Master's thesis

# Opportunity costs of growth-overfishing:
## socioeconomic evaluation of the beach-seine fishery, Bay of Ranobe, Madagascar

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Ísafjörður, September 2014

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*Opportunity costs of growth-overfishing: socioeconomic evaluation of the beach-seine fishery, Bay of Ranobe, Madagascar*

45 ECTS thesis submitted in partial fulfilment of a Master of Resource Management degree in Coastal and Marine Management at the University Centre of the Westfjords, Suðurgata 12, 400 Ísafjörður, Iceland

Degree accredited by the University of Akureyri, Faculty of Business and Science, Borgir, 600 Akureyri, Iceland



Printing: Háskólaprent, Reykjavík, September 2014

## Declaration

I hereby confirm that I am the sole author of this thesis and it is a product of my own academic research.

Laura Nordgren

# Abstract

Beach-seine fishing is a technique that has been used for thousands of years. With the advent of plastic monofilament and mosquito netting, a modern-day beach-seine is, ostensibly, one of the most destructive and non-selective fishing gears. As beach-seines are hauled-in from shore, intertidal seagrass beds are often damaged, which play an important role in providing food and shelter to juvenile fishes. In the Bay of Ranobe the technique often employed by newly-established unskilled fishermen is beach-seining. This research used a combination of ecological and socioeconomic assessments to determine and describe the relative importance and impact of the beach-seine fishery for the Bay of Ranobe area. The findings of this research indicated that beach-seine techniques were used predominantly by migrant people from tribes that were not traditionally reliant on sustenance fishing. The analysis of the beach-seine catch showed to be mostly juvenile fishes. Anecdotal evidence suggests overall catches have been declining in the Bay of Ranobe due to heavy fishing pressure. Targeting juvenile fishes may exacerbate the problem and significantly impair fish stock recovery. An understanding of the socioeconomic importance and ecological impact of beach-seining activities will provide governmental and non-governmental organizations with the necessary information to develop mitigation strategies and help with ensuring the long-term stability of fish stocks in the Bay of Ranobe.

*I dedicate this thesis to my parents,*

*Pertti and Ulla,*

*for their never ending love and support.*

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# Acronyms

| | |
|---|---|
| BRB | Bay of Ranobe |
| ICZM | Integrated Coastal Zone Management |
| MGA | The Malagasy Ariary (the currency of Madagascar) |
| MPA | Marine Protected Area |
| MSY | Maximum Sustainable Yield |
| NGO | Non-Governmental Organisation |

# Acknowledgements

I would, first, like to thank ReefDoctor Org. for providing the wet laboratory and resources for my use during the data collection. Thank you goes also to all volunteers and staff necessary for counting and identifying thousands of juvenile fish alongside with me. Thank you to my family and friends helping me through this process. Thank you to Dagný Arnarsdóttir for support, understanding, and flexibility. A big thank you goes to Lauren Parkhouse for believing in me, and my research assistant Pierre Angelo Rabearisoa. Last but not least a special thank you to Beth Greenwood, Amelia Weiss, and Chelsea Boaler for endless support and encouragement.

# 1 Introduction

Poverty is common with natural resource degradation (Nkonya et al., 2008) whether being caused by unsustainable management or population increase (Scherr, 2000). The ideology of individual property ownership is not a universal concept for rural communities in developing countries; therefore, issues related to natural resource decline are often related to the tragedy of the commons (Vivian, 1991). An example is overexploited fisheries where the rule of capture exists, where any wild animals captured belong to the person who captures them, due to incomplete property rights that are hard to establish because of the migratory nature of most fish (Benjamin, 2001). One of the developing countries struggling with these issues is Madagascar (see Fig 1).

*Figure 1 The island of Madagascar is located on the east side of the African continent across the Mozambique Channel (Vidiani, 2014).*

Although it is one of the most biologically unique places on the planet, it is threatened by extreme poverty. According to the United Nations, Madagascar is one of the least-developed countries in the world, with over 90% of the population living below the poverty line of 2USD per day (EnDev, 2013), and over three-quarters of the population being directly dependent on local natural resource exploitation (WAVES, 2012). Being ranked sixth in the world in terms of chronic malnutrition by the World Food Programme (2013) 50% of children less than five years old are suffering from famine in the country.

Extreme levels of poverty and high dependence on natural resources, over the years, have resulted in high rates of environmental degradation. Together with exposure to natural disasters such as cyclones, flooding and drought can potentially lead to ecosystem collapse and even greater vulnerability to climate change (Burke et al., 2011).

Amongst the regions of Madagascar, the southwest region of Tulear (Toliara), as part of the Western Climate region (see Fig 2) is the poorest, due to its semi-arid environment, infertile soils, and consequently, low agricultural productivity. The usual number of dry months is seven to eight, and the average rainfall is 36cm (Bradt, 2012). Moreover, in recent years, droughts and locust outbreaks have decimated the few remaining crops. The island faced its worst locust plague in 2013 which is still continuing with two thirds of the country under infestation-risk threatening the already weak food security (World Food Programme, 2013).


*Figure 2 The climatic regions of Madagascar differ very much from each other. Tulear, locally called Toliara, is located in the southern part of the Western climate region (Bradt, 2012).*

The harsh living conditions of the region, and the difficulty of sustainable agriculture inland, drive more-and-more people towards the coast to eke out an existence from coastal ecosystems that are already over-exploited by overpopulation amongst the already present people. In addition to the general increase in fishing pressure associated with high population (see Fig 3) with an annual increase of 2,9% (Trading Economics, 2014) there is notable coastal immigration.

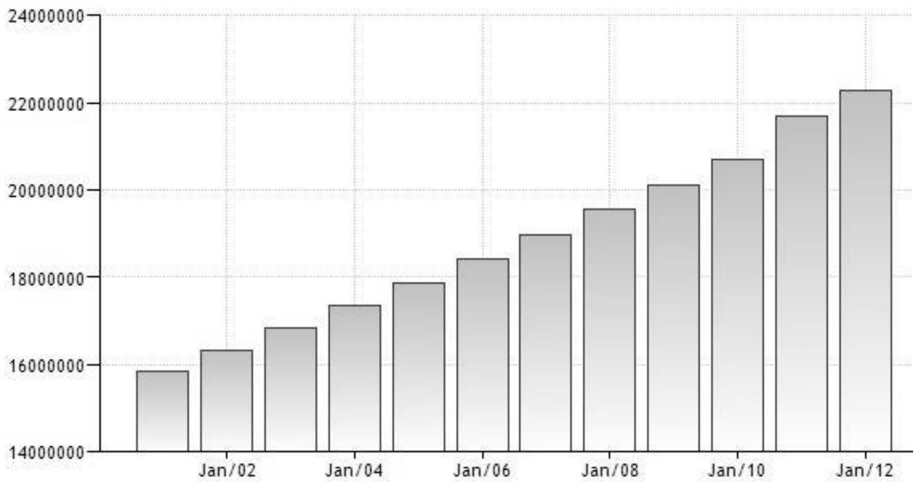



*Figure 3 Total population in Madagascar from year 2001 to 2012 show a notable increase in population over a short time period. (Trading Economics, 2014).*

People from inland unaccustomed to fishing and unaware of indigenous fishing techniques and customs are prone to adopt low-skill fishing techniques that are usually more destructive. The technique often employed by newly-established and unskilled fishermen is beach-seining, a long net taken from the shore with a small canoe type of boat, pirogue, to encircle a school of fish to be pulled back to the beach (see Fig 9, Chapter 5.1). As beach-seines are hauled-in from the shore, the intertidal zone is often damaged, e.g. seagrass beds, which play an important role in providing food and shelter to juvenile fishes. Although the beach-seine is an old fishing technique that has been used for thousands of years (Seafish, 2005), with the advent of plastic monofilament and mosquito netting, a modern-day beach-seine is, ostensibly, one of the most destructive and non-selective fishing gears (Bush, 2013). In the Bay of Ranobe (BRB), the site of the present project, the use of beach-seines is seemingly becoming more common. The more people practise beach-seining, the more juvenile fishes are removed, which will hugely compound the resource’s ability to replenish.

A caught fish has value but when left in the water has little value, if any, except as a potential in increasing future catches and revenue (Hinson, 2010). This raises a concern; what is the impact beach-seining fishery has on the poverty as well as the ecosystem in the BRB? Through socioeconomic surveys and real life beach-seine catch analysis, the current project aims at revealing the impact and importance beach-seine fishing has for the area. The outcome of the project will give the hypothesis of the concern some tangible evidence for future research as well as support other natural resource projects in the area.

## 1.1 Justification

In order to gain understanding and find a starting point for a more in-depth research on the effect of the beach-seine fishery, a socioeconomic and ecologic baseline data is needed. Discovering who is involved in beach-seining as well as the possible extent the practise might have ecologically is revealed with socioeconomic surveys and catch data analysis. The comparison of the beach-seine fishery catch price and other traditional fishery catch prices is an effective way to show local coastal communities the possible monetary loss they are facing. Catch composition demonstrates how modern beach-seine nets with small mesh sizes disturb the habitat pulled through by non-selectively catching small juvenile fish. In addition to a large variety of different fish species, there are a number of invertebrates, a great volume of seagrass and other benthic material, as well as fish and invertebrate larvae that form a significant proportion of the catches. Catch composition, monetary value, as well as catch per unit effort, will also illustrate whether spatial variation exists in the south and north end beach-seine fisheries of BRB. An understanding of the socioeconomic importance and ecological impact of beach-seining activities will provide governmental and non-governmental organizations with the necessary information to develop mitigation strategies to add to and help with the Integrated Coastal Zone Management (ICZM) planning for the BRB.

## 1.2 Structure of the thesis

This research used a combination of ecological and socioeconomic assessments to determine and describe the relative importance and effect of the beach-seine fishery for the BRB area. The paper is organised as follows. Literature review (Chapter 2) looks into the theory on poverty powering topics of tragedy of commons, opportunity costs, growth overfishing and how beach-seine is linked to them. Research questions lead to the study

site (Chapter 4) and the background to the case study (Chapter 5). The background introduces beach-seine fishing; the people (stakeholders) in the supply chain, the local level catch sample composition, and the value chain. Materials and methods (Chapter 6) show how the research was constructed, executed and also the limitations the research project faced. Results (Chapter 7) and Discussion (Chapter 8) present and elaborate findings of the research.

# 2 A review of the beach-seine economy in the developing world

This review attempts to summarise the literature surrounding the beach-seine economy in the developing world, taking into account the opportunity costs, ecological effects of growth-overfishing, and maximum sustainable yield while indicating areas of research which would aid effective resource management.

Forty six years ago Garret Harding brought the term "tragedy of commons", the overuse and decline of the common or open access resources (Wilkinson et al., 2012). Commons can be seen as common-property resources which are fisheries, wildlife, surface and groundwater, range, and forests (Feeny et al., 1990). Despite not being entirely accepted and understood, the concept is reality for more than 500 million people relying on the fisheries resources and services offered by tropical coral reefs, mangrove forests and seagrass beds (Wilkinson et al., 2012). Fish is the natural resource coastal areas of developing countries depend on. However, it is being over-exploited unsustainably for short-term benefits. Sustainability can be defined as providing for the needs of today without compromising the lives of future generations (Reid, 1995).

According to O'Sullivan et al. (2009) there is always a trade-off in everything we do; trading one for another due to limited resources. In more detail, every time we choose to obtain something there are resources used and these particular resources cannot be used for anything else. Or, from another angle opportunity cost (see Table 1) could be seen as the economic cost of what we are giving up to do something else (Hanley et al.., 2013).

*Table 1 Opportunity cost examples.*

| Who made the choice? (Stakeholder) | What they chose | The opportunity cost (what they could have had) |
|---|---|---|
| Students | To go to university | Earnings from three years' worth of full-time, paid employment |
| Fishermen | To catch and sell low-value juvenile fishes through destructive and unsustainable methods | Large adult fish to sell for higher prices using more sustainable gear and maintaining their fishery |

Sanchirico (2002) defines the opportunity cost to be a difference in the response in fishing effort and the bio-economic conditions, for example, before and after restricting the beach-seine fishery. Tietze et al. (2011) recognize the economic loss of beach-seines but find the effect of other juvenile fish catching gear such as purse seines, trawl nets, and ring seines, to have even greater impact on reproduction of fish than beach-seines; therefore, creating larger economic losses. An example of this destruction is illustrated through a case study conducted in Kerala, West coast of India, which showed the economic losses when using purse seines are seven times higher, trawl nets are five times higher, and ring seines are almost four times higher, than the losses generated through beach-seining (Tietze et al., 2011). On the other hand, a study that took place in Antongil bay, located on the east coast of Madagascar, revealed through catch rate comparisons of different gear types that beach-seines yield higher catch rates than other gear used in the area (Doukakis et al., 2007). These case studies show the regional differences in the fish catch volume and fishing gears used and the need to study each gear as well as the combined and possible overlapping effect of different fisheries.

A sustainable fishery, ideally and simply, is fishing the stock at a rate where the fish population does not decline over time because of fishing. Decision making for sustainable resource management, both short-term and long-term, is easier with calculated monetary value for local natural resources, especially in the developing countries (Unsworth et al., 2010). To show the possible revenue loss of catching small juvenile fishes with beach-seines in comparison to adult fishes captured with other gear, one could compare price data collected for each at the same point of sale. This type of direct comparison sheds light on the monetary issues at hand, but theoretically the biological effects should be considered as well, such as mortality.

Mortality comprises natural mortality, predation, and fishing mortality. Also, the estimated number of individuals that leave a population for other reasons should be taken into account. The mortality curve for fish, Type 3, is described with a negative exponential curve where the line for the number of survivors goes down almost diagonally (see Fig 4). This means that when fish hatch, the number surviving the larvae and juvenile stages is very low. The number of survivors stabilises after reaching maturity. A vast issue in fisheries management is that most of the management effort is focussed on protecting the adult fish; the flat, lower portion of the curve (Pierce, 2013).

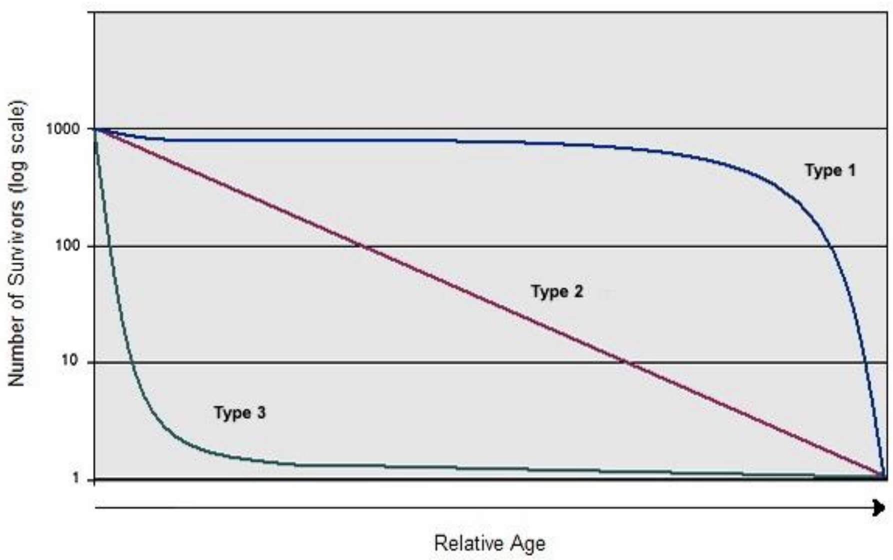



*Figure 4 Survival curves: Type 3, fish, high mortality, low survival when larvae or juvenile - Type 2, birds, mortality is stable throughout the life cycle - Type 1, human, survival high throughout their life, high mortality increase at old age (Pierce, 2013).*

Fishing has greater knock-on effects than merely removing biomass. It also affects the age and size structure of the fish stock that can lead to localised depletions (Berkeley et al., 2004). Recruitment, growth and mortality are the determinants of the changes in size of a fish stock at a given present time compared to the future. There are two main types of overfishing found in the fisheries literature; recruitment overfishing and growth-overfishing. Recruitment overfishing described by Diekert et al. (2011, 2) is “depletion of reproductive part of the stock”. Haddon (2001) specifies that recruitment overfishing occurs when the stock size is being so greatly reduced that the population cannot replace the fish dying naturally or otherwise. Diekert et al. (2011) see growth-overfishing as overexploitation of the young before reaching their full potential biologically and economically. Haddon (2001) also remarks on the stock being fished so heavily that most individuals are caught when they are too small and have not reached their optimal size for fishing. Therefore using gears that catch the largest individuals and have a low overlap with other gear is thought to improve the sustainability of the fishery (McClanahan et al., 2004). Notable is that the value of an individual fish increases with age and growth in most commercial fisheries making growth overfishing a great economic problem, possibly larger than recruitment overfishing (Diekert, 2010). The likely result of growth-overfishing is biological instability that has potential to cause permanent changes with no return (Diekert et al. 2011).

Research in Northern Tanzania revealed the beach-seine net to be a fishing gear encroaching on other fishing gears; while beach-seine catch increased other fisheries' catch decreased (McClanahan et al., 2001). A study from Wakatobi, Marine National Park, Sulawesi, Indonesia, showed that regardless of trophic level, most of the fishes being captured with beach-seine nets have not yet reached reproductive age (Unsworth, 2007). Catches consisting of more juveniles than adults alongside decreases in the average size of fish has been thought to indicate exploitation above maximum sustainable yield (MSY) (Unsworth et al., 2010). MSY is the maximum level at which a natural resource can be routinely exploited without long-term depletion especially in fisheries (Oxford, 2014). Jennings et al. (2001) stated that catch for subsistence fishers was expected to consist of large numbers of small, mixed species fish with few large specimens. A high percentage of these juvenile fishes originate from the seagrass bed areas with most common families being the Emperors (*Lethrinidae*), Parrotfish (*Scaridae*), and Rabbitfish (*Siganidae*) (Unsworth, 2007).

Beach-seines are arguably one of the most destructive fishing practices employed in coastal East Africa due to the common usage of mosquito-nets in different parts of the main net, especially the cod-end section (Gough et al., 2009; Lopes et al., 2003; Dache, 1994; Bush, 2013) which is a narrow pocket at the end of a net restricting the lateral movement of the catch. The small mesh size of the mosquito-net is indiscriminate of which fish it traps (FAO, 2014a). The beach-seine also acts as a trawl (Payet, 1997) when dragged through the seagrass beds upon reaching the shallow waters, damaging the coral reef and seagrass bed habitats threatening the quality of the ecosystem (Gough et al., 2009).

In summary, there exist trade-offs when making choices between competing uses of scarce fisheries resources. Throughout the beach-seine literature there is little attempt at a calculation of the theoretical economic loss associated with beach-seining compared with more sustainable methods. There is a real need for management plans which consider the ecological effects of exploiting juvenile fish, and as such research must be conducted to support this. To conclude, unsustainable fishing methods, such as beach-seine fishing, pose a threat to indigenous people's livelihoods whose vital food source and sole income derives from fish. Exploiting juvenile fish, the crucial yet vulnerable foundation for one of the most important natural resources, has the potential to have serious impacts on the people

depending directly upon fisheries as well as the coastal habitats utilised by growing populations. This review has highlighted the paucity of information and the need for more in-depth research, not only on the biological effects of beach-seining, but on the stakeholders involved in the process and the fisheries-dependent people affected most by beach-seining. South-West Madagascar represents one of many developing regions that sorely need knowledge of the social, economic and biological effects of beach-seining in order to make informed fisheries resource management decisions.

# 3 Research questions

The aim of this project was to understand who the beach-seiner fishermen are, why beach-seining is a growing part of the fisheries in the BRB and what species are caught with this type of fishing gear.

- Socioeconomic:

  1. Who are the beach-seine fishermen and what is the supply chain* of the Bay of Ranobe beach-seine fishery moving from the beach-seine fisherman to end-user?

**There is little paper trace on the transactions from the beach-seine fishery in the Bay of Ranobe. Thus, little is known about where, and in what form, each catch ends up.*

- Opportunity cost:

  2. What is the theoretical* loss in revenue associated with targeting commercially-important, juvenile, reef fish species over their adult equivalence in the Bay of Ranobe?

**Theoretical in the sense that there is no raw field data available to quantify the exact difference in monetary value between a catch consisting of juveniles and a catch consisting of their adult counterparts.*

  3. What is the difference, if any, between the monetary values* of beach-seine catches in the north and the south of the Bay of Ranobe?

**Monetary value being the amount paid in Aryari, the local currency (MGA), for each catch.*

- Biological characterization of beach-seining:

  4. What is the beach-seine catch composition and what is the possible difference of juvenile fish composition between beach-seine sites in the north compared to the sites in the south of the Bay of Ranobe?

# 4 The study site

Coastal habitats are linked to each other by the movement of water and biological material (Unsworth, 2007). Estuaries and shallow waters have a great importance as nursery areas for high volumes of organisms before migrating to areas of adult stocks (King, 1995). These areas are concentrated in mangrove forests and seagrass meadows (Verweij et al., 2008). They provide important ecosystem services. Seagrass beds are a health level monitor for nearshore ecosystems due to being one of the most vulnerable of coastal habitats (Dawes, 1998, 324). They act as pre-indicators of any changes taking place, e.g. contaminant exposure, water quality or changes in the ecosystem. In situ living bio-indicators provide time integrated information on environmental quality and condition when measured for appropriate characteristics (Kilminster, 2013). Seagrass meadows function as carbon sinks naturally absorbing and storing more carbon dioxide from the atmosphere than they release (Gullström, 2002). Nutrient cycling has been measured to be approximately USD1,9 trillion per year (Waycott et al., 2009).

Even though seagrass meadows have global recognition as vital coastal ecosystems, they are declining at record rate and are neglected in most conservation plans (Unsworth et al., 2010a). According to Waycott et al. (2009) the seagrass decline rates were 0,9% per year before 1940 but have risen since 1990 to 7% per year. Disappearing rate since 1980 has been 110 km² per year; 29% of the known areas of seagrass have vanished since the first recordings in 1879 (Waycott et al., 2009).

These complex habitats play an important role in primary production and provide many species, particularly in their juvenile stage, with a direct and indirect food source. Fishing in these coastal habitats and neighbouring areas extract mainly non-target species, and even though many of them may be commercially important, they are still too small to have substantial value (Blaber et al., 2000). Seagrass meadows play an essential role in supporting the fisheries throughout the BRB (Cooke, 2003).

The BRB is a 32km coastal lagoon system (see Fig 5) located approximately 20 km north of the regional capital, Tulear. The BRB lagoon system comprises of coral reef, seagrass,

and mangrove habitats. The reef network forms part of one of the most important coral reef systems in the Western Indian Ocean supporting a high diversity of species and the third largest coral reef system in the world (Cooke, 2003). This complex habitat plays an important nursery role in terms of primary and secondary productivity and in providing refuge, particularly for juvenile stages of fish and invertebrates (Gullström, 2002; Dawes, 1998). In the south at the north side of the river mouth Fiherenana, the reef structure continues with a fringing reef covered with sediment called Récif de Songeritelo. It develops into the barrier reef at Ifaty. It is defined by a lagoon, the BRB, and two distinct passes, Passe Sud and Passe Nord. It is the point where the reef starts to approach the coast again, closing the lagoon, ending at the mouth of river Mamombo and the mangrove forest of Fitsitika (Cooke, 2003). The human population of the BRB has been estimated to be approximately 20 000 people who inhabit 13 villages located along the bay out of which Fitsitke, Songeritelo, Ambotsibotsike, and Belitseky are in the mangrove forest areas where beach-seining is not common (see Fig 5).

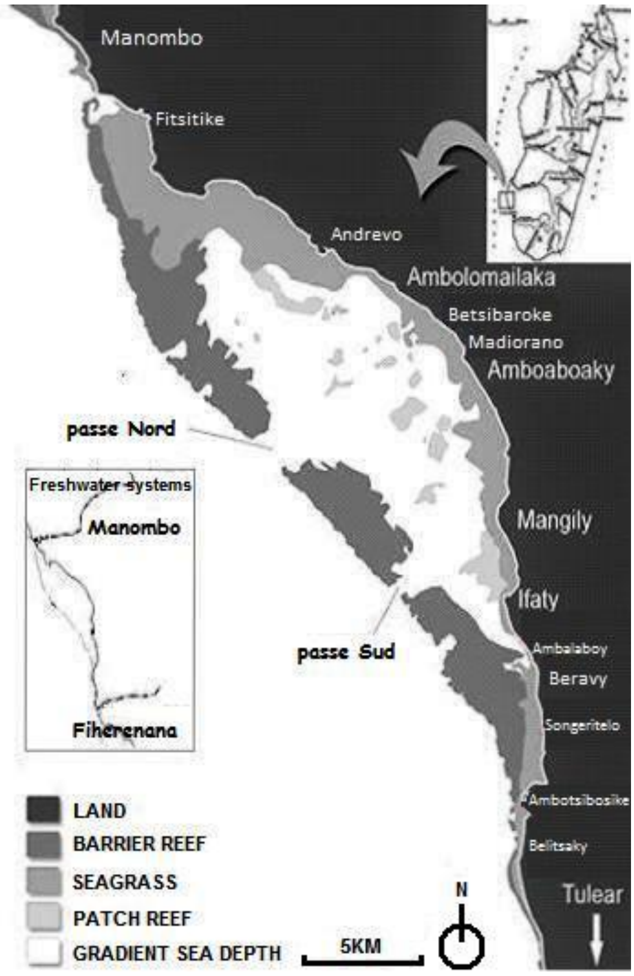



*Figure 5 The Bay of Ranobe area is demarcated by mangrove forests and rivers at both ends. The thirteen villages of the Bay of Ranobe start with Belitsaky in the south and end with Fitsitike in the north (Smaller font represent 500-1500 habitants – Bigger font represent 2000-3000 habitants) (ReefDoctor, personal communication, September 2013).*

For the current project, the BRB was divided into two sections; the southern part of the bay (South) and northern part of the bay (North) (see Table 2). The division was based on the visible existence of the seagrass meadows and also the health of the mangrove forests. There are noticeably more seagrass beds in the North and the mangrove forest is healthier than the one in the South, even with a higher population habiting the coastline in the North. The health of the forest could have an effect in the composition of the fish catch. The other determining factor is the bigger number of sub-collectors present in the North versus South possibly having influence on the pricing strategies.

*Table 2 Northern and southern towns in the Bay of Ranobe engaged in beach-seining activity.*

| North BRB | South BRB |
|---|---|
| Ambolimailaka | Ambalaboy |
| Antsaro | Amboaboake |
| Betsibaroke | Ifaty |
| Madiorano | Mangily |

During the extreme high-water springs and extreme low-water springs, the area is under greatly changing conditions when large masses of water go back and forth (see Fig 6).

*Figure 6 The tidal ranges in the west Madagascar are one of the largest in the Western Indian Ocean and can reach up to 2,6 meters in the Toliara region, west coast of Madagascar (Cooke, 2003) The picture illustrates low (on the left) and high tide in front of ReefDoctor site, Ifaty, Madagascar.*

During low tide, the beach becomes very big and exposed, extending several kilometres, depending on the topography (Mtwana Nordlund, 2012). The fishermen are forced to follow the rhythm of the tides and the pattern of the winds; strong southerly to south-westerly afternoon winds that change direction to northerly and north-westerly during the cyclone season (Epps, 2007), as are all other beach users e.g. gleaners.

# 5 Background to the case study

In the recent years, artisanal and traditional fisheries have expanded to meet the increasing demand from a growing population (Gough et al., 2009). There are approximately 40 000 traditional coastal fishermen in Madagascar using roughly 20 000 dugout canoes, of which most are located in the Tulear region (McClanahan et al., 2001). Traditional fisheries have low operating costs, creating an opportunity for fishing to bring high economic return if resources are not depleted. Unfortunately, the trend in areas of high poverty in the tropics and East Africa is excessive exploitation of fishery resources (McClanahan et al., 2001). As fish stocks decline, there is a financial incentive for fishermen to use less selective equipment. These strategies decimate juvenile fish populations, and also destroy the seagrass habitat (McClanahan et al., 2001). Both national and international organisations (see Table 3) are concerned of the overfishing in the southwest of Madagascar (Le Manach et al., 2013).

*Table 3 Examples of National and international organisations working in the south-west Madagascar region.*

| National organisations | International organisations |
|---|---|
| Reniala association | GIZ (Germany) |
| Tany Meva Foundation | CARE (USA) |
| Bel Avenir Association | Blue Ventures (UK) |
| SAGE (Service de la gestion de l'environment/Environmental Management Services) | ReefDoctor (UK) |

## 5.1 Beach-seine fishing

A part of traditional fisheries, beach-seining, locally called Tarikake (Gough et al., 2009), is one of the oldest fishing methods. A beach-seine net typically is formed out of feripe (i.e., small mesh sized nylon nets) and jahoto (i.e., gill nets) that make a long, often over 200m, net (Gough et al., 2009). In the middle of the entire net there is makarakara (i.e., a mosquito-net) used as a cod-end (see Fig 7).

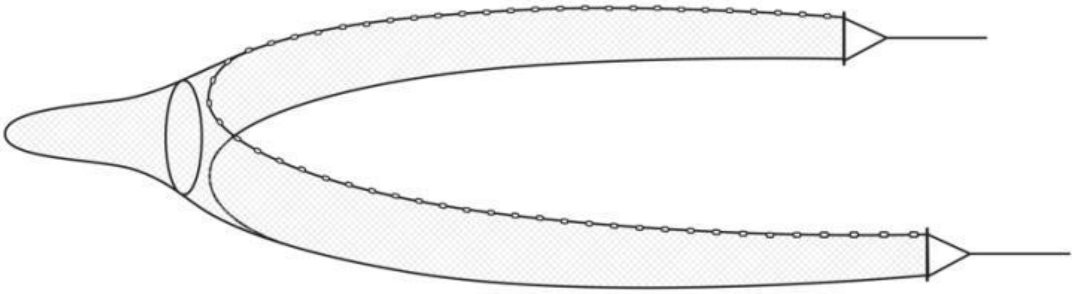


*Figure 7 A beach-seine net with a cod-end in the middle (Tasmanian Government, 2012)*

The makarakara are also used alone to capture the smallest fish and shrimp (see Fig 8). This fishing method, where fish net is pulled parallel to the beach, adds to the similar trawl type destructive effect beach-seine fishing has on the coastal habitats.

*Figure 8 Mosquito-net is also used alone to extract smallest fish and shrimp. In this photo a young boy and a woman with a baby on her back are dragging a mosquito net through the shallow water column parallel to the beach close to Ifaty, Madagascar.*

Most of the beach-seine nets are in contact with both the benthos substrate and the surface and, therefore, are used in the shallow coastal waters (Hahn et al., 2007). Typically a beach-seine is taken from the shore with a small boat, pirogue, to encircle a school of fish and then pulled back to the beach with the ropes attached to both sides of the net to entrap fish (see Fig 9), employing four to ten people at a time. The net stays open with the downwards force of weights attached to the lead line counteracted by floating buoys attached to the float line (Tietze, 2011).

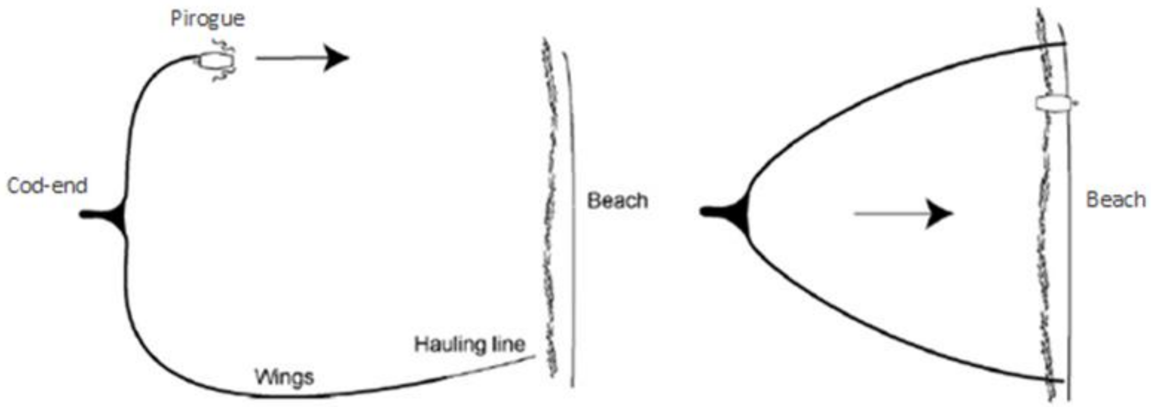



*Figure 9 Method of beach-seine net deployment (Broadhurst et al., 2007)*

The beach-seine is an active gear normally used in water depths less than one half or two thirds the depth of the net (Portt et al., 2006). The aim is to keep the lead line on the bottom and the float line at the same time remaining at the surface while the net is pulled to shore (FAO, 2014a). The size of the fish caught in the beach-seines, like all other mesh-based gear, depends on the mesh size. Another factor affecting the size of the fish that are caught is avoidance; the encircling efficiency of a beach-seine net decreases when fish are bigger and can swim faster because they are able to avoid the net more easily (Portt et al., 2006). A study in Antongil bay, located on the east coast of Madagascar, revealed through catch rate comparisons of different gear types that beach-seines yield higher catch rates than other gear (see Table 4). If beach-seines become more common with other efficient gear, such as Tamis (small mesh seines of mosquito net or thin cloth), there could be a significant impact to the fishery and ecosystem with removal of the juvenile fish from areas fished with mosquito-net.

*Table 4 Results of fisheries monitoring program in Antongil Bay, Madagascar. G: gillnet; L: line; V: Vitry (fence like structures made of wood or reeds); T: Tamis (fine-mesh seine); G/L: gillnet and line combined; BS: beach-seine (Doukakis et al., 2007).*

| Gear | CPUE (kg/fisher/hour) | | | CPUE (kg/fisher/day) | | | Time (minutes) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean (Range) | SE | N | Mean (Range) | SE | N | Mean (Range) | SE | N |
| G | 0.83 | 0.018 | 3351 | 4.50 | 0.103 | 3404 | 306 | 2 | 3364 |
| L | 0.66 | 0.025 | 1245 | 3.45 | 0.166 | 1245 | 293 | 3 | 1215 |
| V | 0.81 | 0.057 | 77 | 3.80 | 0.401 | 78 | 270 | 12 | 77 |
| T | 2.41 | 0.418 | 38 | 7.10 | 0.983 | 38 | 204 | 12 | 38 |
| G/L | 1.53 | 0.296 | 62 | 10.91 | 2.203 | 64 | 416 | 13 | 63 |
| BS | 4.62 | 0.500 | 87 | 9.27 | 0.296 | 92 | 133 | 10 | 86 |
| All | 0.88 | 0.019 | 4865 | 4.43 | 0.094 | 4964 | 300 | 2 | 4843 |

Portt et al. (2006) describe in their paper that demersal species are harder to catch than mid-water species but also state that smaller individuals are more vulnerable than larger ones, making mortality rates high for smaller species. Another example is found in India, where juvenile fishes found near the shoreline waters are disappearing due to an unsustainable number of fishermen using old-fashioned fishing methods such as bag nets, stake nets, push nets, and beach-seines (MANAGE, 2008). Doukakis et al. (2007) examined through dependent and independent observation of the Antongil Bay estuarine seine fishery, and found that these bay habitats are refuges for juveniles of fish species that can be found in the traditional fishery catches. The beach-seine lands high volumes of fish under 5cm whilst at the same time damaging the habitat it is pulled through; the damage to corals with repeated usage limits resettlement (Hicks et al., 2012). Beach-seining is practiced daily in the BRB, sometimes even up to three times a day in the same location. The beach-seine is commonly used especially in the Tulear region where most of the traditional fishermen in Madagascar live (Cooke, 2003).

In a study on mosquito-net fishing by Bush (2013), the cod-ends in the beach-seining fishery are commonly made out of mosquito-net throughout African countries even though many East African countries have restrictive laws on the minimum mesh size. In the case of Madagascar, a colonial Decree (Article 10 du Décret Colonial du 5 Juin 1922 réglementant l'exercice de la pêche par chalutage dans la mer territoriale Malgache, JOM du 29 Juillet 1922) established on June 5, 1922, prohibits the use of any fishing nets with mesh size smaller than 25mm (Rakotosona, 2006). Therefore, the use of beach-seine is illegal under this decree, but, has continued due to lack of enforcement. This can be due to high corruption index 28/100, where 100 is very clean and 0 is highly corrupt, (Transparency International, 2014) and lack of law enforcement personnel in remote areas. It is possible that low quality infrastructure and dispersed human settlements reduce police presence (Fafchamps et al., 2004).

## 5.2 Socioeconomic assessment

A socioeconomic survey helps to define the parameters in which the fishery is working (Tzanatos et al., 2006). The socioeconomic information gathered in the surveys is commonly termed to be different kinds of community characteristics (Kronen et al., 2007). Fishery surveys can include demography, income, living costs, fishing gear, and marketing

structure. Socioeconomic information on status and usage of coastal marine resources is needed for management planning, especially when subsistence and small-scale fisheries are in question (Kronen et al., 2007). Small-scale fisheries, near-shore subsistence fisheries in particular, are often disregarded due to being widely spread along the coast. This lack of attention resulting from limited resources, both financial and human, even though the importance for social, cultural, and food security aspects have been commonly acknowledged (Hardman et al., 2012). According to David (1996), a study carried out in Vanuatu describes how traditional fisheries changed from traditional gear and technique used to a more complex system. Traditionally fishermen have fished, then eaten or sold the goods forward and not shared another thought to it. The new system brings together a resource (the fish), a technology (fishing gear, techniques and preserving methods), a population (producers and consumers), its social and cultural environment (traditional ways and customs, rules and regulations), and the inter-relationships based on the exchange of goods and information that joins all these elements together. It creates an entity that is linked together by the resource moving through the chain from being caught to the final user.

The fishery's management plan needs to consider the possible socio-economic impacts the plan might impose before setting limitations on fisheries (Doukaki et al., 2007). Preikshot (2000) suggests that non-biological information, e.g. data gathered from socioeconomic surveys, can help to strengthen the biological warnings of overfishing such as declining fish catches or big shifts in the trophic levels in the catch. At the same time able to point out any fisheries that need to be studied more. Socio-economic features have been mentioned to be probable reasons of fisheries changes but the actual studies directly observing the effects of these features in small-scale artisanal fisheries is limited (Tsehaye, 2007). In Madagascar there is socio-economic small-scale fishery research done on a more general level, but not focusing on a specific fishing method alone (Langley, 2006; Epps, 2007).

When looking at the socio-economic aspects of fisheries in Madagascar, an important determinant is the tribes involved. A tribe like the Vezo, to whom traditional fishing is not only a sustenance-based livelihood but also part of cultural heritage and identity have very different beliefs and traditions compared with an inland tribe that has been forced to move to the coast for food scarcity and security reasons. Understanding the social characteristics,

such as the motivations, behaviours, and attitudes of fishers are necessary for a complete fishery assessment. Using this non-biological information together with biological warnings can be an effective instrument in preventing overfishing (Preikshot, 2000).

## 5.3 Tribes of Madagascar

There are approximately 18 recognized tribes (see Fig 10) in addition to several smaller sub-tribes and clans in Madagascar.

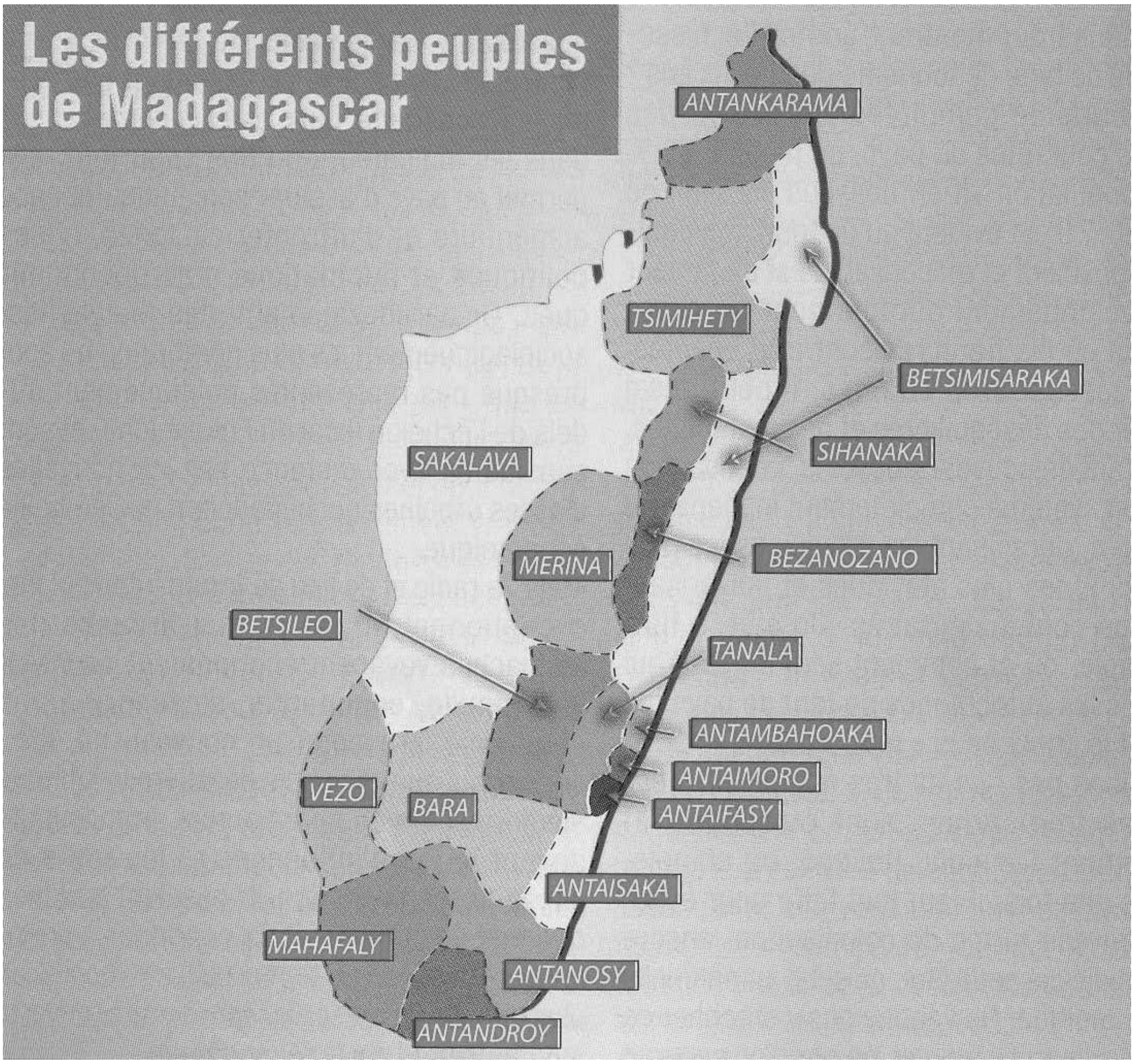



*Figure 10 Tribes of Madagascar (Andriantsoa, 2014).*

Malay-Polynesians migrated from Southeast Asia around 2000 years ago, and were followed by many sets of immigrants from the Arabian Peninsula and mainland Africa,

each one with its own geographical location in Madagascar (Epps, 2007). Asian immigrants settled in the central highlands and formed the Merina (~3 million members) and Betsileo (~2 million members) tribes. The coastal area is mainly inhabited by the Betsimisaraka (~1,5 million members), the Timihety (~700 000 members) and the Sakalava (~700 000 members) tribes who have originated from Africa (Global Edge, 2013).

The Antandroy tribe, which translates into ‘from the spiny forest’ or ‘people of the thorns’, are from the driest and poorest part of Madagascar and are currently facing difficult living conditions but still making their livelihood mainly from farming (Sohl, 2011). The Tanalana is a subtribe of Antandroy. The Sara, Sarambe, Saratsifotihariva, Tejoria and Tejoriakely are all sub-tribes of Mahafaly, which translates into ‘who makes you happy’ or ‘who makes the taboos’. The Mahafaly tribe lives in the highlands of the Southeast coast and its sub-tribes are spread throughout the Southeast of Madagascar. They keep cattle and are highly talented wood sculptors, gold and silver smiths, and tattoo artists. The Vezo and Masikoro are subtribes of the Sakalava - the people ‘from the long plain’ (Rakotondramiadana, 2013). The Sakalava people are shepherds and nomadic, but the subtribes have completely changed their way of life; the Vezo have always been fishermen living on the coast and the Masikoro, living more inland, raise cattle and cultivate rice, maize and manioc. Vezo inhabit the area in the coastal southwest of Madagascar from Morondava village in the north to Itampolo town in the south (Epps, 2007). Due to the migration within the country of people seeking better livelihoods, the tribal people have relocated to new areas where differences in traditions and ways of living can cause conflicts.

## 5.4 Supply and value chain

The supply chain consists of the people living in the area of beach-seine fishery, the transportation routes to markets, the factories, and the end-users. De Silva (2011) states that supply chain has three main levels: the supply, manufacturing and distribution (see Fig 11). Using the model by De Silva in the context of beach-seine fishery means that the fish is the supply i.e. the raw material transported from the beach-seine fishermen’s catch to the manufacturing units. The manufacturing units are the factories, which transform raw material to a product, either semi-finished or finished. These products are sold forward to

end-users through other types of factories, fish markets, hotels or restaurants. Distribution ensures the product reaches its customers through an organized network of distributors, warehouses, and retailers. The stakeholders, especially for the supply chain of small scale fisheries in a developing country, are all very dependent on one another (De Silva, 2011), making them vulnerable to delays.

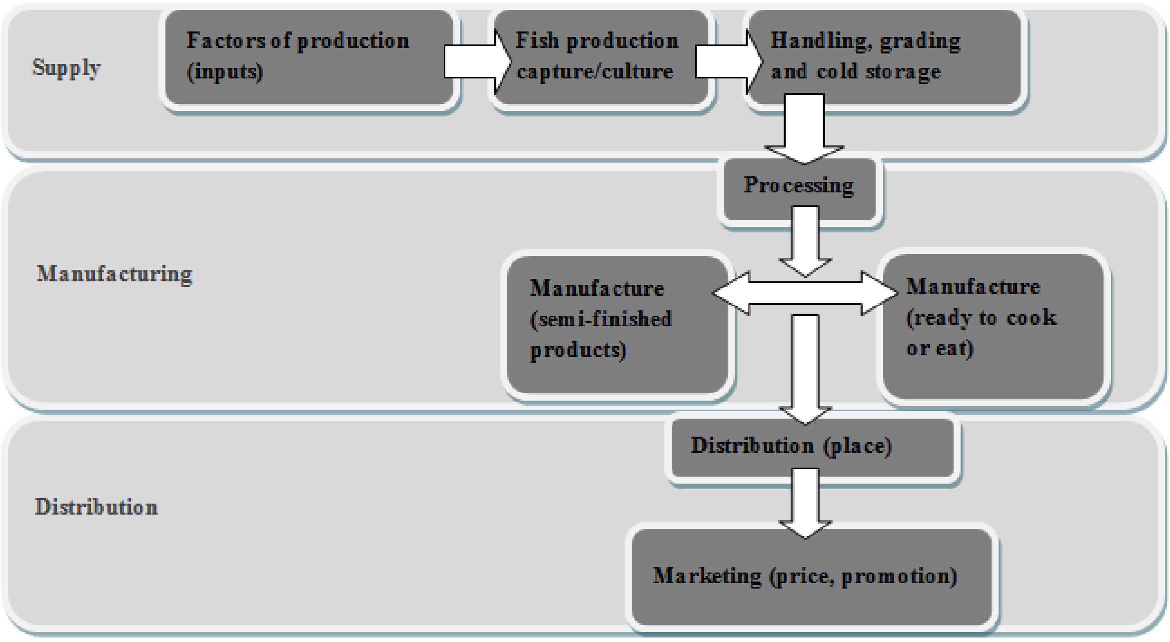



*Figure 11 Key links in fish and fishery product supply chain (De Silva, 2011)*

Value is an important part of creating the supply chain. It is made visible in the value chain. As part of the supply chain, value chain looks into the value-added part that each stakeholder creates for the product. The marginal profit to be made depends on the price that the consumer, the end-user, is willing to pay and how it is divided amongst the supply chain. The fisher-controlled aspect, the beach-seine catch, is cost driven, whereas the latter parts of the value chain are considered the retailer aspect, and therefore more revenue driven (De Silva, 2011).

## 5.5 Catch composition and commercially important species

The catch of fisheries varies depending on the gear and boat(s) available, the experience of fishermen, tides, weather, time of the day, and the season of the year. Seasonal migration and juvenile recruitment of species can affect fish communities over long-term time frames (Bentes et al. 2006, Rooker et al. 1991). When observing fish communities in short-term time frames; diurnal (Santos et al., 2002), hourly or daily (Willis et al., 2006), during night or day (Pierce et al., 2001), during low- and high tide (Lasiaka, 1984; Unsworth et al., 2007), there are assemblage changes but these are more moderate and mainly linked to feeding and predator avoidance (Teather et al., 2012).

The assemblage of coral reef fish in Madagascar resembles those of East Africa and the Mascarenes, with some similarities with South Africa's Natal coast (Cooke, 2003). The structure and sustainability of fish stocks can also be described with trophic levels; the position of an organism in the food chain. The range is from 1, primary producers, to 5, marine mammals and humans as the top predators (see Fig 12). For healthy fish stock the order is the same as in other food chains; more prey and fewer predators. A decline in trophic levels results in shorter food chains. This in turn will leave ecosystems vulnerable to changes, natural or human-induced (United Nations, 2014). The long-term sustainability of fisheries is directly linked to human livelihoods and well-being.

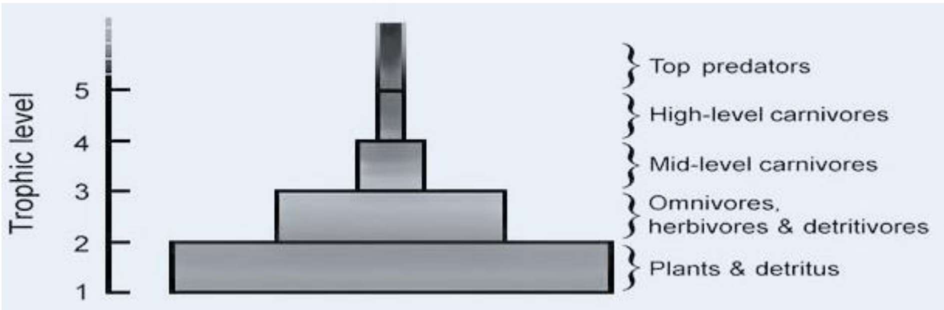



*Figure 12 Trophic levels for a normal sustainable fish stock (Fishbase, 2014).*

The beach-seine catches analysed in the making of this study were found to mostly contain juveniles of all of these families. The location of adult stock is often off shore (see Fig 13) showing the migration fish species experience during their life cycle (Aggrey-Fynn et al., 2011).

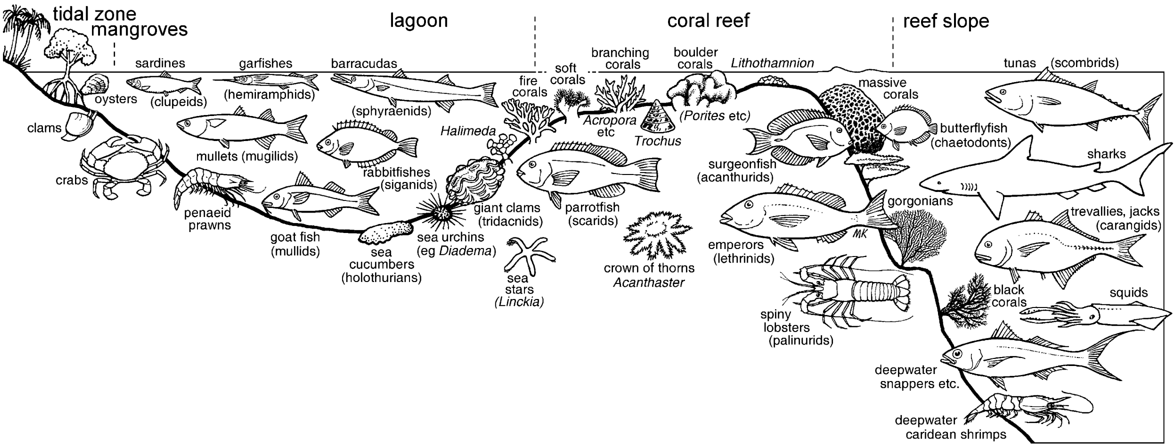



*Figure 13 Lagoon and barrier reef system profile (King, 2012).*

The most common families in the BRB, according to Cooke (2003), with numerous species present are wrasses (*Labridae*), damselfish (*Pomacentridae*), butterflyfish (*Chaetodontidae*), surgeonfish (*Acanthuridae*), parrotfish (*Scaridae*), and soldierfish (*Holocentridae*). Other regularly found families are fusiliers (*Caesionidae*), groupers (*Serranidae*), emperors (*Lethrinidae*), snappers (*Lutjanidae*), goatfish (*Mullidae*), and puffers (*Tetradaontidae*).

Many commercially important species rely on seagrass beds as juveniles. Expensive finfish from *Carangidae* and *Scombridae* families, and average priced finfish from e.g. families *Siganidae, Lutjanidae, Mullidae, Belonidae*, and *Sphyraenidae (*Barnes-Mauthea et al., 2013), all have juveniles living in nearshore habitats. All of the species play an important role in keeping the coastal habitat in balance. The roles of two of the most common species in both, the beach-seine catches in the BRB as well as the fisheries catches in the BRB, are the Rabbitfish, *Siganidae*, and Parrotfish, *Scaridae*. The roles of these two fish species are somewhat similar; Rabbitfish is vital for coral reef food webs due to being a food source for reef fish above its trophic level and also because they keep the coral free from excess plant growth by feeding (Jonna, 2003). Parrotfish serves an important role alongside with the Rabbitfish as an algae grazer to prevent excess growth smothering the corals, but are also food for moray eels, snappers, and a wide range of larger reef fish despite growing to 30-50cm in length (King, 2012).

- Rabbitfish. The distribution of 28 species in the Rabbitfish family, under one genus *Siganus,* cover reefs and coastal habitats of the Indo-Pacific, Red Sea, and

Mediterranean (King, 2012). The life cycle for rabbitfish starts when sexually mature one- to two-year-old adults gather for spawning aggregations at a location with open access to the ocean around the time of the new moon where each female releases up to 2 million eggs to be fertilised by males (King, 2012). The larvae face a mass mortality between hatchings (Emata, 1994), and survivors reach the drifting larval stage that lasts approximately one to two months. The ones that survive, 1/1000, become juveniles and move to shallow seagrass beds in large schools that are called bait balls (King, 2012). The survival rate then becomes marginally higher with 1/100 reaching sexual maturity. As an adult, the separation of families becomes clear when they either pair up or create schools living in the shallow nearshore habitats (Fox, 2012). Rabbitfish can grow up to 35cm in total length (King, 1995). Rabbitfish is highly valued as a food-fish, e.g. in Persian Gulf, Bahrain, Kenya, Tanzania, Seychelles, Philippines, Solomon Islands, New Caledonia and Madagascar (Fox, 2012).

- Parrotfish: There are 90 species of parrotfish that belong to the family *Scaridae* living in shallow tropical waters concentrated in the Indian and Pacific oceans living in a variety of habitats; rocky coasts, seagrass meadows and coral reefs (King, 2012). The spawning aggregation happens in a similar manner as with Rabbitfish at a location with access to the open ocean. Almost all parrotfish species start as females and change later into bright green or blue coloured males of which most grow a forehead bump. Sexual maturity is reached two to three years after birth. The larvae stage is of uncommon length after which they settle at the coral reef (King, 2012).

# 6 Materials and methods

The research followed a multi-method design where two or more research methods are used separately to be combined into a holistic whole at the end (Esteves et al., 2004). The project was divided into socioeconomic surveys and catch composition analyses to examine the extent of beach-seining in the BRB. The socioeconomic study comprised of surveys that were conducted both on the beach with the beach-seining fishermen at work and collectors as well as factory representatives close to the fishery's landing sites or in the capital city of the area, Tulear. The surveys done were to assess circumstances, motivations, and possible impacts relevant to the stakeholders in different positions of the supply chain and identify who these people are. These surveys were conducted using questionnaires that were primarily quantitative in nature. The socioeconomic questionnaire for the beach-seine fishermen started with a section for all crew members. Structured questions included demographics and residence, level of education, and some work related questions that were quantifiable to reflect who the people are taking a part in beach-seining. The questionnaire also included quantitative data collection of the types beach-seine nets used to allow for comparison within the different nets as well as to reflect trends in design. The latter part in the questionnaire was conducted straight after the first part for the whole crew and was aimed at only one fisherman out of the beach-seine crew, the leader. In the case where he had been interviewed before during the research, someone else from the crew was approached. This part of the interview included nine questions. This latter part was needed in order to gain further understanding of the attitudes and perceptions of the fishermen in addition to the demand for the beach-seine catch. The socioeconomic surveys (n=9) carried out in the capital of the area, Tulear, were necessary to form a picture of the entire supply chain involved in the beach-seine fishery. Even with small number of interviews, due to time constraint, the supply chain as well as the value chain was formed. The interviewees were picked randomly from the selection of factories in the area. The factories in the list were contacted and the people, who were available and willing, participated in the survey.

The catch composition analysis began with the beach-seine catch sample being received at the outdoor wet laboratory from the beach-seine landing site where the fishermen were interviewed. The samples were then identified and separated into family and species level. The individuals of each species where counted, measured, and photographed. The information was recorded for statistical analysis to be done. The statistical tests used included Pearson correlation to analyse the net influence on the catch, the Shannon-Wiener index of diversity, and the Mann-Whitney U test to compare the catch sample prices.

The starting points to locate beach-seining were the four landing sites used for traditional fisheries surveys at Beravy and Ifaty in the South and the North Ambolimailaka and Andrevo (see Fig 5, Chapter 4). The research assistants walked randomly towards north or south until they came across a beach-seine. The GPS points for the area of collection for the beach-seine catch samples ranged from most the northern point S23°02'41.3" E043°33'55.1" to the most southern point S23°11'20.3" E043°37'07.7".

The research team included three permanent members and many volunteers. Volunteers were needed to count, identify and measure the fish (in more detail in Chapter 6.2). The three permanent members included two local males, an assistant and a catch collector, that carried out survey interviews and catch sample collection in the field, and one female as the head of the research project. The decision to use native males on the field was due to local experience of foreign Caucasian female researcher's possible negative impact on receiving any unbiased data from the research site area, as well as to address safety concerns. Whereas the site is part of the poorest and remote places in Madagascar, the existing knowledge shows the Caucasian are mainly seen as source of money by the local people. It has also been perceived that women in rural parts of Madagascar do not have a strong social status making it less safe for female researchers in the area especially with no previous experience living in similar areas before.

## 6.1 Socioeconomic surveys

The socioeconomic surveys of the beach-seine fishery included interviews of beach-seine fishermen and also interviews of other stakeholders in the supply chain such as the different buyers to find out the extent of the whole chain. The socioeconomic survey for beach-seine fishermen carried out along the coastline of the BRB through interviews that followed a pre-printed questionnaire with mainly closed ended questions (n=27) designed

to obtain information relating to beach-seining gear characteristics and socioeconomic data from the fishermen. Locations were chosen randomly with no specific pre-plan. The areal division to the North and the South end of the BRB was due to challenging logistics and visual evidence of heavier seagrass cover up at north end of the bay. The North and the South were also chosen due to more landings and collectors present at the north compared to the south of the BRB. The actual location of interview and catch collection was chosen using convenience sampling by the two local assistants. The interviews were done at each observed beach-seine site where a sample of the catch was collected for analyses of sample composition to be made in the wet laboratory. There were 67 questionnaires filled in gathering data from 189 beach-seine fishermen. The socioeconomic research of the upper end of the supply chain included factory surveys (n=11) in Tulear, which included collectors and other parties employed by the factory. The factories located close to or within Tulear area were listed and contacted. The factories in the list were contacted randomly and the people, who were available and willing, participated in the survey.

### 6.1.1 Beach-seine fishermen survey

The questionnaires were written in French to be understandable to all parties involved in the permanent research team. The translation from English to French happened in a team of three people; a French national, a Malagasy national and the head of the research. The questions were closely looked at one by one to make sure the meaning stayed as close as possible to wanted impression.  French was chosen due to Madagascar being a bilingual country with the official languages Malagasy and French, and both two field assistants were familiar with French. The interviews at each observed beach-seine site were performed by the Malagasy research assistants in Malagasy based on the French questionnaire. The answers were written in French. The original interview answers were translated and transcribed into excel sheet in English by one of the Malagasy research assistants who had more experience of socioeconomic surveys and the head of the project for further analyses. The answers were viewed closely with best intention not to lose the meaning of the answers when translating. Due to lack of funds professional translators were not used but local people and volunteers from ReefDoctor who had the best knowledge in languages used in the research.

The first part of the questionnaire included a variety of socioeconomic questions for each member of the beach-seine crew members. The second part, more specific questions, were

posed to either the leader of the crew or, if already interviewed, another member of the crew. Further information collected from the beach-seine site were details on the net design and other beach-seine fishermen in the area, GPS point for location, weight and price for the catch. The questions included the following (see Appendix A):

- Questions pointed to all crew members:
    - The personal details
        - Demographics and residency – Many developing countries have a growing population creating large numbers of youth which in turn affect the demand for fish and fish products (De Silva, 2011).
        - Educational questions – Higher education and literacy levels create a community that is more concerned of consumer safety and sustainability (De Silva, 2011).
    - Work related questions – The level of commitment to beach-seining helps to understand the importance and benefit to beach-seine fishermen as a stakeholder in the value chain (Rich et al., 2009); it also gives an indication to the length of the path to sustainable fisheries in the BRB.
        - Additional work on top of beach-seining
        - How many times per week the fishermen beach-seine
        - At what age the fishermen started beach-seining
        - Salary from beach-seining
        - Ability to swim
- Questions to one of the crew members, mostly the leader but if interviewed earlier then another representative chosen at random after the quantitative questions had been asked from the entire crew:
    - The economic section consists of maximum monetary value received by one beach-seine effort and for one entire week of fishing.
    - Attributes and perceptions:
        - Beach-user conflict, location decision, beach-seine damage to environment, possible changes taken place in the catch within last few years

- Other information collected:
    - Technical information, which will be covered in more detail in the ‘catch and gear analysis’ section
        - Gear design: Length and depth of the net, mesh size, composition and material of panels, rope length (both left and right side), the floats and the weights used.
        - The number of other beach-seine fisherman fishing crews in the area was recorded by the research assistant.
    - Recording of location with GPS, price paid for the catch sample, and the total weight when harvested from the sea- this information will be used more in the two latter sections. The location information will also help to determine if the site is part of the northern or southern area that will be compared to each other which is used throughout this paper to look at local area differences.

### 6.1.2 Supply and value chain

The beach-seine catch supply chain stakeholders were studied using a four-day targeted market survey in Tulear. The Malagasy research assistant conducted the fieldwork for this survey in several factories interviewing different level employees; e.g. collectors and owners, depending on who was available for an interview. The collectors interviewed in Tulear receive their catch from sub-collectors that collect the fish straight from fishermen. The sub-collectors interviewed (n=2) were close to beach-seine sample collection sites because they were present at the location. The sub-collector interview included questions on demographics, residency, and education. Questions relating to the changes the beach-seine fishermen may have noticed in the beach-seine fishery catches, the environmental impacts beach-seining has and how this influences their opinion of it, as well as if they feel beach-seining has increased assessed the perceptions of beach-seining. There was also a question inquiring the buyer for the beach-seine catch the sub-collectors were selling. The factory interviews done in Tulear (n=9) were approached with questionnaires similar to the sub-collector questions. The demographics and residency of beach-seine fishermen were acquired. Work-related questions covered factory's products, what and how treated and where they are sold to. Who the original catch is from, and whether or not the distributors are aware of the methods used, was also asked. The perception questions included changes

in the marine products in recent years, the awareness on the fishery's laws and regulations, and the environmental impact of beach-seining. The beach-seine catch supply chain stakeholders that were studied in Tulear were also approached to inquire about their knowledge on prices for beach-seine fish catches to create an understanding of the value chain taking place amongst the stakeholders in the supply chain.

### 6.1.3 Opportunity costs

There needs to be an incentive for doing beach-seining that counteracts the degradation of near-shore areas in the BRB. The monetary value received from beach-seine catches and the value chain through the supply chain give an indication to the need and use of beach-seine fishery. To show the possible revenue loss of the beach-seine practise the price paid for each sample catch was used to calculate a mean price for one fish and one kilo in beach-seine catch samples bought to compare with the other traditional fisheries catch prices that mainly are for adult fish. This secondary baseline data of other traditional fishery prices was collected by the ReefDoctor Fisheries team from landing sites at four villages along the BRB; Beravy, Ifaty, Ambolimailaka and Andrevo. The data used is from the socioeconomic section of their survey that was collected during May 2013 to October 2013. Mann-Whitney U test was used to compare the monetary value, as paid for each catch, between the sites in the North and South. .

## 6.2 Catch and gear analysis

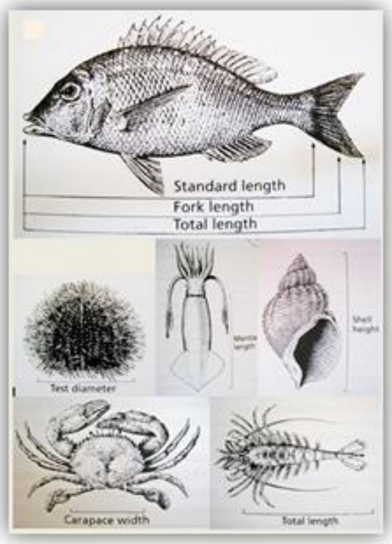
Samples for the analysis bought from beach-seine events represented the total catch, unless the total weight was over 9kg or over USD7,5 (15 000 Ariary) in value, in which case the total weight of the catch was measured and a subsample taken for analyses. When the sample was collected in the southern part of the bay, the two local team members brought the sample directly to the wet laboratory. Samples collected in the northern villages were sent by local public transportation to the lab. The sampling strategy corresponds to tidal cycles and is stratified by region (North versus South). As described prior, the socioeconomic questionnaire was conducted at the same location as the catch collection to enable correlation analyses to be conducted.

*Figure 14 The wet laboratory and fish analysis (Photo credit Jesper Milver Nielsen, 2014).*

Analysis of catch composition was done in the wet laboratory at the ReefDoctor base in Ifaty (see Fig 14). Wet weight was taken in the approximate time frame of four hours using weighing scale Ohaus, Scout Pro, 400 x 0,01g. Length was taken to the nearest mm for all species present (see Fig 15 and Table 5), and the measured catch was photographed.


*Figure 15 Yellowtail barracuda measured at the wet laboratory (Photo credit Laura Nordgren, 2013).*

*Table 5 The body size measurements taken at the wet laboratory (Jennings et al.., 2001).*




| Catch component | Measure |
|---|---|
| Fish | Total length in 1mm accuracy |
| Shrimp | Total length in 1mm accuracy |
| Crab | Carapace width in 1mm accuracy |
| Squid and Cuttle fish | Mantle length in 1mm accuracy |
| Hermit crab | Shell height in 1mm accuracy |

The fish catch sample was divided into species level when possible and family level otherwise. Experienced ReefDoctor staff, identification materials, and the web-based program Fishbase aided in fish identification. All measurements were taken of all fish for each species if less than 20 individuals were present. If more than 20 were present, the measurements of largest, smallest, and 10 random individuals were recorded, as well as the total number of individuals of each species, and the total weight of all of the representatives of the same species or family.

For this project, the focus was on total fish length because this parameter could be measured consistently by the multiple assistants who participated in the four-month field season. The location of the beach-seine survey carried out during the beach-seine event was recorded with GPS (see Fig 16); the beach-seine catches are divided into North and South parts of BRB as shown in Table 1 in Chapter 4. The start time, end time, total weight, and total price, as well as, net design details were also written down to be used with the sample analysis for cost per unit effort (CPUE) and other statistics.


*Figure 16 Beach-seine sample collection locations. The division into North and South is visible (Google Earth.Ink, 2014).*

During the analysis at the wet laboratory, the data recorded included the name, weight, and, length of the species in question. The data was analysed with Minitab statistical program and Microsoft Excel. Data used for analysis were routinely tested for normality ($P>0.05$) with Kolmogorov-Smirnov test. A regression was conducted to analyse the effect of net size (calculated as square meter per mesh size) and the mosquito-net cod-end on the total weight, mean length of fish, mean weight of fish, number of fish, number of families and the mean trophic levels present in each catch. Most of the data tested violated the terms of normality, therefore, a non-parametric alternative, the Spearman rank correlation, was used. Scatterplot with correlation was conducted between total weight and total price. Results were uncertain; therefore, a scatterplot with correlation was done between the mean fish size and total price as well as the count of high or medium value fish compared with the total price. The Shannon-Wiener index ($H = -\Sigma\ Pi(\ln Pi)$) for each catch was used to look at the fish diversity in the BRB for the nearshore habitats in the North and the South. The Shannon-Wiener index combines two quantifiable measures: the species' richness as number of species within a community and species equitability looking at how

even the numbers of individual species are (Begon, 2006); the number of individuals present for each species (or families) in the sample group (Maryland Sea Grant, 2014). The Shannon's equitability (EH = H/lnS) was also counted; it has values between zero and 1 (1=complete evenness). In this report, the family level was studied with the Shannon-Wiener index due to a high percentage of catch not being able to be identified to species level.

## 6.3 Limitations

There are multiple challenges facing researchers when conducting an investigation in a developing country. For the current project the conditions were very basic with no indoor laboratory environment (e.g. no genetics in identification). The low-quality internet and electricity access were unreliable. The poorly maintained infrastructure caused extended transportation times even for short distances, and cancellations of some planned sample catches. The limited resources in fieldwork, the wet laboratory, as well as the identification of fish that was limited to written sources and local knowledge were additional restrictions. One of the practical challenges for fieldwork within the limited resources at hand was the long coastline of the BRB making spotting the beach-seines at the right time demanding.

The changing team of staff and volunteers taking the measurements could have possibly created some variance in the recorded data. Many different people analysing the catch was also the reason the length measurements taken were done as simply as possible, e.g. for fish the total length. Fish are damaged by the beach-seine nets; however the sample catches were mainly intact, with the only visible damage being peeled off scales and discolouration causing some of the prominent markings for identification to be missing. Windy days imposed challenges for weighing at the open air wet laboratory due to the scale being quite vulnerable to surrounding air movement.

Time constraints gave limitations to the number of catch samples as well as to the length of the data collection period, which in turn restricted the allowance for seasonal fluctuations within the catch composition.

Language and culture in Madagascar differ within the tribes and regions within the country making the use of local research assistants essential but still challenging. This was taken into account by choosing two local assistants for the permanent team of which one was from the BRB to reduce bias and misunderstandings.

# 7 Results

The results from the two separate parts for this project, the socioeconomic surveys and catch composition analysis, showed the importance of the current beach-seine fishery as well as a picture of the juvenile fish composition in the BRB.

## 7.1 Socioeconomic

The socioeconomic survey was used to demonstrate who the beach-seine fishermen are and what their role in the supply and value chain is. The supply and value chain were constructed out of the data collected in the socioeconomic surveys.

### 7.1.1 Beach-seine fishermen

Out of the 189 beach-seine fishermen interviewed 39 (21%) were women and 143 (79%) were men. The ages of the beach-seine fishermen ranged from the youngest who was four years old to the eldest who was 70-years-old. Twenty fishermen did not give their age, possibly because they are unsure of it. Most people in remote villages do not receive a birth certificate. Being unaware of one's age is not uncommon. It is illegal in Madagascar to have children working under the age of 16 and permission is required from parents as well as the authorities for children under the age of 18 to work. Out of the beach-seine fishermen interviewed, 31% were under aged to work according to the law (see Fig 17).

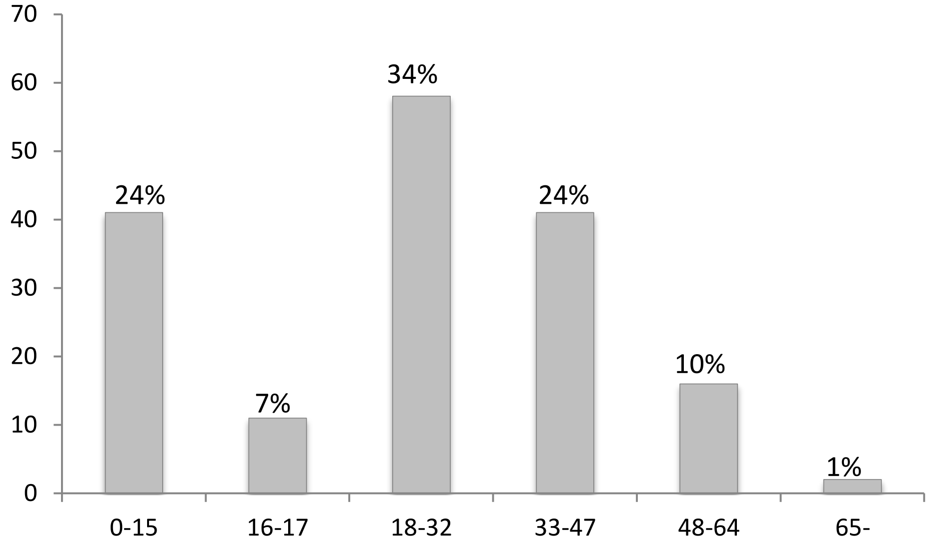



*Figure 17 Age distribution of beach-seine fishermen at BRB. Y-axis shows the percentage of beach-seine fishermen.*

The mean age of the beach-seine fishermen was 27, and the median was 25. 34% of beach-seine fishermen were between the ages of 18-32 and fishermen in the 33-48 age group represented 24% of all beach-seiners. Older citizens, defined here as between the ages of 48 and 64, represented 10% of the age distribution. The life expectancy in Madagascar in the year 2011 was approximately 65 for men and 68 for women (WHO, 2014); there were two people (1%) above this threshold interviewed and they were 70 years old. There was no significant difference in the mean age between North and South; the mean age was 28,17 for the North and 25,66 for the South (see Fig 18). 80 beach-seine fishermen had children and the mean number of these children was 1,98. The youngest to have a child out of the fishermen was 20-years-old.

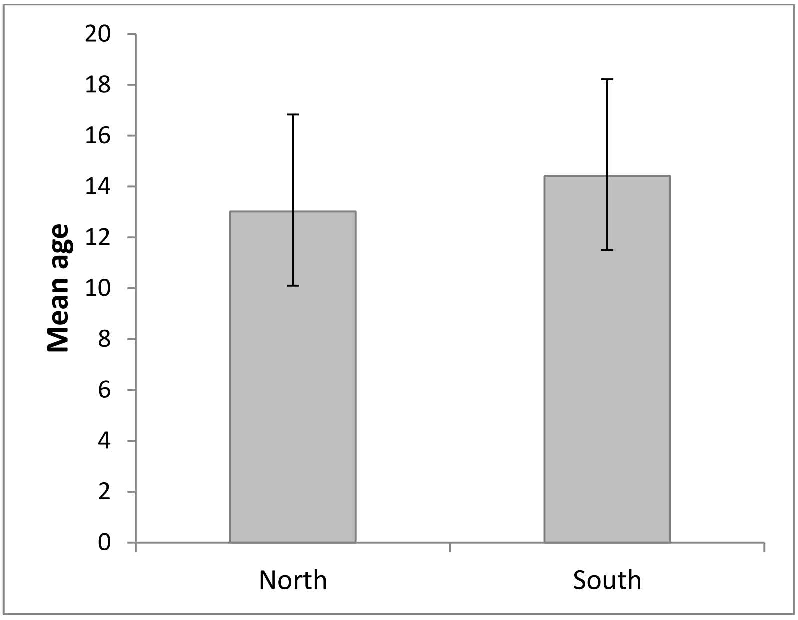



*Figure 18 The mean (± s.d.)  ages for the North and the South BRB.*

Out of the 189 beach-seine fishermen, 167 answered when asked about their tribe. The eight different tribes present were the Sara, Sarambe, Saratsifotihariva, Tanalana, Tejoria, Tejoriakely, Vezo, Antandroy, and Masikoro tribes. Out of these, the Sara tribe represented the majority, 57% (see Fig 19).

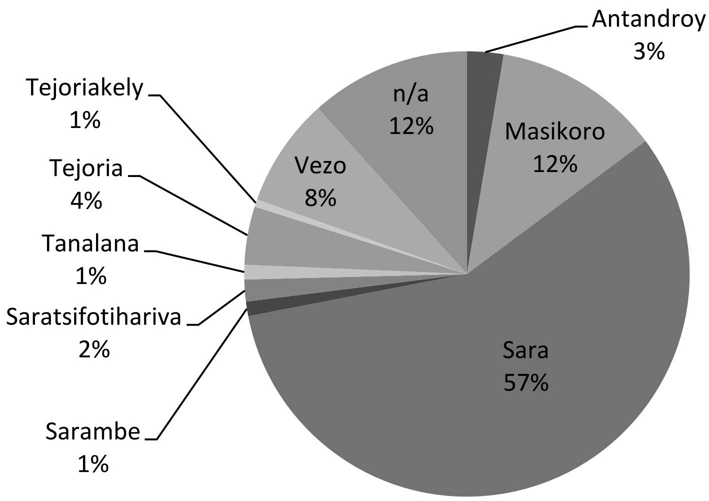



*Figure 19 Beach-seine fisherman tribes present during the project.*

The beach-seine fisherman interviews were conducted nearby eight out the 13 coastal villages in the BRB; Ambalaboy, Amboaboake, Ambolimailaka, Antsaro, Betsibaroke, Ifaty, Madiorano and Mangily. Out of the approached beach-seine fishermen, 39% had moved to the area at some point of their life, and 51% had lived in the same village their entire lives. When educational level and literacy are looked at it is clear that most (51%) of the 189 beach-seine fishermen, interviewed for the project are illiterate with no education (see Fig 20). Out of the total number of beach-seine fishermen interviewed with or without education 55% were illiterate, 52% had no education, 31% had gone through primary school, and 8% had studied up to the secondary school level. Among the beach-seine fishermen, the highest level of education was secondary school. It is the highest level of education available locally in the BRB area. The closest higher education facility is in Tulear.

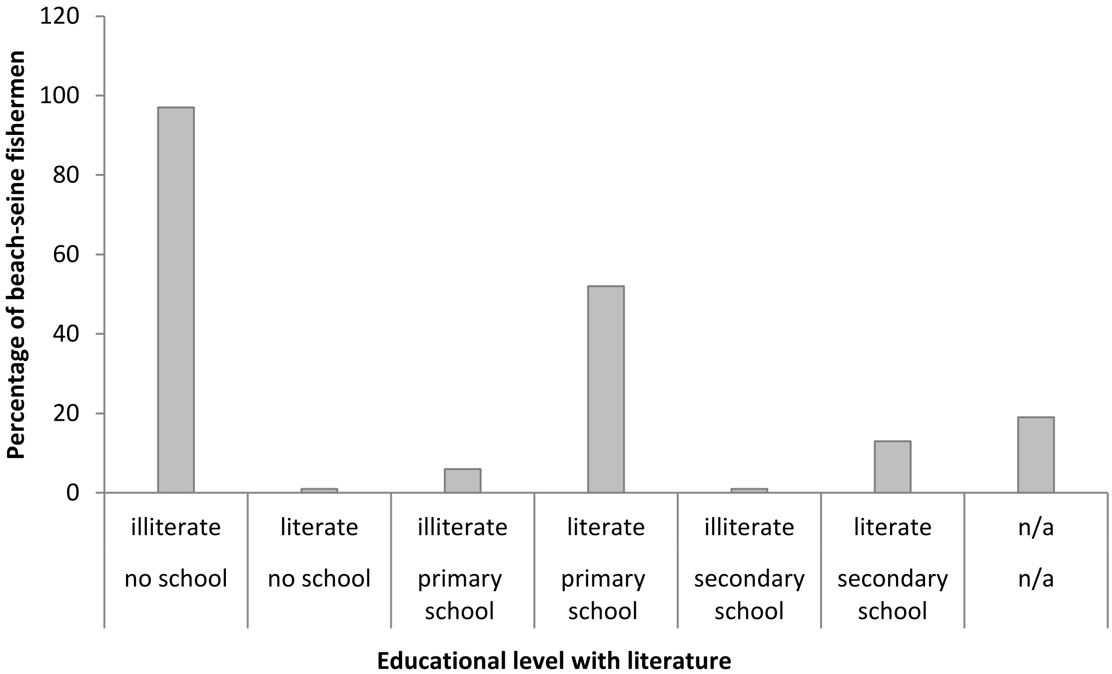



*Figure 20 Beach-seine fishermen's educational level and literacy.*

Most of the beach-seine fishermen received money for their work; crew members who did not get paid or were paid with fish were all under 22-years-old (see Fig 21).

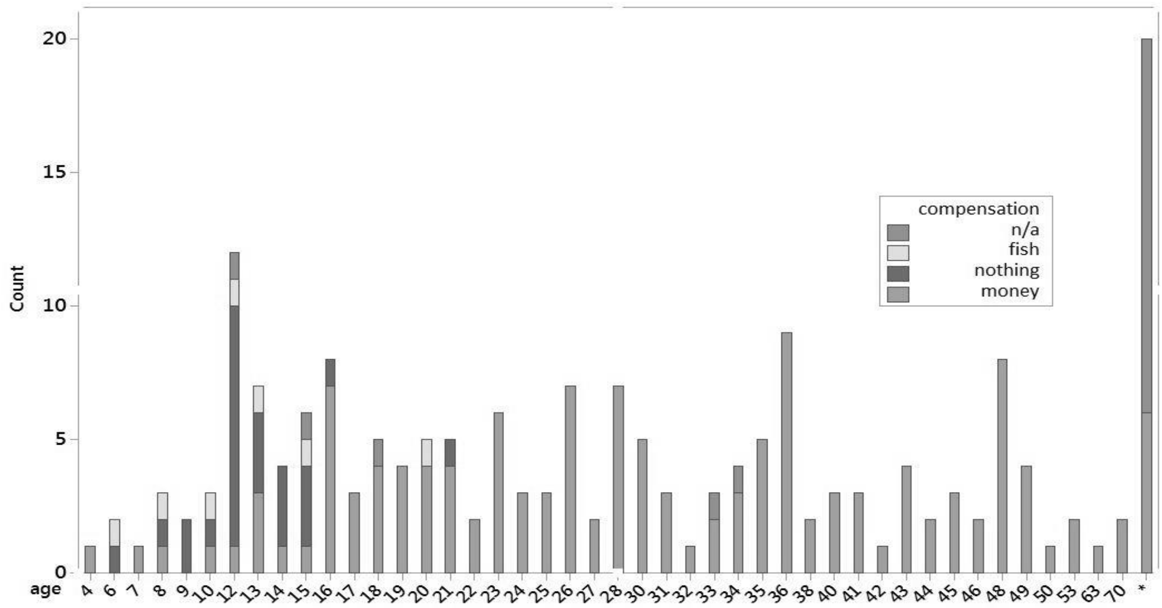



*Figure 21 Beach-seine fishermen's compensation types presented for all age groups in the data collected.*

### 7.1.2 Supply and value chain

The first stakeholders in the beach-seine fishery supply chain (see Fig 22) in Madagascar consist of the beach-seine fishermen who catch the fish and sub-collectors who buy the catch nearby the catch site or the village landing site. The sub-collectors are mainly non-registered collectors who send the catch with local public transportation from the coastal villages of the BRB through collectors to market places and factories in Tulear, Fianar, Morondava, or Antananarivo.

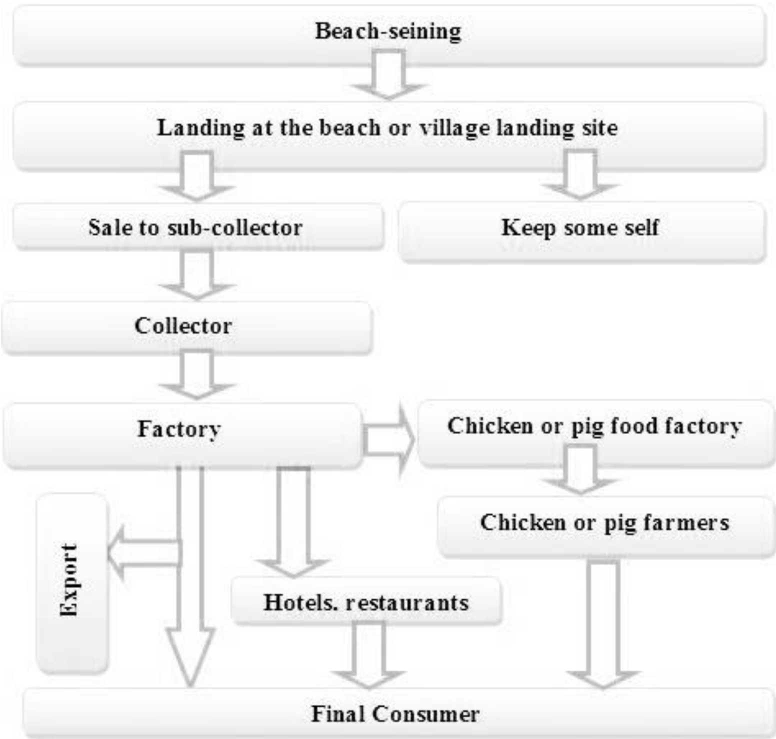



*Figure 21 The Bay of Ranobe beach-seine fishery supply chain.*

Shrimp from the catches, in some cases depending on the size, is sold directly to some bigger hotels in Tulear or the surrounding area, or to the fishermen as fishing bait. Cuttlefish, on the other hand, is sold to a collector from Copefrito. In more detail, the sub-collectors at the beach front filter the fish, gather the large individuals and dry them. Dried fish are then transported in a large bag to Tulear, Antananarivo or Morondava. The small fish are sold at the market place or dried. When there is a larger quantity collected of the dried fish of e.g. herring, orange lined cardinal, anchovies, sweepers, it is sent to pig food or chicken food factories in Antananarivo, Fianarantsoa, Antsirabe, or it is sold to pig farms within in the area of landing. Approximately 60% of the catches are sold through 3000-4000 collectors operating in the country, who then resell the fish (McClanahan et al., 2001). The collectors in Tulear are mostly registered and work for factories in the city area. Two of the three collectors interviewed were also owners of these factories. The nine factories visited in Tulear were all fish retail factories. The products were sold onwards or treated, e.g. dried or made into powder. When the size of the fish in the catch is small it is forwarded to factories in Fianar or Antananarivo to be transformed into food for pigs or

chickens; when the fish size is large it can also be sold at the market place in Tulear or Antananarivo.

In the BRB, the value chain starts with the beach-seine fisherman catching mainly juvenile fish, invertebrates, larvae, seagrass, and other benthic matter. The value adding comes from the catch being roughly sorted to species level for selling if in valuable size and all non-sellable is discarded on the beach. The other value adding action that is sometimes taken by the beach-seine fisherman or his crew and family is drying the fish, but it is done quite seldom. The value chain members in the BRB area following:

- Beach-seine fisherman sells the catch to a sub-collector at the beach and can keep some of the catch himself and is paid depending on the catch size, content, and competition situation among the sub-collectors. During the study period for this project the beach-seine fishermen were paid 2700MGA to 16 000MGA per catch.
- Sub-collector sells the catch to collector who in most cases works for a factory or to the market place.
    - Collector/factory pays sub-collector
        - Large fish and normal catch:
            - 3000-5000MGA/kg for herring, halfbeak and sardine
            - 4000-6000MGA/kg for squid
            - 1000-2000MGA/kg for octopus
            - 2000MGA/kg for shrimp
            - 100 000MGA/big bag for barracuda
        - Small fish:
            - 1000-1500MGA/kg or 6000-10 000MGA/5l bucket depending on the quality and location of the catch
- The factory either sells the catch forward to hotels, restaurants, market places, or when the size of the fish is too small, transforms it into dried fish or powder and sells it to chicken and pig food factories.
    - The factory sells forward for following prices:
        - 5000MGA/kg for herring, halfbeak and sardine
        - 80 000MGA/big bag for shrimp
        - 1700-2000MGA/kg or 30 000MGA/big bag for small fish
        - Barracuda sold in smaller quantities to make better profit

### 7.1.3 Opportunity costs

The second section in the questionnaire was answered by 41 beach-seine fishermen due to some crews being approached more than one time as well as not everyone being willing to answer to more questions. Out of these, six gave an estimation of the maximum monetary value they had been paid for one week of beach-seining. The answers ranged from estimations of 100 000MGA to 600 000MGA. When the beach-seine fishermen were asked to estimate the maximum monetary value paid for them for a single beach-seine effort 36 out 41 gave an answer. The answers had a very wide range with estimations from 10 000MGA to one million MGA (see Fig 23).

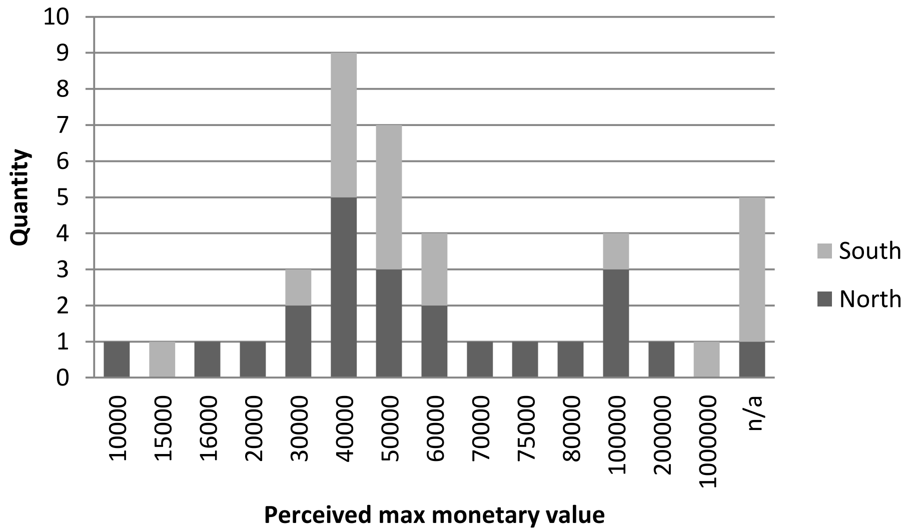



*Figure 22 Max monetary value perception for one individual beach-seine catch.*

The beach-seine fishermen mainly (61%) chose the fishing location due to good conditions, e.g. smooth sea floor, shallow water (see Fig 24). Few (7%) liked the location due to it being close to home, and some (10%) for a good price received for the catch from a sub-collector. Other reasons were given nine times out of which six fishermen mentioned not being fixed on the location but instead beach-seining along the entire BRB coast. The poor infrastructure in the entire BRB area was the reason why easy road access was not impacting the decision making for the beach-seine location.

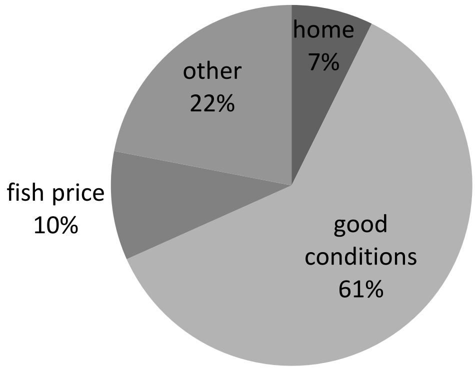



*Figure 23 Reasons for choosing the beach-seine location.*

Most (78%) of beach-seine fishermen felt they had no issues with other beach-users. Hence 19% had experienced issues, of which 75% had people stealing parts of their gear. Additionally, most of the beach-seine fishermen had noticed changes in the beach-seine catch within the last few years (see Fig 25); most had experienced a decrease in fish stock and the presence of large fish, and some felt fishing had become harder than before. Some believed that the changes happened due to seasonal variations only, and a few believed that an increase had happened in the fish stock. Overall, the responses recognised the changes taken place to be negative.

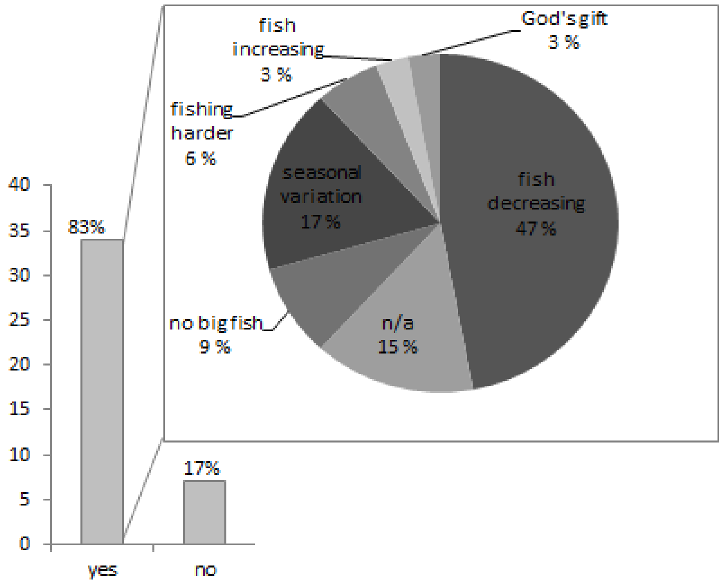



*Figure 24 Perceived changes in the beach-seine catch (y-axis; percentages of changes vs. no changes).*

When asked about the environmental impact of beach-seining, 28 of 41 surveyed said there was none, and out of these, one added that he "did not care" and one replied that he "did not want to think about it" (see Fig 26).

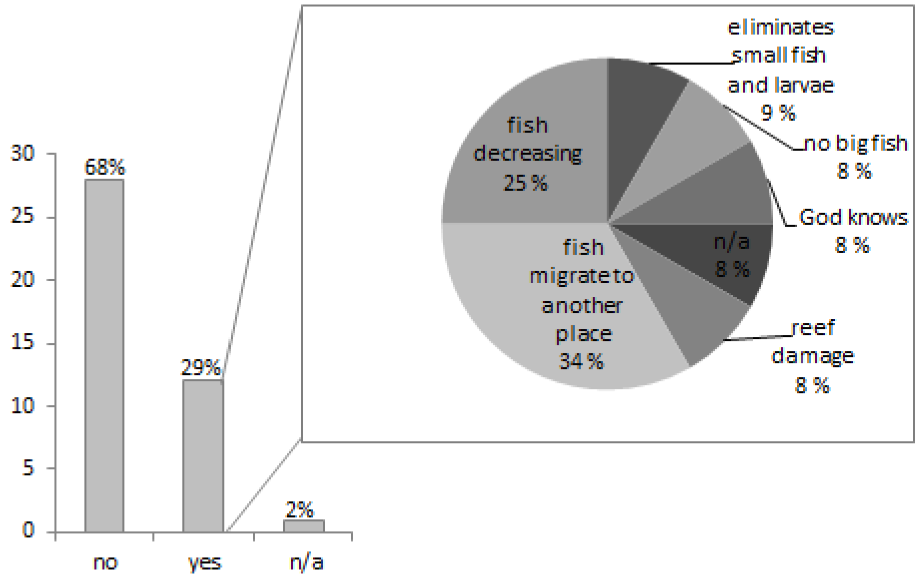



*Figure 25 Perceptions of the environmental impact (y-axis; percentages of impacts vs. no impacts.*

In the current project, the opportunity costs could be seen as the loss of potential future revenue due to the elimination of juvenile fishes before they have reached a size of actual value. It is also useful to take a look into the current situation of value distortion within comparison of the different fisheries as well as between the North and the South beach-seine fishery.

The total price, the total weight, the mean total length, the mean weight per fish, the number of fish, the number of families, the mean trophic level, the Carangidae count, the Rabbitfish count, the mean price for one fish in each catch was all tested for normality using the Kolmogorov-Smirnov test. The data violated the terms of normality. Therefore, a non-parametric alternative Spearman's rank correlation coefficient was used for analyses (see Table 6).

*Table 6 Spearman's rank correlation coefficient between the total price and other variables per catch sample.*

| | The total price (MGA) per catch |
|---|---|
| Total weight (g) per catch | $r_s$ = 0,586, P-value 0,000 |
| Mean total length (cm) per catch | $r_s$ = 0,934, P-value 0,011 |
| Mean weight per fish (g) per catch | $r_s$ = 0,065, P-value 0,614 |
| Number of fish per catch | $r_s$ = 0,146 , P-value 0,253 |
| Number of families per catch | $r_s$ = 0,189 , P-value 0,134 |
| Mean trophic level per catch | $r_s$ = -0,268, P-value 0,034 |
| Mean Carangidae count per catch | $r_s$ = -0,108, P-value 0,404 |
| Mean Rabbit count per catch | $r_s$ = 0,441, P-value 0,000 |

Scatterplot with correlation for total weight and total price for each catch indicate a weak relationship (Spearman's rank $r_s$ = 0,586, P-value 0,000) (see Fig 27) showing possible positive influence the total weight could have on the price level in beach-seine catches.

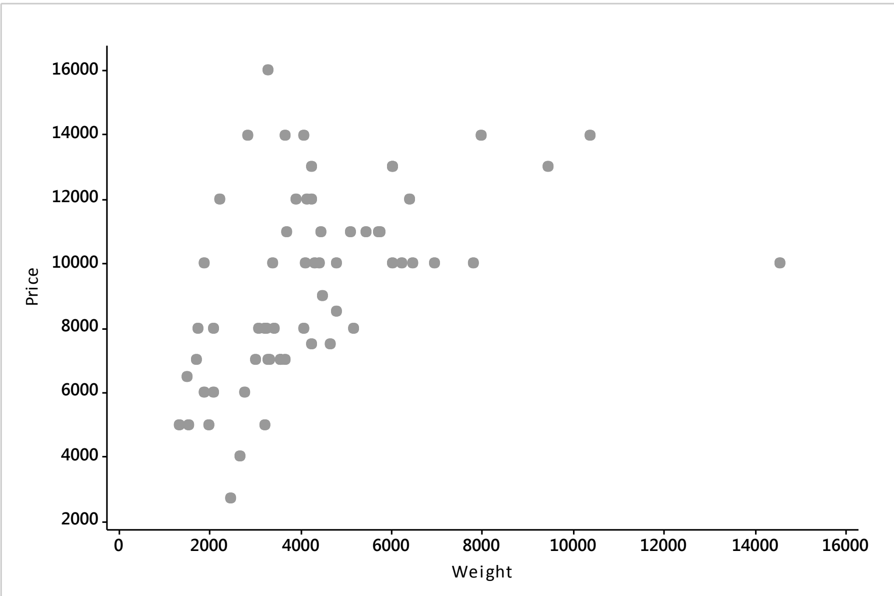



*Figure 26 Total weight (g) and total price (MGA) scatterplot of each catch (Spearman's rank $r_s$ = 0,586, P-value 0,000).*

When the scatterplot with correlation was done for mean weight (g) and total price (MGA) of each catch, the result shows no significant relationship ($r_s$ = 0,065, P-value 0,614). The presence of high value fish, like the Carangidae, does not show a significant correlation on the price (MGA) either ($r_s$ = -0,108, P-value 0,404). When the same test is performed for

Siganidae, the relationship is not highly significant but gives some indication on rabbitfish being valued more ($r_s$ = 0,441, P-value 0,000).

The mean price for one counted sample in the beach-seine catch samples was 8,83MGA. And the mean price for one fish was 9,07MGA. The mean price for one fish in the beach-seine sample catch went down with the increase of the total count of fish (see Fig 28).

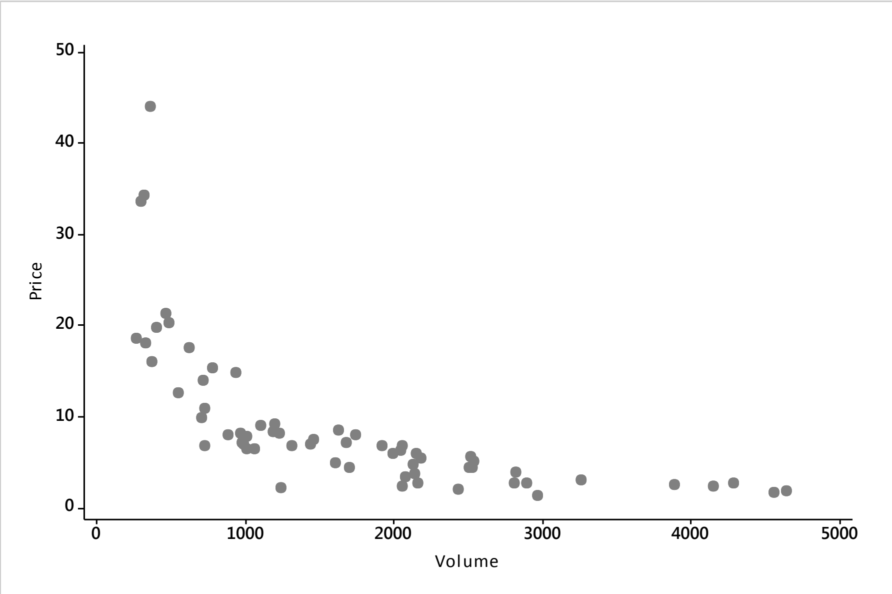



*Figure 27 The mean price (MGA) for one beach-seine catch sample fish compared to the count of fish in each catch (Spearmans's rank $r_s$ = -0,611, P-value 0,000).*

The effort of fisheries is measured by the input given by fishermen; how much time they contribute, the size of the crew needed, the model and number of vessels used, as well as the gear used (Huang et al., 2009). In beach-seine, the effort consists of the crew size; the number of pirogues used, and the design of the net used- which often is similar in design but different in sizes- as well as the time spent per beach-seine. The CPUE for the beach-seine measured with kg per fisherman per hour showed that the mean effort for the BRB was 0,64. The mean wage per hour was 1356MGA. However, it was found to be more appropriate to analyse the mean wage per beach-seine since beach-seines are typically performed one to three times a day. The mean wage per one single beach-seine was 1863,8MGA. During the study period for this project there were four encounters out of 63 (6%) where the fishermen did not get any money; twice when the catch consisted of only jellyfish, two non-edible urchins, and a catch full of seagrass with no fish.

The Mann-Whitney U test was conducted as a non-parametric equivalent since the data, tested with the Kolmogorov-Smirnov test, violated the terms of normality. The median cost paid for a catch in the North was significantly higher than that paid in the South (W=1011, p-value 0.0198).

The data for other fisheries recorded by the ReefDoctor Fisheries team revealed the high volume families being similar to the ones caught by beach-seining. The mean weights are higher than in the beach-seine catches due to a smaller presence of juvenile fishes (see Table 7).

*Table 7 Trevally, Emperor, Rabbitfish and Parrotfish mean price (MGA), mean weight (g) and count (ReefDoctor, personal communication, September 2013).*

| Fish | Mean price (MGA) | Mean weight (g) | Count |
|---|---|---|---|
| Trevally | 14 211 | 893,0 | 604 |
| Emperor | 642 | 514,8 | 11 426 |
| Rabbit | 1065 | 1182,7 | 6480 |
| Parrot | 1341 | 757,57 | 5686 |
| Wrasse | 590 | 360,2 | 2748 |
| **Total** | | | **89 194** |

The mean prices for individual fish in the beach-seine catch compared to catches of other traditional fisheries in the BRB are significant (see Table 8).

*Table 8 The mean price (MGA) differences per individual fish in the beach-seine catch in comparison to the other traditional fisheries catch.*

| Fish | Mean price other traditional fisheries (MGA) | Mean price beach-seine (MGA) | Difference (MGA) |
|---|---|---|---|
| Trevally | 14 211, 00 | 9,07 | 14 201,93 |
| Emperor | 642, 00 | 9,07 | 632,93 |
| Rabbit | 1065, 00 | 9,07 | 1055,93 |
| Parrot | 1341, 00 | 9,07 | 1331,93 |
| Wrasse | 590 | 360,2 | 229,8 |

## 7.2 Biological characterisation

A total of 110 092 fish and invertebrates (see Table 9), weighing approximately 275kg (275 138,11g), were counted during the field work period between 30 October 2013 and 20 February 2014. Within this amount, 101 028 were identified to family level (54 fish families) and 31 852 to the species level (155 species). Total of 10 classes were identified

during the research. Out of these ten classes 96% were *Osteichtyes* (fish), 3% *Crustacea* (crabs and shrimp) and 1% *Cephalopoda* (squid and cuttlefish).

*Table 9 The number of classes found in the beach-seine catch samples.*

| Class | Count |
|---|---|
| *Cephalopoda* | 962 |
| *Crustacea* | 2842 |
| *Cypraeidae* | 1 |
| *Echinoidea* | 2 |
| *Gastropoda* | 104 |
| *Holothuroidea* | 18 |
| *Ophiuroidea* | 5 |
| *Osteichtyes* | 106050 |
| *Scyphozoa* | 57 |
| Unidentified worms | 51 |
| **Total** | **110 092** |

Trophic level ranged from 2 to 4.5 in the beach-seine catches (see Figure 29). Trophic levels of 2 to 3; omnivores, herbivores and detritivores represented 71,04% of the catches. Mid-level carnivores with trophic levels 3 to 4 reached 28,66%. High-level carnivores counted for 0,30% with the trophic level group 4 to 5. The top predators with trophic levels above five were not present in the catches.

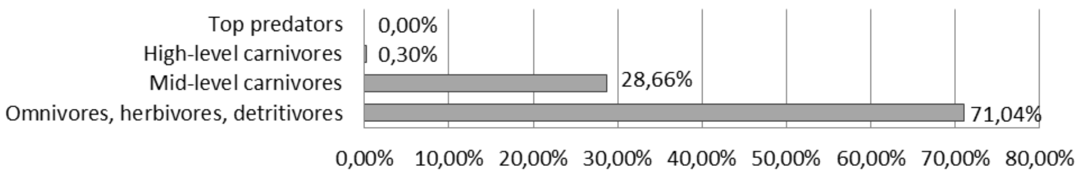



*Figure 28 Trophic levels in the beach-seine catch samples.*

Data included measurements for 17 different beach-seine nets (see Fig 30); eight of these included mosquito-net panelling. The main parts of the side panels were made out of nylon net with mesh size bigger than 20mm. All beach-seine nets encountered during the study included a cod-end made out of mosquito-net. Some of the nets had either patches of mosquito-net on the panels or entire sections of panels constructed with it.

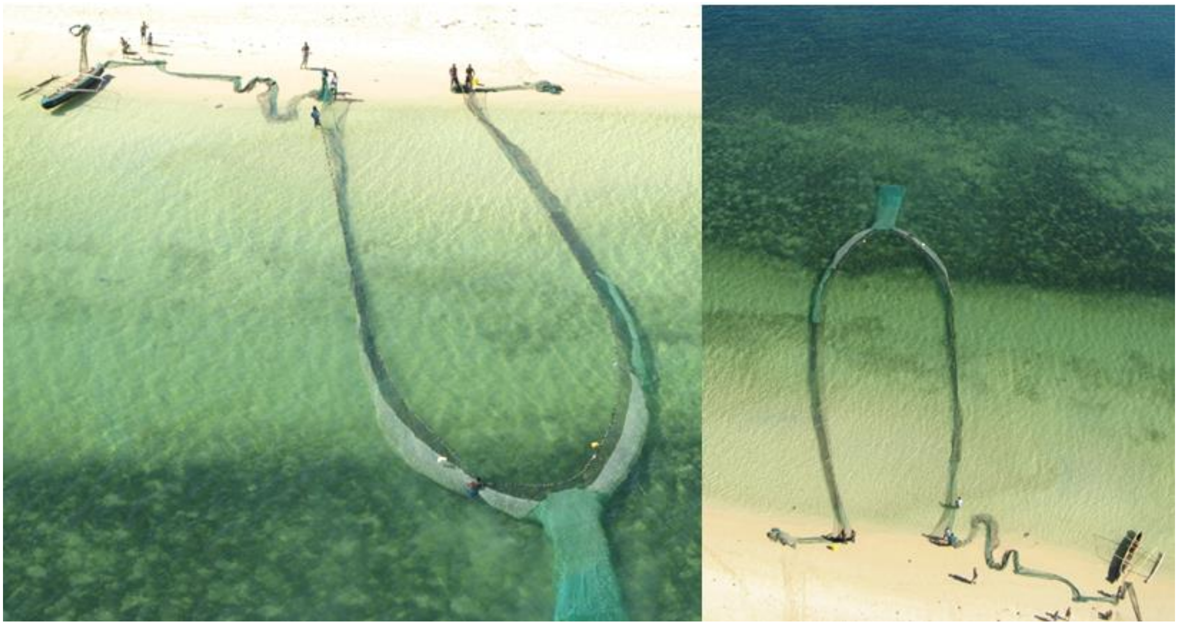


*Figure 29 The beach-seine implementation in real life (ReefDoctor, personal communication, September 2013).*

The nets measured were identified as left and right side by observing from the beach. The minimum left rope length was 30m and the maximum was 1000m. Within all the nets, the right rope ranged from a minimum length of 30 meters to a maximum length of 1200 meters. The net length varied from 20 meters to 1000 meters in length and 0,5 meters to three meters in depth. The nets' surface area were measured and recorded for analysis. The weights used for the lead line were mainly cement and sand, with a small number of nets being weighted down with shells. The float lines were created out of seemingly any buoyant material- flip-flops, buoys, canisters, cork, wood, polystyrene, airbags and plastic bottles. The number of other beach-seine fishermen present varied from one to seven crews within visual site. The average number of other crews for the North and South was similar; the North averaging 2,67 other beach-seine crews present and the South averaging 2,25.

The nets with mesh size bigger than 20mm and mosquito net cod-end were both tested for normality using the Kolmogorov-Smirnov test and the data violated the terms of normality. Therefore, a non-parametric alternative was used for correlation analyses. Spearman's rank correlation coefficient indicated that there is no significant association with the area of net with bigger than 20mm mesh size or the mosquito-net cod-end and the variables tested (see Table 10). The result showed there was no significant effect on the net size or the

mosquito-net cod-end when tested with total weight per catch, meant total length, mean weight, number of fish, number of families, or mean trophic level per catch.

*Table 10 Spearman's rank correlation coefficient between net sizes and other variables (rs ± 1 = significant association, P>0.05).*

| | Net with mesh >20mm | Mosquito-net cod-end |
|---|---|---|
| Total weight per catch (g) | $r_s$ = -0,060, P-value 0,650 | $r_s$ = -0,015, P-value 0,906 |
| Mean total length (cm) per catch | $r_s$ = -0,002, P-value 0,990 | $r_s$ = 0,078, P-value 0,548 |
| Mean weight (g) per fish per catch | $r_s$ = 0,104, P-value 0,434 | $r_s$ = -0,105, P-value 0,422 |
| Number of fish per catch | $r_s$ = -0,031, P-value 0,815 | $r_s$ = 0,016, P-value 0,902 |
| Number of families per catch | $r_s$ = 0,058, P-value 0,664 | $r_s$ = -0,050, P-value 0,704 |
| Mean trophic level per catch | $r_s$ = -0,206, P-value 0,117 | $r_s$ = -0,218, P-value 0,091 |

In total, 54 families were identified, 51 in the south area and 43 in the North (see Table 11). According to the Shannon-Wiener index, samples from the south, on average, had the same diversity as an assemblage with 6,643 equally-common species, whereas samples from the North had diversity comparable to an assemblage with 7,857 equally-common species.

*Table 11 Total number of families and individuals, mean number of families and diversity, for assemblages of beach-seine catch sample fish in the south and north.*

| **Site** | **Total number of families (richness)** | **Total number of individuals** | **Mean number of families per sample** | **Mean Shannon-Wiener index (H')** | **Mean diversity (effective number of families)** | **Shannon's equitability** |
|---|---|---|---|---|---|---|
| South | 51 | 63225 | 21,66 | 1,787 | 6,643 | 0,249 |
| North | 43 | 39872 | 23,59 | 1,884 | 7,857 | 0,270 |

Shannon's equitability shows the evenness of the data, where the value ranges from zero to 1; one being complete evenness. When the south was looked at in comparison to the north, the Shannon's equitability shows low evenness ($EH_{South}$ =0,270; $EH_{North}$ = 0,249). This result indicates that the catches are dominated by certain families. Also, there is no significant difference in the family diversity between the catches in the South and the North (see Fig 31).

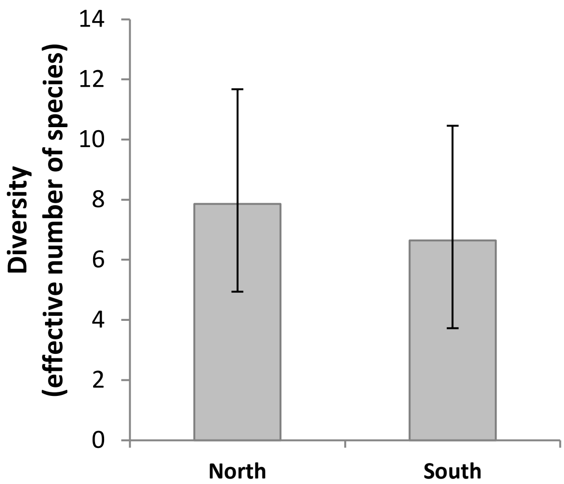



*Figure 30Mean (± s.d.) diversity at North and South. There is no significant difference in the diversity (P<0.05).*

The total number of fish counted for the North was 42 825, and 63 225 for the South. The mean number of fish per catch was 1586 for the North and 1806 for the South. The diversity and evenness in the north are higher than in the South. The highest representation of families in the entire sample catches were *Siganidae* (19 424), *Clupeidae* (15 841), *Scaridae* (12 976), *Apogonidae* (10 936), *Engraulidae* (8026), *Labridae* (7798), and *Gobiidae* (5142). When the South was looked at separate from the North, there was some variation in the dominating families (see Table 12). *Scaridae* and *Siganidae* were present in high numbers, in both.

*Table 12 The dominating families in the North and South of Bay of Ranobe, Madagascar.*

| North | | | | South | | | |
|---|---|---|---|---|---|---|---|
| *Siganidae* | **Rabbitfish** | **12626** | **32%** | ***Clupeidae*** | **Herring** | **14082** | **22%** |
| *Scaridae* | **Parrotfish** | **4585** | **11%** | ***Scaridae*** | **Parrotfish** | **8076** | **13%** |
| *Apogonidae* | **Cardinalfish** | **4141** | **10%** | ***Engraulidae*** | **Anchovy** | **7649** | **12%** |
| *Labridae* | **Wrasse** | **2166** | **5%** | ***Apogonidae*** | **Cardinalfish** | **6120** | **10%** |
| *Blenniidae* | **Blenny** | **1959** | **5%** | ***Siganidae*** | **Rabbitfish** | **5763** | **9%** |
| *Clupeidae* | **Herring** | **1705** | **4%** | ***Labridae*** | **Wrasse** | **5362** | **8%** |
| | **Total** | **42825** | **100%** | | **Total** | **63225** | **100%** |

# 8 Discussion

The beach-seine fishing technique has been used for thousands of years, but the nets in current fisheries contain plastic monofilament and mosquito netting making it one of the most destructive and non-selective fishing gears. The damage done is comparable to the destruction done by unselective bottom trawling- although in smaller scale; the result being severely damaged seafloor ecosystems (Marine Conservation Institute, 2014). In the BRB, the technique often employed by newly-established unskilled fishermen is beach-seining. The beach-seine fishery provides people not familiar with the sea an income opportunity that does not force them far from the shore. As gathered from the research and data provided in this report, beach-seines are one of the most common methods of fishing. Their use destroys vulnerable seagrass beds causing a positive feedback loop putting further pressure on the already overexploited fish stocks. Juvenile fish are not only caught but also have fewer habitats to safely reach maturity in, causing a knock-on effect by lowering the biodiversity of corals and their inhabitants which are already degraded and endangered by climate change and overfishing thus threatening the livelihoods of human coastal inhabitants. An understanding of the socioeconomic importance and the ecological impacts of beach-seining activities provides governmental and non-governmental organizations with the necessary information required to develop mitigation strategies to help the long-term stability of fish stocks in the BRB.

## 8.1 Socioeconomic

The challenging living conditions in the driest and poorest part of Madagascar were highlighted by the fact that the youngest beach-seine fisherman interviewed was just four years of age. The large range of age groups indicated that beach-seining has a strong influence on the livelihood possibilities for people living in the BRB. The question when beach-seine fishermen started the trade, as well as how often they practice it, confirmed that beach-seining is an essential part of everyday income for these people.

The beach-seine fishermen in the BRB area were mainly from the Sara (57%) tribe and with the other sub-tribes: Sarambe, Saratsifotihariva, Tejoria, and Tejoriakely, of Mahafaly, form up to 65% of the tribes present in the beach-seine fishery. Mahafaly

originates from the southeast coast highlands and traditionally keep cattle and earn livelihoods as gold and silversmiths as well as tattoo artistry, making beach-seining a new livelihood for them. Other cattle keepers are the Masikoro tribe (12%). The tribes Antandroy and Tanalana are farmers. Out of the 182 beach-seine fishermen responding to the questionnaire, a total of 80% were originally from non-fishing tribes that have moved into beach-seining, illustrating that the majority of beach-seine fishermen are people from non-fishing tribes who have migrated to the coastal areas because their traditional livelihoods were threatened (Kalaugher, 2013), e.g. due to farm land has being effected by long periods of dryness and locust outbreak. The traditions are changing in the coastal areas with beach-seining being passed on to the next generation instead of the old livelihood trades.

The questionnaire had overall good response rate. The field work revealed that the question on highest weekly beach-seine earning, receiving only six answers, was not a matter of interest to the beach-seine fishermen. In comparison to the question on maximum monetary value received for one beach-seine catch getting replies in all questionnaires, although having a very wide range, it seems there is no understanding or need for one week's worth of information, indicating the beach-seine fishermen's concentration on surviving one day at a time. Poor people have smaller, often more unreliable income sources and whenever there is a greater bulk of money received it is spent right away (Rutherford, 2010). There is a potential for high income for the beach-seine fishermen even though mainly they are getting quite small amounts of money. When they do receive the larger amount of cash they do not have the understanding to saving some of it. Another weighing point is the possibility of anyone knowledgeable of the money robbing it.

The supply chain of the beach-seine fishing industry in the BRB had little paper trace. Following the trail of the catch from the beach-seine fishermen to the end-user revealed couple more levels than what was anticipated in the beginning. The collectors, instead of being just one group, are divided into two layers; the one buying the catch from the beach-seine fishermen called sub-collector and then the one working for a factory and buying it from the sub-collector. The few larger fish from beach-seine catches have the same end-user as other traditional fisheries, people. The difference is with the main part of the catch, the small juvenile fish, which end up as pig and chicken food. The supply chain formed of beach-seine fishermen, sub-collectors, collectors and factories, paints a picture of a well-

functioning fishery with everyone involved needed for their input. The market survey showed that almost everyone involved was aware that beach-seining is illegal and also knew where the catches originate from- making any attempts to reduce and stop it even more difficult. The public opinion was for the government to do something about the illegalities. Since there is almost no enforcement available and corruption is high in Madagascar with a corruption index 28/100 (100 is very clean – 0 is highly corrupt) (Transparency International 2014), any changes without public support will take a long time.

The higher monetary value received by beach-seine fishermen in the North is due to the high number of sub-collectors that push the price up due to competition. The beach-seine catches are paid in lump sums making each fish the same value within the catches. The mean price for individual fish in the beach-seine catches was 9,07MGA. When compared with the mean price for the Trevally, the Emperor, the Rabbitfish, the Parrotfish, and the Wrasse from the secondary baseline data recorded, the difference was significant (see Table 8 in Chapter 7.1.3.). The data shows that the fish in the beach-seine catches, even though being commercially important, were not large enough in size to have a significant value (Blaber et al., 2000) making beach-seining less profitable in comparison to the other traditional fishing methods. There is a need to give this information to the coastal villages in the BRB but with the high poverty people struggle with the education alone is not going to change the destructive fishing traits.

## 8.2 Catch composition

A total of 110 092 fish and invertebrates, weighing approximately 275kg were counted during the field work period between 30 October 2013 and 20 February 2014 in 68 beach-seine samples. This high number of fish caught is a small portion of the total count of fish extracted from the BRB by beach-seines. The visual observations of other beach-seine fishermen in the area during  sample collection indicate towards a great number of juvenile fishes being caught daily. The high extraction rate of juvenile fish leads to growth overfishing, and with the unsustainable extraction of mature fish stocks by other traditional fishing methods in the BRB, can result in Malthusian overfishing (The Nature Conservancy, 2014) where fisheries are exploited to the point of decreased catch levels and fish sizes. This causes an increase in the usage of destructive fishing practises to maintain

the catch level to meet the growing demand resulting in competition and friction between coastal communities. The outcome is rapidly declining marine resources, and more intense fishing levels (Gough et al., 2009). A reoccurring theme in highly populated coastal regions is the high level of poverty amongst the fishermen (Jennings et al., 2001). High poverty brings malnutrition which causes higher mortality. People struggling to feed themselves and their families create pressure on the fish stock on all levels and the area will be facing collapsing fisheries if no changes take place.

The size of the net, over 20mm mesh size or the mosquito-net cod-end, did not have a significant effect on the composition of the catch when different variables were tested with Spearman's rank correlation coefficient. The increase in the net size did not increase the catch size indicating the level of juveniles taken representing the number that exists in the particular area of beach-seining. The Shannon-Wiener index showed the similarity of the catches when the south is compared with the North. Shannon's equitability was below one at both, the North and the South, of the BRB, indicating the catches are dominated by certain families. On the current project the dominating families are Siganidae, Scaridae, Clupeidae, and Apogonidae. The trophic level distribution emphasizes the domination of omnivores, herbivores and detritivores (71,04%). The larger volume of omnivores, herbivores and detritivores, was to be expected when the normal distribution of different levels of feeders was looked at (see Fig 29). It seems all of the trophic levels are present in the beach-seine catches and being affected by it.

The low evenness of diversity index for both the North and the South, as well as the similarities within the catches, emphasizes the linkage of the BRB coastal habitats to each other by the movement of water and biological material (Unsworth, 2007).

## 8.3 Future research

Multidimensional cooperation between different sectors such as science, law enforcement, politics, local people and NGOs is needed to find potential solutions for sustainable natural resource usage. Science enables management decisions to focus on relevant issues with evidence from research showing the current status of the problem.

The indication of current research of beach-seine fishing being common and wide spread within the BRB area should be looked into more closely. The volume of juvenile fishes

extracted during this short period of time and limited number of catch analyses give a strong sign towards growth-over fishing in the area. A research that takes a look into all fishing methods that extract juveniles in the BRB area could give evidence needed to support decision making processes in the thirteen villages in the coast of the BRB. Linked to this is also to find out what the mosquito nets are used for other than its original usage. Malaria is not common in all of the areas of Madagascar. This could give the NGO in charge of giving out the mosquito-nets a possibility to use the money for education and supporting materials to help inhabitants of the coastal areas understand the need to use sustainable fishing. This is not only to ensure the current fish availability but also the availability of this natural resource for future generations.

By-catch is an issue with beach-seine nets. The volume of unusable material discarded with every catch emphasises the destructiveness of this method. Researching the volume of by-catch of the catches will only give more support and understanding for the need to abandon this type of gear usage in the BRB. This not only is an ecological effect but also economical. The bottom line of any fishing should be gathering a catch that is mostly sellable goods whereas beach-seine catches seem to be mostly matter to be discarded alongside with thousands of juvenile fishes.

Juvenile fish habitats overlap with the beach-seine fishing areas. In the BRB these habitats are mainly the seagrass meadows that exist in the near shore marine environment. Seagrass as a vital part of juvenile fish habitat in the coastal region should be studied to see the level of health in the meadows in the BRB. As an excellent bio-indicator, the seagrasses will help to determine the state of coastal habitats, and with longer term follow up, the changes that are taking place. This would also help to pin point suitable Marine Protected Areas (MPA) for juvenile fish protection to enforce the already existing MPAs in the deeper water areas of the BRB lagoon system one of which is the first community-protected site in the area, the Massif des Roses (Belle et al., 2009).

## 8.4 Management and future prospects

It might seem that the simplest solution would be for the officials to enforce the law and make sure the beach-seine fishery is banned. However, the fact that Madagascar is currently one the most impoverished developing countries in the world, imposes challenges

that need to be overcome with bottom up, high local involvement, management strategies, and consideration of ecological and socioeconomic factors.

The catches were dominated by juveniles of economically important families, such as the Rabbitfish, Parrotfish, Emperor, and the Herring. Although there is limited data available in the literature regarding the BRB on the mortality rates of juvenile and adult fish, the sheer number of individuals caught suggest that further research is required to address size and species selection in the BRB beach-seines and especially to implement the mesh size restrictions already existing in the law with the cooperation of the coastal villages. The mesh size increase in the cod-end would lead to less juveniles being caught (Broadhurst et al., 2007).

In the BRB area, there is a continuing need for environmental conservation outreach and education. Concerning the current beach-seine fishery project, it could be beneficial for the members of the coastal villages to receive the results of fish extracted during this project and the families present, to show the high number of juveniles being extracted as well as the number of species that would be of high value when bigger. Another way to possibly make the outcome of this project and the destructiveness of beach-seining easier to understand for the local people could be to instigate a dialogue focused on the potential monetary value of mature individual fish in comparison to the loss of revenue caused by harvesting juvenile fish stocks. This can be shown with a poster given out to all of the 13 villages in the BRB (with the village elders' approval). In its implementations one should take into account that most of the people in the BRB area cannot read or write, and thus showing the monetary value as a pile of cash, not just numbers, would help to illustrate the message.

There has been proof in the BRB area that MPAs have positive impacts on the fish stock levels (ReefDoctor, personal communication, September 2013). This makes it logical to conclude that implementing no-take-zones in the near-shore areas in addition to the already established networks would most likely benefit the diversity of the coral reef systems in the area; after a closer study to establish the most important sites in the area for juvenile fish habitats. This would ensure maintenance of fish stocks as well as ecosystem processes and reduce the possible growth-over-fishing.

The open-access fisheries, where the right to catch fish is free to all, in the BRB create unregulated harvesting by fishermen that has led to overfishing. To provide proper regulations to implement, it is important to continue the current studies to provide a baseline with which governmental and non-governmental organisations can make their management decisions (Fuller et al., 2013). Currently, the coastal villages are scattered and act more as each other's competitors than as a common cohort finding the best solutions for the bay that they all rely on for their livelihood. The existing plan to create an umbrella organisation bringing together all the local small organisations of diverse fields from fishery organisations to mangrove protection associations working in the area through the cooperation and help of NGOs resident in the BRB will help to solve this issue.

For the BRB area, aquaculture could be a possible solution to build an alternative livelihood. The poor and rural coastal communities need access to funding for tools, resources, and education to be able to access the markets. NGOs are a good passway to bring aquaculture into rural communities. In cooperation with the private sector NGOs can train local people into farmers. In some aquaculture industries, the larger companies play an important role in introducing up-to-date technologies; they are often also willing to run training schemes for local farmers - as a socially responsible activity and to foster good relations (FAO, 2014b).

Currently, there are plans to start sea cucumber (a pilot study ongoing) and seaweed farming in the BRB area within the next three year time frame. Aquaculture could bring desperately needed tangible poverty alleviation through increased wealth. This, combined with education, would help to protect the seagrass beds and the biodiversity of the coral reefs through nearshore protected areas and no-take-zones. In theory, this could have a positive feedback effect on fish stocks, creating habitat corridors for juvenile fish species. This would need a strong foundation of local people working towards the same cause as well as following strict aquaculture guidelines. The danger, in a country with lack of enforcement, is that destructive farming practices would be used. Even though seeming like a great opportunity there is also a need to take into account possible environmental effects of the sea cucumber pens and be aware of the maximum capacity the coastal areas are able to carry without cumulating more negative than positive impact on the coastal habitats.

One considerable concern is the shifting of baselines for marine ecosystems; people visiting coastal environments see them as beautiful and are unaware of how they used to be (Olson, 2002). The perception of the surrounding environment (the baseline) differs with people who are older or have visited the area before than it does with the younger generations or people visiting the area for the first time. This will reoccur over and over with the passing of time and generations. This also includes other than visitors. The original population of the coastal areas, such as the Vezo have knowledge from the elders on how things were before but for the people moving into the area the shifting baseline starts on the moving day. The need to record data is especially critical for regions lacking sufficient studies in order to make management decisions that understand what once existed and work towards re-installing a best possible outcome for the current environment.

For long-term management plans regarding fisheries resilience, there is a need to research and record current situations to understand the degradation of relevant marine habitats through comparison to already existing data. When there is no baseline data available, making decisions based on people's perception of the area may not be accurate enough to reconstruct near-shore marine environments. Outreach and education, creating a communal goal, uniting coastal communities to work together to implement solutions conducive to healthy coastal habitats will benefit both human and marine communities in the long-run. Looking into alternative livelihood possibilities for overpopulated coastal areas could ease some of the pressure from the struggling marine environment and fish stocks. By involving local people from the beginning, there is a chance that the management solutions made will respect the local culture, beliefs and norms, and together create local rules to emphasize the need to protect nearshore environments not only for the people living in the coastal areas today, but also for the next generations to come. When community members are involved as local representatives participating in the decision-making process, it is more likely that the projects ensure the long-term rehabilitation and sustainability of coastal nearshore habitats and benefit the local people.

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# Appendix A: Beach-seine fisherman questionnaire

| Date : | Village: |
|---|---|

| Nb pêcheurs : | | | | | |
|---|---|---|---|---|---|
| Liens familiaux | | | | | |
| | 1 | 2 | 3 | 4 | 5 |
| Sex | | | | | |
| Age | | | | | |
| Tribu | | | | | |
| Vill. resid. | | | | | |
| Vill. naiss. | | | | | |
| Année demang. | | | | | |
| Nb.enfants | | | | | |
| Savez vous lire | | | | | |
| Niveau scolaire | | | | | |
| Fois/sem SP | | | | | |
| Age debut SP | | | | | |
| Extra travail | | | | | |
| Argent | | | | | |
| Savez-vous nager | | | | | |

| |
|---|
| Combien de personnes vivent avec vous? |
| Combien d'entre-elles gagnent de l'argent? |

| |
|---|
| Pourquoi faites vous du senne de plage ici? Proche de votre maison ☐ les conditions sont bonnes ☐ les prix de vente ☐ Accès facile à la route ☐ Autres raisons ☐ pourquoi? |
| Avez vous des problèmes avec d'autres pecheurs ou avec des personnes qui utilisent la plage? Oui ☐ Non ☐ Si oui, quels problemes? |
| Avez vous remarqué, ces dernières années, des changements dans vos captures de senne de plage ? Oui ☐ Non ☐ Si oui, quels changements? |
| Pensez vous que le senne de plage a des impacts environnementaux ? Oui ☐ Non ☐ |

| | |
|---|---|
| Quelle est la plus grosse somme d'argent que vous avez fait en une semaine ? | |
| Quelle est la plus grosse somme d'argent que vous avez fait avec un senne de plage? | |
| À qui vendez vous votre pêche? | Poisson: |
| Seiche: | Crevette: |

| **Forme du filet** | | | | Longueur total: | |
|---|---|---|---|---|---|
| Combien mesure la corde? | Gauche | | | Droite | |
| Combien de parties différentes? | | | | | |
| Longueur des parties | | | | | |
| Profondeur des parties | | | | | |
| Taille des mailles | | | | | |
| Materiaux de chaque partie | | | | | |
| Materiaux des flotteurs (liège, bouteilles plastiques...): | | | | | |
| Materiaux des lestes: | | | | | |
| Pochette de fond : Oui ☐ Non ☐ Si oui, quelle matière et taille des mailles? | | | | | |

Frequency:

| **TRACK** | GPS: | Poid total de capture: |
|---|---|---|
| Heure de commencement: | Heure de fin: | Prix total de vente: |

# Appendix B: Market survey questionnaire

| | | |
|---|---|---|
| Date | Village | Factory |
| Nom | Poste | |

| |
|---|
| Quels sont les produits que vous faites ici? |
| |
| |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Qu’est ce que vous faites avec  le produit apres le collecte? | | | | | | | | | | |
| Transformation | | Simple traitement | | Vente | | Exportation | | Autres | | |
| | | | | | | | | | | |

| |
|---|
| Ou es ce que vous exportez les produits? |
| |
| |

| |
|---|
| Connaissez-vous l'origine des poissons que vous achetez? Savez-vous si vous achetez des produits provenant des sennes de plage? |
| |
| |

| | |
|---|---|
| À qui achetez vous pêche? | |
| Poisson | |
| Crevette | |
| Seiche | |
| Calmar | |

| | | |
|---|---|---|
| Avez vous remarqué, ces dernières années, des changements quantitatifs ou qualitatifs sur les produits halieutiques que vous traitez ? | | |
| Oui | Non | Si oui, les quels? |
| | | |

| | | |
|---|---|---|
| Es ce que vous etes au courant des lois et des restrictions concernant la peche? | | |
| Oui | Non | Si oui, les quels? |
| | | |

| | | |
|---|---|---|
| Pensez vous que le senne de plage a des impacts environmentaux? | | |
| Oui | Non | Si oui, les quels? |

| |
|---|
| D'autres informations |
| |

# Appendix C: Timetable for fieldwork

**October 2013 - November 2013**

| *Dim* | *Lun* | *Mar* | *Mer* | *Jeu* | *Ven* | *Sam* |
|---|---|---|---|---|---|---|
| ***27*** | ***28*** | ***29*** | ***30*** | ***31*** | ***1*** | ***2*** |
| | | | *BRB South* | *BRB South* | | |
| ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** |
| | *BRB South* | *BRB South* | *BRB North* | *BRB South* | *BRB south I + II* | |
| ***10*** | ***11*** | ***12*** | ***13*** | ***14*** | ***15*** | ***16*** |
| | | | *BRB South* | *BRB South* | *BRB South* | *BRB South* |
| ***17*** | ***18*** | ***19*** | ***20*** | ***21*** | ***22*** | ***23*** |
| *BRB North* | *BRB North* | *BRB North* **I only jellyfish +II** | *BRB North* | *BRB North* | *BRB North* | |
| ***24*** | ***25*** | ***26*** | ***27*** | ***28*** | ***29*** | ***30*** |
| | | | | | | |

**December 2013**

| **Dim** | Lun | Mar | Mer | Jeu | Ven | Sam |
|---|---|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| | | | | *BRB South* | *BRB South* | |
| **8** | **9** | **10** | **11** | **12** | **13** | **14** |
| | *BRB South* | *BRB South* | *BRB South* | *BRB South* | | |
| **15** | **16** | **17** | **18** | **19** | **20** | **21** |
| NO CATCH - *BRB North* | *BRB North* | *BRB North* | *BRB North* | *BRB North* **I only jellyfish +II** | *BRB North* | *BRB North* |
| **22** | **23** | **24** | **25** | **26** | **27** | **28** |
| *BRB North* | *BRB North* | *BRB North* | | | | |
| **29** | **30** | **31** | | | | |
| *BRB south 2 sea urchins* | *BRB South* | *BRB South* | | | | |

**January 2014**

| **Dim** | Lun | Mar | Mer | Jeu | Ven | Sam |
|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** |
| | | | | *NO CATCH - BRB South* | *BRB South* | |
| **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| | *BRB South* | *BRB South* | *BRB South* | *BRB South* | *BRB South* | |
| **12** | **13** | **14** | **15** | **16** | **17** | **18** |
| | NO CATCH/ *BRB North* | *BRB North* | *BRB North* | *BRB North* | *BRB South* | *BRB North* |
| **19** | **20** | **21** | **22** | **23** | **24** | **25** |
| | NO CATCH/ *BRB North* | *BRB North* **(1 + night)** | *BRB North* | *BRB North* | | |
| **26** | **27** | **28** | **29** | **30** | **31** | |
| | | | NO CATCH/ *BRB North* | *BRB North* **I + II** | *BRB North* | |

| February 2014 | | | | | | |
|---|---|---|---|---|---|---|
| **Dim** | Lun | Mar | Mer | Jeu | Ven | Sam |
| | | | | | | **1** |
| | | | | | | ***BRB North*** |
| **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| *BRB North* | NO CATCH/ ***BRB North*** | NO CATCH/ ***BRB North*** | NO CATCH/ ***BRB North*** | NO CATCH/ ***BRB North*** | NO CATCH/ ***BRB North*** | |
| **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| | | *BRB South* | *BRB South* | *BRB South* | *BRB South* | *BRB South* |
| **16** | **17** | **18** | **19** | **20** | **21** | **22** |
| *NO CATCH - BRB South* | *BRB South* | *BRB South* | *BRB South* | *BRB South* | | |
| **23** | **24** | **25** | **26** | **27** | **28** | |
| | | | | | | **36 S + 32 N = 68** |