivity employed by gear under investigation. In gear studies within the Toliara region using the Simpsons index of diversity, beach seines were seen to have the highest species diversity in their catches (D = 0.91) (McClanahan & Mangi, 2004). This indicates poor selectivity by the gear as diversity of species within catch is seen to be very high.

It's known that fishing causes a decrease in not only biomass but also diversity (Jennings *et al.,* 1999). Those gears with low selectivity will inevitably decrease diversity more so than other gears. Investigations by both Cinner (2009) and McClanahan & Mangi (2004) have shown that at sites where beach seines are not used or are excluded as a gear, other gears catch rate is increased, and in areas where they are used within the same fishing grounds other gears captures are seen to be lower.

As catches decline, the gear that extracts the smallest size and most diverse fish resources may be the 'better competitor' and will reduce the catch of other gear types that select larger and more species-specific targets (McClanahan 2005). A large proportion of low trophic level species in catches also signifies that higher trophic level species have been overfished (Cinner and McClanahan 2006).

In McClanahan's studies, seine nets caught the largest number of species and the smallest individuals, Consequently this suggests that seine nets and also small traps were the two gears that were least likely to maintain maximum sustainable yields because they overlapped in species selectivity and caught smaller individuals than the other gear types. Evidence also shows lower CPUe in fishing grounds where beach seine are in regular use (McClanahan *et al*., 1997; McClanahan and Mangi, 2001).

CPUe

Rather than analyzing and reporting data as actual number of fish caught, fisheries data is typically reported as Catch Per Unit Effort (CPUE). Because sampling effort may differ from area or time. The number of fish captured must be analyzed in such a way as to standardize the effort that was exerted across the sites being investigated. CPUE standardizes catch data based on the amount of the effort exerted in this case over a time period (Jonston, 2008). This level of effort per person per unit of time (hours) can then be compared to other finding or be monitored in on going investigations and related back to. In Madagascar differences in CPUe seem more related to different fishing methods or professionalism of the fishing, rather than variation in resource abundance (Laroche *et al.,* 1997). Therefore CPUe may be a poor means for indicating fish stock quality, but still indicates the return fishers are getting for their effort.

Beach seine CPUe in the Toliara region was found to be between 0.6-2 kg per person per hour in 1997 (Laroche *et al.,* 1997). "The last 10-15 years most fisherman in Toliara region irrespective of fishing gear have observed general decline in size of captures and no. of fish per unit effort" (Laroche *et al.,* 1997). CPUe decline within the Toliara bay during the early 1990's has helped prove that the inshore areas are too heavily fished (Laroch & Ramananarivo 1995). They have continued to be heavily fished since the initial studies showed CPUe declining, therefore lower CPUe levels than those from 1997 should be expected.

In terms of fisherman's wealth, beach seines were seen to be the least profitable to other gears (Cinner *et al.,* 2009), this knowledge is further backed up by Mangi's findings showing that beach seines were seen to be 25% less profitable than the next most profitable gear (Mangi *et al.,* 2007). This indicates there must be other reasons for beach seining activity such as lack of alternatives.

Condition factors and Growth Parameters

The relationship between fishing pressure and the shift in growth rates, ages, size of reproduction and maturity is widely known (Helman *et al., 2009)*. As pressure increases and larger individuals are removed, average size of population decreases and sexual maturity may occur at younger ages and smaller sizes shifting growth characteristics. Fishing has been held partly responsible for decreasing the age of sexual maturity in the following species: North Sea plaice (*Pleuronectes platessa*) Northeast Arctic cod and Norwegian herring. It has also been implicated in causing a decline in body weight of Pacific pink salmon (*Oncorhynchus gorbuscha*). Overfishing is likely to affect the life stages and maturity of reef species too (Hawkins & Roberts, 2003).

Fulton's K condition factor of Isometric growth can be calculated by weight divided by length cubed (Feary *et al.,* 2009). Condition factors of isometric growth allow direct comparison of separate populations of the same species. Condition factor is used in order to compare the "condition" or "fatness" showing general wellbeing of fish. It's based on the hypothesis that heavier fish of a particular length are in a better physiological condition (Bagenal, 1978). Condition factor is also a useful index for the monitoring of other parameters such as: feeding intensity, age, and growth rates in fish (Oni *et al*., 1983). It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Anene, 2005).

Other growth parameters are crucial for understanding the population of fish under fishing pressure. Data collection must include length frequency (Laroche *et al.,* 1997), this and information on the length of maturity of certain species allows assessment of percentage of juvenile fish in the samples investigated. A decrease in exponential length frequency can show exertion of fishing pressure (Gobert, 1994) and increased removal of smaller juvenile fish. Decreasing size of sexual maturity as a result of fishing pressure, in tropical reef species such as parrotfish was investigated by Hawkins and Roberts (2003). Multispecific length frequency technique was used by Gobert where all species are investigated generically in terms of length (Gobert, 1994). This has great importance as size factor is related to ecological or physiological processes, such as predator prey dynamics, prey ratio to body size, production biomass rates according to size of species (Gobert, 1994).

Dominant Species affected in Beach Seines

During a beach seine investigation in Kenya, length at maturity of the same or closely related species to those in the Bay of Ranobe were documented, this allowed some comparison with key species and length of maturity as well as level of juveniles encountered in samples (Mangi and Roberts, 2006). Dominant species of beach seine catches were found to be rabbitfish and parrotfish (McClanahan & Mangi, 2004) and wrasse and parrotfish according to McClanahan (McCanahan, 1994).

Individuals are commonly <10cm in length within the Toliara region (Laroche *et al.,* 1997). Four Species that contributed to a large proportion of the beach seine catches in the Southwest Madagascar throughout August and September were; three-ribbon wrasse (*S. strigiventer*), African white-spotted rabbitfish (*S. canaliculatus)* yellowtail barracuda *(Sphyraena flavicauda)* and the parrotfish *(Scaridae).* The three-ribbon wrasse live in the inner reef flat and seagrass beds they are classed as permanent residents of this area not likely to migrate due to season or age class making them likely beach seine targets (Nakamura & Tsuchiya, 2007). Wrasse are part of the most numerically successful suborder in reef systems usually found in weedy areas of mixed rubble and seagrass (Lieske & Myers, 1999). Wrasse are carnivorous opportunistic feeders trophic level 4 (Hauser 1984, Jennings *et al.,* 1999) market price for three-ribbon wrasse is relatively poor 2400 Ariary/Kg *(*Randall 2000, McClanahan& Mangi 2004, Narozanski A. J. *et al.,* 2000). There was a lack of information on the sexual maturity of three-ribbon wrasse, but the sexual maturity of a close relative the blue lined wrasse *(Stethojulis albovittata)* occurs approximately at a total length of 6.89cm (Mangi & Roberts, 2006).

Yellowtail barracuda are from the *Percoids* family of schooling predators, trophic level 3.76 (Randall *et al.,* 1999). The species is found to be sexually mature at a length of 19.64cm (Mangi & Roberts 2006), yellowtail barracuda are known to inhabit seaward reefs from between 2-25 meters in depth. They use the reef flat and seagrass beds for juvenile nursery grounds, as do many other species (Randall *et al.,* 1999, Mangi & Roberts 2006).

White-spotted rabbitfish are known to congregate in reeds and seagrass as estuarine herbivores (trophic level 2.56), they have hard spines at either edge of the fins with venomous tips, and become sexually mature between 19 -21.5cm in total length sex dependant (Woodland 1990, Juario *et al,.* 1984). White-spotted rabbitfish have very high market value 4000 Ariary/Kg double that of wrasse, they have been known to be highly commercially viable for over 20 years (Bryan *et al.,* 1980, Lieske & Myers 1999, Narozanski A. J. *et al.,* 2000). Parrotfish are grazers of coral and are critical for preventing reverse phase shifts (Hughes *et al.,* 2007, Cinner *et al.,* 2009). In a fisheries management study by Gobert they were only identified to family level, they are seen to be an important make up of reef species for length to weight relationship due to their feeding niche in reef systems (Gobert, 1994). Though parrotfish weren't identified to species level the blue barred parrotfish was observed frequently therefore this seems a good indicator of length at sexual maturity (39.22cm) (Mangi & Roberts, 2006). Species such as parrotfish and triggerfish play an important role in coral reef ecology preventing algal dominance and should not be harvested (McClanahan, 2005). Temporary local restrictions should be placed on the exploitation of individuals that have not yet reproduced to protect population. Not overfishing parrotfish is especially critical seeing as market price is so low 2000 Ariary/Kg (Narozanski A. J. *et al.,* 2000).

Null Hypothesis:

"There is no significant difference in catch effort, growth rate, length, condition and diversity of fish species and populations between different fishing grounds where illegal beach seining is currently in use"

Aims & Objectives:

- To investigate the effects of illegal beach seine activity on 3 sites fish populations within the Bay of Ranobe, comparing the findings of catch effort, species diversity and selectivity between individual sites over the 5-week data collection period.

- To investigate growth parameters from random samples between 3 sites in the Bay of Ranobe, collected from beach seine catches to look specifically at quantitative weight to length relationships, length differences and condition factors of dominant species that may indicate environmental problems between sample sites or fishing grounds causing differences in fish species populations and characteristics.

- Observe differences between the 3 sites within the survey and any differences over time during the 5-week data collection period. Create and compare diversity indices for the sites beach seine activity further investigating the selectivity of illegal gears still used in Southwest Madagascar.

Methodology:

Site Selection:

Three sites were selected and chosen for suitability of data collection for the investigation. The 3 sites see regular beach seining activity and therefore it would be possible to take data collection as a beach seine comes in, rather than surveying fish at market and then attaining where they were sourced which would be increasingly complicated, especially as a percentage of the catch from beach seine activity is commonly used for personal consumption (McClanahan & Mangi, 2004). Therefore a true representation of the diversity of species caught in the beach seine nets wouldn't be ascertained from a market survey.

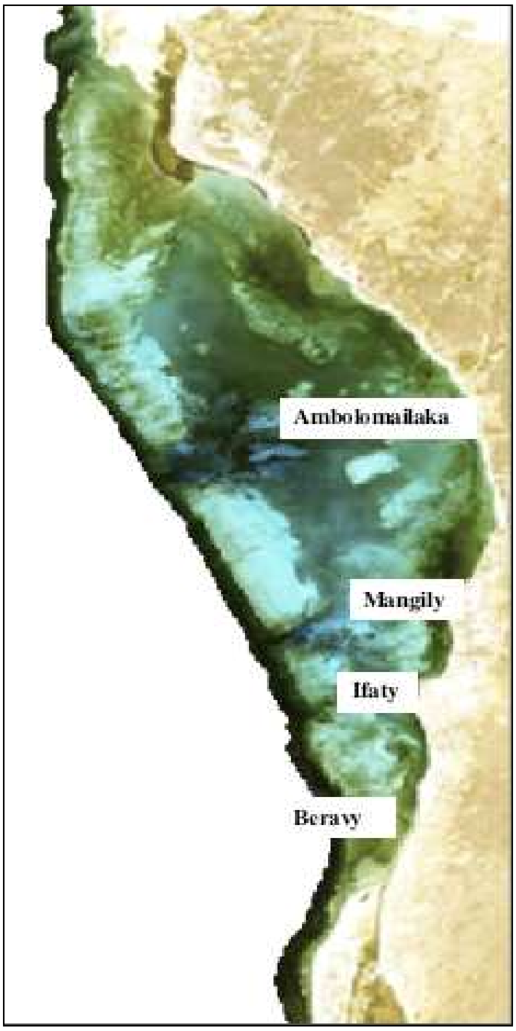

Figure 3 Shows the 3 villages included in the investigation and Ifaty, which wasn't included.

The 3 sites selected for the investigation were Beravy, Mangily and Ambolomailaka (see figure 2). Ifaty couldn't be used for the investigation due to a Dina (Madagascan local law), which bans beach seining on its beaches and therefore prevents the illegal activity to some extent, meaning an investigation in Ifaty would be unfair compared to that of the surrounding areas and be likely to spark social tension caused by attaining data from a beach with a Dina. Dina's and Fady's are discussed and explained by Cinner (2009). This did mean control site data where beach seining didn't occur could not be ascertained. Methodology for sample collection was constructed based on the fish landing studies by Tim

McClanahan & Mangi (2004). A survey of general fishing effort by perogue count and seagrass assessment has been carried out in the Bay of Ranobe, Ambolomailaka was not included in the study, however Mangily showed a perogue count of 143, and 0-10% average seagrass coverage, Beravy was seen to have a lower perogue count of 129, and an 11-30% average seagrass coverage.

Data Collection:

1. Beach Seine Data was collected from three different villages within the Bay of Ranobe (see figures 1 & 2).

2. Samples were taken from 2 beach seine catches in each village once a week. The project was carried out for a trial period of 5 weeks, therefore during the 5 weeks, 30 different samples from the 3 villages were collected.

3. Total weight of catch, hours taken and individuals involved were attained from fishermen as a survey. This was recorded as a brief verbal questionnaire (in Vezo a dialect of Madagassy).

4. A sub sample of the catch was then taken at random for quantitative analysis, which was carried out back at the Reefdoctor office. This included species identification and weight and total length analysis. The sub sample was unselectively attained from the catch for analysis as a representation of the total catch, as it would be impractical to identify,

length and weight of all individuals within the catch. Technique derived from McClanahan (McClanahan & Mangi, 2004).

5. Dated photos of all species and catches were taken as proof of data collection, and for reference.

6. It's sometimes very difficult to identify juvenile reef species, where a species can't be specifically identified, it was identified to generic family level.

7. Where over 50 of one species were present within the random sample, all the individuals of that species were counted and weighed. A random 50 were used for analysis of total length and weight data to produce an average. It was critical to measure length and weight data as quickly as possible to assess wet weight, once out of the water the fish start to dry out, and fish were kept in buckets of water to prevent weight change.

Statistical Analysis:

Species diversity was examined by looking at number of species attained in each random sample, and calculating a Simpsons Index of Diversity for each site sampled. Multispecific length was assessed for all sites together and individually, as used by (Gobert, 1994).

Total catch weight, hours taken and persons involved was attained during the verbal questionnaire, which was then used to create CPUe data (Catch per Unit effort per hour). CPUe is an indicator of the effort required to gain catch and has been used on a variety of studies in the WIO it's explained by Hinton (Hinton & Maunde 2003). This was used in a 2 way Anova test with tide level and site selected to test for differences between these variables (see appendix 1 for tide Toliara System Tide chart).

Growth parameters:

Case study analysis for growth parameters of 4 selected dominant species that appeared in high frequencies within the random samples. Using these species would then provide ample data for growth investigation between sites.

The species selected were: three-ribbon wrasse (*Stethojulis strigiventer*), African white-spotted rabbitfish (Siganus canaliculatus), yellowtail barracuda *(Sphyraena flavicauda)* and parrotfish *(Scaridae).* Parrotfish weren't identified to species level as juveniles were very difficult to identify as colours and characteristics between adults and juveniles differs considerably (McClanahan & Mangi, 2004). A Fulton's condition factor was created for the 4 case study species examined to describe any differences in condition of fish sampled from the 3 sites, this was compared using Tukey's test of significance for comparing means. Length between sites was examined with a simple one-way Anova analysis, and length to weight regressions were produced so a model length to weight relationship could be produced to show growth features for each of the species for each site.

Results:

Species Diversity and Length Frequency:

Number of Species identified in from samples		**Mangily**	**Beravy**	**Ambolomailaka**
Week 0	**Catch 1**		26	
	Catch 2		22	
Week 1	**Catch 1**	39	32	39
	Catch 2	NA	44	49
Week 2	**Catch 1**	23	37	31
	Catch 2	16	NA	27
Week 3	**Catch 1**	27	30	2
	Catch 2	22	36	2
Week 4	**Catch 1**	16	17	37
	Catch 2	19	32	17
Week 5	**Catch 1**	19	23	28
	Catch 2	16	18	33
	Mean	21.89	28.82	26.50
	S.D	9.84	11.59	16.63
	C.V %	44.97	40.21	62.77

Table 1 Shows info on Number of Different species identified in samples of the 3 sites over the 5 week period.

Table 1 shows information on the species diversity of those individuals identified during the random samples taken. The site with the highest mean number of species encountered was Beravy with an average of 28.82. Coefficient of variation is used for comparing variability in samples of populations (Fowler *et al.,* 1999) Coefficient of variation shown in table 1 shows that Ambolomailaka had a higher degree of variability.

Simpson's Index: $D = (n / N)^2$

(Lyons *et al.,* 2000)

The Simpsons Diversity index shows an index reading from between 0-1, (1-D=1 shows infinite diversity) therefore all readings were seen to show a high degree of Diversity (1-D=>0.95) (see table 2 below). Ambolomailaka was seen to be statistically the most diverse (1-D=0.99).

	Mangily	*Beravy*	*Ambolomailaka*
n	315	512	357
N	1556	2622	2955
D	0.041	0.038	0.015
1-D	0.959	0.962	0.985
n = total number of organisms of one species			
N = Total no. of organisms of all Species			

Table 2 Diversity Indices shown for the 3 sites surveyed using the most commonly occurring species (Three-ribbon Wrasse) according to Lyons (Lyons *et al.*, 2000).

Multispecific Length

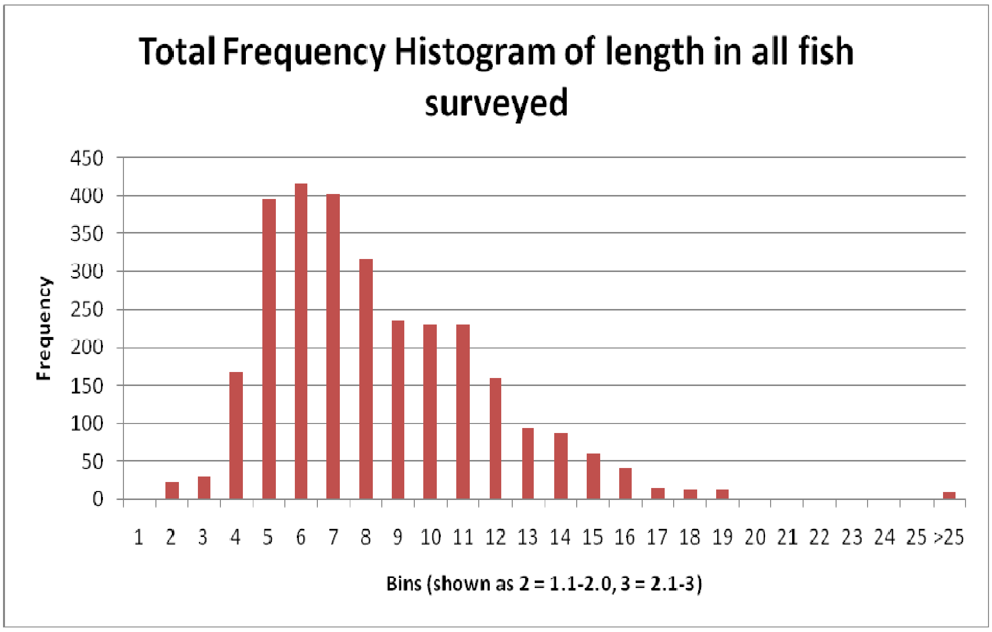

Figure 4 Shows multispecific length frequency of all species surveyed.

Figure 4 shows that the most frequent length to be surveyed was between 5.1-6cm in length. A large majority of fish sampled were between 5.1-12cm, very few fish were surveyed over 17cm long and very few over >25cm in length denoted by the last bin

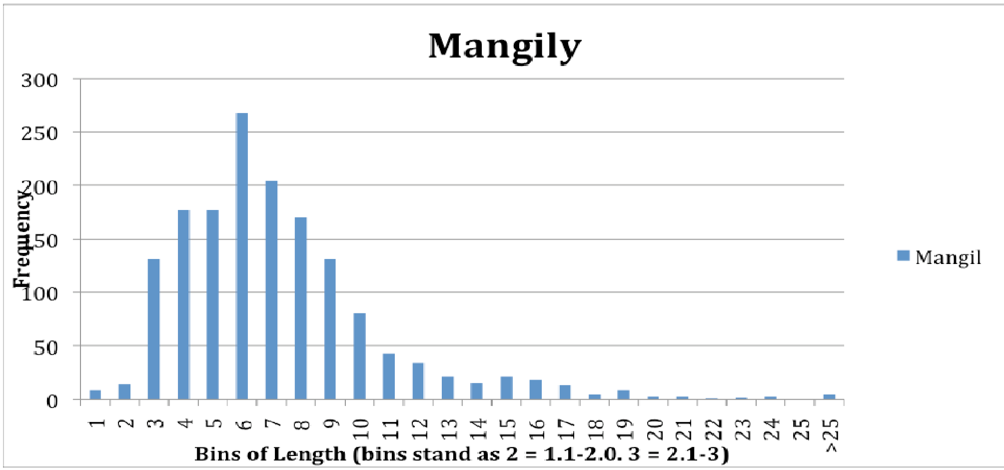

Figure 5 Multispecific length Histogram of all individuals and species sampled.

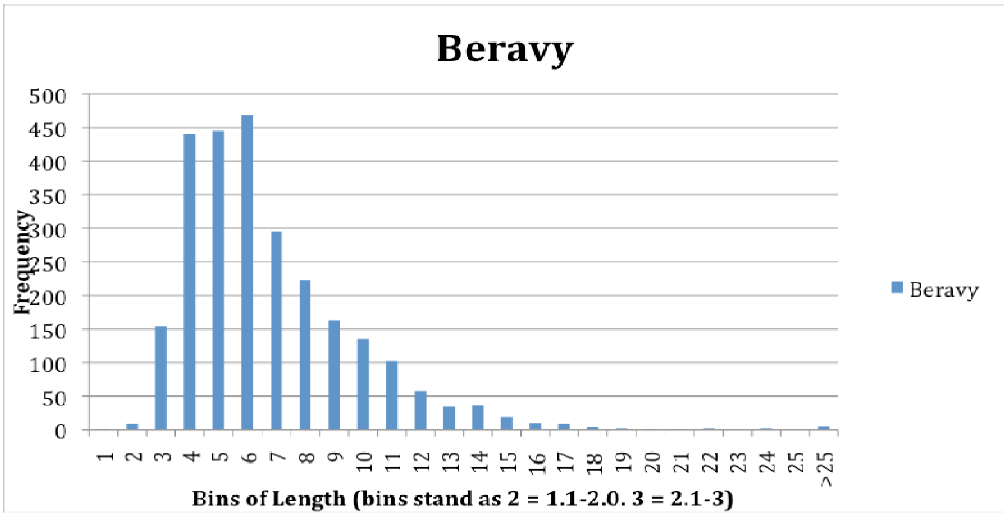

Figure 6 Multispecific length Histogram of all individuals and species sampled.

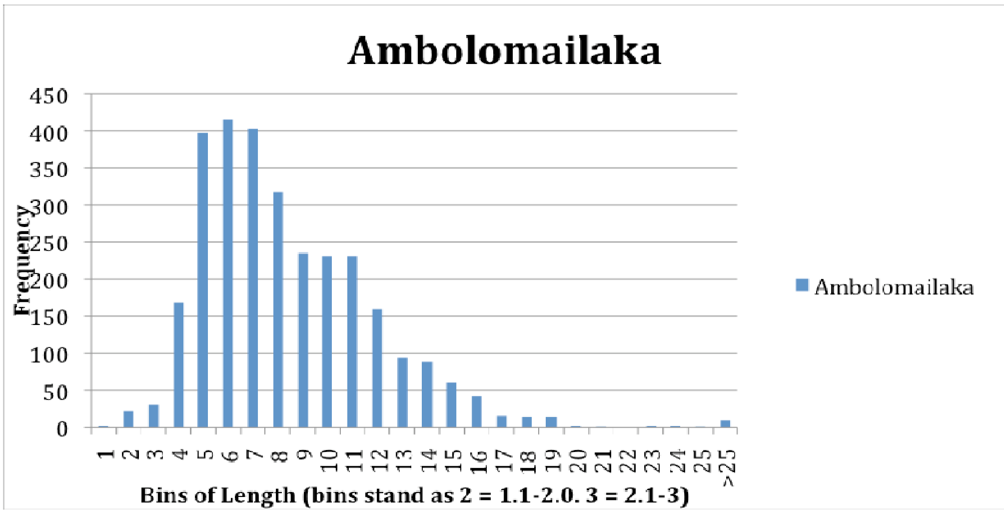

Figure 7 Multispecific length Histogram of all individuals and species sampled.

Figures 5-7 show a break down of Multispecific length frequency between survey sites, each histogram shows a peak in frequency of individuals encountered at 6cm in length, frequency then declines as length increases showing only a very small amount of larger fish are caught in the beach seine nets. Beravy seen in figure 6 encountered the smallest frequency of larger fish shown by the decline in frequency starting at bin 6 (up to 6cm) with few individuals greater than 10cm in length. Ambolomailaka shows the largest frequency of fish >10cm.

Total Catch and CPUe

Week	Beravy	Mangily	Ambolomailaka
W1	12.35	1.3	12.25
W2	2.8	3.73	10.5
W3	9.35	11.25	38
W4	4.25	5.16	16.75
W5	5.75	4.63	4.75

Table 3 Average Total catch data shown per week from each site (kg).

Week	Beravy	Mangily	Ambolomailaka
W1	0.015	0.003	0.008
W2	0.003	0.003	0.008
W3	0.015	0.004	0.024
W4	0.041	0.003	0.006
W5	0.007	0.002	0.003
Total Average	0.016	0.003	0.010

Table 4 Average CPUe kg/per hour per person per week for each site.

Source	F	P
Site	2.23	0.158
Tide	0.67	0.532
S=0.0101650 R-sq= 35.80% R=sq(adj) = 10.11%		

Table 5 A 2 Way Analysis of Variance for CPUe by Tide and Site (see appendix 1).

The findings of the 2 Way Anova between CPUe and Tide and Site have been simplified in the table above (see table 5) The P value for Site and Tide are both above 0.05, this shows there was no significant difference between tide level and CPUe, or site and CPUe. Tables 3 & 4 show the average total catch and CPUe (raw data and tide chart can be seen in appendices). A low R-sq value of just 35.80% shows the data was not tightly distributed and that there may be other variables affecting the results of the Anova other than those compared. CPUe given for Beravy week 4 is very high this is because the time for fishing of this catch was only 17 minutes, therefore it shows a very high level of catch in a small period of time, this increases average CPUe given for Beravy considerably.

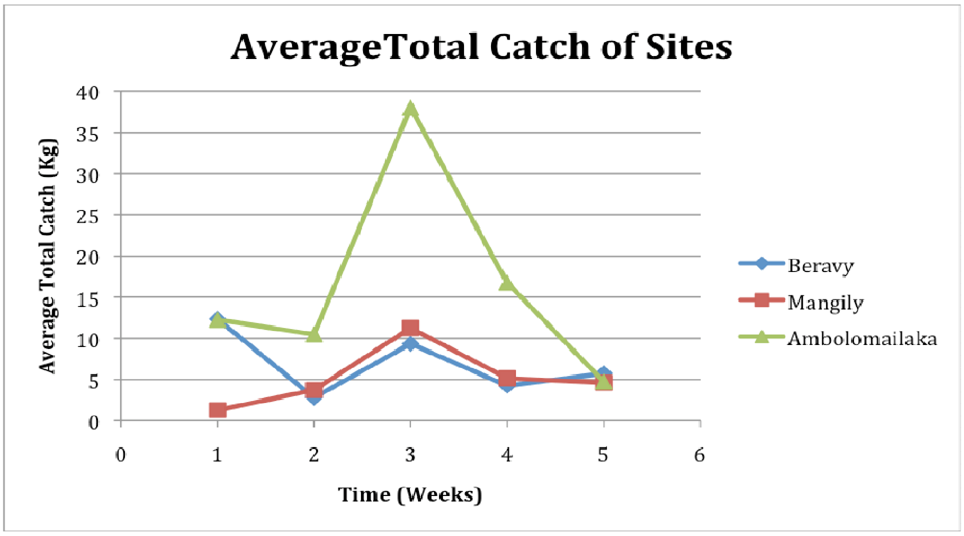

Figure 8 A graph to show average total catch (Kg) combining catch 1 and 2 for each site throughout the 5-week investigation.

Though there was no significant difference between tide level, CPUe and site, when average total catch is plotted in figure 8 above, it's evident that catches differ over time and all 3 sites experience a peak in week 3 and follow the same dynamics over the 5 week data collection period. The peak increase in total catch for Ambolomailaka is emphasized much more than that of Mangily and Bevary, which showed a similar relationship.

Length Analysis

Graphical summaries were produced for all case study species length and weight data on each site. The graphical summary shows the data conforms to normal distribution and each P value is <0.05 showing significance and allowing parametric tests to be used with these data sets (see appendix 2).

Table 6 shows the one-way Anova results in length of the dominant case study species. Yellow tail barracuda and three-ribbon wrasse showed significantly larger fish to be identified in samples from Ambolomailaka, and significantly smaller fish lengths from Beravy. The lowest mean length for all species was seen in samples from Beravy.

Individual 95% CI's for Mean based on pooled Standard Deviation.

African white-spotted rabbitfish

```
Level             N  Mean  StDev --------+---------+---------+---------+-
Mangily_3        83  7.147  4.761                (------*-----)
Beravy_3         90  4.630  1.936  (------*-----)
Ambolomailaka_3 122  6.993  3.837                      (----*-----)
                                 --------+---------+---------+---------+-
                                       4.8       6.0       7.2       8.4
```

Parrotfish

```
Level             N  Mean  StDev -------+---------+---------+---------+--
Mangily_1       248  7.315  3.199   (------*------)
Beravy_1        598  6.759  2.635  (----*---)
Ambolomailaka_1 277  9.175 10.412                  (------*-----)
                                 -------+---------+---------+---------+--
                                      7.0       8.0       9.0      10.0
```

Yellowtail barracuda

```
Level             N  Mean  StDev
Mangily_2       193  7.304  2.304
Beravy_2        118  5.311  1.770
Ambolomailaka_2 136  6.107  2.092


Level           +---------+---------+---------+---------
Mangily_2                            (---*----)
Beravy_2          (-----*----)
Ambolomailaka_               (----*----)
              +---------+---------+---------+---------
            4.90      5.60      6.30      7.00
```

Three-ribbon wrasse

```
Level           N  Mean  StDev -------+---------+---------+---------+--
Mangily       315  6.076  1.609           (----*----)
Beravy        512  5.477  1.387  (--*---)
Ambolomailaka 357  6.397  1.763                   (----*---)
                               -------+---------+---------+---------+--
                                    5.60      5.95      6.30      6.65
```

Table 6 One Way Anova Analysis for Length of Case study species between sites.

Table 6 shows the result for analyzing lengths of the 4 case study species between the 3 sites. There is a significant difference between the lengths of individuals from Beravy with three-ribbon wrasse, yellowtail barracuda, white-spotted rabbitfish, but not with parrotfish. Ambolomailaka produced significantly larger mean lengths for parrotfish and yellow tail barracuda compared to other sites.

Largest mean length of African white spotted rabbit fish from samples caught in beach seine catches in this investigation was 7.14 (Mangily), two individuals out of the 295 sampled can be seen to be over 19cm. The largest sampled yellow tail barracuda were between 12-13.5cm in length (see appendix 2 regression analysis), no individuals were over 19.64cm. No parrotfish individuals over 20cm in length were sampled from any sites. Average length of parrotfish ranged from 6.8-9.2cm.

Mean lengths of three ribbon wrasse were between 5.5-6.4cm, though many wrasse sampled were over 6.89cm. Fish sampled from Beravy show a clear peak in length distribution between 4.5-6cm (see appendix 2 length histogram), where as Ambolomailaka fish show another peak at between 9-10.5cm.

Length weight Regressions

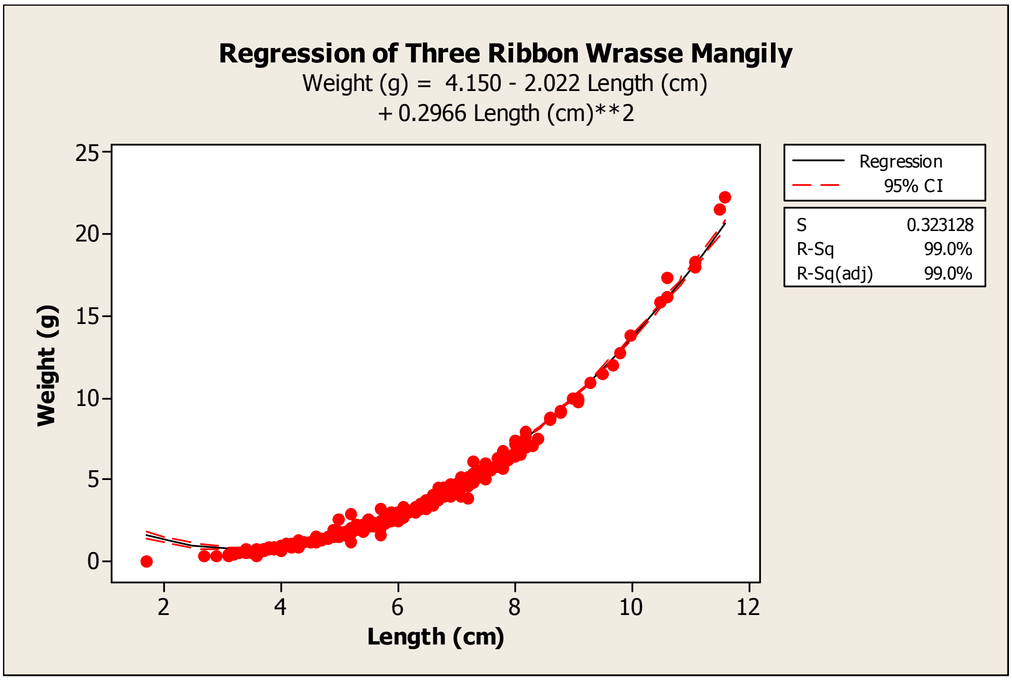

Figure 9 shows a Regression Analysis between length and weight data of *S.strigiventer (*three-ribbon wrasse) from Mangily.

Figures 9-11 show regressions from the weight and length data of three-ribbon wrasse from the 3 different sites. Regressions for White-spotted rabbitfish, yellowtail barracuda, and parrotfish are also available (see appendix 2). High frequency of individuals used in the regression analysis (1,184 Three ribbon wrasse, 295 African white spot rabbit fish, 1,123 parrotfish, 640 yellow tail barracuda) and high R squared values in figure 9-11 (all >98.5) give high confidence in the regressions produced. This shows that the change in weight is due to increase in length and not other influences. This means it's suitable to use the equation the regression produces to create a predictive length to weight model for these species. Only the most commonly occurring species could be used in this way as they were observed a sufficient amount in our random sampling to have enough data for regression analysis. Data showing graphical summaries of the case study species length to weight data can be seen in appendix 2, all length to weight data used had a p value less than 0.05 showing significant data sets that could be used for regression (see appendix 2).

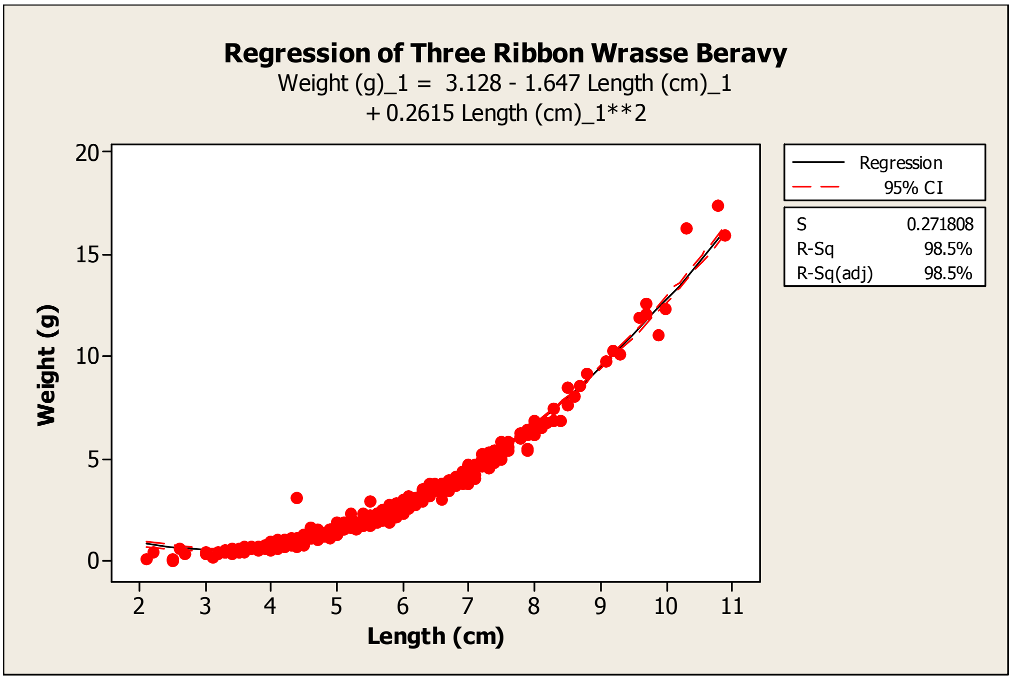

Figure 10 shows a Regression Analysis between length and weight of *S.strigiventer* (three-ribbon wrasse) from Beravy.

A heavy cluster of data points around the trend line signified by a high R squared value seen on all the regression plots shows strength in the model produced (see figure 10 above). In figure 10 the weakest part of the model relates to the area of fish between 10-11cm in length as there were less fish measured of this size so the predictive model weight to length relationship is bound to be weaker for larger fish.

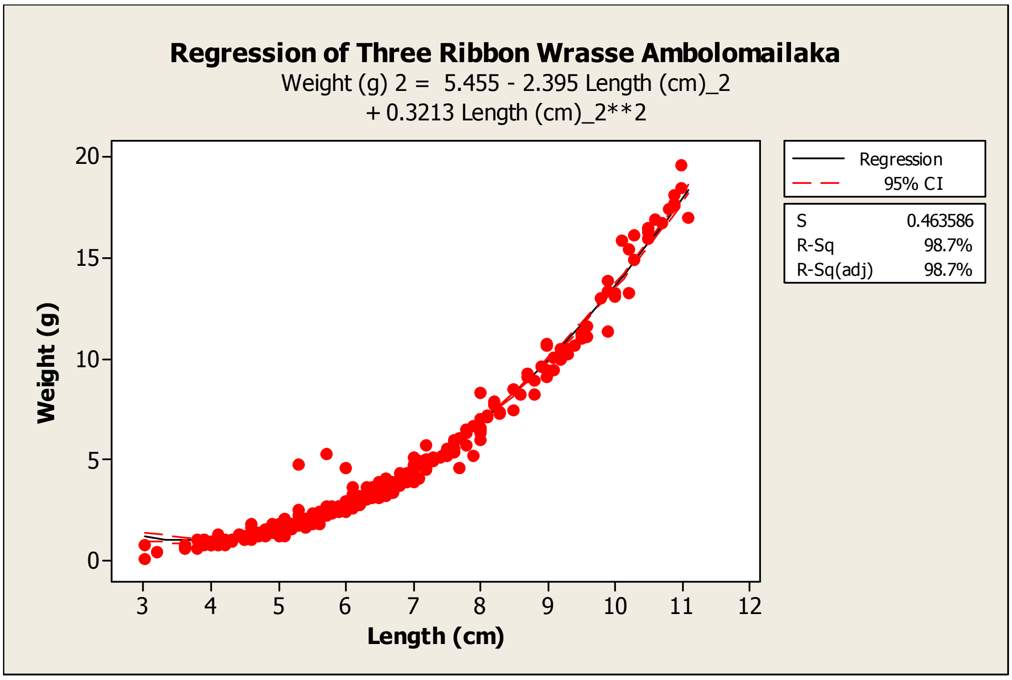

Figure 11 shows a Regression Analysis between length and weight of *S.strigiventer (*three-ribbon wrasse) from Ambolomailaka.

Figure 11 shows a very significant weight to length relationship with a large amount of data well spread out along the trend line, an R squared of 98.7 proves a high degree of strength in the model as the data is tightly clustered and there are no outliers. For regression analysis of African white-spotted rabbitfish, parrotfish and yellowtail barracuda see appendix 2.

Species Growth Models

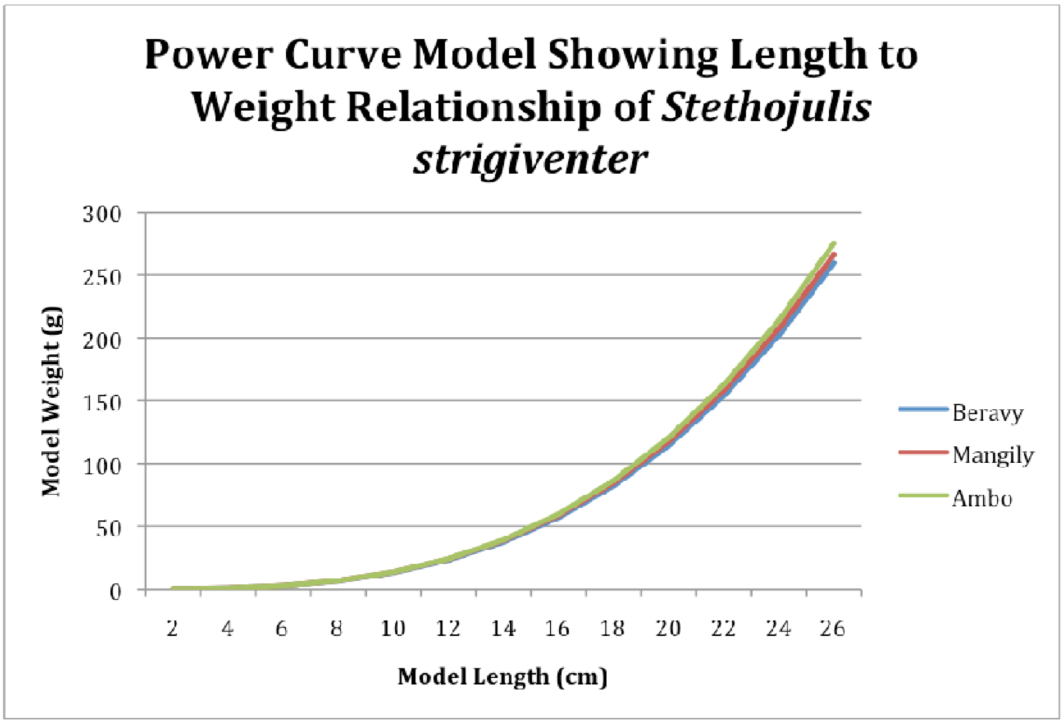

Figure 12 shows a Power Curve model of Length to Weight relationship of *S.strigiventer* (three-ribbon wrasse) in the 3 sites, produced from the equation shown in Power Regression (See Appendices)

Figures 12-15 shows the power curve predicted models of length to weight relationship, based on the power regression equation provided (see appendix 2). The 3 lines represent the data from the 3 sites. As length increases from left to right its seen that weight is slow to increase up until fish of all 4 species were over 12cm in length. After this point weight increases more rapidly in proportion to growth in length.

Figures 12, 13 and 14 show very little variation in growth curves for three-ribbon wrasse, parrotfish and African white-spotted rabbitfish over the 3 different sites. Figure 12, 13, 14 and 15 all show Ambolomailaka to have marginally the highest weight to length relationship. The Beravy site is seen to have the lowest weight to length relationship signified by the blue line on the graph underlying the other lines.

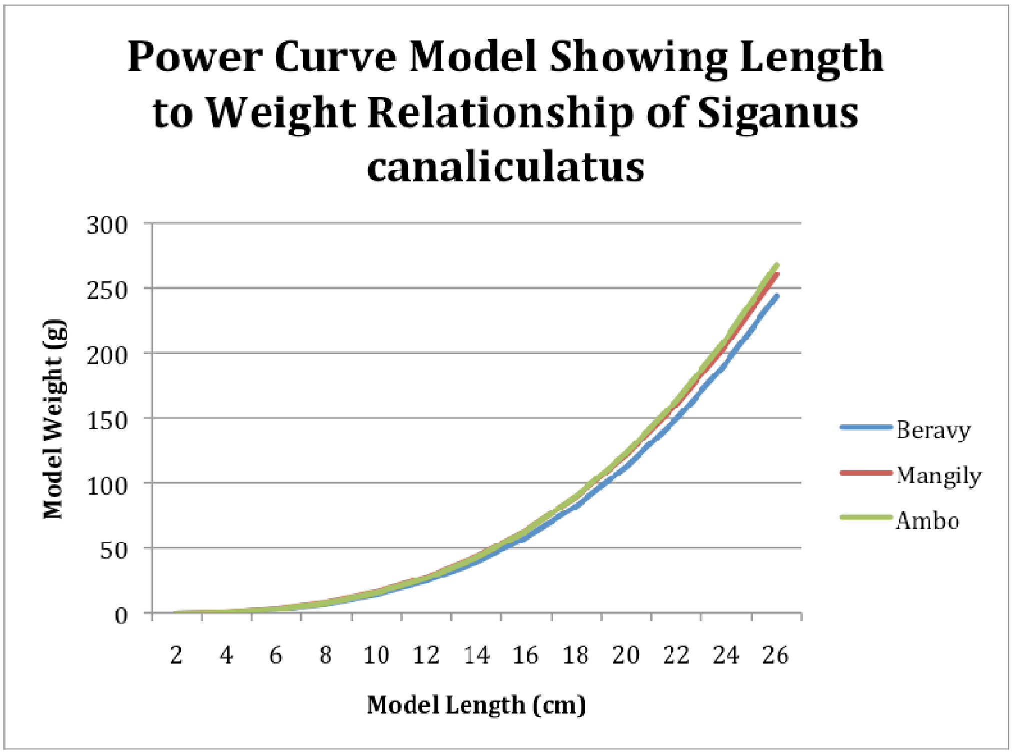

Figure 13 shows a Power Curve model of Length to Weight relationship of *S.canaliculatus* (white spotted rabbit fish) in the 3 sites, produced from the equation shown in Power Regression (See Appendices).

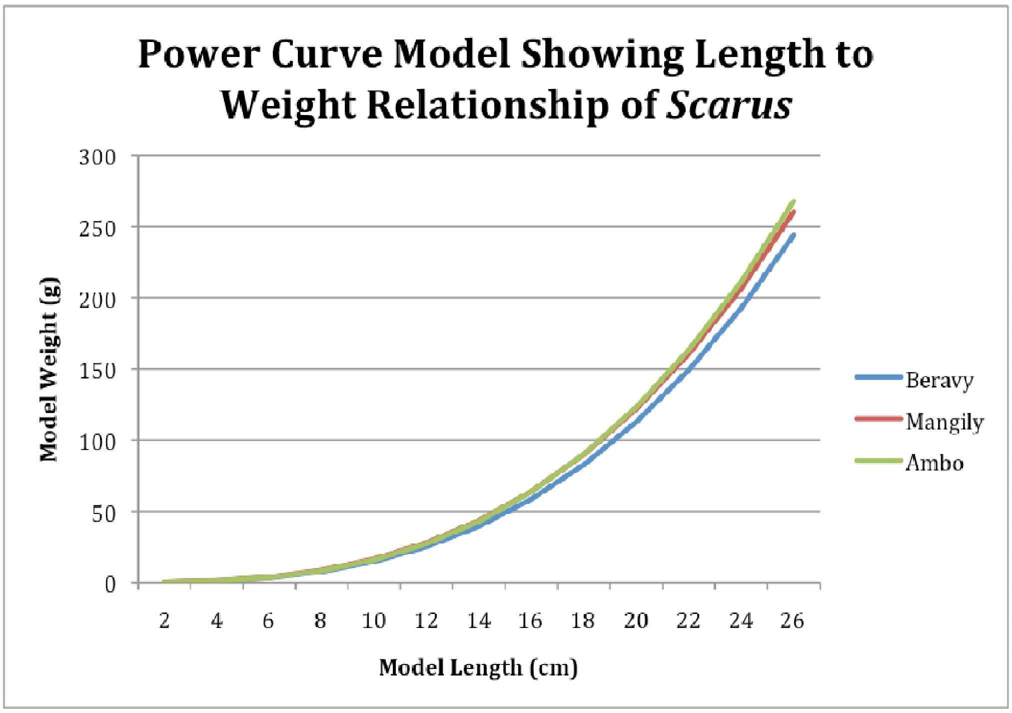

Figure 14 shows a Power Curve model of Length to Weight relationship of *Scarus* (parrotfish) in the 3 sites, produced from the equation shown in Power Regression (See Appendices).

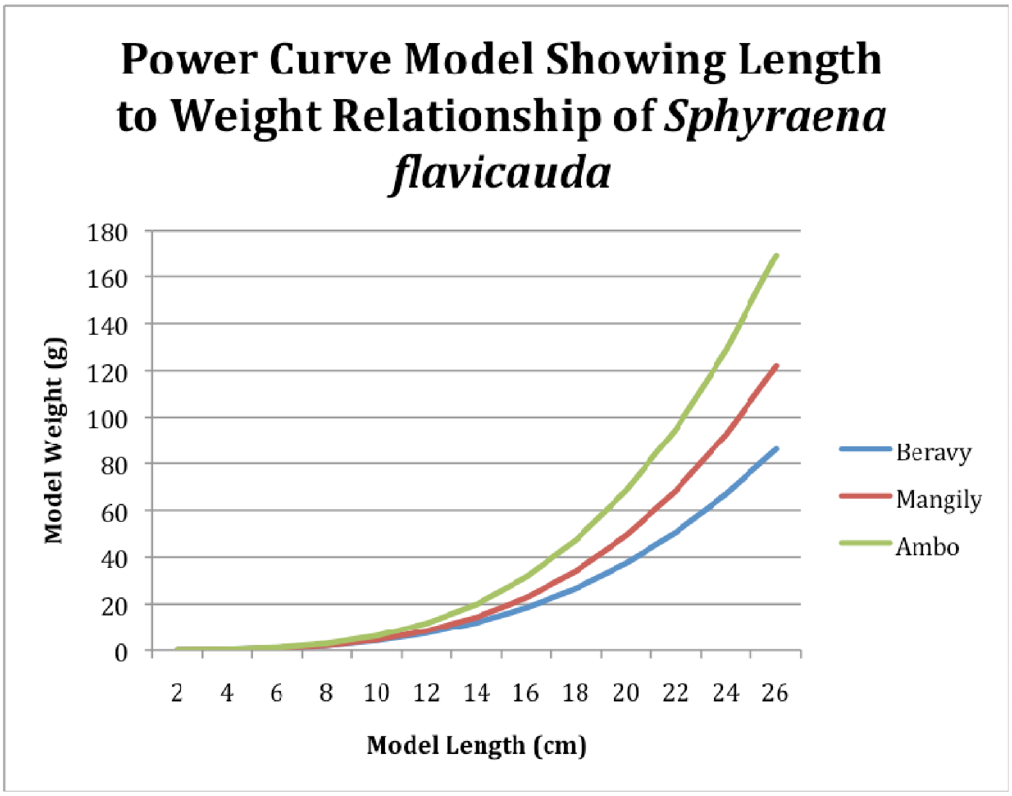

Figure 15 shows a Power Curve model of Length to Weight relationship of *S.flavicauda* (yellowtail barracuda) in the 3 sites, produced from the equation shown in Power Regression (See Appendices).

Figure 15 above shows the power curve model for yellowtail barracuda, as apposed to figure 12, 13 and 14 above the length of 10cm the different sites show differing relationships for length to weight. Ambolomailaka has the steepest weight to length relationship, with Beravy showing the lowest predicted weight to length model.

Condition Factors of Species Sampled:

Fultons K condition factor of isometric growth equation was used to look at relationship between weight of fish as length altered and give a degree of 'fattyness' representing condition normally governed by Environment and diet.

Fulton's K Condition factor of Isometric Growth:

$$K = W/L^3$$

(Feary *et al.,* 2009)

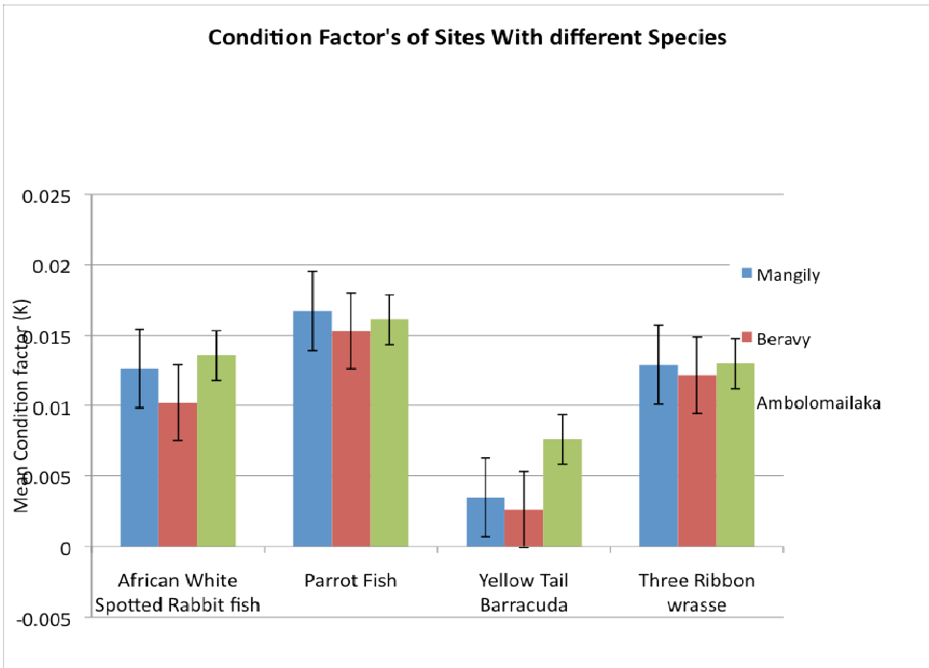

Figure 16 Shows the condition factors indentified for each site with the selected case study species. Fulton's condition factor's use with juvenile reef fish is demonstrated by Feary (Feary *et al.*, 2009)

The condition indices (see figure 16) show how good the condition of the four case study species were in the 3 sites sampled based on their length and weights, figure 16 doesn't show a big difference in the condition of any of the species seen, signified by the standard error bars overlapping on all 4 species. Although yellowtail barracuda from Ambolomailaka appear to have higher condition factors than those in samples from Beravy and Mangily. Across all 4 species those samples taken from Beravy seem to have a slightly lower condition than the other two sites.

Species	Individual 95% CI's for Mean based on pooled standard Deviation.
African white-spotted rabbitfish	mangily (----*-----) beravy (----*----) Ambolomailaka (---*---) +---------+---------+---------+--------- 0.0096 0.0108 0.0120 0.0132 **S = 0.002879 R-Sq = 20.01% R-Sq(adj) = 19.46% P = 0.000**
parrotfish	mangily_1 (--------*--------) beravy_1 (-----*-----) Ambolomailaka_1 (-------*--------) -------+---------+---------+---------+-- 0.01540 0.01610 0.01680 0.01750 **S = 0.005013 R-Sq = 1.28% R-Sq(adj) = 1.11% P = 0.001**
yellowtail barracuda	mangily_1_1 (---------*---------) beravy_1_1 (------------*------------) Ambolomailaka_1_1 (-----------*-----------) ------+---------+---------+---------+--- 0.0000 0.0040 0.0080 0.0120 **S = 0.02875 R-Sq = 0.52% R-Sq(adj) = 0.08% P = 0.312**
three-ribbon wrasse	mangily_1_1_1 (------*-------) beravy_1_1_1 (-----*-----) Ambolomailaka_1_1_1 (------*------) +---------+---------+---------+--------- 0.01200 0.01230 0.01260 0.01290 **S = 0.002062 R-Sq = 3.20% R-Sq(adj) = 3.04% P = 0.000**

Table 7 Tukey test of significance showing CI's of mean condition factors for each Species.

Species	Site	N	Mean	Grouping
African white-spotted rabbitfish	Ambolomailaka	122	0.014	A
	Mangily	83	0.013	A
	Beravy	90	0.010	B
parrotfish	Ambolomailaka	248	0.017	A
	Mangily	277	0.016	AB
	Beravy	598	0.015	B
yellow Tail barracuda	Ambolomailaka	136	0.008	A
	Mangily	193	0.004	A
	Beravy	118	0.003	A
three-ribbon wrasse	Ambolomailaka	357	0.013	A
	Mangily	315	0.013	A
	Beravy	512	0.012	B

Table 8 Significant Difference grouping between mean condition factors for each species.

A Tukey test was done to look at the difference in mean condition factor for each species from each site (See Tables 7 and 8). A significant difference between Beravy's mean condition factor and Mangily and Ambolomailaka's was seen with African white-spotted rabbitfish and three-ribbon wrasse, When looking at parrotfish Beravy had a significantly different condition factor from Ambolomailaka but not a significant difference from Mangily. No significant difference was seen in condition factors of yellow tail barracuda between sites.

Discussion:

Diversity

Beach seines are said to be the least likely gear to maintain sustainable yields in artisanal fisheries (McClanahan et al., 1997; McClanahan and Mangi, 2001). The Bay of Ranobe was known to be part of a highly dynamically varying ecosystem (McClanahan, 1988) high species diversity expected from the findings of previous studies (Cooke 2002, McKenna & Allen 2003, Webster and McMahon 2002) was found (D-1 = >0,95). Mean number of species from survey sites can be seen in table 1 and findings for Simpsons diversity indices can be seen in table 2. The mean species identified for Ambolomailaka is seen to be skewed, only 2 species were recorded during week 3. This was highlighted by the high variation (C.V=62.66%). Reasoning for this is the sample on the 26th of August only consisted of migratory fish *Scomber scombrus* (mackerel) and *Spratelloides delicatulus* (blue sprat) therefore a true representation of Ambolomailaka's diversity is not encompassed nor can high levels of confidence be placed on the species diversity index produced as 1-D seen in table 2. The mean number of species identified would be 32.6 if week 3 data were removed giving Ambolomailaka the highest mean number of species of the 3 sample sites. High abundance of Clupeidae were found to also skew Laroche & Ramnanarivo's (1995) CPUe findings in the Toliara region during the cold season September-October.

The Simpsons diversity shown in table 2 showed the highest level of diversity compared to previous studies (1-D=>0.95), Ambolomailaka showed the highest species diversity though no sites showed significantly decreased diversity levels. Davies (1999) found Simpsons index of diversity from beach seine samples in the Bay of Ranobe (1-D=0.7), McClanahan (2004) found species diversity of beach seine samples from the Toliara region (1-D=0.91), diversity of samples (D-1=0.95) was found with net fishing in Papua New Guinea (Cinner and McClanahan, 2006) and diversity of catch was not seen to be correlated to socioeconomic characteristics.

The high species diversity seen represents the very unselective nature of the fishing gear as it's currently used (Davies *et al.,* 1999, McClanahan & Mangi 2004). The problems of unselective fishing gears and diversity were talked about previously, it seems a range of investigations have found similar levels of diversity and therefore this gives confidence that these results are valid.

Despite fishing pressure being known to decrease diversity (Jennings *et al.,* 1999) diversity is still very high in the Bay of Ranobe. Fishing may be cropping fish newly recruited to the fishery, this has been proven to increase regeneration rate of mature adults, part compensating for fishing removal by overfishing (Jennings *et al.,* 1999). This means that removing juvenile fish may not be preventing recruitment and survival of sexually mature individuals (Mahon and Hunt 2001, Mangi and Roberts 2006). The question is more 'how much of the population do catches of immature fish represent and are sufficient fish reaching maturity to replenish stocks'. Jennings found that only small proportions of fish move between fishing grounds (Jennings *et al.,* 1999) though egg and larval phases can cause recruitment and movement, so although repetitive stripping of juveniles greatly reduces recruitment, if there are neighboring areas of high larval output, juvenile populations may still sustain within heavily fished areas.

Multispecific Length Frequency

Multispecific length analysis of all species in all sites is shown in figure 4, Figures 5-7 show histograms for multispecific length across the 3 sample sites studied. Figures 5-7 show that the majority of individuals sampled from Beravy and Mangily were between 2cm-11cm. Fish length in Ambolomailaka appeared larger with greater frequencies of individuals between 14.1-15cm. Irrespective of this difference the highest frequency for all sites was bin 6 representing 5.1-6cm individuals, the majority of individuals from samples in all 3 sites were seen to be less than 10cm with the exception of Ambolomailaka where the majority of individuals were below 14cm (see figure 7). This analysis of non-species selectivity is important due to the wide range of species present in catches seen by the diversity findings, and it being impractical to look in great deal at all species. Seine captures <10cm individuals is normal in the Toliara region according to Laroche (1997), these often produce a low sale value suggesting overfishing of resources. According to Mangi & Roberts (2006) lack of fish length >30cm is likely to be due to increased fishing pressure, as larger fish are removed species length and size of sexual maturity decreases as previously explained (Hawkins & Roberts 2003).

Total catch

Over the 5 week trial period average total catch is graphically displayed in figure 8, the peak in week 3 for all sites coincides with a high tide period. Data collection on week 3 took place on the 23rd, 24th and 26th of August (see tide chart in Appendix 1). Despite the high tide possibly having a positive impact on fishing success, of total catch subsample from Ambolomailaka on the 26th was made up of just 2 species blue sprat (*Spratelloides delicatulus*)

and mackerel (*Scomber scombrus*) (see table 1). This Skewed data was due to the large quantity of higher value (>5000 Ariary/ Kg) migratory fish passing through the bay of Ranobe (Narozanski *et al.,* 2000) which was therefore preferred to normal catch species. Migratory fish in the Bay of Ranobe was also found to skew data in investigations by Laroche and Ramananarivo (1995) and Davies *et al.,* (1999). Despite the week 3 total catch information in Ambolomailaka, total catch levels in Beravy and Mangily are still lower than Ambolomailaka's in weeks 1, 2 and 4. Reasons for this could include net size, mesh size, fishermen's experience. Greater abundance of fish species, though this can't be proven from this information alone.

CPUe

As talked about earlier by Laroche & Ramananarivo (1995) a decline in CPUe can be seen to have occurred in the Toliara region during the early 1990's, this has helped prove that the inshore areas are too heavily fished. The survey findings in this investigation showed that the CPUe data had no significant relationship when looked at in a 2-way Anova with tide and site. The reason for no difference in effort may be due to the fact that at low tide or high tide the fishermen alter where they fish to still ensure a catch, therefore they are likely to catch regardless of tide level. Tracking the area actually seined wasn't possible in this project. If fishermen failed to catch or failed to catch enough to give a sub sample for analysis a different beach seine team was chosen, meaning CPUe data is not realistic, as very low or zero CPUe couldn't be recorded with this methodology. CPUe data showed a low R-sq value this may be due to other factors affecting the catch per unit effort per hour of the fishermen, for instance net length, their skill level and experience, mesh size or net quality etc. There are many variables that will affect any projects where data is collected from open systems, which can skew results and can't be controlled. This aside an approximate indication of the fishing effort of a gear may be assessed.

Actual average CPUe of the 3 sites found was very low (Mangily = 0.02, Beravy = 0.003, Ambolomailaka = 0.01). A beach seine investigation in the Toliara region in 1997 produced CPUe data of between 0.6-2 kg per person per hour (Laroche *et al.,* 1997). This gives reason to believe not only was there an initial decline in CPUe in the 1990s but there has been another decline in CPUe from between 1997-2010. A CPUe analysis in the Diego-Suarez Bay in the north of Madagascar showed much higher catch per unit effort from beach seines of 3.1kg per fisherman per hour (Narozanski *et al.,* 2000).

Though this investigation shows very poor return for the hours worked by the fishermen involved in this fishing gear, CPUe may be poor as a fisherman's time for duration of fishing is likely to be inaccurate (McClanahan & Mangi, 2001).

Species Length Analysis and Sexual Maturity

Table 6 shows there are significant differences in length groups of species between different sample sites within the Bay of Ranobe, this matches other findings that fishing ground was positively correlated to length (Cinner and McClanahan, 2006).

Though the reasons for these differences could not be examined in this study, the lengths of maturity for the dominant species or at least family (i.e. *Scaridae*) was noted in the introduction (Mangi & Roberts, 2006). The link between growth rates, size of sexual maturity and effects of fishing pressure and the 'cascade effect' potentially caused were discussed earlier (Helman *et al.,* 2009, Mares 2011, McClanahan and Shafir 1990, McManus *et al.,* 2000, Sheffer *et al.,* 2005). Sex changing species like the parrotfish family are likely to be even more susceptible to the problems of increased fishing pressure changing time and size of sexually mature fish (Hawkins & Roberts, 2003), though actually determining if these individuals are maturing at earlier levels would need further investigation.

Going on information gained from the species investigated seen in table 6 and expected length of sexual maturity researched earlier (Mangi & Roberts, 2006), all yellowtail barracuda and parrotfish individuals were likely to be juvenile fish if the length of maturity information and measurement of fish was accurate. Many of the parrotfish were blue barred parrotfish *(Scarus ghobban)* (see appendix photos) though not actually identified to species level due to the difficulties in identifying juvenile parrotfish (Gobert, 1994), this species is considered sexually mature at 39.22cm and in comparison with information of generic parrotfish in this study no individuals were of this size and likely to be mature. As discussed earlier due to the feeding niche performed by parrotfish, their removal can cause cascade effects and phase shifts on reef systems therefore fishing pressures, particularly on immature individuals, should be banned (McClanaham, 2005). Intentionally not catching parrotfish with a gear as highly unselective as beach seines would not be possible.

African white-spotted rabbitfish samples produced two exceptions of mature sized fish over 19cm from 295 fish sampled. The only species to have many fish sampled of a mature size was three-ribbon wrasse, assumed to have similar size of maturity as blue-lined wrasse maturing at 6.89cm (Mangi & Roberts, 2006), mean lengths were between 5.5-6.4cm, though many wrasse sampled were over 6.89cm and therefore were likely to be sexually mature. The second peak in distribution of wrasse lengths seen in Ambolomailaka is likely to be showing a second age class of older fish present (see appendix 2 length distribution).

Three-ribbon wrasse were seen to be the only dominant species investigated which consisted of a large amount of both mature as well as juvenile individuals. This is likely to be due to life style as talked about within the introduction they are so called 'permanent residents' of the reef flat and seagrass beds not migrating at a certain age class or season (Nakamura & Tsuchiya, 2007). Wrasse are also said to seem only moderately affected by beach seine netting (McCanahan, 1994).

Regression Analysis

The case study data analysed from the random subsamples collected was used to produce regressions of weight to length relationship before producing growth models with the results. The regression analysis for three-ribbon wrasse from each sample site can be seen in figures 9-11 (see appendix 2 for regression analysis of other species). Beravy had the smallest fish encountered and lowest weight to length relationship compared to the two other sites in all four species investigated. With the exception of yellowtail barracuda for each species a greater distribution of individuals is visible at larger sizes of fish in samples from Ambolomailaka and a greater distribution of smaller fish around the base of the curve were witnessed from Beravy (See appendix 2).

Reasons for slight differences in distribution of larger or smaller fish in Ambolomailaka and Beravy, could be due to direct anthropogenic influence i.e. differences in beach seining technique, equipment, general fishing pressure or due to the quality of environment, this was further looked at by condition factors from species at different sample sites. Perogue counts show a general level of fishing pressure, this was known to be lower in Beravy (129) than Mangily (143) (Reefdoctor 2010) therefore not explaining any difference in fish size found. Despite these differences in distribution between sites, the weight to length relationship was very similar for each species.

Growth prediction models

Creating growth curves with the regression equations produced enabled the comparison of length to weight relationship of the same species from the different sites sampled. Figures 13-15 show the growth models produced for the species investigated. Marginal difference between sample sites was seen for figures 12-14 representing three-ribbon wrasse, white-spotted rabbitfish and parrotfish. Yellowtail barracuda (figure 15) shows altering curves of growth for the three sites at increased length levels. Due to models being produced with the regression equations they are dependant on their reliability, barracuda sampled were mainly <10cm in length, therefore confidence in the model for >10cm where the difference in growth rates from the 3 sites occurs can't be strong. African white-spotted rabbitfish, as talked about previously the species fetches high market price (4000 Ariary/kg) and is known to be commercially viable (Bryan *et al.,* 1980, Lieske & Myers 1999, Narozanski A. J. *et al.,* 2000). Figure 13 shows growth model for African white-spotted rabbitfish, most of the fish caught were less than 15cm and therefore expected to weigh 50g or less. If these fish were not fished until maturity, at lengths of around 20cm and weights of 100-150g they would be worth 3 times the amount, therefore few individuals would be needed to provide an average income. Conserving stocks of African white-spotted rabbitfish could be economically important for the Bay of Ranobe.

Lack of difference between growth models for dominant species investigated shows that if there are environmental differences in the 3 survey sites i.e. substrate type or seagrass coverage, that these differences didn't seem to affect fish growth. The average seagrass coverage as indentified in the unpublished Reefdoctor report, showed Beravy had an average seagrass coverage of 11-30% as opposed to Mangily 0-10% (Reefdoctor, 2010), this wasn't seen to alter the rate of growth, but may have impacted on the frequency and size of species.

Condition factors

Condition factors have been shown to have important use in fisheries investigations (Bagenal 1978, Oni *et al.,* 1983). Poor condition of fish species may be caused by the energy ties and links to the rest of the reef system, introduced previously (Mares 2011, Moberge & Folke 1999, Suchalek 2003). Looking at the condition factors found, shown in figure 8 and analysis in table 3, Beravy was seen to have the weakest average condition factor for all 4 case study species. The relationship between fishing pressure and the shift in growth rates, condition, ages, sizes of reproduction and maturity is widely known (Helman *et al., 2009)*. Lower condition factors in Beravy compared to the other two sites were noted, slightly decreased length to weight relationships were also shown in the growth models of all four species. Therefore this brief investigation may show that Beravy's fish population is of poorer condition according to Bagenal's theory (1978) to that of surrounding areas, this could be due to fishing pressure or environmental influences that influence growth and abundance (Jennings *et al.,* 1999).

Lack of sexually mature individuals of many species is evident in the beach seine catches seen within this investigation. Potential reasons for this are speculative though the plausible reasons consist of:

i. Fish movement of larger fish away from seagrass beds after nursery stage of life cycle, therefore changes in spatial distribution of species.

ii. Increased fishing pressure has reduced exponential length (Gobert, 1994), sexual maturity is altered and more fish sampled were mature than thought from previous knowledge

iii. Smaller fish are present due to spawning and time of year (work on spawning aggregation times and for no-take zones with reef species is currently under investigation (Robinson *et al.,* 2010)).

iv. There is some evidence to believe larger fish are generally more difficult to catch i.e. swim faster escape the net (McGinley, M. *et al.,* 2010).

v. As samples taken were only small subsamples there is a chance that larger valuable species may be retained by fisherman in the perogues and therefore weren't available to be sampled.

Limitations

Ideally the data would consist of a control sample site where beach seining did not take place. Due to the Dina preventing beach seining on one length of beach around the village of Ifaty this would represent a good location, but for obvious reasons beach seining to attain the data would not be allowed.

CPUe may be poor as fishermen's time for duration of fishing is likely to be inaccurate (McClanahan & Mangi, 2001), and distinguishing who to count as fisherman actively involved from a group of up to 20 people can be difficult. Catch per unit effort per area of net size may have been fairer than per hour due to varying length and quality of nets, this technique has been tested (Conner and McClanahan 2006) though this would involve the ability to measure a beach seine which has potential difficulties.

Beach seine catch are seasonally variable (Laroche & Ramananarivo, 1995). Larger beach seine catches are seen during the warm season (January and February) noted by increasing CPUe due to the abundance of fish in the shallower water of the reef flats. Therefore 5 weeks was not a long enough period of data collection to attain a realistic view of catches and didn't account for seasonality.

Recommendations for future research

Further research is necessary to fully understand the current state of juvenile fish in the Bay of Ranobe, this research couldn't quantify if the stock of any site were depleting or under greater pressure than previously from increased beach seine activity due to lack of historic data. A periodic analysis of fishing catches throughout the year will show likely seasonal variations in catch and help better explain the growth and breeding state of the Bay of Ranobe. Measuring of other gears is needed because the use of gears like beach seines that catch many small species, reduce the catch of other gear types that select larger and more species-specific targets (McClanahan, 2005).

The lengths of sexual maturity in many species are known to decrease under heavy fishing pressure, further investigation as to whether sexual maturity is decreasing in specific species (*S.strigiventer, S.canaliculatus*, *S.flavicauda and S.ghobban)* within the Bay of Ranobe is necessary.

Seagrass, being of such great importance in the nursery stages of juvenile development to many species in a reef system (Nagelkeren *et al.,* 2000), should be surveyed and results of coverage compared between years, time of the year and survey sites selected, this will help establish the potential damage caused by the removal of the seagrass as discussed in the introduction, and varying affects in connectivity to the reef system (Mares, 2011).

Conclusion

It seems likely that beach seine fisherman in the Bay of Ranobe have experienced a 2nd drop in CPUe in the last 10 years aswell as that found by Laroche *et al.,* (1997). Many species caught were found to be largely juvenile with the exception of three-ribbon wrasse. There is reason to believe that Beravy showed a weaker fish population when it was looked at in terms of condition factor, diversity and mean length of dominant species compared to those of other sites. Reasons for these differences require further investigation though the null hypothesis for this investigation can be rejected. Protection especially of economically important rabbitfish and environmentally important parrotfish families should be crucial to sustainable fisheries management for the community. As banning the gear completely is unlikely to work (Evans 2009, Cinner 2009). Increase in use of local laws set down in the form of Dina's are still seen to be the only way to help totally prevent the use of this gear and even then low levels of formal enforcement capacity and lack of alternatives often leads to low levels of compliance with these regulations (Cinner, 2009). Marine sancturies can play a major role in reef management, though they must be associated with non-fishing activities and stabilizing population growth (Laroche *et al.,* 1997). For long-term survival establishing no take zones, enforcing mesh size and gear restrictions are all necessary (Narozanski *et al.,* 2000, Mangi & Roberts 2006) thus helping ensure a more sustainable long-term management strategy.

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