THE IMPACT OF SHARK LIVER OIL TRADE ON THE CONSERVATION AND MANAGEMENT OF THREATENED SHARK SPECIES IN ZANZIBAR, TANZANIA.

MASTERS OF SCIENCE IN AQUATIC ECOSYSTEMS MANAGEMENT

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AFRICA CENTER OF EXCELLENCE FOR WATER MANAGEMENT

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A thesis submitted to the African Centre of Excellence for Water Management (ACEWM) in partial fulfillment of the requirement for Master's Degree in Water Management (Aquatic Ecosystems Management) of Addis Ababa University.

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Supervisor: Prof. Abebe Getahun (PhD)

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DECLARATION.

I, **Frank Mirobo**, do declare that this research thesis, "***The impact of shark liver oil trade on the conservation and management of threatened shark species in Zanzibar, Tanzania***" is my own work except where due acknowledgement is made in the text and that it has never to the best of my knowledge been submitted for any prior academic award or qualification.

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CERTIFICATE OF APPROVAL

The undersigned, certify that this thesis is a result of the authors work, and that to the best of my knowledge it has not been submitted for any other academic qualification within Addis Ababa University or elsewhere. The thesis is acceptable in form and content, and that satisfactory knowledge of the field covered by thesis was demonstrated by the candidate through oral examination held on 11th June 2021 at African Center of Excellence for Water Management (ACEWM) Addis Ababa University, Ethiopia.

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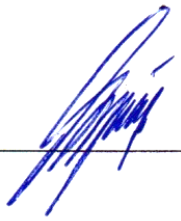
Prof. Abebe Getahun Signature  Date 27/07/2021

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DEDICATION.

This thesis is dedicated to my lovely mother, Mrs. Annie Sabath Mirobo for her spiritual and moral support throughout my entire life.

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I thank our almighty God for giving me an opportunity to undertake this study for my academic fulfillment. My deepest gratitude goes to my supervisors, Prof. Abebe Getahun and Dr. Saleh Yahya for their guidance and valuable contribution in writing this research thesis. Their commitment made the whole study successful.

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ABSTRACT.

For decades shark fishery in the world has been one of the economic activities to most fishing villages including those in Zanzibar, Tanzania. The trade of live sharks and shark products has been one of the international trades that pose a major threat in the existence of sharks worldwide. However, information on the impact of shark liver oil trade in the conservation and management of threatened shark species in Zanzibar, Tanzania is so far lacking.

This study aimed to determine the impact of the shark liver oil trade in the conservation and management of threatened shark species in Zanzibar, Tanzania. The study used focus group discussion, structured and unstructured questionnaires, key informant interviews, and shark oil sampling. Additionally, acidic value and viscosity of the shark liver oil and shark catch landings were also used as sources of data for this study.

The findings of this study reveal that species like Tiger shark, Sickletin lemon shark, Bull shark, Giant guitarfish, and Shortfin mako shark were the most prone species to shark liver oil trade. Additionally, shark oil of Giant guitarfish was the most preferred shark oil for wooden boat maintenance with viscosity of 10.3 $m^2 s^{-1}$ and 70.5 mg NaOH/g acid value however, less in quantity production of 60 liters of shark liver oil. Whilst, tiger shark with 360 liters of shark liver oil, was the shark specie with higher quantity of shark liver oil. However, elasmobranchs catch landings have increased up to 1.7 million tons per year in 2020 which implies the continued exploitation of elasmobranchs in the Island compared to other years after the banning of production and trading of shark products in Zanzibar. This has been accelerated due to verbal restriction of shark products, less enforcement of the rules, increase in the foreign fishing vessels and unaccountability on the part of government officers. However, banning of shark products trade has affected the livelihood of shark fishermen by 92%, hence low wages gain in the trade and fishermen struggles in providing for their family needs.

Overall, the continued trading of the shark liver oil affects the conservation and management of all IUCN listed threatened shark species in Zanzibar as majority of them are also overexploited for meat and fin trade in the region. Results of this study show that besides the shark fin and meat trade, shark liver oil also affect the shark conservation and is a contributing factor. Strong management and conservation strategic plan and use of shark oil alternatives are highly required to regulate the status of shark species prone to this kind of trade in Zanzibar, Tanzania.

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ABBREVIATIONS.

ANOVA: ____Analysis of Variance

FAO: _____Food and Agriculture of Organizations of the United Nations

IUCN: _____International Union for Conservation of Nature.

P.O.P: _____Phenolphthalein solution

SPSS: _____Statistical Package for Social Scientists.

WIO: _____Western Indian Ocean.

WHO: _____World Health Organization

WWF: _____World Wide Fund for Nature.

ZBS: _____Zanzibar Bureau of Standards.

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CHAPTER ONE: INTRODUCTION.

1.1 Background information.

Since 1997 shark and shark products have been one of the most utilized fisheries resources in many countries in the world (Anak, 1997). As a result of the expansion of trade of shark and shark products such as shark liver oil, cartilage and mostly shark fins, many different shark species were declared by IUCN as critically endangered (Anak, 1997; IUCN, 2011). Sharks, as one group of chondrichthyans, are extremely vulnerable to overexploitation as they are caught as both targeted species and incidental catches (Arai & Azri, 2019; Dulvy *et al*., 2014; Ferretti *et al*., 2010; Gallagher & Hammerschlag, 2011; Worm *et al*., 2013). To most countries, shark catch is still unmonitored or unregulated although there are restrictions in shark trade in some countries such as Zanzibar, Tanzania.

Shark trade includes live specimens, parts and products such as fins, meat, liver oil, skin, internal organs and other edible products such as eggs, cartilage, brain, ovaries, jaws, teeth and curio trade, fishmeal, fertilizer and fish oil and used as bait (Anak, 1997). For years, shark fin trade has been the most valuable trade and by far has been the largest proportion of the parts and products traded worldwide and has been the leading course in the overexploitation of the shark in the ocean (Schaeffer, 2004).

The findings from the report of FAO back in 1994 collected from the regions of Europe, India, East and Southern Africa, North and South America, South East Asia, East Asia and Oceania has been showing increase in the landings of chondrichthyans (Anak, 1997; Schaeffer, 2004). Approximately 182,000 tons of landings were for sharks, 197,000 tons for skates and rays, 5,000 tons account for chimaeras and 347,000 tons stands for other unidentified groups of chondrichthyans. The report pointed out that out of the number of the shark exploited, the extraction of the shark liver oil was reported to be 412 tons between 1984 and 1993 and other shark oil product was found to be 227 tons (Gallagher & Hammerschlag, 2011). However, the shark liver oil imported alone in South Korea annually was 327 tons. FAO reported that 15 countries were considered as the leading countries for this kind of trade meanwhile Hong Kong customs data of 1980-1995 detailed the import from 125 countries (Barnett, 1997).

However, less concern has been put towards the shark liver oil and its effects, as historically the shark liver oil (rich in vitamin A and squalene) and its constituents has been used for cosmetic

and pharmaceutical products but mostly as a lubricant in the process of tanning and curing of leather (Banjo, 1979; Anak, 1997). Different methods have been reported for the extraction of shark liver oil. In the Philippines it is through chopping of the shark liver and boiling with water, and as the oil rises the surface is skimmed off and, allowed to cool before the removal of the residues (Barnett, 1997).

The market for the shark liver trade historically can be traced in Japan being one of the most prominent producers but world's largest consumer of shark oil and squalene has been South Korea with 364 tons of shark liver oil recorded to be imported in 1994 alone (Barnett, 1997). The other main suppliers in records were Norway, Indonesia and the Philippines where in 1994 alone Indonesia has been reported to have supplied 93% of the total imported shark liver oil (Anak, 1997; Schaeffer, 2004); however, production and trade information is still very limited to most western Indian ocean countries including Zanzibar, Tanzania.

In the Western Indian Ocean, including Zanzibar, Tanzania, 27 species of shark species have been listed as threatened species in the IUCN red list (Richmond, 2017). Artisanal fisheries in Zanzibar have been involved in the production of dried/ salted shark meat, and the local people are well known for the usage of the shark liver oil in the maintenance of the traditional fishing vessels (Barnett, 1997; Schaeffer, 2004). Shark oil being inexpensive and nutritious, the trade has been reported to expand in late 1997 to most of the non-costal countries. The oil liver trade was between countries like Eritrea, Somalia, Kenya, Tanzania and Madagascar (Barnett, 1997). Although in 2010s shark fin trade was declared illegal in Zanzibar, Tanzania but still fishermen have been reported to catch different shark species for various purposes including liver oil extraction. This poses a question whether the banning of the shark fin trade was effective in minimizing overexploitation of the shark species in coastal area of Zanzibar. However, no studies so far have gathered the detailed data concerning the effects of the shark liver oil trade on the conservation and management of the threatened shark species in Zanzibar, Tanzania.

1.2 Statement of the problem.

Shark and shark products trade has been among the most important income generation to most coastal communities along the Western Indian Ocean for decades. The decline of the elasmobranch population in the ocean has ecological implications in the conservation, endangerment of organisms and social-economic concerns in the livelihood of the people in the coastal areas (Barrowclift *et al*., 2017). Despite the fact that, shark trade involves trading live specimens, parts and products such as fins, meat and liver oil, sharks have been one of the most remarkable marine organisms caught for a number of uses in the industry of shark fishery (Anak, 1997).

A bulk of data exists on the shark biology, genetics, diversity, ecology and shark trade. There are plenty of information on how shark can be used as good source of meat and fins soup for human consumption, how shark skin is used for leather purposes, how shark cartilage is a good source for medicinal uses, jaws and teeth for curios purposes and how shark liver oil can be used as lubricant, vitamin A and for cosmetic purposes (Carlson *et al*., 2007). But there is scanty information on how shark liver oil trade, shark skin, internal organs and other edible products such as eggs, cartilage, brain, ovaries, jaws, teeth and curios affect the conservation of threatened shark species in the western Indian ocean (Dent & Clarke, 2015), including Zanzibar, Tanzania. There is so much focus and pressure on the shark fin trade since it is more profitable and it is a leading trade in the exploitation of sharks in the world (Barrowclift *et al*., 2017).

A report by Traffic-East/ southeast of Atlantic Oceans in 1994, pointed the trade of shark and shark products in the western and southern ocean including Kenya, Tanzania mainland and Zanzibar, Mozambique, Eritrea, Somalia, Seychelles, South Africa and Madagascar. The study included an in-depth investigation on the fishing practices, the fin trade and the market of the other shark products in Zanzibar, Tanzania. Also, another report by Anak (1997) described the overall patterns in shark catches and shark trade in Zanzibar and concluded that the over exploitation of shark was due to the increase in pressure in the shark stock.

The study by Schaeffer (2004), which assessed the artisanal fishery and local shark fin trade on Unguja Island, Zanzibar concluded that before the effective management of overexploited shark species, there is an immediate need to understand the biology of the sharks as less was known about the species of sharks in Zanzibar. On the other hand, the recent study carried out by

Barrowclift *et al* (2017) on social, economic and trade characteristics of elasmobranchs fishery on Unguja Island, Zanzibar, also concluded that the elasmobranchs caught provide a source of income as well as subsistence to the merchants and fishermen involved in the elasmobranch fishery.

Studies have pointed out shark oil where shark squalene is extracted has been very vital and important for human uses especially for medicinal values (Drugs, 2020). The oil has been used to treat cancer, skin conditions and respiratory ailments, as well as to reduce recurrent aphthous stomatitis and prevent radiation sickness. Shark liver oil is well known for human uses especially in medical aspects. Currently it has been pointed out that the shark squalene found in the shark liver oil, is considered to be used in the manufacturing of the vaccines for the COVID 19 disease in which the oil have been proved to be useful in boosting immune system, heal wounds and fighting infections. This poses another major threat of increase in the extraction of the shark liver oil and half a million of shark species could be at risk of extinction (Campbell, 2020).

However, data are limited for shark liver oil being used for boat maintenance (Anak, 1997). Only what is less known is the use of shark liver oil to coat the hull of wooden boats as a preservative against fouling (Kuang, 2020; Oddenyo *et al*., 2018). Moreover, information is lacking on the quality of the shark liver oil suitable for this kind of activity, the species involved and what quantity of oil is being extracted in this part of Zanzibar. The variation of the composition of the shark liver oil differs among shark species, size of the shark, diet, sex, growth rates, swimming depth and reproduction (Drugs, 2020). However, there is no information regarding which species produce the best quality and quantity of oil among the shark species prone for shark liver oil trade.

Furthermore, when assessing the impact of shark liver oil trade on the conservation and management of threatened shark species in Zanzibar, Tanzania, is lacking and this creates knowledge gap regarding the effects brought by shark liver oil trade on the conservation and management of threatened shark species in Zanzibar, Tanzania. Therefore, this study seeks to examine the effects of shark liver oil trade on the conservation and management of threatened shark species in Zanzibar, Tanzania.

1.3. Research questions.

i. What are the shark species that are prone to shark liver oil trade in Zanzibar, Tanzania?
ii. Which shark species produce best quality and quantity of shark liver oil for fishing vessels maintenance, human uses and which are alternative to shark oil and its availability?
iii. How effective is banning of trading shark products in the conservation and management of threatened shark species in Zanzibar, Tanzania?

1.4 Objectives

1.4.1 General objective

To examine the impact of shark liver oil trade on the conservation and management of threatened shark species in Zanzibar, Tanzania, the recommendation of which would assist in the development of management plans for sustainability of the shark population in that part of the Indian Ocean.

1.4.2 Specific objectives.

i. To determine which of the threatened shark species are prone to shark liver oil trade.
ii. To determine which shark species produce best quality and quantity oil in respect to human uses and wooden boat maintenance.
iii. To examine the effectiveness of banning shark products trade in the conservation and management of threatened shark species in Zanzibar, Tanzania.

1.5 Social-economic significance of the study.

The findings from this study have help planners, policy makers, stakeholders, managers and conservation officers to design measures which can help the proper management and friendly conservation policies that will insure maximum protection, conservation and management of endangered shark species in Zanzibar, Tanzania. The findings of this study have also, provide the

baseline for the government to evaluate the effectiveness of their conservation and management effort of threatened shark species in Zanzibar, Tanzania and it provide different methods that can be adapted to ensure conservation of threatened shark species for future sustainability of marine biodiversity. In addition, the study have assisted the government in putting more effort on the conservation of threatened shark species that are prone to shark liver oil trade and provided alternatives to shark liver oil for fishermen when maintaining marine fishing vessels and in the conservation at large. The study also, helped the proper utilization of the shark species at the same time insuring the future survival of threatened shark species in Zanzibar, Tanzania.

1.6 Scope and limitation of the study.

The study was delimited to examining the impact of shark liver oil trade on the conservation and management of threatened shark species in Zanzibar, Tanzania. However, the research did not address the impact of the shark fin trade on the livelihood of the fishermen in Zanzibar, Tanzania. Future research works can make use of this finding to improve policies and management of threatened shark biodiversity in Zanzibar, Tanzania.

CHAPTER TWO: LITERATURE REVIEW.

2.1 Biology of sharks.

Sharks are group of fishes with possession of both cartilaginous skeleton and jaws, belonging to the group of vertebrate fishes known as Chondrichthyes (Walker, 2014). They represent one of the important group of top marine predators that play a great role in the energy transfer within the high trophic levels in the marine ecosystems as they range in sizes of 30cm to 12 m and they are recognized as one of the speediest swimmers in the ocean (Arai & Azri, 2019; Heist, 2004). Sharks are unique as they have unique characteristics distinguished from teleosts or any other group of bony fishes (Schaeffer, 2004).

Both sharks and rays make up a group known as Elasmobranchii which is known for its members to have sandy skin instead of scales, internal fertilization and skeleton made of cartilages instead of bone (Richmond, 1995). Some sharks and rays are recorded to be oviparous but majority are known to give birth to live young either by oviviparity or viviparity. Most shark species produce several young at once and they reach sexual maturity in 10 to 15 years (Gallagher & Hammerschlag, 2011; Hammerschlag *et al*., 2013). The slow reproductive rate of sharks and rays make them more prone to overfishing and the increase shark trade over the past 60 years has been the driving force towards threatening the extinction of some shark species (Richmond, 1995).

2.2 Distribution and abundance of sharks.

Sharks are distributed throughout all the 5 major ocean and seas found in the world, they can be found from the shallow water to the deepest water parts of the world oceans. Some species of sharks are migratory species that tend to move from one ocean to the other finding suitable areas for feeding and breeding, which makes them to be distributed worldwide (Shiffman, 2018). There are nearly 1,200 species of shark and shark-like fishes distributed in the world oceans but still the discovery of shark continues on daily basis (Bodiguel *et al*., 2017; WWF, 2019). Sharks

are said to be more than 500 species of different unique characteristics regardless of their difference in size but all sharks are said to have the same anatomy (Arai & Azri, 2019).

The Western Indian Ocean (WIO) has been one of the world 'hotspot' in terms of shark species discovery after Australia, in which about 290 species of shark are said to have been identified (Bodiguel *et al*., 2017). The discovery of new species of shark has increased in recent years; there were 157 species up to 2007, but in 2013 the number reached 199 species. The increase in discovery of new species of shark has not been seen compared to the years 1970-1999 (Bodiguel *et al*., 2017). However, the Western Indian Ocean (WIO) region being the center of attention, both sharks and rays are heavily overexploited and they are either critically endangered, endangered or vulnerable.

2.3 Shark fisheries and shark products trade.

For decades shark fishery in the world has been one of the economic activities to most fishing villages including Zanzibar, Tanzania. The trade of the shark products especially shark fin trade from Zanzibar to the east Asian countries can be traced back to the early 1919 with the exportation of 6.6 tons in 1923 alone (Anak, 1997). Back in 1960s the shark fin trade was controlled by most of the businessmen from East Asia and the trade in Zanzibar was monopolized by 3 and Tanzanian mainland was monopolized by 4 Asian businessmen. In 1980s there was a rising competition in the trade of the shark fins as most of the local fishermen were directly involved in the trade, which resulted in the rising of the price for the shark fins in the world market (Barnett, 1997; Schaeffer, 2004). The trade of the shark fins has been one of the international trades that pose a major threat in the existence of sharks worldwide. The higher demand of the shark fins soup in most Asian countries as a traditional delicacy, China and Hong Kong being the major trade markets, has estimated the importation of shark products being twice of what is known in the records (Schaeffer, 2004).

Increase in the demand for the shark soup for most privileged in the far east and other uses of the shark products pose a major threat to the conservation of threatened sharks in most countries. However, banning of shark fin trade in Zanzibar has not been effective in the region, as most of the fishing markets in Zanzibar (Malindi and Darajani) shark meat of some threatened shark species has been seen sold like any other fish species (Schaeffer, 2004).

As most countries and international organizations focus on declaring the shark fin trade as illegal trade, less pressure has been put in the other shark products like jaws, skin, eggs, cartilage, brain, ovaries, teeth and shark liver oil, as they are seen to not threatening the lives of this endangered shark species in the region (Dent & Clarke, 2015). Shark liver oil has been reported to be used by most local fishermen in the maintenance of the marine wooden vessels (Barnett, 1997). But shark liver oil, worldwide has been reported to be used for extraction of pharmaceutical food, paint, cosmetics, soap, printing ink, leather tanning, oilcloth, linoleum and in tempering of steel parts such as springs (Banjo, 1979).

The shark fishery for the African continent has not been extensively exploited compared to other continents. In the continents of Asia and Europe, there are a lot of work on shark fishery for fin and meat trade but still there are clams that still, there is scanty information on the trading data for shark oil trade, curio trade, jaws and teeth (Hin Keong, 1996). Shark meat has been considered as low value product of shark while in contrast the trade of shark fins has been one of the most expensive sea food in the world sold up to 500 €/kg for desirable species (Carlson *et al*., 2007; Schaeffer, 2004). Although, this specifies the importance of the elasmobranch catch and trade to fishermen and merchants being highly affected by external factors including seasons, weather constrains, fishing efforts, fishing gears, target species preferred by consumers as they affect the prices of trade (Barrowclift *et al*., 2017).

2.4 Status of the sharks in WIO region.

Up to 2010 it was estimated that more than 15% of shark species worldwide were listed as either critically endangered, endangered or most likely vulnerable species with one-third of all pelagic sharks faced high rate of extinction (Gallagher & Hammerschlag, 2011). The IUCN Red list of threatened species categorizes species that are under risk of extinction as shown in Fig. 1.

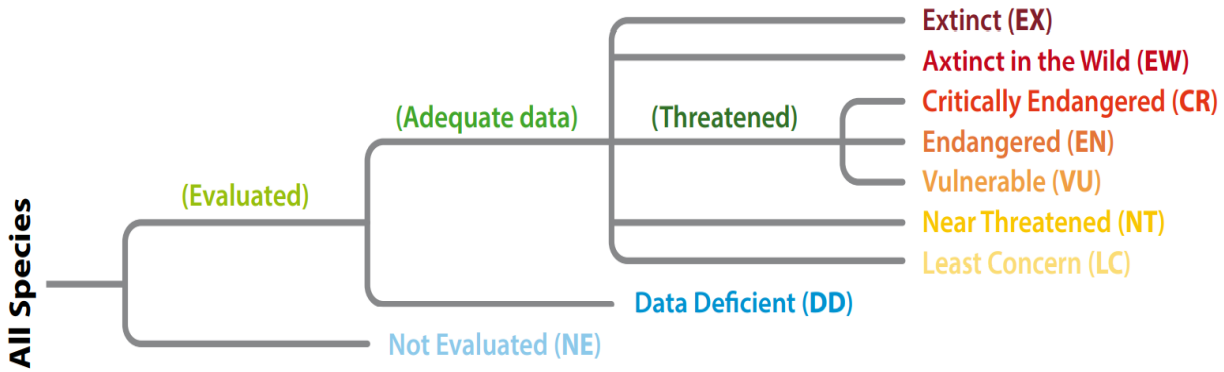

Figure 1: The IUCN Red List categories, used to identify the species in the WIO that are threatened (Source: (Richmond, 2017)).

Threatened species are those species that are either considered as critically endangered, endangered or vulnerable in their own environment. In the western Indian Ocean more than 161 species have been listed as threatened species over a short period (Richmond, 2017). This includes 126 species that are vulnerable, 27 species being endangered and 8 species are considered as critically endangered. There are a total of 27 species of sharks in the Western Indian Ocean which have been listed as threatened shark species, these include 22 species being vulnerable, 4 species that include Honeycomb izak (*Holohalaelurus favus*), African spotted catshark (*Holohaelues punctatus*), Scalloped hammerhead shark (*Sphyrna lewini*) and Great hammerhead shark (*Sphyrna makarran*) being endangered and 1 species Natal shyshark (*Haploblepharus kistnasamyi)* is critically endangered (Richmond, 2017). Other shark species that are vulnerable in the western Indian Ocean, include; Smooth hammerhead shark, Grey reef shark, Dusky shark, White shark, Sandbar shark, Whale shark, Spinner shark, Bull shark, Blacktip reef shark, Tiger shark, Great white shark, Bignose shark, Silky shark, Winghead shark, and Sharpnose seven gill shark (Ebert, 2014).

Zanzibar being one of the regions in the Western Indian Ocean, in the early 2010s it declared the official banning of shark or any shark products as illegal trade as one of the way to conserve these threatened shark species, but still many fishing villages and markets including Darajani and Malindi markets have been reported to fish and sell shark and some of the shark products (Schaeffer, 2004). The continuation of this kind of extraction of shark species pose a huge threats

to the lives of the declared threatened shark species in Zanzibar. Some of the main issues of shark being threatened is the increased overexploitation in the ocean, unregulated fisheries, increase in bycatch and increase shark fishing pressure due to the decline in the other fishing industries or the profit obtained from the shark trade (Clarke *et al*., 2006; Dulvy *et al*., 2014; Herndon *et al*., 2010; McClenachan *et al*., 2016; Musick *et al*., 2000).

However, no studies have been carried out to determine what side effects this kind of trade has on the conservation of threatened shark species in WIO region specifically in Zanzibar as the island has more than 30 species of sharks threatened to this kind of trade. Therefore, this study provided a brief yet in-depth investigation of the impacts of the shark liver oil trade in the conservation of threatened shark species and determine the species of sharks that are prone to this trade, the amount of oil they produce, alternatives to the sharks oil and improve the policies that govern the conservation of the threatened shark species in Zanzibar Island.

CHAPTER THREE: METHODOLOGY.

3.1 Study sites.

This study was conducted in the Zanzibar archipelago found in the coastal water of East African Indian Ocean, 35 miles off coastal of mainland Tanzania and 6 degree below the equator (Schaeffer, 2004). Zanzibar is part of the United Republic of Tanzania and is made up of many small islands but two large ones, Unguja and Pemba with tropical climate and the temperature ranging from 20-32°C (Barrowclift *et al.*, 2017). Specifically, the study was conducted in Ugunja Island and it covers 4 villages, Nungwi, Mkokotoni, Stone Town and Kizimkazi. These villages were selected as they are among the main shark landing sites in Unguja (Schaeffer, 2004).

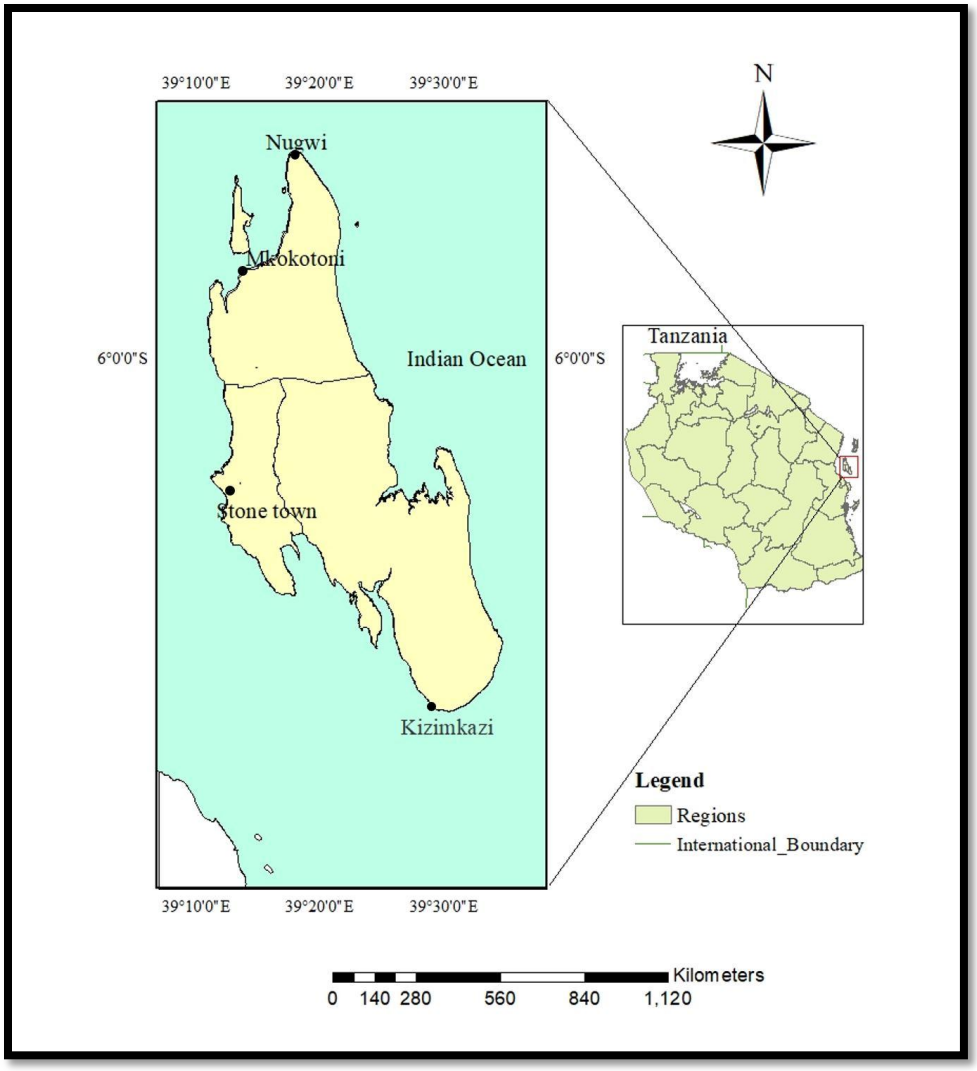

Figure 2: Part of Tanzania and a map of Unguja Island showing different study sites. (Google earth, 2021).

3.2 Sampling design.

The study was conducted in 4 villages, for 2 months (3rd February to 3rd April). A study design of both purposive and random sampling with a sample size n=156 which involves field survey, supported with both qualitative, quantitative, and experiment was used in this study. Primary data were collected through field survey, oil sampling (n=5), and supported with a random questionnaires (n=76) (Appendix 1), a purposive key informant interviews (n=5) (Appendix 2), a random interview (n=27) (Appendix 3, 4, 5, and 6) and a random focus group discussions (n=48) (Appendix 7). The verbal and signed consent was asked from the participants, on their willingness to participate and taken pictures in the study, and anonymity was guaranteed before

undertaking face to face interview. A mixture of these methods facilitated cross-checking and validate the collected information. A purposive sampling of the secondary data were collected from the Ministry of Fisheries Zanzibar, under the Department of Blue Economy and Fisheries. Other secondary data were acquired from literature reviews of published and unpublished reports, websites, and reputable Journals.

Prior to actual data collection, a reconnaissance survey was carried out in the 4 study sites, during which consultative meetings with village leaders, chairperson of village fishery committee, shark oil traders, processors, collectors, influential elders, beach recorders, and shark fishermen were introduced to the study. This aimed to get them familiar with the study and collect important preliminary information that helped to design and correct the actual survey. Drafted key informant interviews (n=5), focus group discussion (n=48) and shark fishermen questionnaire (n=76) checklist were tested for their validity and reliability. Testing of these instruments was conducted once in each village in which 5 randomly selected shark fishermen were interviewed to check whether the questions asked were correct and clear. Discussions for the checklists on topics under study were held with all the above mentioned stakeholders. Necessary modifications were made to improve their precision and reduce biases. The survey tools were then translated from English to Swahili for easy administration and data were collected.

Sampling for shark liver oil was conducted in the 3 villages including Nungwi, Mkokotoni, and Kizimkazi by using plastic tubes, in which duplicate samples of shark liver oil in each species were taken to Zanzibar Bureau of Standards laboratories (ZBS) for viscosity and acid test. The CODEX standard for fish oil, (FAO/WHO, 2017) was used, as a checklist to verify the standards of shark liver oil. The actual surveys and the sampling were carried out as defined in the following section.

3.3 Data collection methods.

Data were collected and analyzed according to the specific objectives of this study.

3.3.1 Shark species prone to shark liver oil trade.

Field observation (Plate 1), in line with qualitative data using a structured and unstructured questionnaire (n=76), which cover approximately 30% of the population of shark fishermen (according to the size of the shark fishermen population), were used to collect data. As defined

by Shoesmith (2020), selected shark fishermen were involved in the 4 villages (Nungwi, Mkokotoni Stown town and Kizimkazi) to determine which species they usually prefer for the shark oil trade and which one they explore over the other.

Plate 1: Shark fishing practices and wooden-boat repair by using the fiber nets method. (Photo credit: Ustazi Pandu, 2021).

Field survey which were in line with focus group discussion, where site observation of shark fishing boats, nets, including visiting boat repair areas and observe the whole process of wooden boat fiberglass net maintenance (Plate 1) were also carried out. This was to facilitate understanding of the real situation under the study and to cross-check for information collected from other sources of information. Focus group discussion (n=48) that covers approximately 5 to 8 shark fishermen as according to Dilshad & Latif (2013) was used to collect information, using onboard guide for identification of pelagic shark and rays in the Western Indian Ocean (Ebert, 2014). A checklist (Appendix 7) was used to guide the focus group discussion which explored

information on the socio-economic determination of shark species that are prone to shark liver oil trade in Zanzibar, Tanzania, and in each village, 2 focus groups were formed (Plate 1).

Plate 2: Focus Group Discussion with shark fishermen. (Photo credit: Haji Nawawi, 2021).

3.3.2 Shark species, best in quality and quantity of oil production.

3.3.2.1 Determining the quality of the shark oil.

Shark liver oil of shortfin mako shark, tiger shark, giant guitarfish, sicklefin lemon shark, and bull shark was collected from the study sites. The specimens were dissected to obtain shark liver and measured for length and weight to determine any significant relationship in the amount of oil production from each species (Plate 5). The shark liver was placed on a plastic polythene sheet, chopped into small size and put in a 20 liters plastic jug, and stored in the house at room

temperature, for 3 weeks to undergo chemical decomposition (Plate 3) (according to the fishermen traditional way of making shark liver oil).

After 3 weeks, the sample of fermented shark liver oil was taken by using 150 ml plastic tubes from each species and immediately taken to Zanzibar Bureau of Standards (ZBS) laboratories for acid and viscosity (Appendix 12). The analysis was done using Brookfield Viscometer (Brookfield Engineering Laboratories Inc., 2017) for viscosity. The acid value determination method was effective in identifying the acid content of individual liquid, following CODEX standard for fish oil, (FAO/WHO, 2017), for human consumption as shown in Plate 4. The process of wooden boat maintenance involves the use of the fermented shark liver for its viscosity while the shark liver oil for consumption purposes involves the process of boiling the liver oil with the meat of the shark famously known as "ujea"(according to fishermen traditional way of uses).

Plate 3: The dissection of the shark, filling half of the 20 liters gas jug and taking a sample of the fermented shark oil.

The determination of the acid value of shark liver oil was performed following the procedure by international standards, (ISO 660, 2009) (Appendix 15). The 2.5 grams of shark liver oil was weighed and added to a 500 ml size of a conical flask (Plate 3). By using a measuring cylinder, a 50 ml volume of methanol (specially dried) of 95-99% was added to the shark liver oil sample in a conical flask, followed by the addition of 3 drops of phenolphthalein solution (P.O.P.) and heated in a 370-380 heat for 1-2 minutes (Plate 3). Then, the solution was titrated against 0.1concentration of sodium hydroxide solution (NaOH) until the color changes into pale pink or pink (Plate 3). The volume of NaOH was then recorded and used in a relation shown below to determine the acid value of the solution. The same procedure was carried out twice for each sample of the shark liver oil.

Acid Value $=\frac{56.1\ x\ Vx\ N}{W}$

Where,

V= Volume in ml of standard sodium hydroxide.

N= Normality of sodium hydroxide solution

W= Weight in gm of the sample oil.

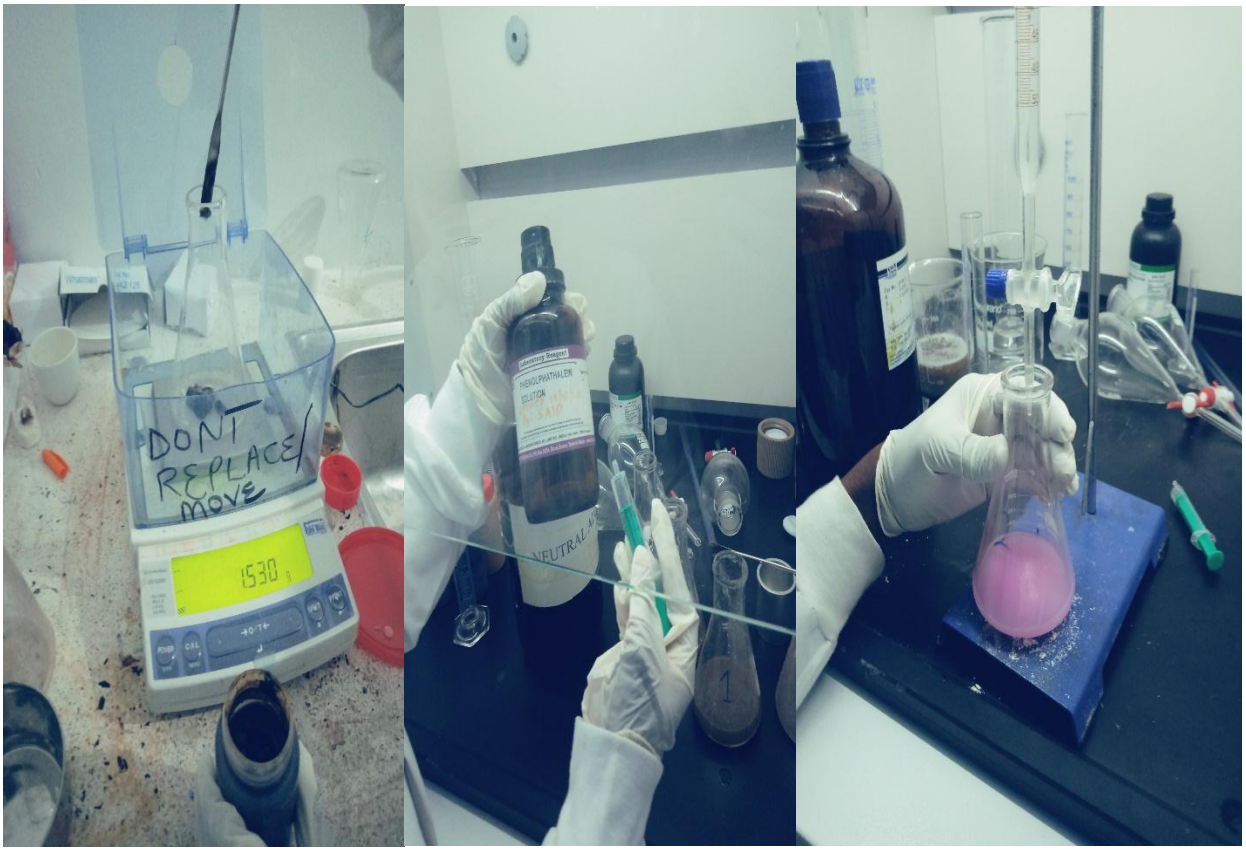

Plate 4: Determination of the acid value of the shark liver oil. (Photo credit: Suleiman Ally, 2021).

On the other hand, determination of the viscosity quality of the shark liver oil was performed following the method suggested by Paper (2016). This involves measuring kinematic viscosity

by the use of gravimetric capillary in which, the Cannon fenske direct (number 78808 and 83421 used in the conversion, see Appendix 8) were involved in the experiment. A syringe of 6 mills with shark liver oil sample, was used to take the sample from a container and poured in the cannon fenske glass tube (Plate 4). The KV-6 viscometer bath was then filled with distilled water and the direct flow capillaries (cannon fenske glass tube) were introduced in the KV-6 viscometer bath, heated at 100 degrees of centigrade for 30 minutes (Plate 4). Then the oil was suctioned into the tube until it reaches the start stage, where two marks are visible on the tube. Then the oil sample was released to flow through the operated capillary portion of the tube by gravity measuring the time of the meniscus to pass the start point to the final mark by a stop watch. The more viscous oil is, the longer it takes for it to flow through a capillary under gravitational force (Plate 4). The process was repeated twice to confirm the time taken and then recorded. The kinematic viscosity was then calculated by multiplying efflux time by the viscometer constant of respective cannon fenske tubes used as shown in Appendix 8. The capillary viscometer measurements depend on the relationship between time and viscosity.

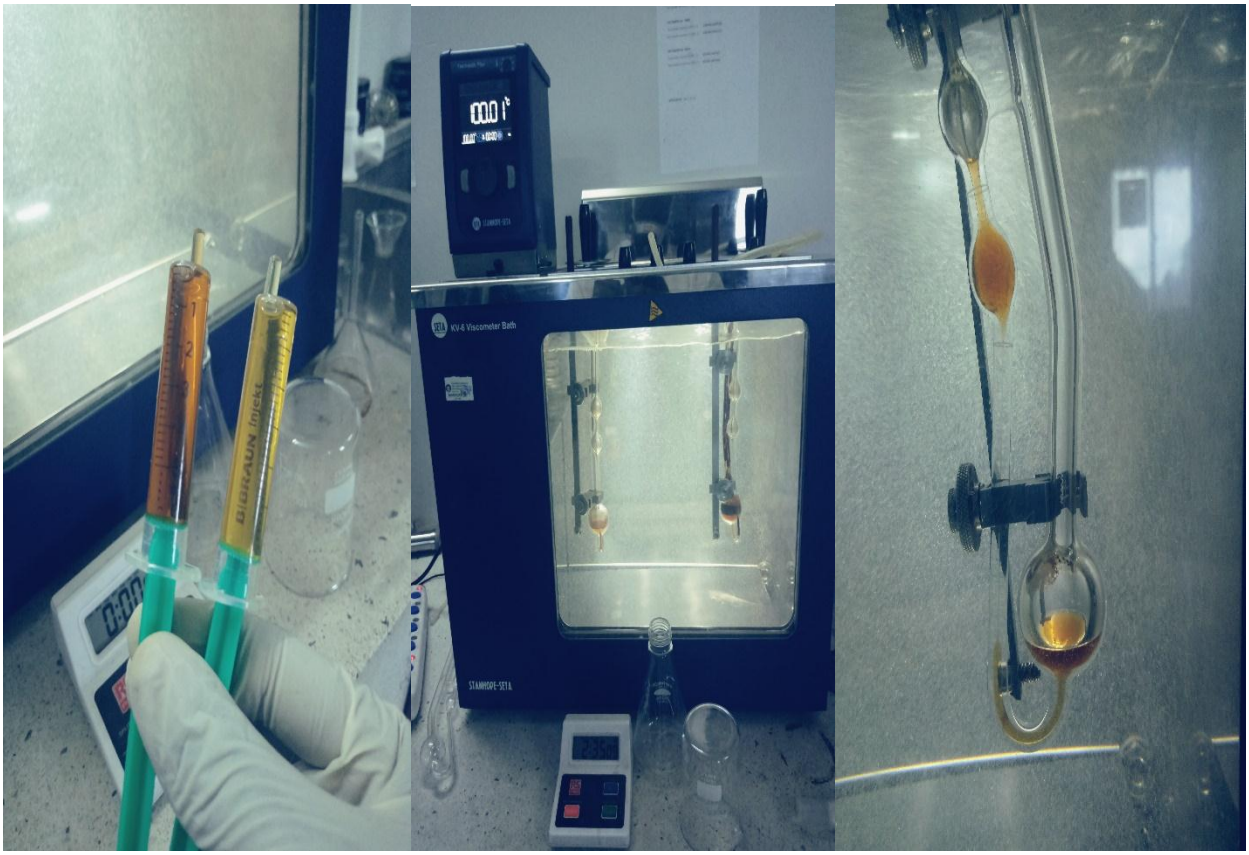

Plate 5: Insertion of the shark oil, KV-6 viscometer bath and Cannon fenske glass tube immersed in a viscometer.

3.3.2.2. To determine the quantity of the oil production.

The field sampling (n=5), parallel with focus group discussion (n=48), and questionnaire (n=76), were also used to determine what amount of shark liver oil is produced in respect to each species in liters. Each fisherman (n=124) , in Zanzibar town village (Stone town) was asked what amount of oil is being produced in respect to species they usually come to harvest for oil making as attached in Appendix 1, and 7. This interview regarded individuals who are willing to talk, accessible, and who have in-depth knowledge on shark liver oil trade, alternatives to shark oil, and their availability (Plate 7). Also, the length-weight relationship was measured (Plate 6), for the liver sample to determine any significant relationships to the quantity of oil produced by each species in relation to the size of the shark. The process involved taking the length of the shark liver by 100 meters tape measure and the weight by weighing balance. The measurements were then recorded and analyzed with respect to species as shown in Plate 6.

Plate 6: Measurement of the shark liver length and weight to determine the significance of the weight: length ratio to the quantity of oil production.

3.3.3 Effectiveness of banning shark products trade, in management of threatened shark.

The quantitative data for shark catch landings statistics for 10 years, 5 years before the banning of the shark products trade and 5 years after banning of the trade, was obtained from the Ministry of Livestock and Fisheries in Zanzibar under the Department of Blue Economy and Fisheries, Zanzibar. Key informant interview with government officers (Plate 7) was carried out and data were recorded for analysis and discussion.

Plate 7: Key informant interview with government officers and interactive interview with shark oil collectors. (Photo credit: Juma Seif, 2021).

3.4 Data analysis methods.

The data from field observation (n=5) and focus group discussion (n=48), which were qualitative in nature, all key issues were recorded in Microsoft excel, summarized, and presented in the tabular, diagrammatic, and chart forms for easy analysis and were discussed and compared during the discussion to draw argumentative conclusions. The data collected through the questionnaire (n=76) were examined, variable coded and then imported to SPSS version 22.0. This efficiently and accurately help in the process of further analysis of data collected through the questionnaire in which graphs and tables were used to represent the findings. The data from the acid value, length weight relationship and viscosity analysis by viscometer, were analyzed and compared by using ANOVA (Analysis of Variances) and Microsoft excel between shark species and were presented by tabular and graphs for further discussions in respect to human consumption and vessels maintenance. Data collected via shark catch landing statistics and key informant interview (n=5), and interview (n=27) was quantitative and qualitative in nature hence, all key issues were inserted in Microsoft excel for catch statistics, recorded, summarized, and presented in the tabular and diagrammatic forms for easy interpretation and more discussed and compared during the discussion to draw argumentative conclusions on how effective the banning of the trade has been effective for policies and enforcement of rules governing the conservation of the endangered shark species in Zanzibar.

CHAPTER FOUR: RESULTS AND DISCUSSION.

4.1 Species prone to shark liver oil trade in Zanzibar, Tanzania.

Most common species found in Zanzibar water have been known to be involved in the shark liver oil trade, preferably large-sized shark species (according to fishermen). The fishermen (n=124) involved in the shark oil trade prefer shark species that have large stomachs in particular, since the larger the stomach the bigger the size of the shark liver. During the period of the study, the field observation in parallel with the support of the fishermen discussion (n=48), were used to determine the most commonly beach recorders caught landings of shark species (Table 1); caught either for meat or shark oil trade in the landing sites as they were all big in terms of size (Plate 2) and have large liver oil (Plate 6). These findings were in agreement with Schaeffer (2004) who documented the relative landings of shark species in the major market in Unguja island in Zanzibar were large in size.

Table 1: Most commonly beach recorder catch counts of shark species for shark meat and oil trade in Zanzibar, Tanzania between 2020 to March 2021.

Common Name	Local Name	Scientific name	Count
Tiger shark	Papa Madebe/Mandori	*Galeocerdo cuvier*	37
Giant guitarfish	Papa Joza//Charawanzi/Barobaro	*Rhincobatus djiddensis*	33
Scalloped hammerhead	Papa Pingusi / milime/ mapembe	*Sphyrna lewini*	31
Shortfin mako shark	Papa Mambwe	*Isurus oxyrinchus*	28
Bull shark	Papa Ngozi mweusi	*Carcharhinus leucas*	22
Sicklefin lemon shark	Papa Ngozi mweupe	*Negaprion acutidens*	18
Dusky shark	Papa Kitumbo	*Carcharhinus obscuris*	12
Black tip tope or lesser soup fin	Papa Upanga	*Hypogaleus zanzibariensis*	10
Spadenose shark	Papa Sumbwi	*Scoliodon laticauldus*	9
Nurse shark	Papa Komba	*Ginglymostomatidus sp.*	5
Angel shark	Papa Jiwe	*Rhina anacylostoma*	3
Snaggletooth	Papa Meno	*Carcharhinus ellioti*	2
Hardnose shark	Papa Mwamba	*Carcharhinus macloti*	2

During the period of this study, 27 specimens of shark were obtained from the landing sites, which belong to 5 different species (Table 2). The findings of this study reveal that 5 most prone shark species used for the shark liver oil trade are the Tiger shark (*Galeocerdo cuvier*), Sickletin lemon shark (*Negaprion acutidens*), Bull shark (*Carcharhinus leucas*), Giant guitarfish (*Rhincobatus djiddensis*), and Shortfin mako shark (*Isurus oxyrinchus*) (Table 2). According to the fishermen (n=124) these species are most preferred as they are widely distributed along the coastal water of Zanzibar, they are large in size hence with large shark liver oil, they produce a large amount of the oil, and their oil "SIFA" (local way of pronouncing "Shark liver oil" according to fishermen) is most preferred in wooden boat maintenance in Zanzibar.

These 5 species are fished by using longline (72%) and shark nets (19%) (Table 3) as major fishing gears and fishermen either use dhow or fiber boat to catch these shark species (Plate 2). Similar to the findings of Barrowclift *et al* (2017) longlines are the most preferred fishing gear for elasmobranch fishing in Zanzibar. Others gears such as handline, bottom set gillnet and drift gillnet are used as auxiliary fishing gears although they do not directly target elasmobranchs. Most of these species have been seen to be widely distributed to the southern part of Ugunja Island (Kizimkazi) than the other side of the island, although all five species can be found on all sides of the island. This finding is in contrary to the argument made by Schaeffer (2004) who reported the northern side of Unguja island (Nungwi) as the leading village in the shark landing in Zanzibar Island. This implies that there has been decline in shark landings in the northern side of Zanzibar.

Table 2: Shark species that are prone to shark liver oil trade in Unguja Island Zanzibar, Tanzania.

	Tiger shark	**Giant guitarfish**	**Shortfin mako shark**	**Bull shark**	**Sicklefin lemon shark**
No of Specimen	20	1	1	3	2
No. of Counts	37	33	28	22	18
Gear used	Shark net & Longline	Shark net & Longline	Shark net & Longline	Shark net & Longline	Shark net & Longline
Vessels used	Dhow/ Fiber	Dhow	Dhow	Dhow/ Fiber	Dhow/ fiber
Availability	Good	Bad	Average	Average	Average
Villages In	Kizimkazi	Kizimkazi/	Nungwi/	Kizimkazi	Kizimkazi

counted		Mkokotoni	Mkokotoni		

Table 3: Major fishing gears used in shark fisheries in Zanzibar, Tanzania.

		Frequency	Percent	Cumulative Percent
Valid	Longline	55	72.4	72.4
	Handline	5	6.6	78.9
	Shark nets	15	19.7	98.7
	Missing	1	1.3	100.0
	Total	76	100.0	

4.1.2 Catch condition of 5 shark species prone to shark liver oil trade in Zanzibar.

According to the number of landings from different sites, and fishermen self-observation (n=124), the catch condition of the 5 most prone shark species for shark liver oil trade is 51.3% average catch (Figure 3). This is followed by the 30.3% being bad catch condition to most of this species as their availability as time goes on, keeps on decreasing. However, the availability of species such as Giant guitarfish has become very rare in recent days, unlike the previous years where sawfish was pointed out as a very rare shark species to be seen. It may take 2 to 8 months to catch Giant guitarfish as they are believed to be seasonal (fishermen opinion). This is contrary to Schaeffer (2004) who reported that Giant guitar fish (Barobaro) were the species of high record but exhibit limited distribution. Perhaps, the decline in the abundance of Giant guitarfish is also accelerated by being one of the species with higher demand of its fins in the fin trade markets as reported by Schaeffer (2004). The overall field observation shows that during the period of the study only one specimen of Giant guitar fish was collected from all the study sites. This implies that immediate research, management and conservation strategies are highly required in determining the status, distribution, abundance and conservation of this shark species in Zanzibar.

It is believed that the decline in catch has been accelerated by the increased invasion of foreign fishing vessels along the coastal water of Zanzibar, fishing pressure, increased demand to some shark species, poor fishing methods, climate change in the island, and challenges of getting

suitable baits (according to fishermen opinion). These findings are in parallel with the argument of Schaeffer (2004) and Barrowclift *et al* (2017) who documented higher decrease in the shark landings in the village of Kizimkazi, Mkokotoni and Stone Town in Ugunja Island and accounted it to similar reasons mentioned above.

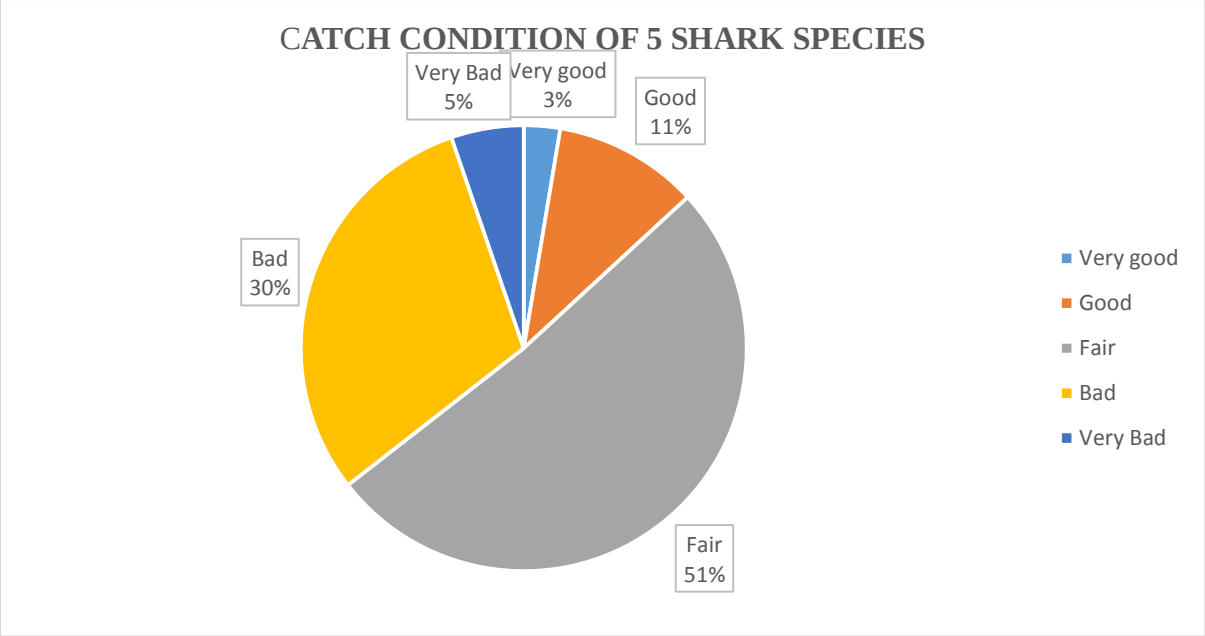

Figure 3: Catch condition of 5 shark species prone to shark liver oil trade in Zanzibar.

Most of shark species (Table 2) are sold by auction 57.9% and 39.5% in the normal market (Table 4). This is because most of the larger sized sharks are taken to the bigger markets in Stone Town (Malindi and Darajani) to be sold for a higher price in comparison to the markets in the villages. While the smaller sized shark species are mostly sold within the village markets to be used for food. This observation conform with Barrowclift *et al* (2017), who reported that the market of the shark in Ugunja Island is based on auction of the whole shark or parts of the shark in the market. This is also similar to most of the Western Indian Ocean countries as it conform with Oddenyo *et al* (2018) to the side of Kenya and Dent & Clarke (2015) to the global market for the shark products to the side of Taiwan a Chinese province and Hong Kong which are world markets for shark products. From observations made, fishermen (n=124) often encounter 1 to 3 sharks landing in a weekly basis or sometimes none during the whole week as compared to previous times when many landings were observed daily. This seems to be in contradiction with

the observation made by Schaeffer (2004) who reported the increase in landings in most villages in the Ugunja Island, in Zanzibar.

Despite documentation by Jiddawi & Shehe (1997), Jiddawi & Öhman (2002), Schaeffer (2004) and Barrowclift *et al* (2017) still there is insufficient reporting of shark data to some villages in Zanzibar, Tanzania. The only data collected are from those villages where shark has been seen to be dominant landing spots in the islands. Hence, data collection and recording in every fishing village is very vital so as to determine the statistical overall catch of elasmobranch (Shark) in Zanzibar, Tanzania.

Table 4: Method of sales of the shark obtained for meat and shark liver oil trade.

		Frequency	Percent	Cumulative Percent
Valid	By Auction	44	57.9	57.9
	In Market	30	39.5	97.4
	To Hotels	1	1.3	98.7
	Missing value	1	1.3	100.0
	Total	76	100.0	

4.2 Shark species, best in quality and quantity of oil production.

4.2.1 The quality of the shark oil.

This study reveals that only sample D of tiger shark and sample E of sicklefin lemon shark ranged between the required ranges, where sample D had the acid value of 6.24 mg NaOH/g and sample E had 5.67 mg NaOH/g (Table 5). According to Food Safety and Standard Authority of India (2016) standards of testing the quality of the fish oil, if 2.5 grams of the sample oil were used the expected acid value should range from 4 to 15. This implies that only the shark oil of tiger shark and sicklefin lemon shark were having the required acid quality standards of fish oil to be used by humans, not the remaining species (Table 5).

The findings of this study reveals that very minority of the villages tend to use the shark oil for consumption purposes. They usually use the oil in cooking the meat obtained from the shark itself famously known as "ujea". For most of those who eat this kind of food, it increases the taste of the shark meat unlike when the shark meat is cooked with a different oil. Although, the finding of this study was based on the determination of acid value of the shark oil only and left out other values like peroxides, it is very important for future research to be able to use other values or both of the values in determining the quality of the shark oil in respect to consumption purposes.

Table 5: Acid value of shark liver oil of 5 shark species prone to liver oil trade.

Samples	Mass (g)	Average Mass(g)	Vol. NAOH (*i*)ml	Vol. NAOH (f)ml	Vol. NAOH ml used	Ave. NAOH	Acid value mg NaOH/g
SampleA1	2.505	2.507	0	15	15	14.5	**32.45**
SampleA2	2.509		15	29	14		
SampleB1	2.531	2.5225	29	43.9	14.9	31.7	**70.5**
SampleB2	2.514		0	48.5	48.5		
SampleC1	2.53	2.522	0	14.5	14.5	14.65	**32.58**
SampleC2	2.514		14.5	29.3	14.8		
SampleD1	2.516	2.5155	0	2.5	2.5	2.75	**6.24**
SampleD2	2.515		2.5	5.5	3		
SampleE1	2.508	2.521	5.5	8	2.5	2.55	**5.67**
SampleE2	2.534		8	10.6	2.6		

KEY:

Sample A 1&2 = Shortfin mako shark

Sample B 1&2 = Giant guitar fish

Sample C 1&2 = Bull shark

Sample D 1&2 = Tiger shark

Sample E 1 &2 = Sicklefin lemon shark

The viscosity measurement among shark species differs from one another. The more viscose the oil is the more preferred in the wooden boat maintenance (Table 6). This study reveals that giant guitar fish is one of the shark species that is highly prone to shark liver oil trade (Table 2) in

wooden boat maintenance. The viscosity of oil of this species is also found to be higher (10.3 $mm^2/s/s$) than the rest of the shark species (Table 6). This may be why this species was more prone to shark liver trade than the rest of the species. However, the giant guitar fish tend to produce very low quantity of the shark liver oil (60 liters or less per individual) in comparison to the other species (Figure 4). Most of the fishermen sell the oil of the giant guitar fish with the same price as other species that produce higher quantity of the oil, which is approximately 30,000 to 40,000 Tanzania shillings, which is approximately to 13$ to17$ (Table 9) per 20 liters of a plastic jug.

Table 6: Viscosity value of shark liver oil of 5 shark species prone to liver oil trade.

Samples	Time (*i*) sec	Time (*ii*) sec	Ave. Time	Degree of heat	Tube used	Bath Constant	Viscosity $m^2 s^{-1}$
Sample A1	27	29	28	100	83421	0.01587	**0.44436**
Sample B1	1324.2	1396.8	1360.5	100	78808	0.007565	**10.29218**
Sample C1	376.2	376.8	376.5	100	83421	0.01587	**5.975055**
Sample D1	1021.8	972.6	997.2	100	78808	0.007565	**7.543818**
Sample E1	446.4	454.8	450.6	100	83421	0.01587	**7.151022**

4.2.2 The quantity of the oil production.

Most of the shark species involved in the shark liver oil trade are known for having large liver. The findings of this study indicate that tiger shark species produce high quantity of shark oil of about 360 liters (Figure 4). Other shark species are scalloped hammerhead shark with 260 liters, and Nurse Shark with 240 liters.

The quantity of the shark liver oil depends on the growth rate of the shark species, the weight of the liver and the size of the shark liver. This study showed that there is a significant positive

relationship between the length (cm) of the shark liver and weight of the shark liver (Kg) in the production of the shark liver oil (L). It means that there were significant positive relationship between the length of the shark liver and the quantity of the oil produced, $r(5) = 0.089$, $P<0.005$ (see Appendix 10). Also, there is a significant positive relationship between the weight of the shark liver and the quantity of the oil produced, $r(5) = 0.96$, $P<0.0003$ (see Appendix 10). This implies that the more grown shark species are, the larger the liver hence higher quantity of shark liver oil (Table 7).

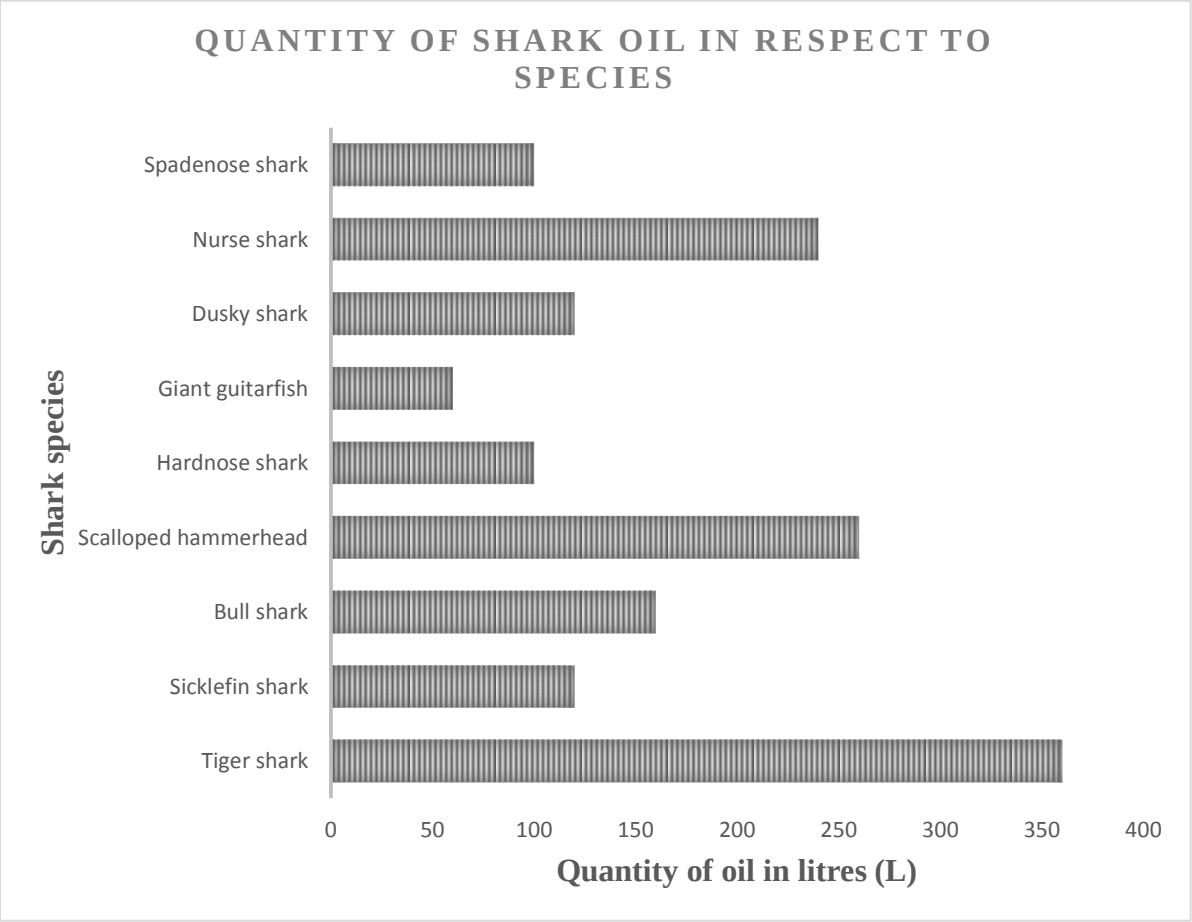

Figure 4: Quantity of shark oil in respect to shark species.

Table 7: Length-weight relationship in production of the shark liver oil.

Species	Length (Cm)	Weigh (Kg)	Oil produced (L)
Sicklefin lemon shark	128	32	50
Tiger shark	147	42	63

Tiger shark	157	51	80
Tiger shark	168	53	100
Shortfin mako shark	164	42	60
Bull shark	85	24	40
Giant guitar fish	65	5	10

4.2.2.1 The market of the shark oil in Zanzibar, Tanzania.

Most of the shark liver oil markets are found within the village for about 72.4% and outside of the village for about 27.6% (Figure 5). The study shows that the markets found within the village, involve those villages with higher number of wooden boats than fiber boats, which were Nungwi and Mkokotoni villages. Meanwhile, the market outside of the village was from Kizimkazi village, which has higher number of the fiber boats due to the existing dolphin tourism activities in the village than the wooden boat. Other market outside the villages are said to be found in Pemba Island, Mafia Island and Bagamoyo, the part of mainland Tanzania (Appendix 11). Most of the buyers of the oil are the fishermen themselves (71.1%), followed by wooden boat makers (18.4 %) where the number of buyers of shark liver oil varies from 1 individual to 3 people by 86.8% of buyer of the shark liver oil per every seller of the oil (Table 8).

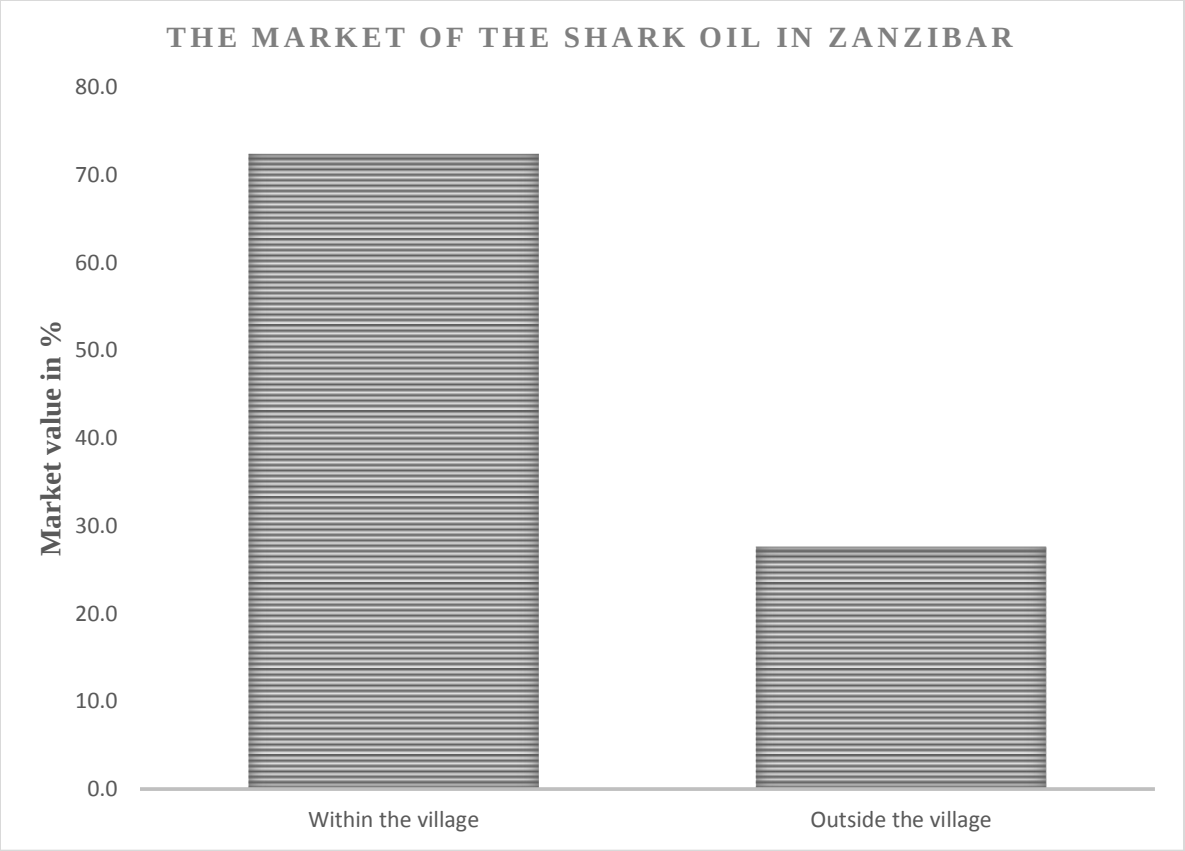

Figure 5: The market of the shark oil in Zanzibar, Tanzania.

Table 8: The Merchants and their correspondent number of buyers of shark oil.

Buyers of oil		Percent	Number of buyers		Percent
Valid	Traders	3.9	Valid	1-3	86.8
	Fishermen	71.1		3-6	7.9
	Wooden boat makers	18.4		6-9	2.6
	To anyone	5.3		9 over	1.3
	Total	98.7		Total	98.7
Missing	System	1.3	Missing	System	1.3
Total		100.0	Total		100.0

4.2.2.2 The uses and price of the shark oil in Zanzibar, Tanzania.

The most common use of the shark liver oil is wooden boat maintenance (88.2 %), followed by medicinal values (10.5%) and consumption (1.3 %) (Figure 6). Traditionally, shark liver oil is believed to cure swelling of the lymph and hand/ foot worm disease in Zanzibar. The findings of this study reveals that the price of the shark liver oil tend to vary according to availability and profit gain by most traders. This is in agreement with the findings of Barrowclift *et al* (2017) who discovered the price for shark is affected by demand and supply of the product in the month of Ramadan as majority of Zanzibar people are Muslims. Hence, during the fasting period the prices go higher for shark and shark products and sometimes when there is bad weather where majority of the fishermen are not going for fishing activities. As the result of this, price of the shark liver oil varies from Tsh. 30,000 to 40,000 per 20 liter plastic jug, which is equivalent to 13$ to17$ and sometimes even higher than that (Table 9).

However, it was observed that, the price of the shark liver oil seems to be more affordable to shark fishermen as it is sold in a 20 liters plastic jug in comparison to one of the shark liver oil alternatives (Shahamu) which was sold per kilograms. Most fishermen were observed to prefer shark liver oil as it was higher in quantity, quality and affordable for their wooden boat maintenance than other alternatives to shark liver oil (Figure 7).

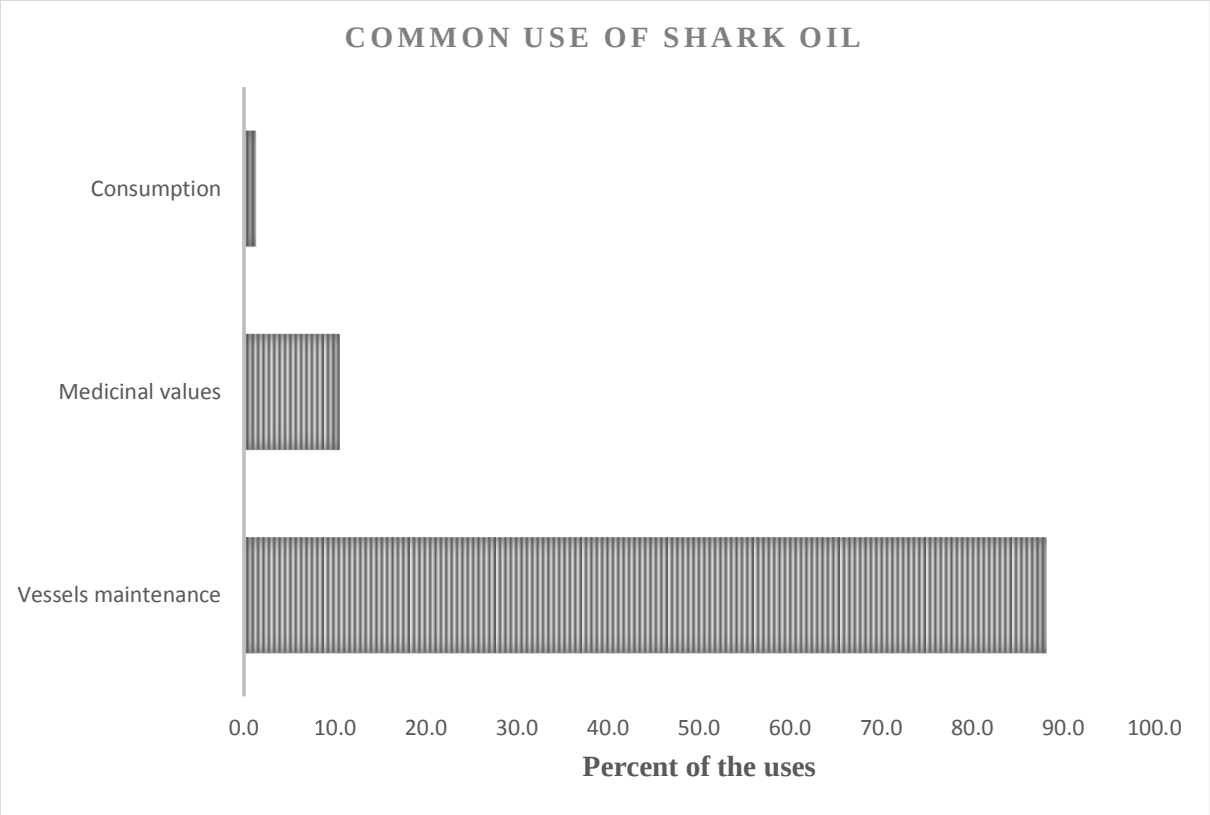

Figure 6: Common uses of shark liver oil in Zanzibar, Tanzania.

Table 9: Variation of price of the shark oil in Zanzibar, Tanzania.

		Frequency	Percent	Cumulative Percent
Valid	20,000 per 20 ltrs	2	2.6	2.6
	30,000 per 20 ltrs	15	19.7	22.4
	40,000 per 20 ltrs	42	55.3	77.6
	50,000 per 20 ltrs	10	13.2	90.8
	Above 50,000 per ltrs	7	9.2	100.0
	Total	76	100.0	

4.2.2.3 Alternatives to shark liver oil in wooden boat maintenances.

Apart from the shark liver oil (SIFA) in wooden boat maintenance, this study found out that there are other alternatives including shahamu (57%), paints (21%), fiber glass nets (12%), and others (Table 10). Shahamu is the oil that comes from the fermented gut of animals like cow, goat and sheep while paints are normal paints which are of oil nature. Fiber glass nets is the more recent technology which is most preferred by the majority but it is the most expensive than all other alternatives. It involves mixing of 5 layers of fiber nets with TALC powder and glue, then sticking it on top of the wooden boat and at the end applying paint (Plate 8). The process costs about 3 million Tanzanian shillings which is only for almost 9 inches of a wooden boat and this is equivalent to 1304-1500 which most fishermen cannot afford. The bigger the wooden boat the higher the price encountered in the fiber glass technology (Appendix 13). Other alternatives like varnish, diesel and sometimes oil from rays are used when other options are not available in the villages. Most fishermen are said to prefer the ray oil since it is thicker than oil of some of the shark species. The availability of these alternatives in the villages is about 38.2% (Table 10).

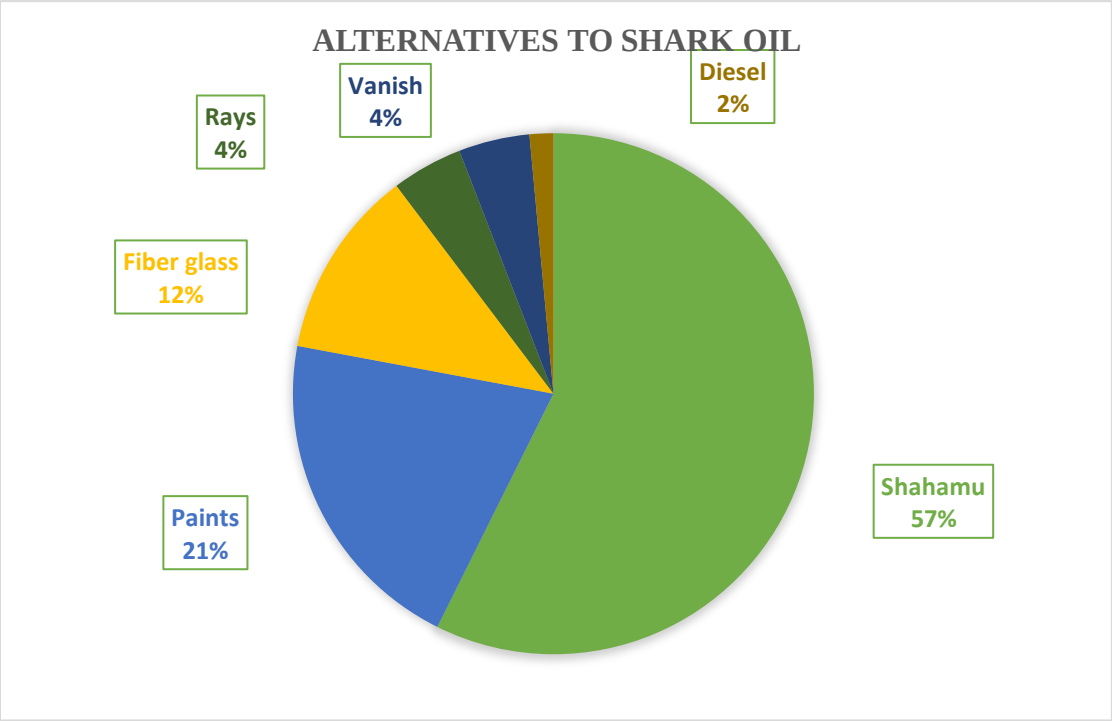

Figure 7: Alternatives to shark oil in Zanzibar, Tanzania.

Table 10: Availability of the shark alternatives in Zanzibar, Tanzania.

		Frequency	Percent	Cumulative Percent
Valid	Very often	29	38.2	40.3
	Fair	22	28.9	70.8
	Not available	21	27.6	100.0
	Total	72	94.7	
Missing	System	4	5.3	
Total		76	100.0	

Plate 8: The process of carrying out Fiber net technique in a wooden boat.

4.2.2.4 Impact of the fiber boat in the demand for shark liver oil.

The findings of this study indicate that considering the fact that fiber boats are becoming more common in most villages, this has a positive impact on the demand for shark liver oil (64.5%) (Figure 8). The minority believes that they have not been directly impacted by the existence of fiber boats in their villages since they only make shark liver oil to sell to other villages where their market is outside their villages. This simply reflects that the more invasion of the fiber boats for fishing activities, the less demand for the shark liver oil. Hence, fiber boats are other alternatives that can be enforced to decrease the exploitation of the sharks for shark liver oil making (Appendix 14). However, most of the fishermen cannot afford buying fiber boats for themselves since the price for a single fiber boat ranges from 12 to 14 million Tanzania shillings which is equivalent to 5220$ to 6080$ without the engines. But it is through fishing groups that they can afford this kind of boats, although there are some few individuals who own fiber boats privately. It is important for the Revolutionary Government of Zanzibar to see a way in which they can empower more fishermen in using modern fishing equipment such as fiber boats for fishing activities. By doing so it will minimize the increased risk of the use of shark liver oil for wooden boat maintenance.

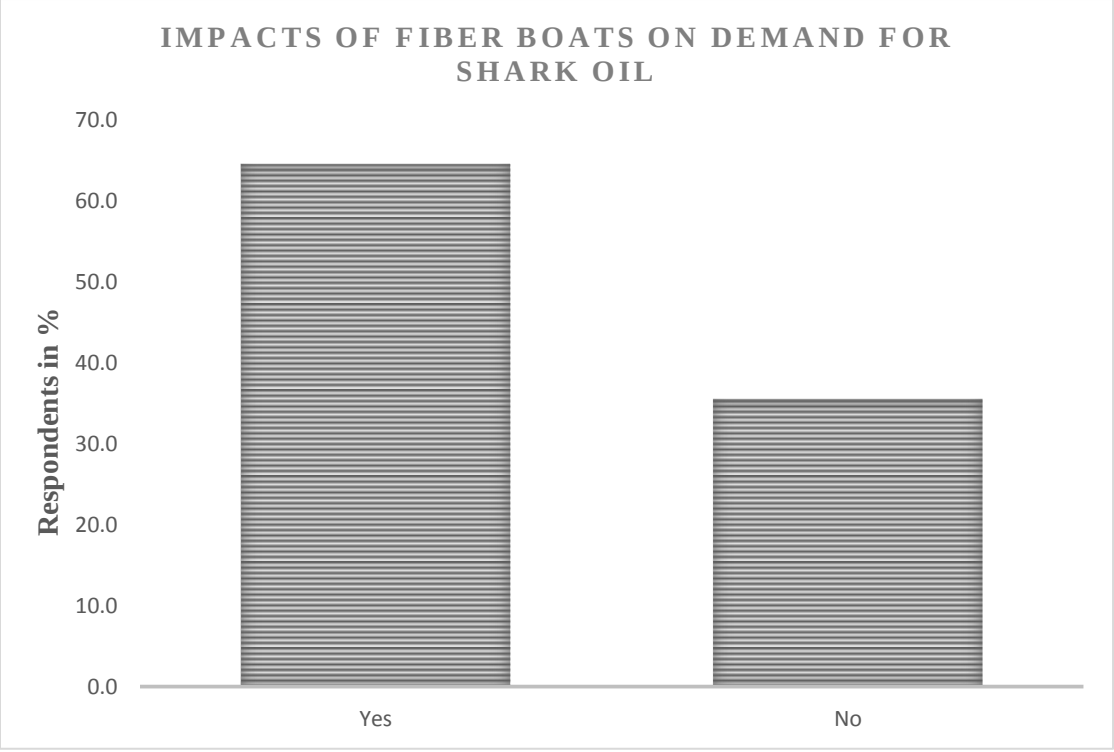

Figure 8: Impacts of fiber boats on demand for shark oil in Zanzibar, Tanzania.

4.3 Effectiveness of banning shark products trade in management of threatened shark.

4.3.1 Elasmobranch landing statistics in Zanzibar, Tanzania.

There has been a variation of the catch statistics of elasmobranch in Zanzibar, Tanzania (Figure 9). Before the banning of the shark products trade in the 2014s, the elasmobranch landing was higher in which approximately 6.6 billion elasmobranch landings were recorded in 2011. After the verbal banning of the shark products trade in Zanzibar, this has helped to minimize elasmobranch landing up to approximately 1.6 million in the year 2016 to 2019. Following the trends of the elasmobranch landing records in 2020 the landing has been seen to increase up to 1.7 million (Figure 9), which continues to pose a threat to elasmobranchs. According to the discussion made with the government officers (n=5) at the Ministry of Agriculture and Fishery in Zanzibar, the banning of the shark products was mainly based on the verbal restriction and there is no any documentation made to enforce such restrictions. From different landing sites, it was observed that the trade of products of shark (fins, skin & teeth) or other elasmobranch species such as rays, is still on going and the only difference is that the price of products has gone down (Plate 9).

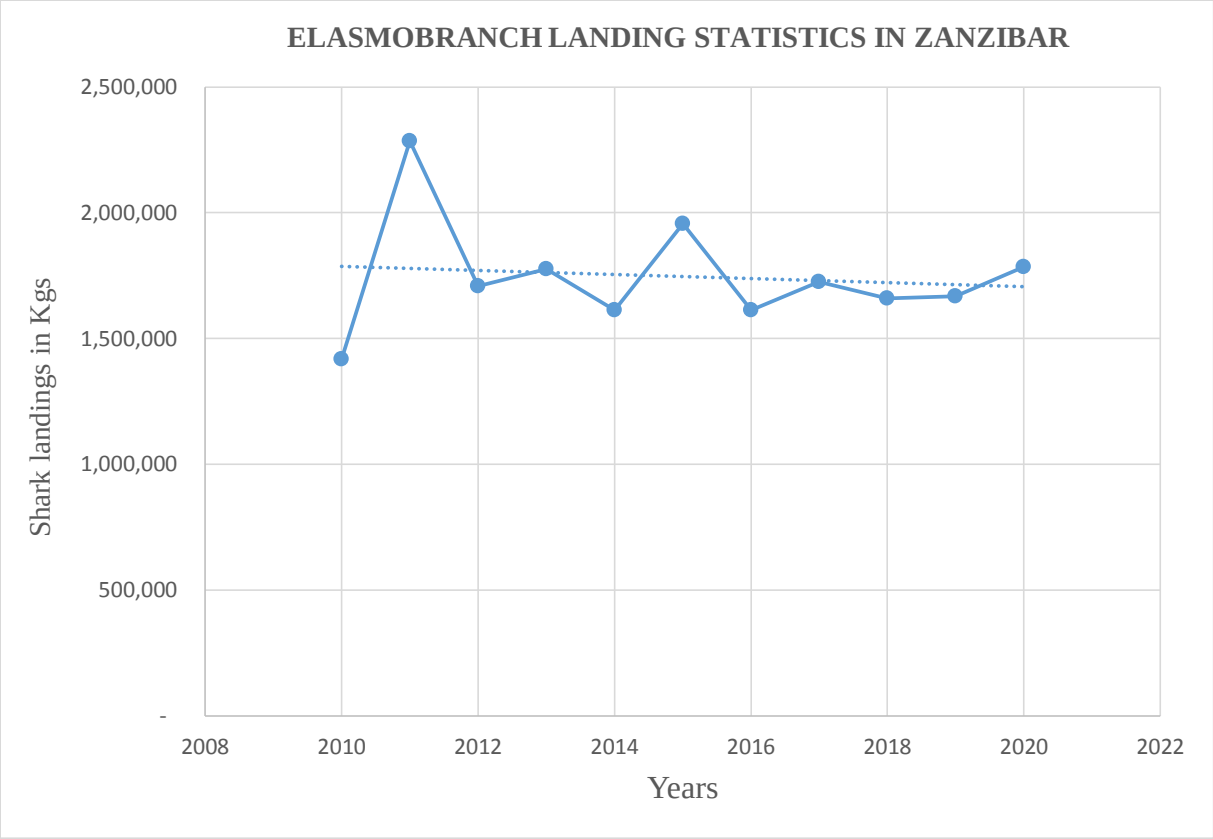

Figure 9: Elasmobranch landing statistics in Zanzibar, Tanzania. (Source Ministry of Agriculture, Natural resources, livestock and Fisheries Zanzibar, Department of Blue economy and fisheries-Zanzibar, 2021).

Plate 9: Shark products (shark fins, shark teeth and shark skin) in Zanzibar, Tanzania.

This study also reveals that up to date the collection and record keeping of the landing data for shark, rays and skates in Zanzibar is still too general as it doesn't distinguish among elasmobranch species. This caused hardship in determining which group of elasmobranch are more vulnerable for extinction and what immediate measures need to be taken towards the conservation of such species. The findings of this study is in line with the report of FAO (2014) and Barrowclift *et al* (2017) where the data for capture fishery of shark, batoids and chimaeras in Zanzibar were mixed and do not distinguish between species. It is therefore important to have proper data collection, recording and management into species level of every group of elasmobranch found in Zanzibar for proper management and conservation measures and for policy making. This will help in the proper management of threatened shark species by making a follow up on the catch trends and hence taking positive measures that could improve the status of those that show threats.

4.3.2 Impacts of banning shark product trade on livelihood of fishermen.

The banning of the shark products trade in Zanzibar had effects on the livelihood of fishermen by about 92.1% where the price for the shark products have gone down starting with shark fins, shark oil, meat and other shark products (Figure 10). Fishermen have been getting low profit gain in comparison to the years before the banning of the trade. This made most of the fishermen to be involved in other alternative activities to be able to provide basic needs for their families. These activities include farming (44.7 %), small business (10.5%), construction, net repair and others being government employees (Table 11). The above fact is in agreement with Barrowclift *et al* (2017) who documented the supplementary occupation for fishermen in Ugunja Island Zanzibar, which included farming, tourism, construction and boat engine maintenances. These activities help the shark fishermen in getting money to provide for their family when the ocean resources are depleted or when there is bad weather condition in the ocean and they can no longer fish.

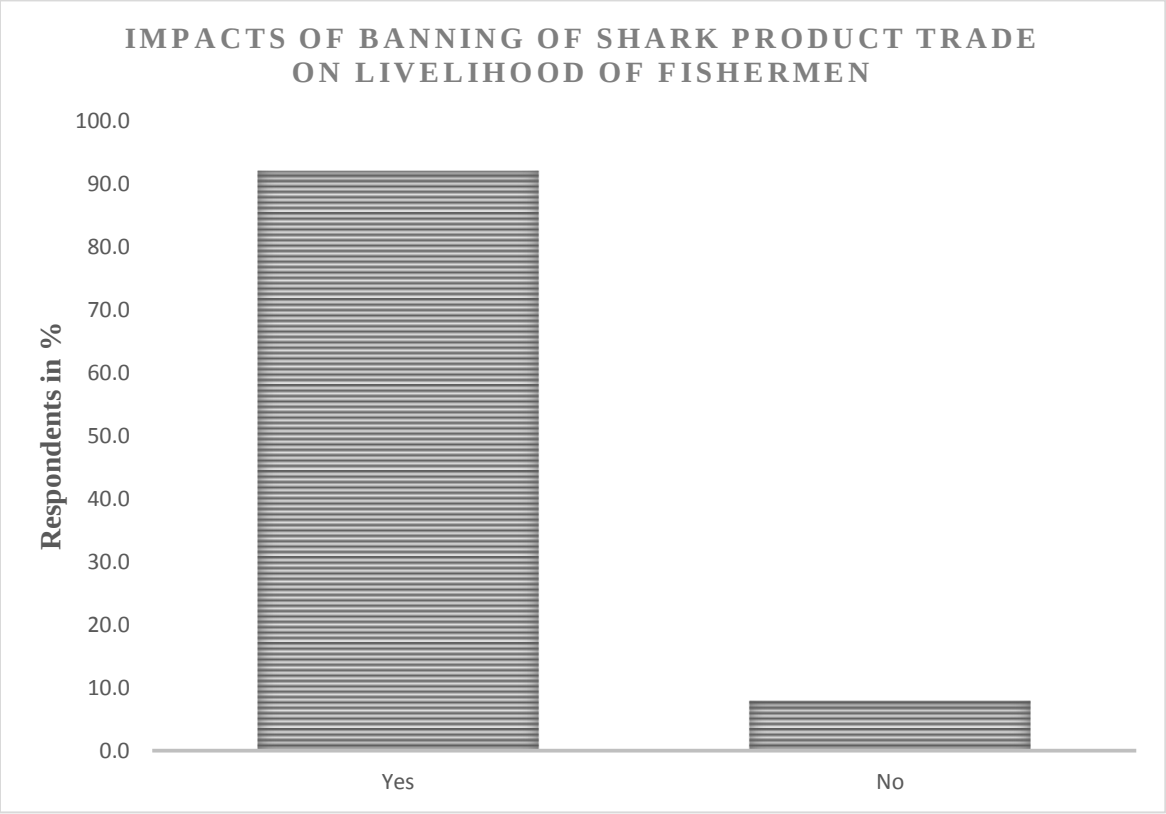

Figure 10: Impacts of banning of shark product trade on livelihood of fishermen.

Table 11: Job alternatives to fishermen after banning of shark products in Zanzibar.

Jobs		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Farming	34	44.7	59.6	59.6
	Construction	7	9.2	12.3	71.9
	Net repair	7	9.2	12.3	84.2
	Small business	8	10.5	14.0	98.2
	Government employee	1	1.3	1.8	100.0
	Total	57	75.0	100.0	
Missing	System	19	25.0		
Total		76	100.0		

4.3.3 Awareness about the threatened shark species in Zanzibar, Tanzania.

Before determination of shark species that are prone to the liver oil trade, this study investigated fishermen's (n=124) awareness of the existence of threatened shark species in their respective villages. The findings of this study showed that 93.4% of the respondents (n=76) were aware of the threat of shark species in their respective areas, while only 6.6% were not aware (Figure 11). This implies that a good number of fishermen are aware and have been involved in the observation of the declining trend of shark species in their areas, hence conservation strategies are essential in empowering these fishermen to conserve threatened sharks in Zanzibar, Tanzania. The majority of the fishermen confirm that there is no restriction in fishing certain shark species in their areas. This means that all shark species are allowed to be harvested for different needs in the community. This continues making the shark species that are already threatened and endangered to be more prone to overexploitation in the island.

Perhaps, close monitoring and follow up of red listed threatened shark species is highly recommended in conserving them. Activities such as fishermen trainings, campaigning and workshops are highly recommended in keeping shark fishermen aware on which species of shark are critically endangered and hence they should not target them in their normal fishing activities.

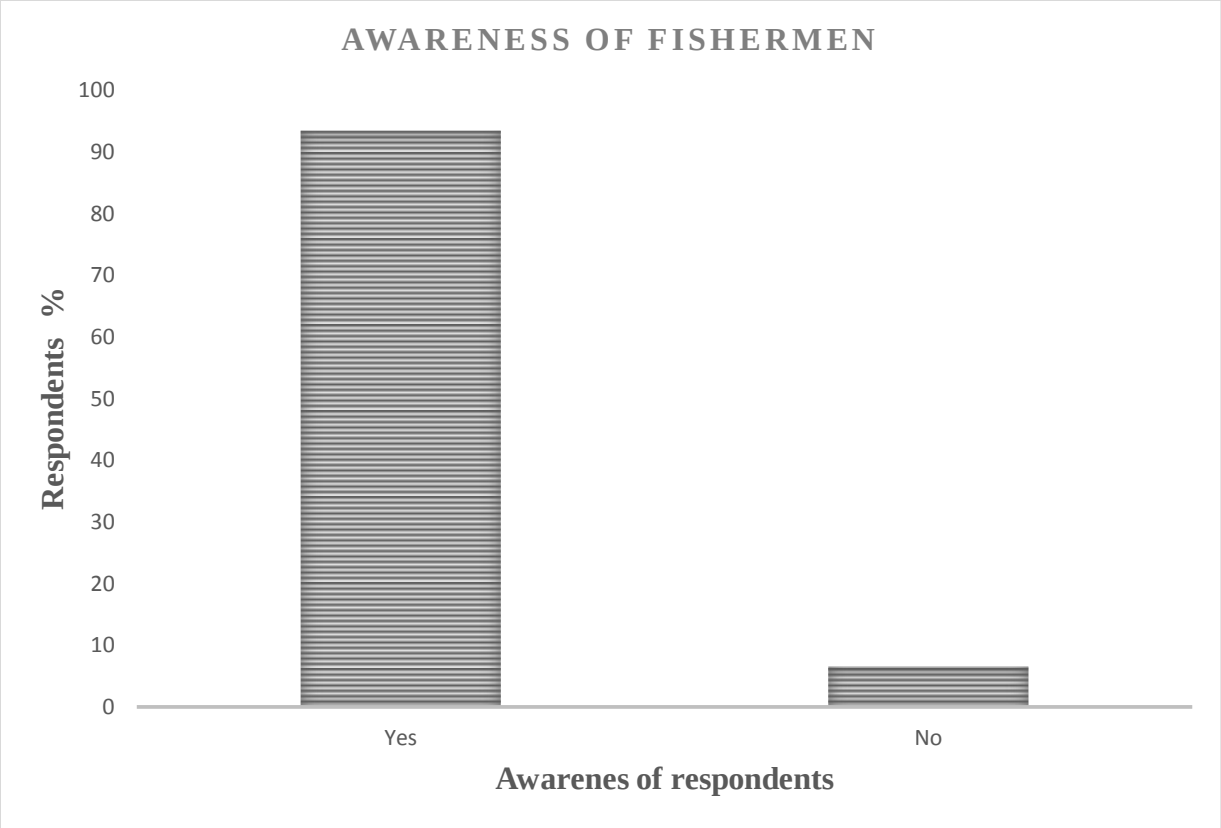

Figure 11: Awareness of fishermen on endangerment of shark species in Zanzibar, Tanzania.

4.3.4 Specific regulations on shark fishery in Zanzibar, Tanzania.

The findings of this study indicated that there were no specific regulations that govern the conservation and management of threatened shark species in Zanzibar, Tanzania (Figure 12). Although the Revolutionary Government of Zanzibar is one of the member states that have adopted the CITES and IUCN red list of endangered shark species but still the enforcement and strategic conservation efforts are very poor as there is no accountability from the fisheries officers. 92.1% of respondents (n=76) had no idea of any specific regulation governing shark fishery while only 7.9% said that there were but unfortunately, they were not able to state them at all. On the other hand, 98.7% believe that there are no management measures taken in threatened shark species while only 1.3% believe that there is some sort of management actions (Figure 12). This implies that the majority of fishermen are not aware of any specific regulation or management aspects of the shark species in their respective areas. Hence, immediate measures

are needed to ensure the survival of shark species that are prone to extinction due to overexploitation of the resources for meat, oil, and even fin trade in Zanzibar.

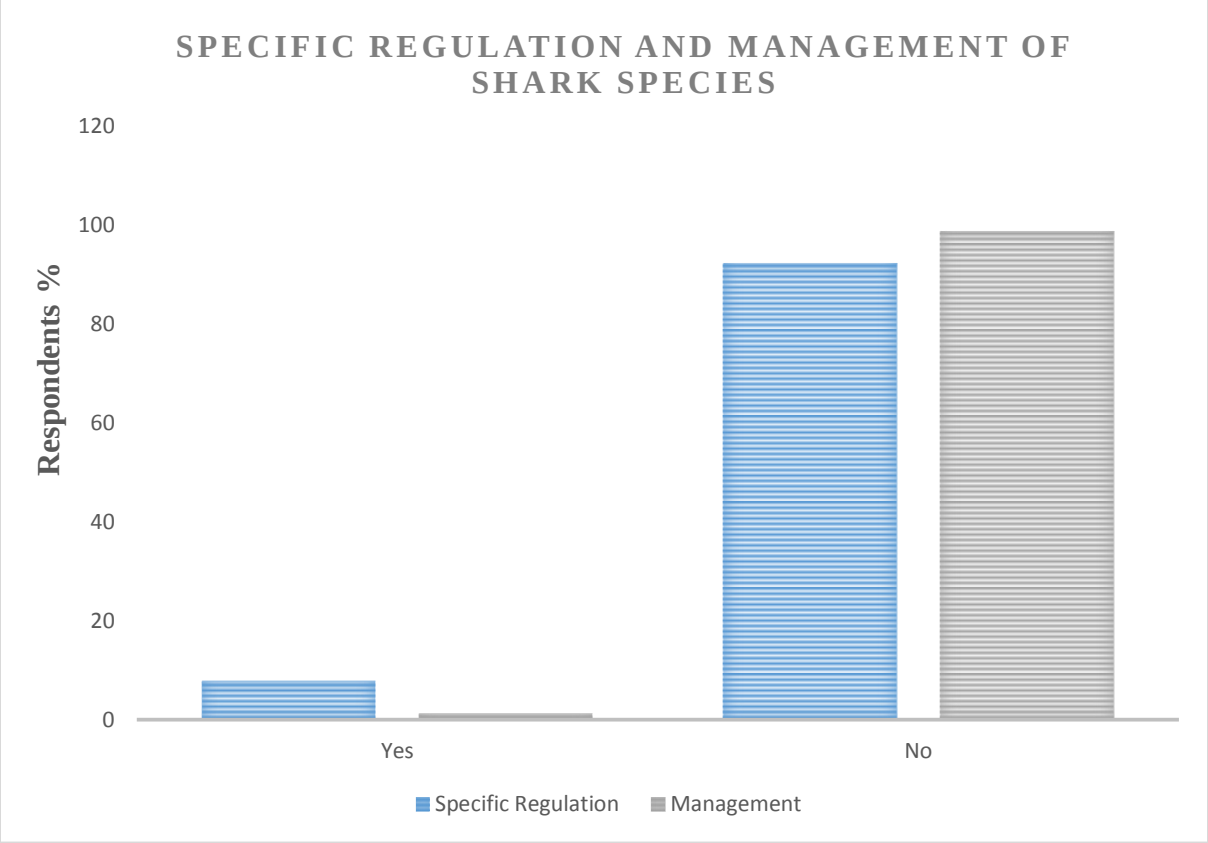

Figure 12: Existence of specific regulation and management of shark species in Zanzibar, Tanzania.

4.3.5 Shark management and conservation in Zanzibar.

There is scant information reaching out to fishermen when it comes to the conservation and management of these threatened marine animals. This study found that only 47.4% of the participants (n=76) depend on social platforms to gain conservation information, 23.7% get information from the village committee, 19.7% depend on beach recorders, 5.3% from the fishery ministry, and 3.9% of the respondents had no information on conservation and management of shark in Zanzibar (Figure 13). There is lack of direct interaction between fisheries officers and fishermen for the past 1 to 2 years in some villages concerning management trainings and workshops to fishermen regarding conservation of marine organisms in general. This increases the risk of more over-exploitation of the shark resources without

proper management strategies given to fishermen as most of the fisheries officers are said to remain in the officers without visiting the field sites.

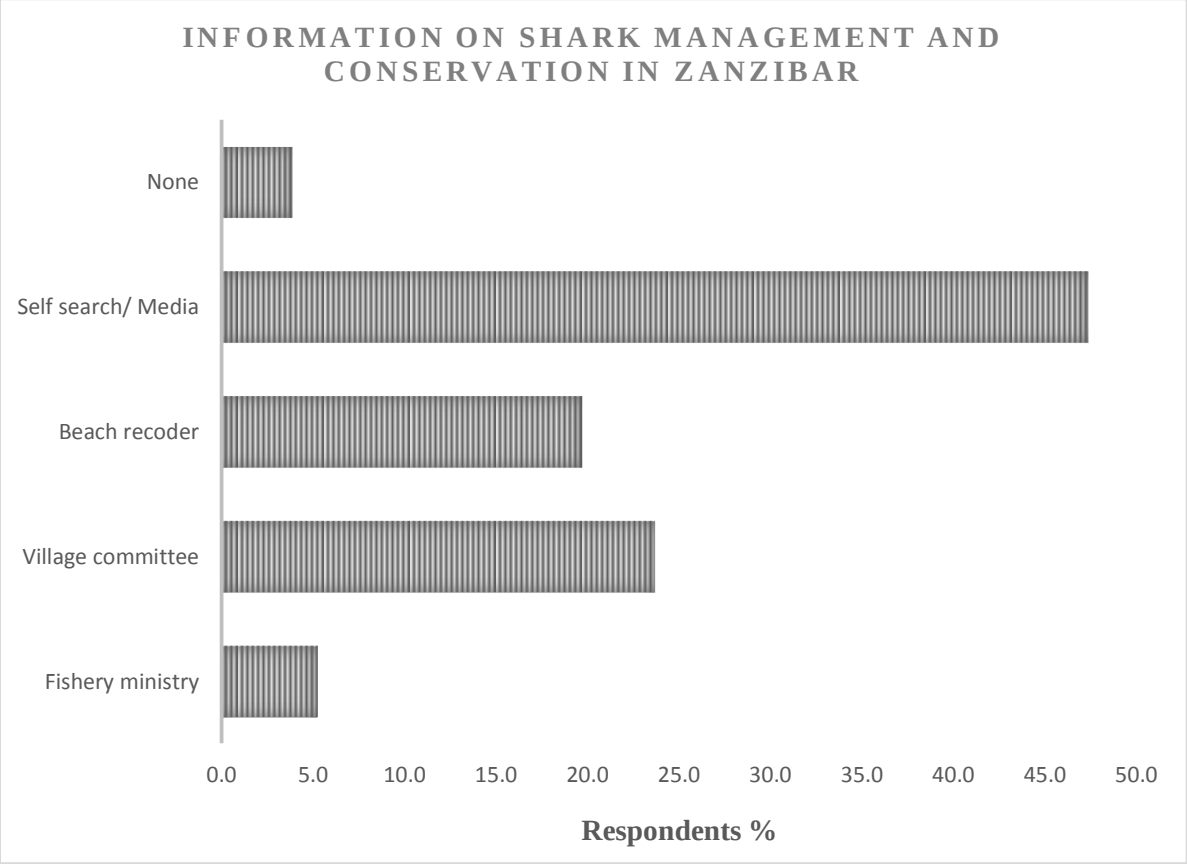

Figure 13: Information on shark management and conservation in Zanzibar, Tanzania.

Perhaps, regular field visit by fisheries officers will help them to understand the real situation that is happening in the field and get them close to interact with the shark fishermen. Proper conservation and management strategies that would help the fishermen to continue harvesting sharks resources sustainably in Zanzibar, would have been suggested by both fishermen and fisheries officers in order to contribute to the conservation effort made by different reginal and international world organizations. Hence, shark fishermen and fisheries officers interaction is very important in conserving and management of any threatened species in the marine ecosystem.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATION.

5.1 Conclusions

The impact of the shark liver oil trade in the management and conservation of threatened shark species in Zanzibar, Tanzania has not previously been determined. This is the baseline study and the case for the majority of the western Indian Ocean countries despite the wide recognition of the shark fins and meat trade as the major impactful trades in Western Indian Ocean region. The finding of this study is adding up more information in the development of management and conservation strategies in the tailored fisheries in Zanzibar. Here, findings show that the shark liver oil trade has a huge impact in the conservation and management of threatened shark species in Zanzibar as more species are continued being highly utilized (Tiger shark, Sickletin lemon shark, Bull shark, Giant guitarfish, and Shortfin mako shark) even though the status for some of them being critically endangered and threatened without any conservation strategies in place. The oil from Giant guitarfish (*Rhincobatus djiddensis*) is the most preferred shark oil in the wooden boat maintenance as it is highly viscous but small in quantity. The catch for this species is highly declining, hence immediate conservation and management measures are needed to rescue this species. On the other hand, tiger shark, scalloped hammerhead shark, Nurse Shark, bull shark, Sickletin lemon shark and dusty shark are known to produce high quantity of shark oil. They have large stomach which implies that they have large liver and hence, the length-weight relationship of their liver to the amount of the oil produced is statistically significant. The banning of the shark products in Zanzibar was verbal restrictions hence, no strategic plan was made to make a follow up and emphasize on the restrictions and perhaps this accelerates the random utilization of the threatened shark species in Zanzibar, Tanzania. Still, the elasmobranch data keeping in Zanzibar is too general as it doesn't differentiate between groups of elasmobranchs and, hence create difficultness in making immediate conservation measures to rescue the group of elasmobranch which is highly vulnerable for extinction. Perhaps, if the data were separated in respect to groups of elasmobranchs, it will be easy and simple to make a follow up and taking immediate action in the fishing practices in Zanzibar.

This is the first initiative to examine the impact of the shark liver oil trade in the conservation and management of threatened shark species in the western Indian Ocean. It highlights that the

trade has large impact in the conservation of threatened shark species in Zanzibar, although the shark liver oil trade is perceived as none impactive trade in the Island.

5.2 Recommendations.

Although the coverage of this study is limited in both area and time, this study recommends the following to be done until a large more comprehensive study in the determination of impact of shark liver oil trade in the conservation and management of threatened shark species in Zanzibar, Tanzania is conducted:

5.2.1 Management and conservation recommendations.

- The government should have a conservation strategic plan that involves the fishing communities themselves and other stakeholders in insuring other groups that are directly involved in the chain of shark liver oil trade participate fully in the creation of good trade that doesn't overexploit the limited resources of sharks in the Island.
- Proper data recording and keeping is highly recommended so as to allow easy evaluation of which group of elasmobranch needs immediate measures to rescue its existence in the area.
- The government should lower the cost of the importation of the law materials for fiber glass net technology in order to accelerate majority of the fishermen to afford this kind of modern technology in the wooden boat maintenance, so as to reduce dependence of the shark liver oil.
- It is important for the government officers to be accountable in monitoring and making follow up in the conservation of threatened shark species in order to reduce the risk of extinction in Zanzibar, Tanzania.
- Increase education and spread of awareness to fishermen on the importance of conserving the limited resources found in their areas for sustainable future is very crucial through workshops, training, campaigning and provision of modern fishing equipment.
- Regular site visit from the government officers is very important so as to create strong connection and interaction with the fishermen and keep themselves up to date with what is really happening in the area than waiting for data to reach to the fisheries officers on their desk in the office.

5.2.2 Future research recommendations.

- This research has only covered one side of the Zanzibar Island and therefore, similar studies should be conducted on the other sides of Zanzibar Islands, (Pemba island and other small islands that make up Zanzibar) to have a clear picture on the whole Zanzibar island and on the impact brought by the shark liver oil trade in the conservation and management of threatened shark species in the island.
- This study has only used acidic value to determine the quality of the shark oil and therefore, it is important for future study to use other values such as peroxide value, p-anisidine value, moisture value, or combined values in the determination of the quality of the shark oil.
- Seasonal variation of the shark liver size and weight in the production of the shark oil should also be determined during the rainy season, to determine if there is negative significant relation in shark liver oil production.
- This study has examined the oil sample of 5 shark species (Tiger shark, Sickletin lemon shark, Bull shark, Giant guitarfish, and Shortfin mako shark) in determining the quality and quantity of the oil and therefore, it is important to determine the oil of other species existing in Zanzibar so as to have a conclusive argument on the content of the oil in quality and quantity measures.
- The impact of the shark catches on the food web of the Western Indian Ocean (WIO) region is also strongly recommended where by the Ecopath models and other related models can be applied in determining the ecological impacts in the WIO food web.
- This study have only use a quite very common approaches in drawing out conclusions hence, same study can be conducted using a different approach such as DPSIR framework (Drivers, Pressure, State, Impact, Responses) framework in determining the impact of the shark liver oil trade in the management and conservation of threatened shark species in Zanzibar, Tanzania.

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APPENDICES

Appendix 01: Questionnaire for fishermen involved in shark fishery at Nungwi, Mkokotoni and Kizimkazi.

Confidentiality statement*: The purpose of this study is to examine the impact of shark liver oil trade in the conservation and management of endangered shark species in Zanzibar, Tanzania.* ***DO NOT*** *write your name in this questionnaire, your response will be anonymous and will never be linked to you personally. Your participation is entirely voluntary and if there are items you do not feel comfortable answering, please skip them.*

If you agree to participate kindly sign …….. Thank you for your cooperation.

Section A: Personal information. Circle the correct answer of your choice.

1. Gender; 1=Male 2= Female
2. Age …….
3. Occupation…….....
4. Location; village……
5. Did you attend school? 1=yes 2=no
6. If yes, which level of education? 1=formal education 2= informal education

Section B: Determination of threatened shark species that are prone to shark liver oil trade.

KNOWLEDGE:

7. Are you aware that, sharks are threatened in Zanzibar? 1=yes 2=no
8. Are you allowed to fish any kind of shark species in your village? 1=yes 2=no
9. Is there any specific regulations for shark fishing in the village? 1=Yes 2=No
10. Are the shark managed in the village? 1=Yes 2=No

11. Are the rules accepted by all shark fishermen? 1=Yes 2=No
12. Where do you get information about shark management and conservation? 1=Fishery ministry 2=Village committee 3=Beach recorder.

OPERATIONAL:

13. Which shark species do you usually catch?…….
14. Which shark species do you prefer to make oil (SIFA) and why?……..
    ……..
15. What is the condition of catch 1= Very good 2=Good 3=Fair 4= Bad 5=Very Bad
    Why?.....
16. How do you sell you caught sharks? 1=By Auction 2= In Market 3=To Hotels
17. How often do you sell you shark? 1=everyday 2=Once a week 3=2x a week 4=3x a week 5=4x a week 6=5x a week 7=2x per month 8=4x per month 9=6x per month
18. Which kind of gear do you use? 1=Longline 2=Handline 3=Trawling nets 4=
19. Where do you sell or buy the oil?.....
20. How do you make shark liver oil? …….....
    ……
    ……
    ……
    ……
    ……
21. Considering, fiber boats are becoming more common. Has this had an impact on demand for shark liver oil, 1=yes 2=no
    why? ……..

Section C: Shark species which produce best quality and quantity oil in relation to human consumption and vessels maintenance.

22. Which species of sharks produce high quantity and quality of oil in L/Kg?.....
    ……

23. To whom do you sell that oil? 1= Collectors, 2=Traders, 3=Fishermen, 4= Wooden boat owners, 5=To anyone who want it.
24. How many collectors or traders do they buy oil from you? 1=1-3, 2=3-6, 3=6-9, 4=9over
25. What is the most use of shark liver oil to your customers? 1=Consumption 2=Vessels maintenance 3=Medicinal values 4=Other uses
26. What price do you sell/ buy the oil? 1=Tsh5000 per ltr, 2=Tsh10000 per ltr, 3=Tsh15000 per ltr 4= Above Tsh15000
27. Is there any alternative to shark? 1=yes 2=no
28. What are the alternative to shark oils?.....
29. What are the availability of alternatives in the community? 1=Very often 2=Fair 3=Not Often
30. Is there a price fluctuation of the shark oil per liter? 1=Yes 2=No
31. If yes, why price fluctuation? 1=Availability 2=Profit gain

Section D: The effectiveness of banning shark products trade in the conservation and management of threatened shark species in Zanzibar, Tanzania.

32. The banning of shark products trade, have it affected your life, why? 1=yes 2=No
33. Is there any alternative activity that you can do apart from shark fishing? 1=yes 2=No
34. Which activities?.....
35. How can we reduce the overexploitation of shark and fish for sustainability in Zanzibar, Tanzania.?

    ……

    ……

    ……

    ……

Appendix 02: Key informant interview for government officers.

1. Are you aware of the existence of shark products trade in Zanzibar?
2. What is the catch statistics of sharks/ shark trade for 5 years banning and 5 years after banning?
3. What measure have the government took since banning of the shark fins trade and shark products?
4. Is there any specific prohibition in shark fishing gears, species, places or size of the fish?
5. Do you keep on monitoring the trend of shark catches?, How is it now?
6. What conservation initiatives have the government put in place to insure the conservation of threatened shark species?
7. Do you have policies that govern the conservation of threatened shark species in Zanzibar,? which one are those?
8. Do you think policies are effectively implemented,? how?
9. How did the existence of the shark trade affect the management of these threatened species?
10. What do you think is the sustainable solution for the shark oil/fin trade and why?

Appendix 03: Interview for Wooden Boat users.

1. Do you use shark liver oil (SIFA) for maintenance of your boat?
2. Why do you use shark/ ray liver oil (SIFA)?
3. Where do you buy it?
4. What is the price?

5. Do you think there is alternative to shark/ ray oil (SIFA), what is that?
6. Is it available, what is the price?
7. Can you use the alternative to shark/ ray oil?

Appendix 04: Interview for Traders of shark liver oil.

1. Where do you obtain the shark liver oil?
2. Where do you distribute your oil?
3. What price do you buy oil from fishermen?
4. What price do you sell the oil?
5. Is there any fluctuation of price in oil in the market? Why?

Appendix 05: Interview for Processors of the oil.

1. What price do you buy the liver oil from the fishermen?
2. How do you make shark oil?
3. What price do you sell the oil?
4. How many are processors you know apart from you?
5. Is there any fluctuation in availability of the shark liver?

Appendix 06: Interview for Collectors of the oil.

1. Where do you collect the shark oil?
2. Where do you take the oil after collecting it?
3. What price do you collect the oil?
4. What price do you sell the oil?
5. Is there any price fluctuation of the shark oil in the market?

Appendix 07: Checklist of Focus group discussion for shark fishermen.

i. What names of shark species you see in the picture?

ii. Which shark species do you usual catch in this village?

iii. Which species do you usual prefer to make shark oil (SIFA)? Why?

iv. Which specie has the best quality of shark oil?

v. Which specie produce large amount of shark oil?

Appendix 8: Viscosity Constants.

VISCOMETER BATH CONSTANT NUMBER.

VISCOMETER NO. 83421

Viscometer constant at 40°C, C: **0.01595 (mm^2/s)/s**

Viscometer constant at 100°C, C: **0.01587 (mm^2/s)/s**

VISCOMETER NO. 78808

Viscometer constant at 40°C, C: **0.007603 (mm^2/s)/s**

Viscometer constant at 100°C, C: **0.007565 (mm^2/s)/s**

VISCOMETER NO. 84763

Viscometer constant at 40°C, C: **0.01565 (mm^2/s)/s**

Viscometer constant at 100°C, C: **0.01557 (mm^2/s)/s**

APPROVED BY: MR P. M. ALI

Appendix 9: Personal information of respondents, Age, Occupation and level of education of respondents.

9.1 Personal information of respondents.

This study involved 156 participants, of which 124 were shark fishermen, 24 shark trades/ wooden boat users, 5 government officers, and 3 beach recorders. The information from respondents was collected via various methods. Out of 124 shark fishermen, 76 members was through questionnaire and 48 members was through focus group discussion. 27 members was through interactive interviews and 5 members was through key informant interviews. Information from the government officers was obtained from the director of fishery research Zanzibar, head of the department of fishery and blue economy Zanzibar, fishery officer and fishery statistician department of fishery and blue economy Zanzibar, Tanzania.

9.2 Gender and occupation of the respondents.

Out of 156 participants, 154 respondents were males and only 2 females were involved in this study. This reflects that most of the deep sea fishing activities are dominated by male dominance and the only female were found in the offices. In terms of respondents' occupation, most respondents were full-time fishermen.

9.3 Age of the respondents.

The study grouped the age of the respondents from 20 years to years and above as indicated in table 1. The study reveals that the highest age of fishermen involved in shark fishery was between the age of 30-39, which was 30.3% of the respondents while the lowest age was between 70-79, corresponding to 6.6% of the respondents. This implies that most of the energetic and active young generation are the ones which are actively involved in the shark trade fishery than the old generation as seen in the below table.

Age of Respondents.

		Frequency	Percent	Cumulative Percent
Valid	20-29	9	11.8	11.8
	30-39	23	30.3	42.1
	40-49	14	18.4	60.5
	50-59	16	21.1	81.6
	60-69	9	11.8	93.4
	70-79	5	6.6	100.0
	Total	**76**	**100.0**	

9.4 Level of education of respondents.

As indicated in table 2, the majority of the respondents in this study had attended school. 52.6% of the respondents had formal education, while 30.3% had informal education which makes a total of 82.9% of the respondents who had education and only 17.1% had not attended any form of education. It implies that most of the respondents had knowledge of the existence of endangered shark organisms and how the resource has been depleting as time goes. This also reflects that most of the fishermen of the rural area are now educated in comparison to the late years. There is an increase in the provision of formal education to rural areas which raises the level of awareness to most fishermen.

Level of education of respondents.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Formal education	40	52.6	63.5	63.5
	Informal education	23	30.3	36.5	100.0
	Total	63	82.9	100.0	
Missing	System	13	17.1		
Total		76	100.0		

Appendix 10: Regression statistics

Regression statistics of the Length (cm) of the shark liver oil and the amount of the oil produced (L).

Regression Statistics								
Multiple R	0.8984							
R Square	0.8071							
Adjusted R Square	0.7685							
Standard Error	13.843							
Observations	7							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	4010	4009.5	20.923	0.006			
Residual	5	958.2	191.63					
Total	6	4968						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-25.65	18.93	-1.355	0.2334	-74.3	23.0134	-74.317	23.013
Length (Cm)	0.6374	0.139	4.5742	0.006	0.279	0.99557	0.2792	0.9956

Regression statistics of the Weight (Kg) of the shark liver oil and the amount of the oil produced (L)

Regression Statistics								
Multiple R	0.969009							
R Square	0.938978							
Adjusted R Square	0.926773							
Standard Error	7.786413							
Observations	7							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	4664.573	4664.573	76.93732	0.000319			
Residual	5	303.1411	60.62822					
Total	6	4967.714						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-1.25251	7.323672	-0.171022	0.870912	-20.0786	17.57359	-20.0786	17.57359
Weigh (Kg)	1.653685	0.188532	8.771392	0.000319	1.169049	2.138321	1.169049	2.138321

Appendix 11: Shark market survey.

Appendix 12: Shark liver oil Sampling.

Appendix 13: Wooden boat maintenance (Fiber glass net technology).

Appendix 14: Invasion of fiber boats as alternatives.

Appendix 15: Laboratory analysis.