ASSESSING THE IMPACTS OF BEACH SEINES ON THE POPULATION STRUCTURE OF *Leptoscarus vaigiensis* QUOY AND GAIMARD, 1824 AND *Siganus sutor* VALENCIENNES, 1835 IN SOUTH COAST KENYA

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A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in Fisheries of Pwani University

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DECLARATION

This is to certify that:

This thesis is my original work and has not been presented in any other University or any other Award.

Signature  .... Date 07/06/2023

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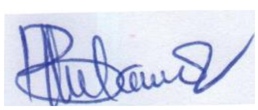
We confirm that the work reported in this thesis was carried out by the candidate under our supervision.

Signature  .... Date 07/06/2023

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DEDICATION

This thesis is dedicated to my little daughters, Michelle and Blessing for their love and endurance during my absence on fieldwork and thesis writing.

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ABSTRACT

The small-scale fishery in Kenya is an important source of food and livelihood for the coastal fishing communities. The fishery is characterized by multi-species, multi-gear, open access, and poor management. This has resulted in increased pressure due to increased fishing effort augmented by the use of destructive fishing gear, threatening the sustainability of these fishery resources. This study assessed the impact of beach seines on the population structure of the shoemaker spinefoot rabbitfish *Siganus sutor* and the marbled parrotfish *Leptoscarus vaigiensis* in the fisheries of the Majoreni seascape in south coast Kenya. The *Siganus sutor* and *L. vaigiensis* are among the most common commercial fish species of the small-scale fisheries of the Kenya coast. The study was conducted through monthly shore-based catch assessments during February through August in 2015, covering both the northeast monsoon (NEM) season (February, March and April) and the southeast monsoon (SEM) season (July and August). A sub-sample of 186.5 kg, (35.6%) of the landed fish was sampled out of a total catch of 524.35 kg (64.4%) composing of 67 species belonging to 22 families. The two species, *Siganus sutor* and *L. vaigiensis* collectively made up 33.8% of all fish species sampled by weight. Analysis estimated the overall daily catch rate at 1.51± 0.15 kg/fisher/day over the study period. Further analysis showed distinct separation of catches by months (nMDS), while ANOSIM showed significant differences in species composition between months ($r = 0.170$; $p<0.05$). The daily catch rate per fisher differed between months but was not significantly different (1-way ANOVA: $df = 4$; $f = 2.007$; $p = 0.109$). The total length sizes at sexual maturity (L_{50}) were determined as 22.8 cm for *S. sutor* and 14.5 cm for *L. vaigeinsis*. Both species showed differences in the proportion of mature individuals during the survey months. *Siganus sutor* showed immature individual's sizes ranged between <15 to <20 cm and mature individual's sizes from <20 to over 30 cm while *L. vaigiensis* showed immature individual's sizes that ranged between <12 to 18 cm and the mature individual's sizes from <18 to over 24 cm. Generally, majority of the landings were dominated by juveniles and small-sized individuals of the targeted species where monthly size differences showed larger individuals of *L. vaigiensis* dominant during July through August while larger *S. sutor* individuals dominated the months of February through March. Results of length-weight relationship indicated both species of *S. sutor* and *L. vaigiensis* had a positive allometric growth pattern of b > 3 for both the NEM and SEM seasons This study recommends beach seine mesh size restrictions and modifications of the footropes as well as lengths and height to improve selectivity and reduce catches of juvenile stages. Further, more efforts should be made to facilitate the small-scale fisheries to access alternative fishing grounds during both SEM and NEM season in order to ease fishing pressure on the inshore waters.

Key Words; Artisanal fishery, Beach seine, Catch composition, Catch rate, Majoreni, South coast Kenya

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LIST OF ABBREVIATIONS/ACRONYMS

ANOVA	Analysis of Variance
ASCLME	Agulhas and Somali Current Large Marine Ecosystem
BMU	Beach Management Unit
BW	Body Weight
CAS	Catch Assessment Surveys
CBFM	Community-Based Fisheries Management
CPUE	Catch per Unit Effort
EAME	East African Marine Eco-region
FAO	Food and Agriculture organization
GoK	Government of Kenya
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
KCDP	Kenya Coast Development Project
KMFRI	Kenya Marine and Fisheries Research Institute
KWS	Kenya Wildlife Services
LWR	Length-Weight Relationship
MPA	Marine Protected Area
NEM	North East Monsoon winds
SDF	State Department of Fisheries

SEM	South East Monsoon winds
TBCA	Trans-Boundary Conservation Area
TL	Total Length
TMPRU	Tanzania Marine Parks and Reserves Unit
WIO	Western Indian Ocean
WIOMSA	Western Indian Ocean Marine Science Association

CHAPTER ONE

1.0 INTRODUCTION AND BACKGROUND INFORMATION

The coastal and marine small-scale fisheries along the Kenya coast are majorly supported by near shore ecosystems including the coral reefs, mangrove wetlands, coastal forests, estuaries, sandy beaches, sand dunes, and seagrass beds (Government of Kenya, 2011). The coral reef ecosystem comprises the near shore and lagoon areas limited by shallow depth making them easily accessible by the small-scale fishers. The majority of species targeted by artisanal fishers are demersal and are mostly found within the reefs. They are easily exploited using relatively small boats in the shallow waters.

Coral reef ecosystems are among the most biologically varied and productive marine ecosystems, providing a wide range of ecological products and services (Costanza et al., 2007; Costanza et al., 2014). They are complex ecosystems restricted to shallow, nutrient-deficient coastal waters in the tropics and subtropics between 30°N and 30°S latitudes (Gattuso et al., 1998). Multiple interactions among the diversity of physico-chemical, environmental, and species interactions culminate in the dynamic coral reef ecosystem (Done, 1999). The number of essential organisms such as coral diversity, algae, herbivores, and predators is commonly used to determine the health of coral reefs (Talbot and Wilkinson, 2001). A stable coral reef ecosystem, according to these authors, is usually coral-dominated and characterized by low macroalgal biomass and a significant number of herbivores. High coral cover and macroalgae grazing encourage the development and recruitment of juvenile corals, ensuring coral dominance (Carpenter & Edmunds, 2006; Mumby & Steneck, 2008).

Coral reef deterioration has been linked to decreased fishery production and income in coastal fishing communities. Increased suspended sediments, nutritional imbalances, temperature change, herbivore predation pressure, illnesses, and fishing activities are all examples of natural and manmade stressors that can cause coral reef damage (Buddemeier et al., 2004).

Critical habitats are important for supporting life underwater as nurseries and feeding grounds. The most important are mangroves, seagrass beds, and corals. Kenya has nine mangrove species, these include: *Avicennia marina*, *Rhizophora mucronata, Ceriops tagal*, *Lumnitzera racemosa, Bruguiera gymnorrhiza*, *Sonneratia alba*, *Xylocarpus granatum, Xylocarpus moluccensis,* and *Heritiera littoralis* According to Government of Kenya, 2017, mangroves cover 8,354 hectares in the south coast of Kenya, accounting for 14 % of the total cover in Kenya. A rapid loss of mangrove cover due to natural and anthropogenic impacts has presently put mangrove coverage in the area at 6,624 hectares representing a loss of 21 % (Government of Kenya, 2017). Mixed stands of *Ceriops* and *Rhizophora*, as well as pure stands of *Avicennia*, dominate the Majoreni mangrove forest. *Sonneratia alba* dominates the Majoreni Channel mangrove forests.

Mangrove forests provide vital habitats for a variety of fish and invertebrates that rely on them for food and as breeding and nursery grounds. The mangrove forest environment also supports a diverse range of bird species, acts as a carbon sink, and protects the shoreline from erosion. The mangrove habitat provides a significant portion of the harvest for artisanal fishermen. Spiritual and cultural functions, aesthetic utilization of forest biodiversity in eco-tourism, and beekeeping are some of the other non-consumptive uses of mangrove forests. Mangrove forests are exploited for timber, construction poles, wood fuel, and herbal remedies, among other things. Over-exploitation of wood and non-wood products, conversion of mangrove forests to other land uses such as solar salt works, infrastructure development, and pollution consequences are all threats to mangrove forests

(Government of Kenya, 2017). Encroachment by human settlements, siltation, and clearance to make room for aquaculture activities are all risks.

Seagrasses are marine angiosperms that can be found all over the world. Seagrasses can be found in Kenya's sheltered tidal flats, lagoons, and creeks, with the exception of the Tana Delta's coastline stretch (Tychsen and Klinge, 2006). Seagrass supports marine food webs and serves as a primary food source for threatened and endangered species such as the green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*), and dugong (*Dugong dugon*), all of which rely on it for nutrient cycling and carbon sequestration (Olendo et al., 2017). Furthermore, seagrasses operate as a wave buffer, preventing coastal erosion, and the shape of their leaves works as a silt trap. A total of 12 species of seagrasses including *Halophila ovalis, Halophila minor, Cymodocea rotundata, Cymodocea serrulata, Halodule uninervis, Halodule wrightii, Halophila stipulacea, Syringodium isoetifolium, Zostera capensis, Enhalus acoroides, Thalassia hemprichii,* and *Thalassodendron ciliatum* have been reported to occur in Majoreni. Fishing operations such as beach seining and trawling, pollution, dredging, and boating, all of which are exacerbated by climate change effects, are all threats to seagrass ecosystems (Uku et al., 2021).

Reef fisheries resources in Kenya are intensively exploited using artisanal fishing gears such as gillnets, traps, seine nets, and hand lines (Mangi and Roberts, 2006; Samoilys et al., 2011). This is in addition to the use of illegal and destructive fishing gear such as spear guns and beach seines, and the ever-growing pressure due to the increasing demand for fish as a source of animal protein. Anthropogenic impacts are due to overfishing and fisheries-related damage, urbanization, tourism development, agriculture, and industrialization (Tuda and Omar, 2016). All these have affected the sustainability of many reef fisheries in Kenya and the Western Indian Ocean (WIO) region at large (Aswani, 1999; McClanahan and Mangi 2001).

The main fishing grounds for the artisanal coastal and coral reef-associated fisheries include the rich inshore areas of the Lamu Archipelago, the North Kenya Bank, and the shallow reefs in Diani-Vanga, south coast Kenya (Government of Kenya, 2008). According to Government of Kenya (2016a), the Majoreni fishing area contributes substantially to the proportion of fish catches from the south coast of Kenya. For example, in the year 2015, this fishing area contributed over 18 % of the total fish landings from the south coast fishing areas that include Vanga (37 %), Shimoni (21 %), Msambweni (19 %), and Diani (5 %). According to Munyi (2009), beach seine is the main fishing gear constituting 72 % of the gear used in Majoreni contributing the largest proportion of the total fish landings in the area.

Artisanal coastal and marine fisheries management in Kenya focuses on restricting fishing gear that are illegal and destructive to habitats and land immature and small-sized individuals. The use of such fishing gear is frequently restricted through cultural traditions and national legislation. Of particular concern are the impacts of beach seines on commercial reef fishes, such as the commercially important species *Leptoscarus vaigiensis* (Scaridae) and *Siganus sutor* (Siganidae) which are among the target species (Samoilys et al., 2011). At the Majoreni fishing area, annual landings of reef fishes have reportedly been on the decline (Government of Kenya, 2016a; 2017). As reef fisheries provide a source of food security and protein for the Majoreni fishing community in addition to employment and income, reef fisheries are an important social safety net, any form of destruction and unsustainable exploitation of these resources is a risk to the health of the ecosystem and the wellbeing of the local communities.

According to Mangi and Roberts (2006), beach seines are defined as long nets of at most 150 m with a mesh size of 1-3 cm and a weighted line to hold down the net while it is dragged across the bottom substratum. The non-selective and dragging nature of beach seines and their continued use in many coastal and marine fisheries have been a source of numerous conflicts with other fisheries and fisheries managers within the artisanal coastal and marine fishery sub-sector (Mangi and Roberts, 2006; Karama et al., 2017). These conflicts associated with the use of beach seines are more pronounced among small-scale basket trap fishers, as well as in gillnet and handline fishers due to the resource use overlap, use of the same fishing grounds, and target species (McClanahan and Mangi, 2001; 2004; Mangi and Roberts, 2006). Anecdotal evidence points out that most of the fishers consider beach seine as unselective and therefore lands juveniles and small-sized individuals. Other associated impacts include the destruction of the benthic habitats, as well as feeding and breeding grounds, thereby impacting fish recruitment and population stocks. (Broadhurst et al., 2007; Signa et al., 2008; Motlagh, 2011; Samoilys et al., 2011).

As poverty is prevalent in most coastal communities exploiting the coastal and marine fisheries, little capital is available for plow-back into the purchase of better fishing boats and gears to venture into offshore fishing grounds. Consequently, the majority of the fishers are economically forced to use less expensive but highly efficient, non-selective, and often very destructive fishing gear. Fishing methods such as beach seines employ mostly younger men to fish with a crew size of up to 30 fishers on one net and boat (McClanahan and Mangi, 2001; Mangi and Roberts, 2006; McClanahan et al., 2008; Fulanda et al., 2009; Munga et al., 2012).

Most of the fishing grounds along the south coast of Kenya are located close to the diverse and rich Kisite-Mpunguti Marine National Park and Reserve (KMMNPR). This Marine Protected Area (MPA) is ideally designed for conservation benefits and sustainability of fisheries resources to the adjacent fishing grounds through the 'spillover' phenomenon (Lorenzo et al., 2016). Less selective but highly efficient methods such as beach seining are becoming the preferred fishing methods, strongly impacting not only on the composition of the catches, but also the overall potential benefits of the MPA to the local community (Maarten and Karunaharan, 2006; Fulanda et al., 2009).

The continued over-exploitation of under-sized individuals is aggravated by the ready market for the small-sized fish (including juveniles) landed by the beach seines due to the poverty levels within the local village markets, especially the women fish-mongers (McClanahan and Mangi, 2001; McClanahan et al., 2008; Fulanda et al., 2009, 2011). The use of beach seine has been banned in Kenya since 2001 (Government of Kenya, 2001). Despite the legal ban on beach seining along Kenya's coastal waters, elimination of this fishing gear has become administratively challenging over the years, and to date, there are still numerous beach seines in use within various fishing grounds along the coast (McClanahan and Mangi, 2001; McClanahan et al., 2008; Fulanda et al., 2009; Karama et al., 2017), more so in Majoreni, in Kwale county fishing grounds. Demersal fisheries resources of family Lethrinidae, Lutjanidae, and Haemulidae, parrotfishes (Scaridae), rabbitfishes (Siganidae), grunters (Haemulidae), and surgeonfishes (Acanthuridae) are the most commonly exploited artisanal fish species (Government of Kenya, 2016a). Barracudas (Sphyraenidae), kingfishes (Scombridae), and mullets (Mugilidae) are among the important pelagic fisheries resources. Mangrove crabs (Portunidae) dominate the crustacean fishery, which is harvested in shallow waters and mangrove habitats. Spiny lobsters (Palinuridae) are also captured in small numbers in shallow-water fishing locations. Squids (Loliginidae) and octopuses (Octopodidae) are the primary targets of cephalopod artisanal fisheries resources (Government of Kenya, 2016a).

Management interventions including the implementation of a gear exchange program (beach seines for gillnets) conducted during the late 2000s were met with little success, with the fishers often selling the new environmentally friendly and legal fishing gears given to them, and opting back to use of the destructive beach seines, partly due to the market demand for the small-sized fish landed from beach seines (pers. observ.) as well as provision of employment to most youth in the beach seine fishery which absorbs a large number of fishers for a single net.

This study, therefore, assessed the impacts of beach seines on the population structure of two commercial reef species; *Leptoscarus vaigiensis* Quoy and Gaimard, 1824 and *Siganus sutor* Valenciennes, 1835 at Majoreni south coast Kenya. Specifically, the study determined overall species composition, abundance, catch rates of the beach seine fishery; size structure, gonad maturity, and length-weight relationships of the two commercial fish species of *L. vaigiensis* and *S. sutor*.

1.2 Problem Statement

Majoreni fishing grounds on the south coast of Kenya are located close to the biodiversity-rich Kisite-Mpunguti Marine National Park and Reserve (KMMNPR). Beach seine is the main fishing gear in Majoreni accounting for over 70 % of all fishing gear in the area (Government of Kenya, 2016a). Due to the active dragging effect, small mesh size coupled with the large size of the net, the use of beach seines has been negatively impacting critical marine habitats such as seagrass beds and corals (Mangi and Roberts, 2006). The gear has also been associated with the landing of juveniles and small-sized individuals coupled with its unselective nature reported landing 98 fin fish species and crustaceans, mollusks, cephalopods, and echinoderms (Samoilys et al., 2011; Karama et al., 2017). The number of beach seines along the Kenya coast has remained relatively high over time. Karama et al., (2017) documented a total of 139 beach seine nets in 2008, 211 nets in 2012, and 193 nets in 2014. This persistent use of beach seine nets is due to a lack of alternative income opportunities for the artisanal fishers (Cinner et al., 2009). The use of beach seine has been embraced by more fishing communities in Kwale county bringing about persistent use and an increase in the number of beach seines. The use of this fishing gear has been assimilated into the fishing culture after having been introduced by migrant fishers about 30 years ago (Karama et al., 2017).

1.3 Justification of the Study

Fisheries managers and policymakers have been continuously grappling with finding a lasting solution to the prevalent use of beach seines along the Kenya coast (McClanahan and Mangi, 2001; McClanahan et al., 2008; Fulanda et al., 2009). Proposed solutions to reduce the use of beach seines have been implemented through various engagements with the stakeholders. Although the impacts of beach seines are fairly well studied in other areas such as the Faza fishing area in Lamu (Karama et al., 2017), there is need for an in-depth study of the impacts of this gear in the Majoreni fishing area so as to better understand how the gear impacts the biology of the target reef fishes, as well as the influence on spatial and temporal distribution of the populations of the affected commercial fish species. It is known that destructive fishing gear such as beach seines and the use of dynamite has been on the rise since the year 2005 and this has continued to damage sea grass beds, corals, and associated fauna and flora (Samoilys et al., 2015) with resultant degraded habitats and reduced fish yields (Mangi and Roberts, 2006).

Majoreni fishing grounds are adjacent to Kisite-Mpunguti Marine National Park and Reserve (KMMNPR) as well as to several Community Conserved Areas (CCAs) in south coast Kenya all together constituting the larger Shimoni-Vanga Fisheries Co-management Area. It’s therefore considered critical for conservation efforts being made to the

KMMNPR. The Beach Management Units (BMUs) of Vanga, Majoreni, Shimoni, Kibuyuni, Mkwiro, and Wasini have formed a network of CCAs in south coast Kenya. The use of the beach seine in this critical habitats therefore negates the very efforts and management regimes put in place to conserve the areas.

According to Government of Kenya (2016a), the fishing area of Majoreni has the highest number of beach seines within the expansive Kwale County coastal waters and the second-highest number of beach seines along the entire Kenya coast after the Faza fishing area in Lamu County. The area had a total of 28 beach seines and 28 canoes each with about 7 fishers per canoe that operate throughout the year (Government of Kenya, 2016a). In Majoreni village, the use of beach seines forms the main fishing technique constituting over 70 % of all the fishing gear used and has therefore traditionally been used by the local fishers (Munyi, 2009). According to Munyi (2009), this fishing gear is perceived to be very efficient and lands more fish; therefore, fishermen who use it argue that those who complain about its use are simply jealous of its perceived high income. Further, Munyi (2009), points out that fishermen in Majoreni village using the beach seines earn an average of US$ 4.19 per person per day during the NEM season while those who use basket traps earn slightly lower (US$ 4.13), and those using gill nets earn more at an average of US$ 6.00 per person per day. During the South-East Monsoon (SEM) season, the study adds that fishermen using beach seines earn an average of US$ 3.06 per person per day. The beach seine fishing is the only fishing that goes on when all other fishing types have stopped due to the rough and windy sea during SEM. This points out the importance of Majoreni in terms of fisheries resources, as well as social, and economic significance.

The selectivity of the fishing gears used are the key determinant of the size composition of the target species (Liang et al., 2014; Zimmermann and Jørgensen, 2017). However, little attention has been given to understanding the various aspects of the gear-fishery dynamics, including the selectivity of the fishing gears employed in these fisheries and their associated impacts. The assessment of fish landings at Majoreni is important for the determination of species composition, total catch for the area, and catch rates of the most abundant and economically important fish species from beach seines. This is fundamental to increase understanding of the impacts of beach seining that is rampant in the area.

Further, the determination of some aspects of the biology of target species such as population size structure, gonad maturity levels, individual mean sizes, and other critical population parameters is fundamental to any gear-based fishery assessment (Gray and Kennelly, 2003; McClanahan et al., 2008). The Spatio-temporal variations in fish landings by gear types are also important in such assessments, and information on population parameters of the target species caught by different gear types can provide a sound basis for scientifically based management recommendations (Gray and Kennelly, 2003; Munga et al., 2012).

1.4 Overall Objective

The overall objective of this study was to assess the impacts of beach seines on the population structure of two commercial reef fish species; *Leptoscarus vaigiensis* Quoy and Gaimard, 1824 and *Siganus sutor* Valenciennes, 1835 at Majoreni, south coast Kenya. The specific objectives were:

i). to determine the monthly catch composition of beach seine fishery;

ii). to determine the monthly catch rates of beach seine fishery

iii). to determine the monthly gonad maturity composition and length at 50% maturity sizes of *Leptoscarus vaigiensis* and *Siganus sutor* landings from beach seines, and iv). To evaluate the length-weight relationship of *Leptoscarus vaigiensis* and *Siganus sutor* from beach seine landings

1.5 Research Questions

This study answered the following three questions;

i. What is the monthly relative abundance of *Leptoscarus vaigiensis* and *Siganus sutor* from beach seine fishery at Majoreni?
ii. What is the monthly variation in catch rates of *Leptoscarus vaigiensis* and *Siganus sutor*?
iii. What is the monthly gonad maturity levels and the length at 50% maturity for *Leptscarus vaigiensis* and *Siganus sutor* individuals?
iv. What is the seasonal length-weight relationship of *Leptoscarus vaigeinsis* and *Siganus sutor* from beach seine landings?

CHAPTER TWO

2.0 LITERATURE REVIEW

Beach seines have been used in the exploitation of both inland, coastal and marine fisheries resources for centuries worldwide (Motlagh et al., 2011). It has been observed globally that the beach seine fishery is often concentrated in areas adjacent to populated coastal villages (Karama et al., 2017) where ready and cheap market exists for beach seine landings dominated by small-sized fish (Mangi and Roberts, 2006). The impact of this gear has consequently attracted significant public scrutiny and conflict with other artisanal fishers, fisheries managers, and conservationists (Lamberth et al., 1997). The gear lands large numbers of species due to its non-selective nature (Aswani, 1998; McClanahan and Mangi, 2001; Mangi and Roberts, 2006). Consequently, beach seine fishers exploit variable sizes of both pelagic and demersal fish species and the most reported include *Leptoscarus vaigiensis* (Scaridae), *Siganus sutor* (Siganidae), *Lethrinus sanguineus, L. harak*, *L. xanthochilus, L. nebulosus* and *Sardinella* sp. (McClanahan and Mangi, 2001; Mangi and Roberts, 2006; Signa et al., 2008).

The targeting of such a wide range of species from small pelagic to demersal fish species has often drawn numerous conflicts with other types of fisheries such as traditional fish traps, gillnets, and small-purse seines, with a lot of controversy among resource-user groups (Gray et al., 2001). As a result, the gear is either banned (Government of Kenya, 2016b) or strong recommendations have been made to ban it (Gray et al., 2001) due to concerns over the negative impacts on primary species targeted due to the capture of large numbers of juveniles and small-sized individuals, many of which are discarded (Lamberth et al., 1994; Gray et al., 2001); and the environmental impacts of beach seines on benthic habitats as studied by Mangi and Roberts, (2006). In the majority of the fisheries, discards represent a significant waste of target and non-target species resulting in economic losses to target fisheries, modification of biological community structures in ecosystems, and impacts on severely overexploited fisheries.

Overall, the impacts of beach seines on species composition and benthic habitats have been well-studied globally (Al-Sayes et al., 1981; Lamberth et al., 1995; Rizkalla and Faltas, 1997; Faltas and Akel, 2003; Akel, 2005; Akel and Philips, 2014). In Kenya, several similar studies have been conducted on the beach seine fishery and its impacts along the coast (McClanahan and Mangi, 2004; McClanahan et al., 2005, Mangi and Roberts, 2006; Signa et al., 2008, Cinner et al., 2009). Many of these studies have documented the destructive nature of beach seines as often leading to lower overall fishery yields (McClanahan and Mangi, 2001; Cinner et al., 2009), and increased landings of small-sized fish species and juveniles of commercially important species (Hicks and McClanahan, 2012; Samoilys et al., 2011). However, none of the literature pinpoints detailed impacts of beach seines on key species namely Siganus *sutor* and *Leptoscarus vaigiensis.*

Beach seines are operated actively by dragging them over shallow fishing grounds. During fishing, beach seines are dragged over the seafloor on a substrate such as sand, sea grass, corals, and rubble (Mangi and Roberts, 2006). The possible direct impact of such an operation includes physical damage to sedentary organisms, crushing and dislodging of corals, and reduction of habitat topographical complexity also linked to a high rate of direct coral damage per unit catch and unit area (Mangi and Roberts, 2006; Samoilys et al., 2011). The indirect impacts may include increased predation pressure attributable to the exposure of infauna species, alteration of substratum texture and sediment re-suspension with resultant clogging of gills, and smothering effects to fish and other marine benthic organisms (Kaiser et al., 2003; Messieh et al., 1991), as well as increased sediment resuspension, negatively impacting on corals and seagrasses (Karama et al., 2017). Therefore, the damage to the benthic habitat may influence other factors driving the fish population dynamics such as food availability and breeding (Glaesel, 2000; Mangi and Roberts, 2006; Cinner et al., 2009).

Many fisheries managers have enacted regulatory measures on the use of beach seines including mesh size restriction, spatial closures, and imposition of a total ban (FAO, 2011; Fletcher and Bianchi, 2014; Government of Kenya, 2016b) declaring the gear as illegal. In West Africa for example, countries such as Ghana, Ivory Coast, and Benin, fishers have organized themselves into Community-Based Fisheries Management Committees (CBFMC) to check irresponsible fishing throughout their coasts (FAO, 2011). The CBFMC is a participatory framework involving local stakeholders and government fisheries resource managers with observed high compliance levels, similar to what is being observed with the beach management unit (BMU) framework in Kenya.

Along the Kenya coast, fisheries legislation bans the use of beach seines (Government of Kenya, 2016b). However, despite these restrictions on the use of the gear, beach seining is still rampant within the coastal and marine fisheries of Kenya. Karama et al., (2017) documented a total of 139 beach seine nets in 2008, 211 nets in 2012, and 193 nets in 2014. Most beach seine nets are predominantly found in Lamu East sub-County (45 %), Kwale (34 %), and Mombasa (18 %) (Government of Kenya, 2016a). In Lamu, beach seines are considered a traditional fishing gear in the area, therefore, making its ban almost impossible.

In Kwale County, the spatial distribution of beach seines shows a higher concentration in the Majoreni fishing area (Government of Kenya, 2016a). Consequently, due to the long history of beach seine fisheries in many fishing areas, despite the ban, there is a need to continuously monitor the impacts of the gear on other fisheries, and habitats, especially concerning population structure, benthic habitats, and biodiversity.

Beach seine is illegal fishing gear and wherever is used it has a common size and shape. The gear's general design and mode of operation are similar in many countries where this gear is in use. In most cases, the gear is used either with or without a cod-end (McClanahan and Mangi, 2001). Karama et al., (2017) documented the impacts of beach seine by comparing the effectiveness of three different mesh sizes of cod-end. The smallest mesh size of 0.25 cm was observed to land the smallest size and juvenile individuals (Karama et al., 2017). Typically, beach seine is a large net with small mesh sizes measuring at least 100 m and at most 150 m in length. The gear is usually set in shallow waters parallel to the beach or back reef and then hauled onto the beach (Mangi and Roberts, 2006; FAO, 2011). The beach seine is constructed by joining 6 or more pieces of small mesh sizes between 0.5 and 1.5 inches with each piece measuring 25 m long and between 3 and 4 m wide. Beach seines vary greatly in quality in terms of mesh sizes and tears as well as material types used and the length usually measuring between 100 m and over 150 m long (Figure 1a). Beach seines are mostly operated from non-motorized traditional canoes although in some cases these canoes are fitted with outboard engines and this has become more common over the last few decades.

Beach seines are operated by being dragged over the sea bottom and therefore, are non-selective just like trawl nets. This gear catches fish, and by its design with sinkers and floaters incorporated, it aids to herd all species and sizes along the swept area into its cod end (MacLennan, 1992; FAO, 2011). A typical beach seine is pulled through the water by a team of fishers to entrap fish. It can also be operated by setting the net at some distance from and parallel to the shore, but in shallow waters, and then hauled onto a canoe (Figure

1b). This latter method evolved historically into the development of what is nowadays the encircling nets represented by purse seines, lempira, and ring nets (FAO, 2011).

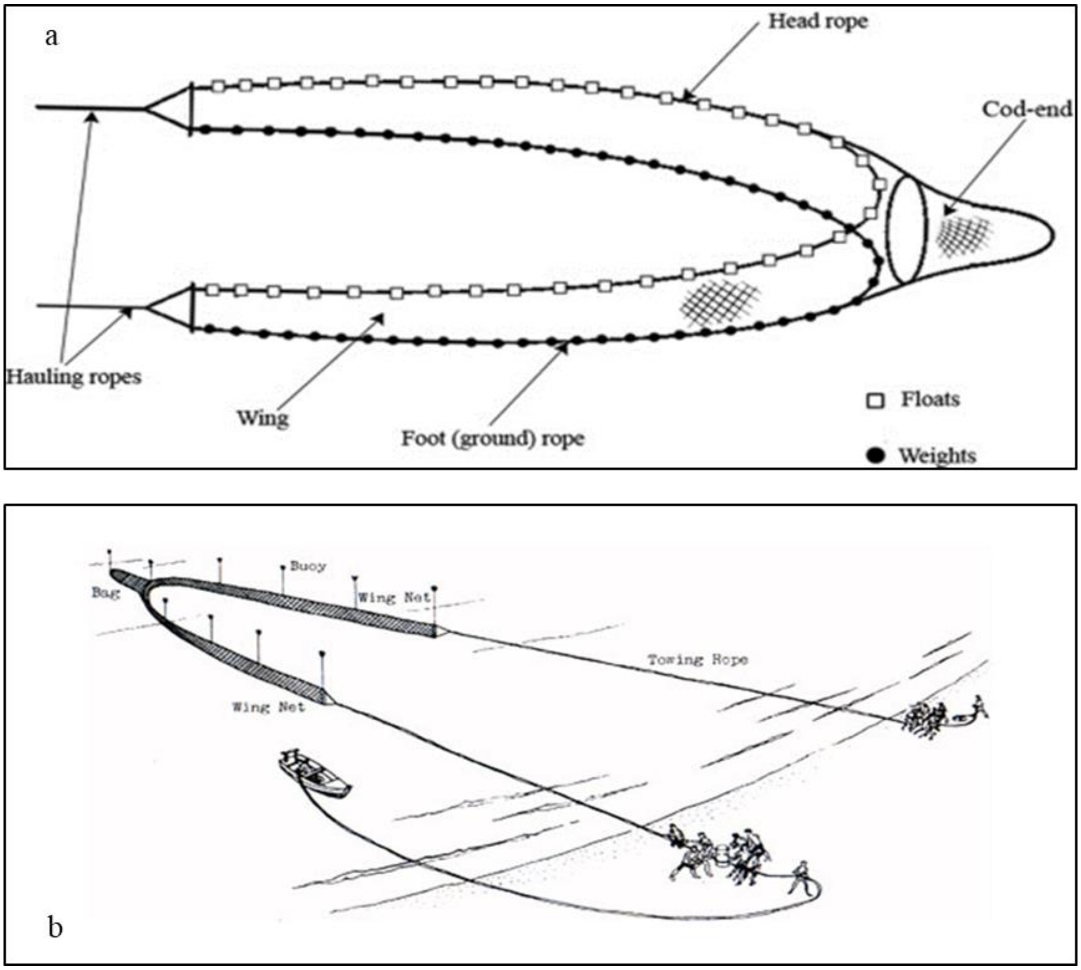

Figure 1. Diagram of a typical beach seine a), and b) demonstration of the operations of a beach seine (https://www.google.com/search?q=beach+seine)

For a long time, the use of beach seines has become controversial due to the perceived impacts on benthic habitats (Gray and Kennelly, 2003; McClanahan et al., 2008). Critics of beach seines have highlighted a wide range of negative environmental impacts due to the destructive nature of the gear. These impacts have been evident in vulnerable coastal and marine ecosystems such as nurseries and breeding grounds. Negative impacts of this gear have also been reported on fish stocks through over-harvesting of juveniles and the landing of small-sized individuals (Kazimoto, 2005; Wells et al., 2007; Signa et al., 2008;

Cinner, 2009). As a result of these negative impacts, many countries have imposed regulations on the use of beach seines and a few countries including Kenya have banned the use of this gear altogether (Government of Kenya, 2016b).

In Kenya, the use of beach seines is illegal and prohibited since the year 2001. Their use is still illegal under the current Fisheries Management and Development Act No. 35 of 2016 as the gear causes overfishing and habitat destruction. This has, therefore, resulted in a dilemma of balancing peoples' livelihoods and food security needs with the need to protect ecosystem health. This remains a big challenge to fisheries managers and policy makers (McClanahan and Mangi, 2001; McClanahan et al., 2008). This dilemma is not unique to beach seine fishery but has become more and more common with increased fishing pressure in the coastal and marine artisanal fishery where beach seines almost comprise the bulk of the fishing gears under use (McClanahan and Mangi, 2001; McClanahan et al., 2008).

Beach seining in the coastal fishing grounds along the Kenya coast is especially commonly practiced in the coastal waters of the Lamu archipelago on the north coast of Kenya (Karama et al., 2017). In this fishing area, a total of 64 beach seines have been recorded to operate (Government of Kenya, 2016a). The beach seine hot spots in the Lamu archipelago coastal waters are the highest reported in Kenya (Government of Kenya, 2016a). In Kwale coastal waters a total of 38 beach seines have been recorded out of which 9 have been reported to operate in the Majoreni fishing area, where this current study was conducted (Government of Kenya, 2016a). In Kilifi County coastal waters, a total of 11 beach seines have been recorded, and in Mombasa County, a total of 18 nets have been reported to operate especially along the Nyali-Reef fishing area (Government of Kenya, 2016a).

Overall, Lamu County fishing coastal waters in the Lamu archipelago and Kwale county Majoreni fishing coastal waters remain the most prevalent areas along the Kenya coast with the highest number of beach seines (Government of Kenya, 2016a). In Lamu beach seining is more common in sheltered fishing grounds during the southeast monsoon (SEM) season that prevails between the months of April and August when the sea is rough and cool (McClanahan, 1988; Okoola, 1999).

Existing knowledge of fishing gears has been gained over time and how important fishing gear types are operated and how these gears have evolved over time (McClanahan et al., 1997; Glaesel, 2000; Tuda et al., 2016). Research findings have documented the influence of fishing gear types and area restrictions (Marine Protected Areas, MPAs) on total fisheries catches (McClanahan et al., 1997; McClanahan and Mangi, 2001). Most of these studies have concentrated on the wet weight of catches landed by the various fishing gears. Further research findings have documented the analyses of fish identification only at the family taxonomic level. A clearer understanding of gear selectivity and potential resource-use overlap between gears can be gained if the catch is analyzed at the finer taxonomic resolution of species level (Wright and Richards, 1985; Bellwood, 1994).

Research findings by Lewis (1997) indicate that high levels of physical damage to coral colonies by the dragging effect of fishing gear affect the health of reef ecosystems. Similarly, bottom-dragging gear such as beach seines has resulted in damage to corals and other coastal habitats (McClanahan et al., 1996) as well as directly affecting habit structure causing degradation of coral reefs. Hughes (1994) and McClanahan et al. (1996) have documented that there has been increasing evidence that fishing has facilitated shifts in reef ecosystems changing from coral to algal-dominated phases, which is a sign of habitat or ecosystem degradation. In addition to impacts resulting from fishing, natural disturbances within reef ecosystems also play a role in damaging individual coral colonies.

For example, the 1998 *El-Nino* phenomenon resulted in coral bleaching and mortality with reduced coral cover in most coral reef habitats along the Kenya coast by 50 – 90% (Talbot and Wilkinson, 2001; McClanahan and Mangi, 2001). Other than the *El-Nino* phenomenon, corallivorous gastropods and fish species and over-dominance by algae in coral ecosystems have been noted to cause detrimental effects on the coral structure and associated biodiversity (Miller and Hay, 1998; Turner et al., 1999).

The Marbled Parrotfish *Leptoscarus vaigiensis* (Quoy and Gaimard, 1824) belongs to the class Actinopteri, order Labriformes, and family Scaridae (parrotfishes) (Froese and Pauly 2021). These species inhabit sheltered bays, harbors, and lagoons. Also, these species inhabit seagrass beds with hard substrates heavily under algal cover. Naturally, this species occurs in small groups. Unlike other parrotfishes, males and females look very similar and do not change sex at any stage of growth. Seagrasses and algae form the main food items for this species. As food fish, this fish is usually marketed fresh (Froese and Pauly 2021). The species usually spawn in shallow waters above seagrass flats during the low tide. Investigation of the sexual identity of large samples has suggested that the species is gonochoristic that is, sex-reversal does not occur at any one time during its growth history. The species matures to reach a maximum of 35.2 cm total length (TL) (Froese and Pauly 2021).

Leptoscarus vaigiensis are extremely important for the health of coral reefs. This is the only species out of thousands of reef fish species that regularly scrapes and cleans inshore coral reefs (Bellwood and Choat, 1990). According to Humann and DeLoach (2002) this species' feeding activity is important for the production and distribution of coral sands in the reef biome and can prevent algae from choking corals. The teeth of this fish species grow continuously, replacing material worn out by the feeding activity. The pharyngeal teeth of this fish species are used to grind up the corals and coralline algae ingested during feeding (Murphy, 2002; Bellwood and Choat, 1990). After they digest the edible portions from the rock, they excrete it as sand, helping to create small islands and sand in coastal and marine waters. It has been documented that one parrotfish can produce about 90 kg of sand annually (Murphy, 2002).

The Rabbitfish *Siganus sutor* belongs to the class Actinopteri, order Perciformes , and family Siganidae . This species exhibits a fast growth rate (Kaunda-Arara and Rose, 2006), diurnal schooling, and browsing in shallow water habitats, and this makes it ideal for trap fishing and fish farming or mariculture production (Bijoux et al., 2013). The fish is associated with coastal, brackish, and marine environments at a depth range of between 1 and 50 m but commonly in a water depth range of 1-12 m. In Kenya, the maximum total length (TL) of *Siganus sutor* is 46.0 cm (Froese and Pauly, 2021).

Siganids are cosmopolitan demersal fishes commonly found in the Indo-Pacific, Red Sea, and Eastern Mediterranean regions inhabiting shallow inshore reefs within seagrass beds. This is among the most common species in the coastal and marine fisheries of Kenya accounting for about 1,651 metric tons of the total annual landings with a current market value of US$ 4,201,778 (Kenya Marine and Fisheries Research Institute, 2017).

The species is widely targeted and heavily fished along the Kenya coast (McClanahan and Mangi 2004; Samoilys et al., 2011). This species contributes significantly to food security and nutrition in many coastal communities along the Kenya coast. Fishers' knowledge of reef fish spawning aggregations has been documented in the Western Indian Ocean, including those of *S. sutor* since 2006 (Kamukuru et al., 2006; Robinson et al., 2007; Robinson et al., 2014). Sustainable management implications are important for the fisheries associated with such spawning aggregations (Sadovy and Domeier, 2005; Grüss et al., 2011; Robinson et al., 2011).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

The study was conducted at the Majoreni in Msambweni sub-County, Kwale County on the south coast Kenya located about 87 km south of the city of Mombasa. Majoreni comprises the fishing villages of Aleni and Chete-cha-Kale and the area straddles 4° 34' S and 39° 17' E (Figure 2) and is situated on a delta-like bay fringed by a mangrove forest (Munyi, 2009). Seawards, Majoreni borders the highly biodiverse Kisite-Mpunguti Marine National Park and Reserve (KMMNPR). The area further straddles what is considered an ecologically important zone, connecting several Beach Management Units (BMUs) for the promotion of marine conservation.

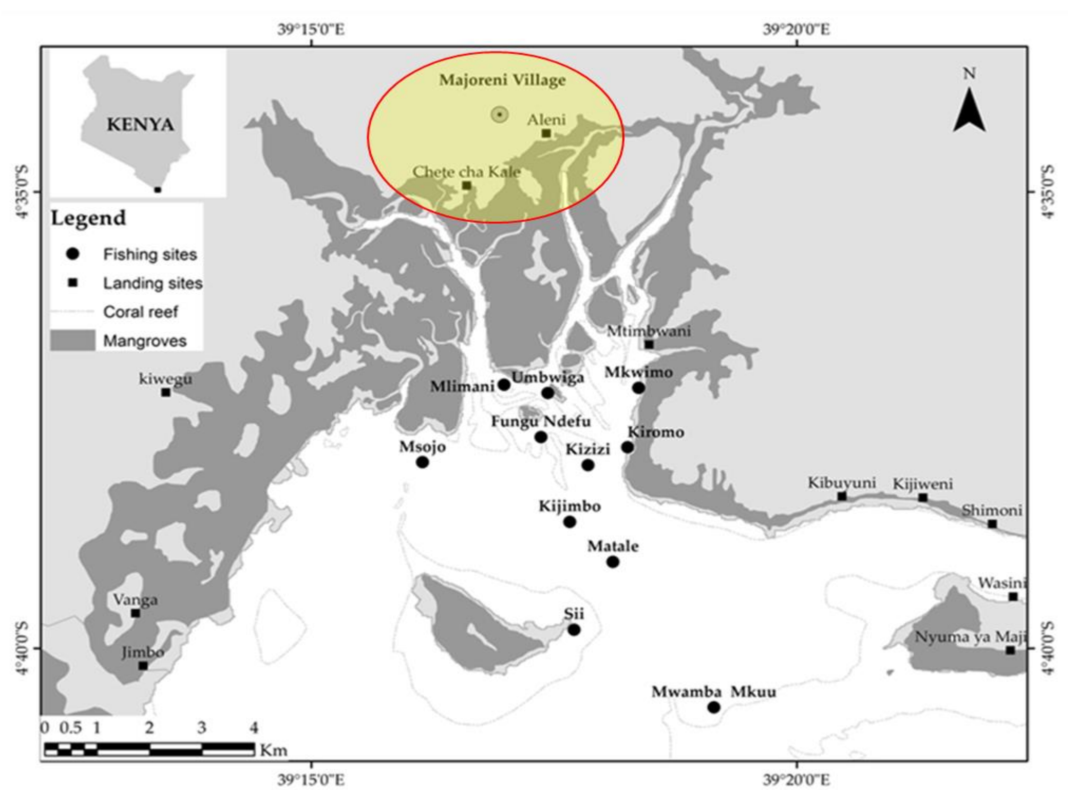

Figure 2. A map of the study area showing the location of Majoreni in south coast Kenya (modified from Munyi, 2009)

The artisanal fishery at Majoreni is dominated by the use of beach seines compared to other fishing areas along the Kenyan coast (Government of Kenya, 2019a). The main targeted fish species in the area are emperors (Lethrinidae) and parrotfishes (Scaridae) (Government of Kenya 2016a). The continued use of beach seines in Majoreni has resulted in declining fish catches. To cope with this trend, fishers in the area are also involved in collecting sea cucumbers as well as practicing subsistence farming (Ochiewo et al., 2010). Fishing activities in the area are influenced by North-East Monsoon (NEM) season experienced from October to March and characterized by calm seas and low wind speed. Generally, this is a dry season with little rainfall. The South-East Monsoon (SEM) season experienced from April through September is characterized by strong winds and rough seas, hence fewer artisanal fishers go out fishing as they use small fishing crafts (McClanahan, 1988). Annual rainfall has a distinct seasonal pattern, with the highest levels occurring between late March and early June. A shorter rainy season occurs between October and November, with a quick decrease from December to a minimum in January and February (Government of Kenya, 2019b). The average annual rainfall in the area is 940 millimeters.

Temperatures range from 23 to 28°C throughout the year. The months of November to April have the hottest temperatures (mean daily temperature of 27°C), whereas May to October has significantly colder temperatures (mean daily temperature of 24.5°C). The relative humidity is high all year, but it peaks in the rainy months of April through July (Government of Kenya, 2019).

Semi-diurnal tides occur in Kenya's inshore waters, with a spring tidal range of little more than 4 m (Brakel, 1982; Tychsen and Klinge, 2006). Wave swells, whose magnitude changes throughout the year, batter the coastline offshore waters. The northeast monsoon winds generates 80% of the waves throughout the northeast monsoon season, with a maximum significant height of 6 meters. During the inter-monsoon period (March-April), the sea is normally calm, and wave height reduces to 2.5 m, shifting counter-clockwise to a southerly approach with huge oscillations. During the Southeast monsoon (May to October), the waves are typically very huge, reaching a maximum notable height of 8 m and approaching the coast primarily from the southeast and southwest. During the inter-monsoon season, calm conditions prevail, and waves tend to approach the coast from the northeast.

3.2 Shore-based Catch Data Collection

Shore-based catch data collection was conducted at the Majoreni fish landing site, south coast Kenya for five months, February, March, April, July, and August 2015 (Table 1). Sampling for the catch was not conducted in the months of May and June due to lack of research funds. For each month, sampling was done for a total of 8 sampling days representing 2 consecutive sampling days for each week.

Table 1. Summary of sampling events of beach seine catches at Majoreni (note: sampling was not conducted in the months of May and June due to lack of funds)

Sampling dates	**Season**	**No. of days sampled**
5th – 12th February 2015	North East Monsoon	8
5th – 12th March 2015	North East Monsoon	8
9th – 15th April 2015	South East Monsoon	6
18th – 25th July 2015	South East Monsoon	8
10th – 18th August 2015	South East Monsoon	8

On each sampling day, data were collected from beach seine fishers at the Majoreni landing site. Arrangements were made with specific beach seine fishers to obtain samples from them for an average of 2 days every week. For each beach seine boat, the number of fishers, time in and time out, fishing duration (hr), and fishing ground were recorded. The total weight of the catch for each boat was measured using a spring balance to the nearest 0.1kg. Using fish identification guides by Smith and Heemstra, (1986), and Heemstra and Randall (1993) all the fish species in the catch were identified before individuals of each of the two target fish species *L. vaigiensis* and *S. sutor* were separated and their total weight measured. Representative individuals of each of *L. vaigiensis* and *S. sutor* samples were measured for weight (BW, g) to the nearest 0.1g using a digital weighing balance, and individual total length (TL, cm) measured using a graduated fish measuring board to the nearest 0.1 cm.

To examine reproductive attributes, 30 specimens per boat for each target species of *L. vaigiensis* and *S. sutor* in each sampling session were randomly picked, chilled in ice, and transferred to the Kenya Marine and Fisheries Research Institute (KMFRI) laboratory for gonad maturity analysis. On arrival at the laboratory, the specimens were immediately preserved at -20^{o} C pending further analysis. Prior to taking lengths and weights, specimens were thawed at room temperature for about two hours. Specimens were dried using tissue paper to remove excess water from their body surfaces.

In the laboratory, individual total length (TL, cm), and body weight (BW, g) were measured using a measuring board and a digital weighing balance, respectively. Total length was measured as a straight-line distance from the front of the upper lip (mouth closed) to the posterior end of the hypural plate and the extended tip of the caudal fin respectively. Determination of sex and gonad maturity status of the individuals was done by dissecting using a scalpel, and physical observation of the gonads macroscopically

(Table 2). The gonads are two parallel tubules located on the dorsal of the abdominal cavity. The males had gonads with smooth exterior, while those of females were rough on the exterior. The gonads for *S. sutor* were categorized following the method adapted from Ntiba and Jaccarini (1990). Based on a macroscopic examination, gonad maturity stages were assigned as Immature (I), Maturing (II), Mature (III), Ripe (IV), Spawning (V), and Spent (VI) for *Siganus sutor* following the classification scheme by Ntiba and Jaccarini (1990), (Table 2). Gonad maturity stages were classified according to the colour and size of the gonads. The *L. vaigiensis* gonads were determined following Bagenal (1978) maturation scheme where: I- immature; II- immature; III- maturing; IV- mature; V- active; and VI- spent. In both methods used, gonadal sexual maturity determination by Bagenal (1978), and Ntiba and Jaccarini (1990) bare very close similarities.

Table 2. Classification of gonad maturity stages of a) ovary and b) testis of *Siganus sutor* (Ntiba and Jaccarini, 1990) and *Leptoscarus vaigiensis* (Bagenal, 1978)

(a) Ovary	**Macroscopic features**
Stage I: Immature	Ovary small, strand-like and transparent; Most advanced oocytes (eggs) are at yolk vesicle stage.
Stage II: Maturing	Gonads reduced in size; Ovaries pink to pale yellow; Most oocytes in early vitellogenesis stage with few in late stages. Brown bodies visible.
Stage III: Ripening	Ovaries yellow in color; increased blood vessels, volume, and size structure recorded. Most oocytes in late vitellogenesis stage; Few are in early vitellogenesis stage. Brown bodies visible.
Stage IV-V: Spawning	Gonad well developed; Ovary yellow to orange; Nucleus migrating; Oocytes hydrated oocytes, visible through' wall; egg release possible with light abdominal pressure. Brown bodies recorded.
Stage VI: Post-spawn / Resting	Most advanced oocytes (eggs) at yolk vesicle stage; gonad enlarged and gonad wall thick; easy to differentiate resting ovaries from the immature ones.

(b) Testis Macroscopic features	
Stage I: Immature	Difficult to determine sex macroscopically. Testis small, threadlike and transparent; Spermatogonia in the first spermatogenesis stage.
Stage II: Maturing	Testis transparent/pale white; tissue predominantly of primary and secondary spermatocytes; few quantities of spermatids in lobules.
Stage III: Ripening	Testis white; tissue predominantly of spermatocytes, spermatids, and spermatozoa. Spermatozoa in lobules but none in spermatic ducts.
Stage IV-V: Spawning	Testis white and enlarged; mature spermatozoa fill the spermatic ducts.
Stage VI: Post- spawn / Spent	Testis dull brown in color; developed lobules contain few remaining sperms; flat, white-grayish testes spermagonia in the first spermatogenesis

3.3 Data Analysis and Statistical Tests

Data was entered into an MS Excel worksheet. Data included the total catch landed, number of fishers, species composition, individual TL (cm), individual BW (g), and proportions of gonad maturity stages for male and female individuals. Monthly catch rates were calculated as kg.fisher^{-1} boat^{-1}. The assumption of ANOVA as a parametric test was confirmed from normality of variance that was tested using Levene's test ($p > 0.05$). Where assumption was not met, the alternative non-parametric Kruskal Wallis test was used. Having met the assumption of ANOVA, 1-way ANOVA was used to test for significant difference in fish sizes between months over the study period. Significance levels for both non-parametric and parametric tests were set at $p < 0.05$. The size distributions were analyzed using length frequencies in 2 cm size classes. Gonad maturity stages of combined sexes for *Leptoscarus vaigeinsis* and *Siganus sutor* were analysed using linear regression based on individual length and weight data. The proportions of gonad maturity levels based on length and weight data were used to analyze the respective length at 50% maturity of each species following logistic equation as applied by Obota et al. (2016):

L_{50}: M (TL) = 100/ (1+exp (-a*(x-b))) …………………………………………. (i)

where 'a' is a constant and 'b' is the L_{50} .

All statistical analyses were conducted using R Language Software Version 4.2.1.

The number of individuals per species was used to calculate the relative abundance (%) using the following formula (Manyenze et al., 2021):

$$\text{Relative abundance } (\%) = \frac{\text{Number of individuals of species 'A'}}{\text{Total number of individuals of all species}} x100 \quad \text{……………. (ii)}$$

Percent proportions were used to analyze the composition of gonad maturity stages for combined sexes and by month.

Length-weight relationships were analyzed by linear regression on log-transformed total length and body weight data and the degree of association was tested by the coefficient of determination (r^2). The length-weight relationship (*LWR*) was determined using the power curve: $W = aL^b$ (Le Cren, 1951) where: W = fish weight in g; L = fish total length in cm;

and a and b are regression constants. A straight-line relationship was provided by the formula:

$$\text{Log } W = \log a + b\log L \quad \text{……………………………………………………………… (iii)}$$

The coefficient of determination (r^2), *a,* and *b* were calculated by least-squares regression according to Anam et al., (2019).

3.4 Multivariate Analysis for Catch Composition

Multivariate analysis was performed using PRIMER v6 statistical software. The non-Metric Multidimensional Scaling (nMDS) computational technique was applied based on Bray-Curtis similarity resemblance for the beach seine catch data according to Clarke et al., (2014). An MDS algorithm starts with a matrix of item-item similarities and then assigns a location of each item in a low-dimensional space. In this case, a 2-dimensional graphing representation was used. The resultant nMDS plots give scientific data visualization for the purposes of exploring associations between samples. Similar catch samples are placed closer to each other on the nMDS configuration signifying similarity in catch composition than samples that are dissimilar.

The stress value of an nMDS is a measure of confidence that the 2 or 3-dimensional ordination plot is an accurate representation of the sample relationships where stress values ranging from 0.0 to 0.2 are acceptable (Clarke et al., 2014). Data were standardized into relative abundance (%) to achieve the acceptable stress value.

3.4.1 Analysis of Similarity (ANOSIM)

One-way ANOSIM technique was applied to test for significant differences between a *priori* defined groups with R-value tending to negative 1 accepting the null hypothesis that there are no differences in catch composition, and R tending to positive 1 rejecting the null hypothesis that there are significant differences in catch composition. ANOSIM carries out an approximate analog of the standard univariate 1- and 2-way ANOVA tests. This technique was applied to the resemblance matrices and tested for the assemblage change of the studied catch composition. The pair-wise comparison test significantly differentiated catch composition whenever the p-value was less than 0.05.

3.4.2 Similarity Percentage Breakdown (SIMPER)

This technique was used to identify the influential taxa in an nMDS plot by comparing two groups of samples at a time. In this case, 1-Way SIMPER was used to identify the species contributing to the greatest dissimilarity. More influential taxa were represented by a higher percentage contribution than less influential taxa.

CHAPTER FOUR

4.0 RESULTS

4.1 Overall total catch and catch rates

A total of 7 beach seine nets in 7 wooden canoes were recorded in Majoreni fish landing site during the study period. Crew size ranged from 4 to 5 members per boat. A total of 186.5 kg of beach seine catch was sampled over the study period comprising 67 fish species (see appendix 1) belonging to 22 families and an overall daily catch rate of 1.51 ± 0.15 kg/fisher/day. From the total sample weight of 186.5 kg, *Siganus sutor* dominated with a total weight of 35.8 kg (19.2 %) followed by *Leptoscarus vaigiensis* with 25.3 kg (13.6 %) (Figure 3). From the top twenty landed fish species with the highest total weight, comprised a total of 11 families of which 9 families were demersal and 2 pelagic fish families.

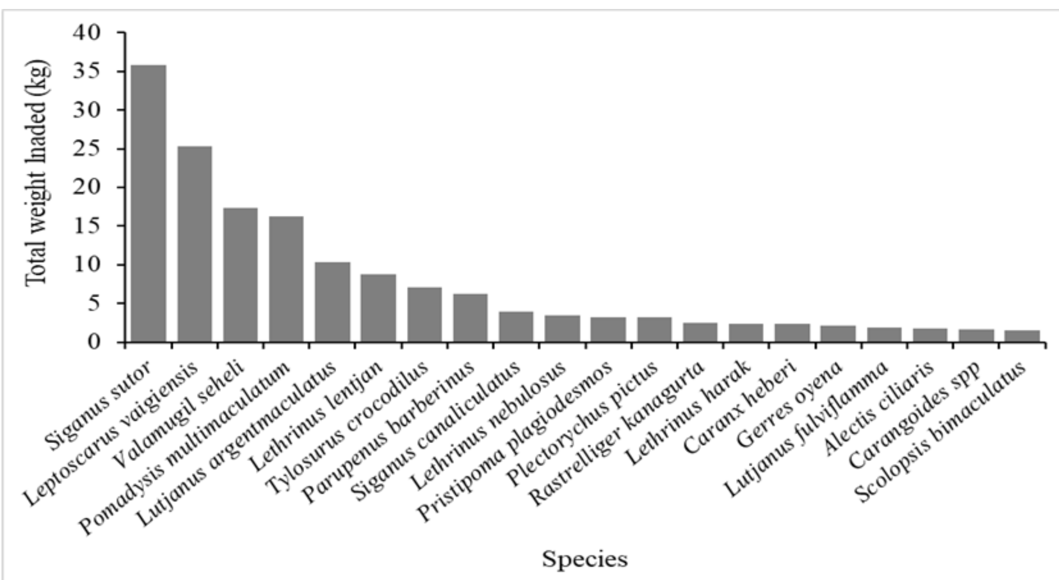

Figure 3. Top twenty fish species by weight landed by beach seines sampled at Majoreni in south coast Kenya over the study period

A total of 22 fish families landed (Figure 4) were sampled at Majoreni over the study period. The most speciose was the family Scaridae (n = 14) followed by Haemulidae (n = 9), Carangidae (n = 5), Lethrinidae (n = 5), Nemipteridae (n = 4), Serranidae (n = 4), Siganidae (n = 4) and Sphyraenidae (n = 4) in that order. The rest of the families were represented by either 1 or 2 species and these were the families Acanthuridae (n = 2), Belonidae (n = 2), Gerreidae (n = 2), Lutjanidae (n = 2), Hemiramphidae, Mugilidae, and Scombridae each with a record of 1 species.

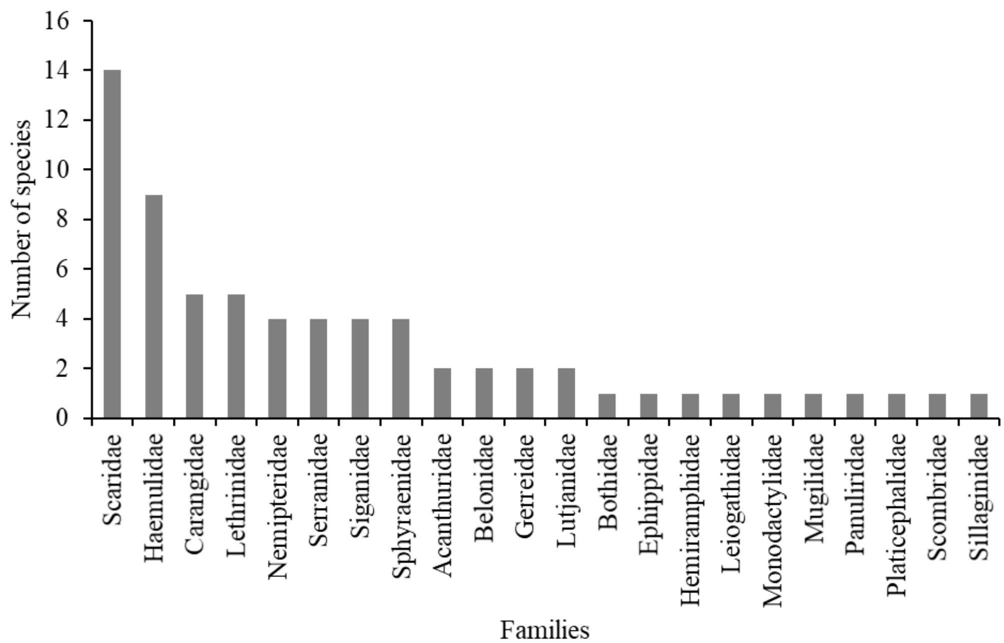

Figure 4. Fish families and the number of respective species of beach seines sampled in Majoreni south coast Kenya over the study period

The monthly catch rate of beach seine varied over the study period with the highest daily catch recorded in July followed by August (Figure 5) both months falling in the cool and wet South East Monsoon (SEM) season. The month of February recorded the lowest daily catch rates of less than 1 kg/fisher/day. Results of 1-way ANOVA however, indicated no significant difference in daily catch rate between months (df = 4; f = 2.007; p = 0.109).

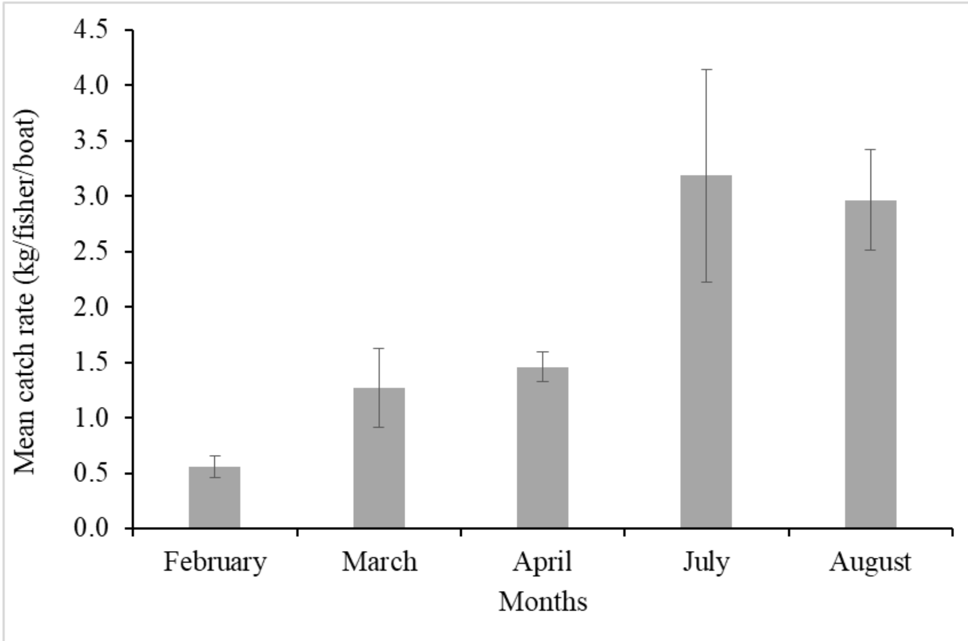

Figure 5. Monthly mean catch rates (±SE) of beach seines at Majoreni, south coast Kenya recorded over the study period

4.2 Species composition and abundance

A total of 957 finfish individuals were sampled during the study belonging to 67 species (Appendix 1). Figure 6 shows that the top twenty most abundant fish species were dominated by the 2 species of *Siganus sutor* and *Leptoscarus vaigiensis*. The species *L. vaigiensis* was the most abundant (19 %) and *S. sutor* was the second most abundant (14 %). Collectively the 2 species under investigation in this study formed 33 % of all fish species sampled over the study period. The least abundant of the top twenty most abundant species each with a contribution of 2 % and below were: *Parascolopsis erioma*, *Epinephelus merra, Sillago sihama, Epinephelus coioides, Sphyraena jello*, *Trachinotus blochii* and *Diagrama pictum*. The top twenty most abundant species belonged to 12 fish families out of which the most speciose were Siganidae (n = 3), Carangidae (n = 3), Lutjanidae(n = 2), and Lethrinidae (n = 2).

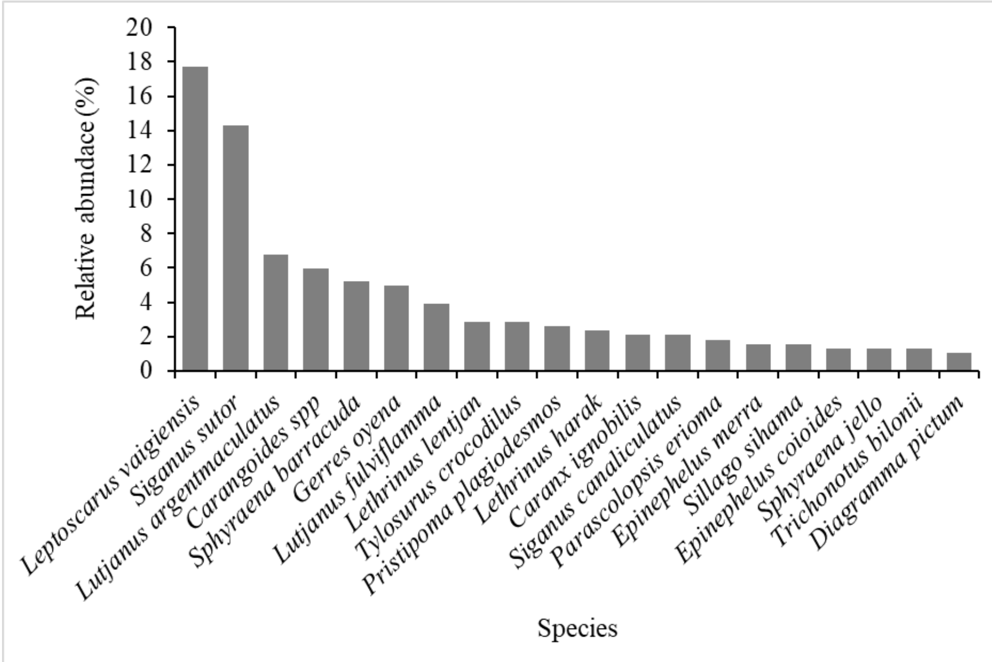

Figure 6. Relative abundance by number of the top twenty most abundant fish species sampled from beach seines at Majoreni, south coast Kenya over the study period

Non-metric Multidimensional Scaling (nMDS) plots showed a distinct separation of catch samples by months where samples of February, March, and April were grouped and separated from those of July and August (Figure 7). Results of 1-way ANOSIM indicated a significant difference in monthly catch samples of the beach seines ($R = 0.170$; $p = 0.047$). Results of pair-wise comparison tests (Table 3) confirmed February catch samples significantly differed from catch samples of July and August ($p < 0.05$ in both cases). Results of 1-way SIMPER analysis showed that all fish species contributing to the highest dissimilarity between February and July were more abundant in July than February except for *Leptoscarus vaigeinsis* which was more abundant in February than July (Table 4).

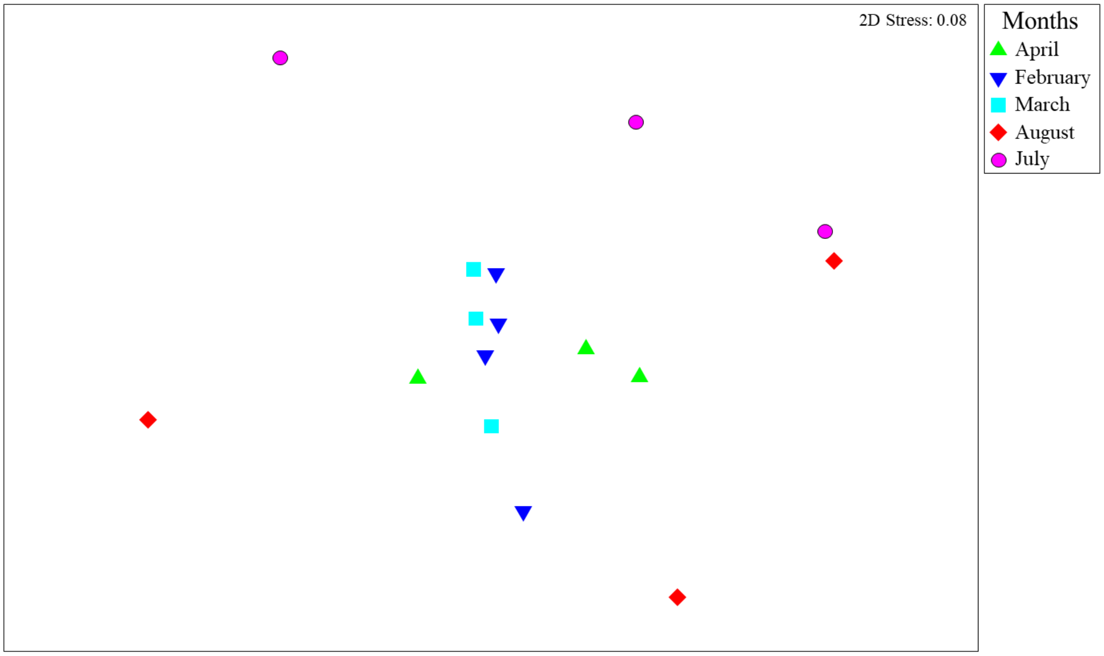

Figure 7. Non-Metric Multidimensional Scaling plots showing beach seine samples assemblage on standardized catch composition of beach seines by months

Table 3. Results of pair-wise comparison tests confirming significant differences in catch composition between the month of February and those of July and August at Majoreni over the sampling period ($p < 0.05$ bold and italic)

Month comparisons	R statistic	p-value	Possible Permutations	Actual Permutations	Number >=Observed
April *vs* February	0.009	0.514	35	35	18
April *vs* March	0.333	0.200	10	10	2
April *vs* August	-0.056	0.600	10	10	6
April *vs* July	0.222	0.100	10	10	1
February *vs* March	-0.389	1.000	35	35	35
February *vs* August	0.389	***0.029***	35	35	1
February *vs* July	0.528	***0.029***	35	35	1
March *vs* August	0.056	0.400	10	10	4
March *vs* July	0.333	0.100	10	10	1
August *vs* July	-0.074	1.000	10	10	10

Table 4. Results of 1-Way SIMPER analysis showing the most abundant (%) species contributing to dissimilarity (bold values) in catch composition between February and July with an average dissimilarity of 89.89%

	February	July		
Species	Average abundance (%)	Average abundance (%)	Average dissimilarity (%)	Contribution (%)
Siganus sutor	8.40	**40.00**	18.60	20.69
Sphyraena barracuda	7.50	**11.11**	6.81	7.57
Leptoscarus vaigiensis	**13.06**	0.00	6.53	7.26
Parapercis hexophthalma	0.00	**11.11**	5.56	6.18
Thysanophrys otaitensis	0.00	**11.11**	5.56	6.18
Lethrinus lentjan	3.67	**6.67**	3.95	4.39
Sphyraena jello	1.47	**6.67**	3.58	3.98
Alectis ciliaris	0.89	**6.67**	3.48	3.87
Epinephelus malabaricus	0.00	**6.67**	3.33	3.71

Results of 1-way SIMPER analysis showed that the most abundant fish species contributing to the dissimilarity between February and August were all more abundant in the month of August than February (Table 5).

Table 5. Results of 1-Way SIMPER analysis showing the most abundant (%) species contributing to dissimilarity (bold values) in catch composition between February and August with an average dissimilarity of 91.76%

	February	August		
Species	Average abundance (%)	Average abundance (%)	Average dissimilarity (%)	Contribution (%)
Leptoscarus vaigiensis	13.06	**16.67**	10.51	11.45
Siganus sutor	8.40	**16.67**	9.73	10.61
Carangoides ferdau	0.00	**16.67**	8.33	.08
Pomadasys multimaculatum	0.00	**16.67**	8.33	9.08
Gerres oyena	3.26	**11.11**	6.10	6.65
Lethrinus harak	0.00	**11.11**	5.56	6.05
Valamugil seheli	0.00	**11.11**	5.56	6.05

4.3 Monthly gonad maturity composition

An overall total of 159 individuals of *L. vaigiensis* were sampled for gonad maturity analysis representing 133 female individuals (83.6 %) and 26 male individuals (16.4 %). From the overall total of *L. vaigeinsis*, 75.5 % represented immature individuals (gonad maturity stages I and II) and only 24.5 % represented mature individuals (gonad maturity stages III, IV, V, and VI; (Figures 8). February and March recorded the most immature gonad maturity stages of this species at 98.5 % and 76.1 %, respectively. Most mature gonad maturity levels were recorded in the months of April, July, and August representing 53.8 %, 50 %, and 100 % (Figure 8).

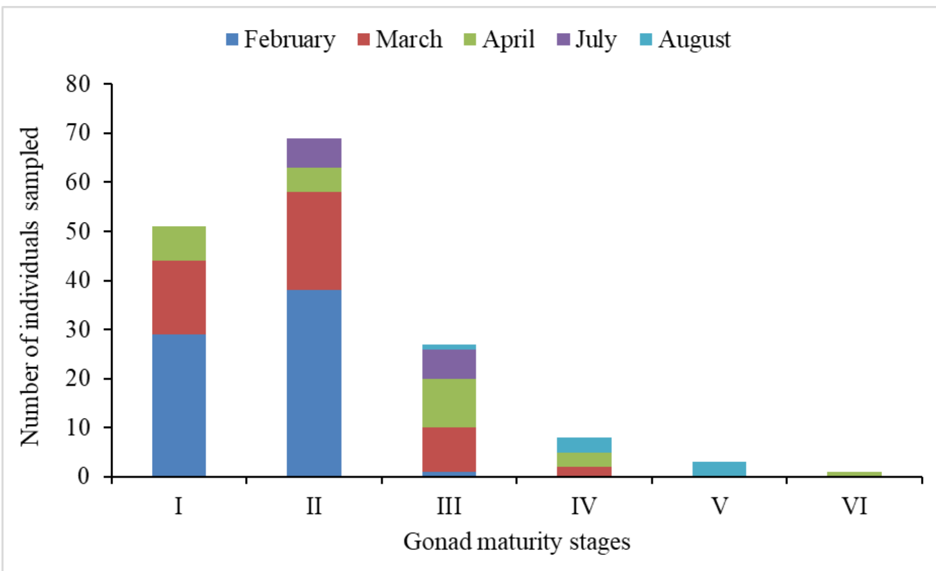

Figure 8. Monthly gonad maturity composition of *Leptoscarus vaigiensis* from beach seines sampled at Majoreni, south coast Kenya (sexes combined)

An overall total of 125 individuals of *Siganus sutor* were sampled for gonad maturity analysis representing 42 female individuals (33.6 %) and 83 male individuals (66.4 %). From the overall total of *S. sutor*, 98.4 % represented immature individuals (maturity stages I and II) and only 1.6 % represented mature individuals (maturity stage VI).

Throughout the sampling period, *S. sutor* recorded more immature gonad maturity levels of between 95 – 100 % (Figure 9).

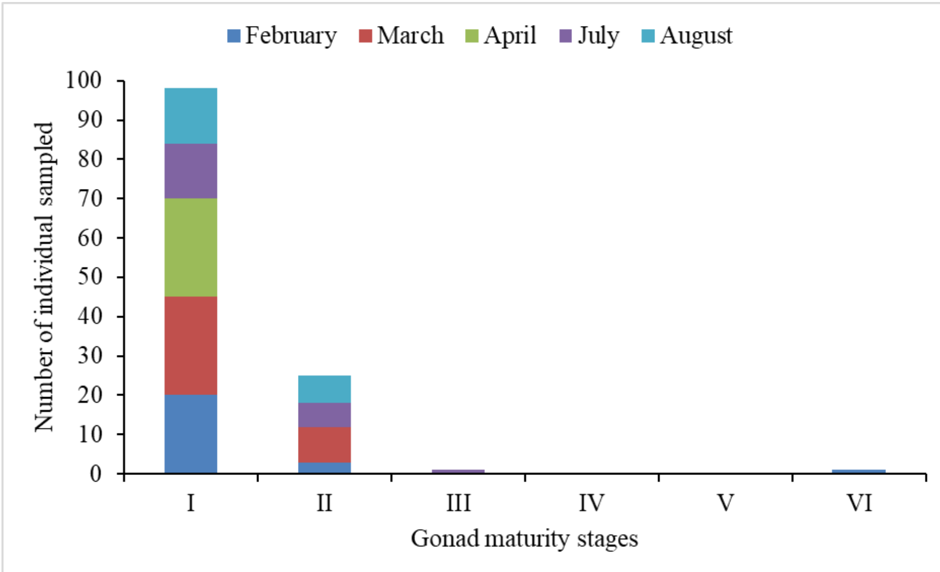

Figure 9. Monthly gonad maturity composition of *Siganus sutor* from beach seines sampled at Majoreni, south coast Kenya over the study period (sexes combined)

4.4 Monthly mean sizes of *Siganus sutor* and *Leptoscarus vaigeinsis*

Larger sizes of *Siganus sutor* were landed in the months of February and March with mean total lengths of 20.1 ± 2.4 cm and 19.6 ± 2.4 cm, respectively coinciding with the NEM season. Smaller individuals of the same species were observed in April (18.6 ±1.4 cm), July (19.2 ± 4.5 cm), and August (16.6 ±1.9 cm) coinciding with the SEM season (Figure 10). Results of non-parametric Kruskal-Wallis test indicated significant difference in sizes of *S. sutor* between months (H = 27.026; p = 0.000). Results of multiple comparison tests confirmed significant differences in sizes between August and February (p = 0.00002) and between August and March (p = 0.0001). The length at 50% maturity (L_{50}) for *Siganus sutor* was 22.8 cm based on gonad maturity proportions from a total of 84 individuals (Figure 11).

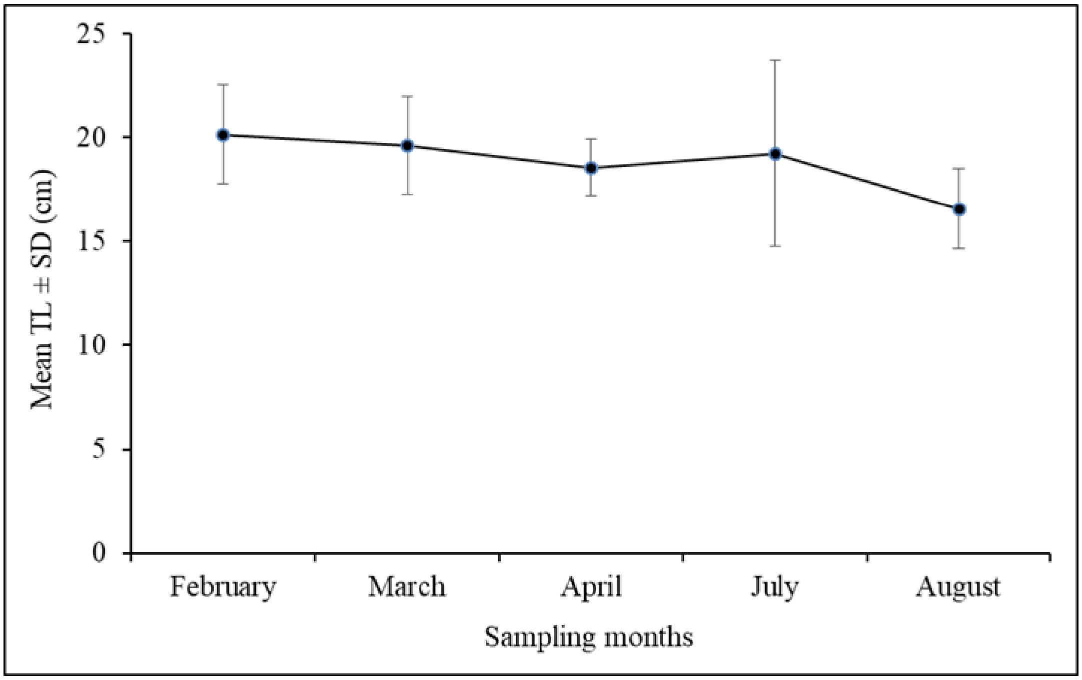

Figure 10. Monthly mean (± SD) sizes of *Leptoscarus vaigiensis* from beach seines sampled at Majoreni, south coast Kenya over the study period

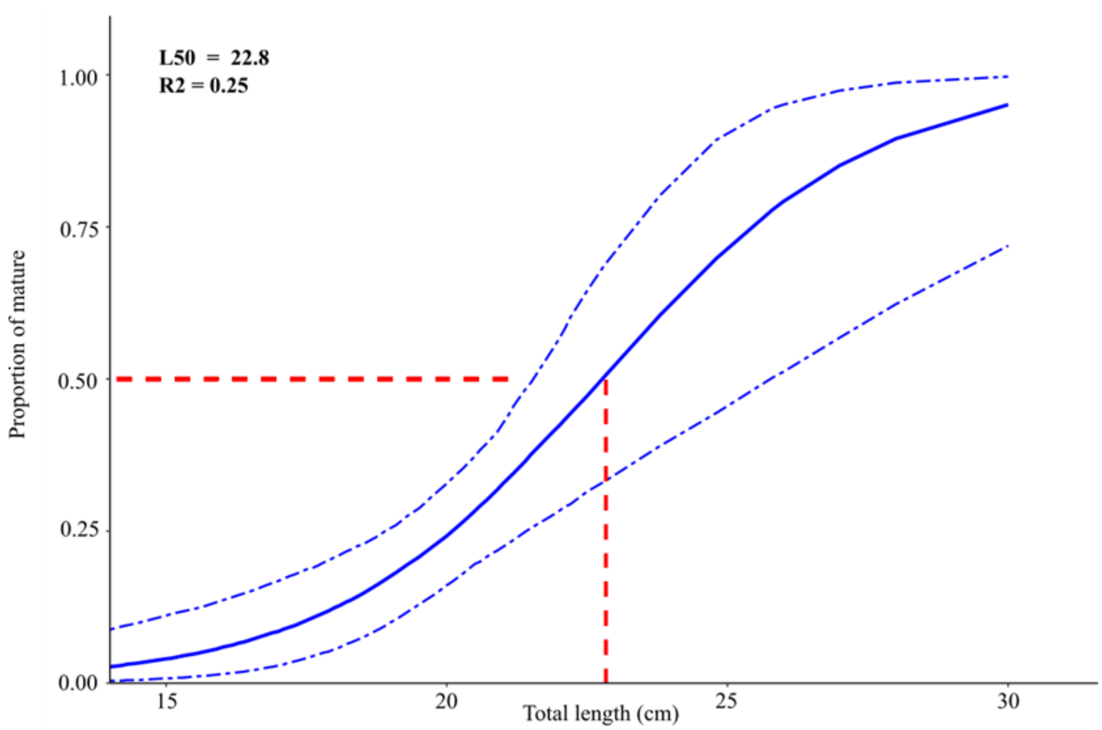

Figure 11. Length at first maturity for *Siganus sutor* sampled in south coast Kenya over the study period

Smaller mean sizes of *Leptoscarus vaigiensis* were landed in the months of February and March with mean TL of 15.5 ± 1.5 cm and 16.9 ± 2.5 cm, respectively coinciding with the NEM season. Larger mean sizes of the same species were observed in April (19.4 ± 2.0 cm), July (18.6 ± 3.6 cm), and August (20.1 ± 3.2 cm) coinciding with the SEM season (Figure 12). Results of non-parametric Kruskal-Wallis test indicated a significant difference in sizes of *S. sutor* between months (H = 50.497; p = 0.000). More results of multiple comparison tests confirmed February significantly differed from April, July, and August ($p < 0.0001$ in all cases), and April significantly differed from March ($p = 0.0008$). The length at 50% maturity (L_{50}) for *L. vaigeinsis* was 14.5 cm based on gonad maturity proportions from a total of 159 individuals (Figure 13).

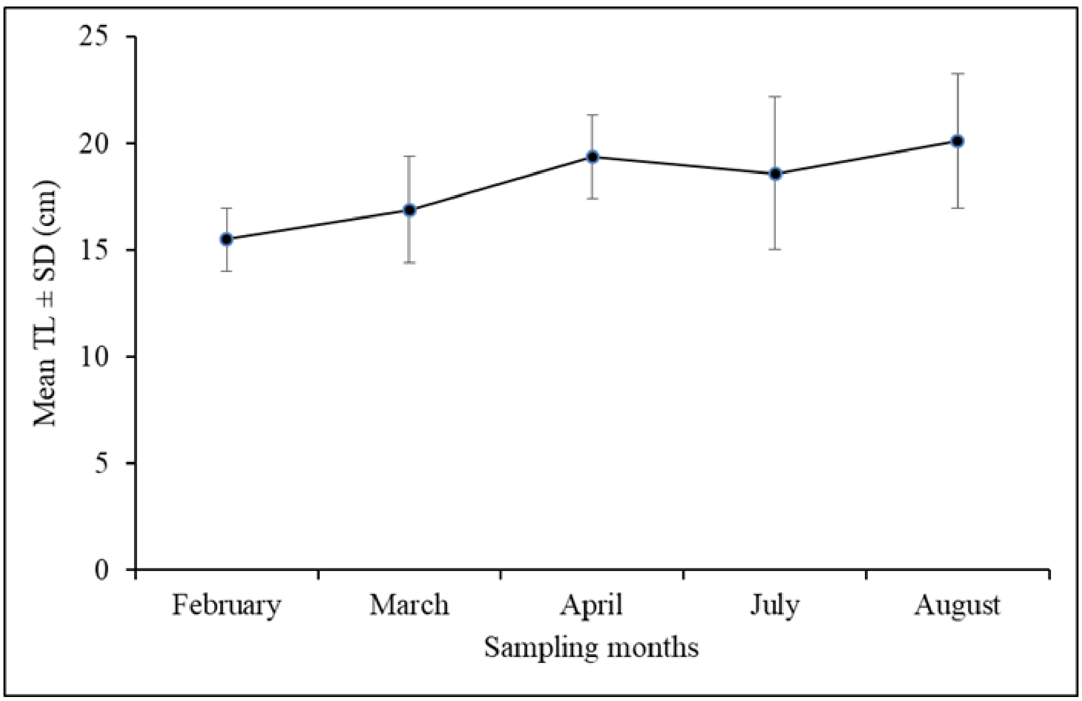

Figure 12. Seasonal mean (± SD) sizes of *Leptoscarus vaigiensis* from beach seines sampled in Majoreni, south coast Kenya over the study period

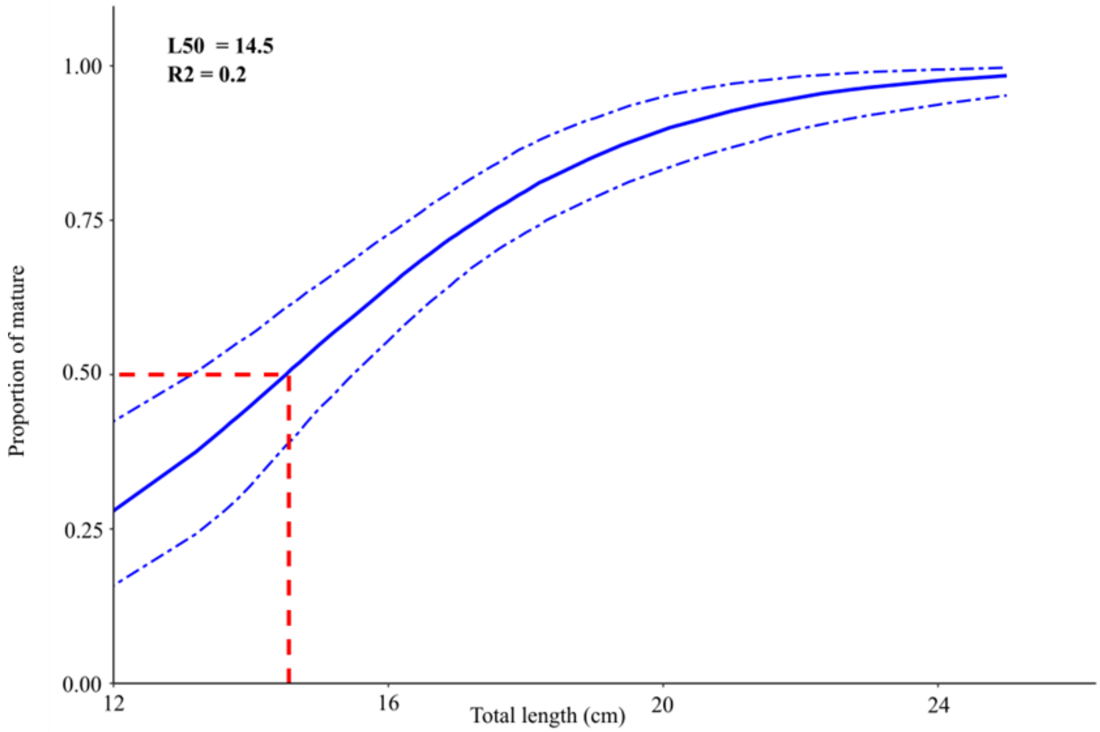

Figure 13. Length at first maturity for *Leptoscarus vaigiensis* sampled in south coast Kenya over the study period

4.5 Length-Weight Relationship

Mixed sex data were used to determine the seasonal length-weight relationship (LWR) for *S. sutor* (Figure 14) and *L. vaigiensis* (Figure 15). For *S. sutor* during the NEM season, this relationship was described by the equation Log y = 3.8103 Log TL – 6.7929 (r^2 = 0.795); and described by the equation Log y = 3.2099 Log TL – 4.8849 (r^2 = 0.8251) during the SEM season. For *L. vaigiensis*, LWR was described by the equations Log y = 3.2115 Log TL – 4.8145 and Log y = 3.1256 Log TL – 4.5465 during the NEM and SEM seasons with r^2 = 0.9457 and 0.9492, respectively. The values r^2 were thus higher during SEM season for both species. The '*b*' values were 3.81 for *Siganus sutor* and 3.21 for *L. vaigiensis* during NEM and 3.21 for *S. sutor* and 3.13 for *L. vaigiensis* during SEM. The '*b*' values were higher during NEM than during SEM (Figures 14 and 15). These '*b*' values are indicative of a positive allometric growth pattern.

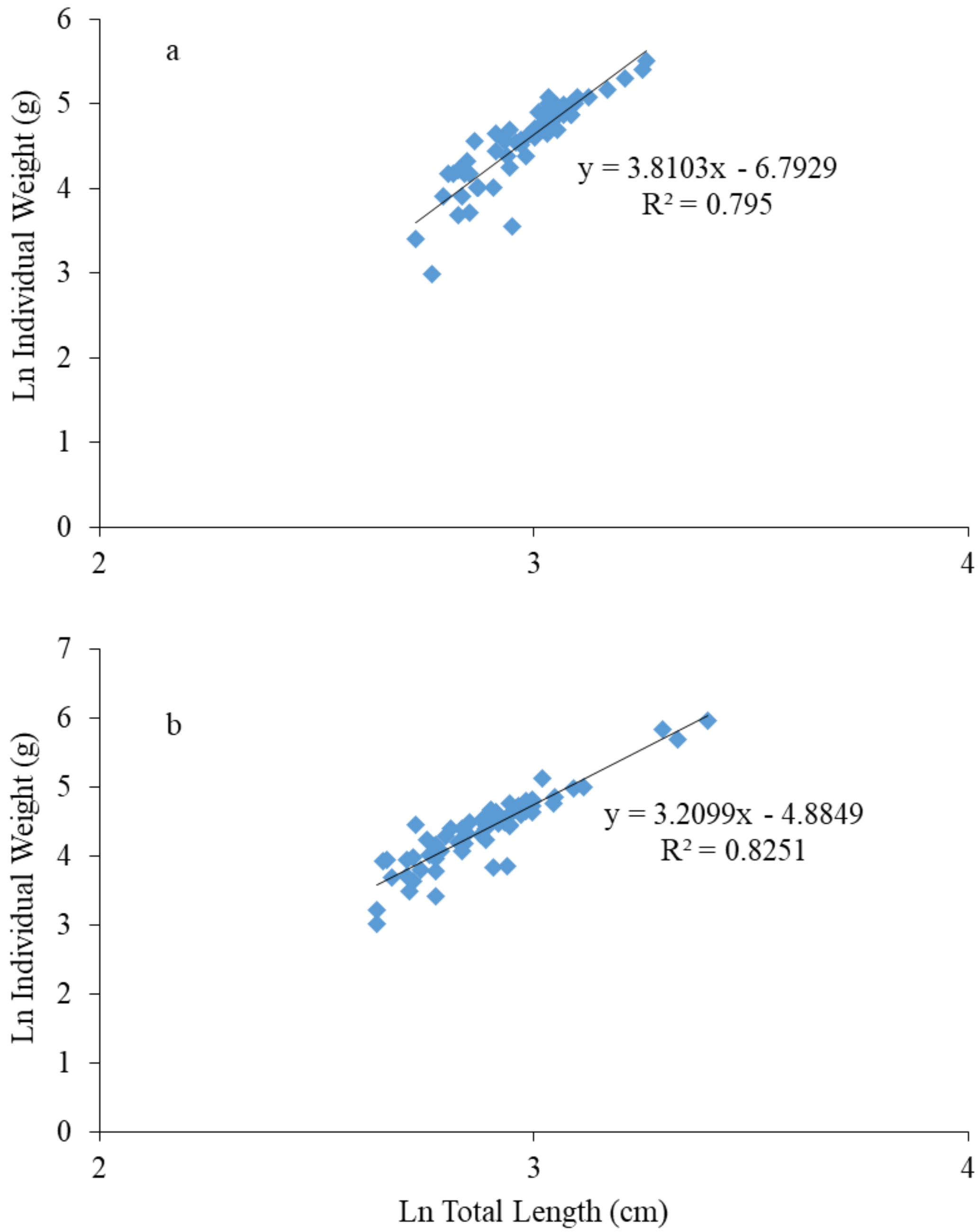

Figure 14. Length-weight relationship for *Siganus sutor* sampled in a) northeast monsoon season, and b) southeast monsoon season at Majoreni, south coast Kenya over the study period

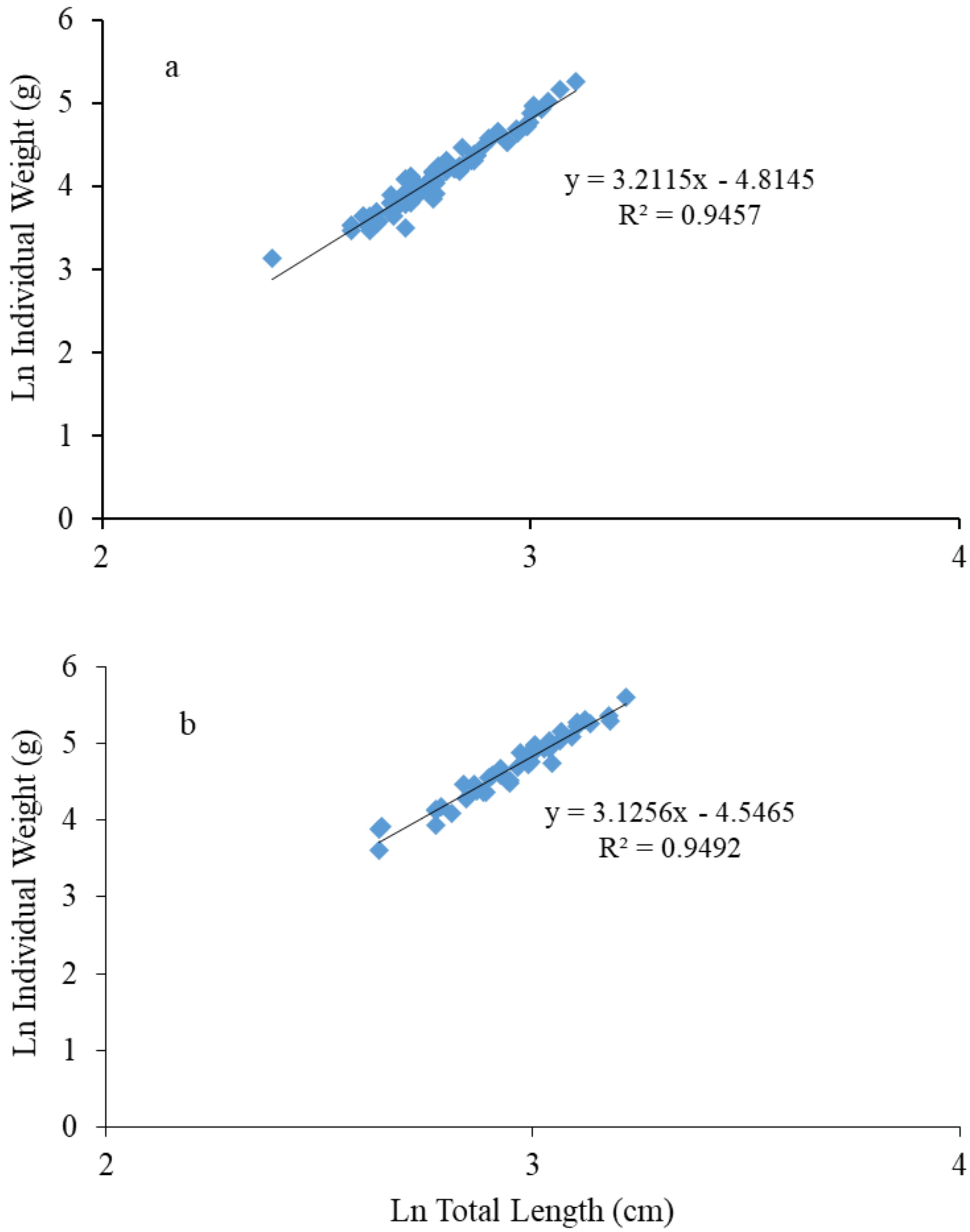

Figure 15. Length-weight relationship for *Leptoscarus vaigiensis* sampled in a) northeast monsoon season, and b) southeast monsoon season at Majoreni, south coast Kenya over the study period

CHAPTER FIVE

5.0 DISCUSSION

5.1 Beach Seining at Majoreni

Beach seine nets are still commonly used in Majoreni as depicted by the existence of a relatively high number of these nets recorded in the area. A total of seven beach seine nets were observed and studied over the study period at Majoreni. Such a number is considered relatively high at a single fish landing site as beach seines are considered large nets measuring up to a length of 150 m. Therefore, the impact of such relatively large number of beach seines on a site is bound to be destructive both to the benthic environment as well as to the targeted and associated by-catch species. Beach seine nets have a tendency of attracting youthful fishers as the gear provides accessible labor as crew. The gear being actively operated has the tendency of attracting energetic and youthful fishers who find ready employment as a requirement of the gear. Up to a crew size of at most 30 fishers per beach seine net has been recorded (Mangi and Roberts, 2006) depending on the size of the net and the boat used. Also, a relatively small crew size of between 4 – 13 fishers associated with this gear has been reported by Okemwa et al., (2017) for smaller boats of not more than 6 m as also observed in the present study where the crew size was 4-5 individuals per boat

5.2 Beach Seine Net Productivity at Majoreni

The catch rate for beach seines at Majoreni, south coast Kenya was relatively low at a daily average of 1.51 ± 0.15 kg/fisher/day compared to catches of other artisanal fishing gears (Okemwa et al., 2017). This recorded daily catch rate is considered the lowest compared to the productivity of other artisanal fishing gear, and this is attributed to the landing of small-size and juvenile individuals associated with the destructive and unselective nature of beach seines.(Mangi and Roberts, 2006; Karama et al., 2017). Higher proportions of undersized individuals landed by beach seines have been reported in other studies. For example, undersized individuals of the species *Lethrinus xanthchilus*, *Lethrinus nebulosus*, and *Lethrinus harak* have been landed by beach seines at between 94 % to 100 % and this is indicative of serious growth overfishing (Mangi and Roberts, 2006) threatening the sustainability of the artisanal fishery along the Kenya coast. The negative impacts of beach seining are exacerbated by reducing further the mesh size of the net's cod-end and this has been reported in the Lamu beach seine fishery (Karama et al., 2017) where reduced mesh size of beach seine cod-end has been associated with higher proportions of discards. Among six artisanal fishing gear studied, beach seine was reported with the lowest catches of 2.77 kg/fisher/day compared to small-scale purse seines (15.1kg/fisher/day), large mesh gillnets (8.25kg/fisher/day), small mesh gillnets (7.23kg/fisher/day), hand lines with 4.53kg/fisher/day, and reef seines (4.16 kg/fisher/day) (Okemwa et al., 2017).

Artisanal fish catches have been known to vary with seasons along the entire Kenya coast (McClanahan, 1988; Fondo, 2004). Monthly landing comparisons of beach seines varied where higher landings were observed in the months of July and August coinciding with the SEM season compared to February and March coinciding with the NEM season. These differences in monthly landings were however not significant (Figure 5). Usually, the fishing effort is higher during the NEM season and this is characterized by calm waters allowing smooth running of fishing activities and navigation to and from the fishing grounds. On the other hand, fishing effort is lower during the SEM season characterized by rough sea conditions where fishing and navigation operations become difficulty and dangerous with the small boats where the majority are manually operated by either wind sails or oars (Signa et al., 2008). However, high fishing effort such as that of beach seines does not always correspond to high fish catches as evidenced by previous studies (McClanahan and Mangi, 2001; Cinner et al., 2009). Higher fish catches can also be experienced during the SEM season, especially in safer and sheltered fishing grounds with calm waters (Mirriam, 2010). This was the case for Majoreni fishing grounds in this study where higher landings from beach seines were observed in the months of July and August (Figure 5).

The higher catches for beach seines at Majoreni observed in the months of July and August could be an indication that beach seine fishers prefer fishing during this season to avoid competition over resource use from other artisanal fishers such as spear gun and basket trap fishers with reduced fishing activities during the SEM season. This is supported by findings of a study by Signa et al., (2008) on the social, economic, and environmental impacts of beach seining in Kenya, which reported that beach seine fishers preferred operating during the SEM season however, in shallow and protected fishing grounds from strong winds and waves.

The results of the present study concur with several studies which have shown that *S. sutor* and *L. vaigiensis* make up the highest proportions of overall artisanal landings, especially on the south coast of Kenya (Fondo, 2004; Locham et al., 2010). In the present study, these two species contributed 32.8 % of the overall total landings sampled over the study period. In the present study, the abundance of *S. sutor* and *L. vaigiensis* were observed to be highest in the months of July and August coinciding with the SEM season (Tables 4 and 5) compared to other fish species.

5.3 Sizes and Length at First Maturity of *Siganus sutor* and *Leptoscarus vaigiensis*

Majority of *S. sutor* and *L. vaigeinsis* individuals were undersized and immature. Undersized and immature *L. vaigeinsis* individuals measured less than 18 cm in total length and those of *S. sutor* measured less than 15 cm in total length (Figures 12 and 14). Monthly size differences were observed where larger sizes of *S. sutor* were recorded in the months of February and March coinciding with the NEM season (Figure 12) and larger sizes of *L. vaigiensis* were recorded in the months of April, July, and August coinciding with the SEM season (Figure 14). Immature *S. sutor* individuals dominated landings throughout the study period (Figure 9) and immature individuals of *L. vaigiensis* dominated in the months of February and March (Figure 8). The length at 50% maturity of these two species recorded in this present study to some extent differed from those of a previous study by Mangi and Roberts (2006). In this present study, the length at 50% of *S. sutor* was larger at 22.8 cm compared to 20.3 cm (Figure 13) and smaller for *L. vaigeinsis* at 14.5 cm compared to 15.1 cm (Figure 15). These differences in length at 50% maturity for the two species in this present study indicate differential exploitation levels by the beach seines with *L. vaigeinsis* experiencing more pressure compared to *S. sutor*.

The species *L. vaigiensis* despite being exploited at small sizes, influences the fish to undergo early maturity so as to contribute to the next generation to avoid being wiped out by the negative impacts of beach seines. For *S. sutor*, gonad maturity composition remained similar throughout the study period. The generally high proportions of juvenile or small-sized individuals of these species are due to the small mesh size associated with beach seine nets at 1 – 3 cm. Landing of smaller-sized individuals by beach seines was noted to contribute to the low productivity of this gear (McClanahan and Mangi, 2001; Cinner et al., 2009).

Along the East African coast, fish spawning is known to occur throughout the year with a peak during the NEM season for both pelagic and demersal fish species (Fondo, 2004; Locham et al., 2010). Studies have also shown that *S. sutor* spawns during the NEM season (Samoilys et al., 2013). This likely explains the high abundance of individuals with mature gonads of *S. sutor* and *L. vaigiensis* during this season. Locham et al., (2010) observed that the occurrence of mature gonad stages in *L. vaigiensis* was throughout the year indicating continuous spawning of this species across sites. The study also showed a higher abundance of mature gonad stages of IV and V during the months of April and May in partially protected fishing grounds, April and July in strictly protected sites, June and July in non-protected sites (Locham, 2016). The same author reported a higher percentage of spent gonads (maturity stage VI) in July among park and reserve sites and in October in non-protected sites. This agrees with the results of this present study which indicated that most mature individuals of *L. vaigiensis* in gonad maturity stages III and above were recorded during the months of April, July, and August coinciding with the SEM season (Figure 8).

Agembe (2012) observed two distinct spawning peaks for *S. sutor*, a short peak in June-July and a more protracted peak from November to January/February. The results of this study (Figure 10) illustrate a different trend where a higher abundance of immature gonad maturity stages of *S. sutor* to occur throughout the study period. The month of October according to Agembe (2012) was observed to be the likely period when the onset of ovary maturation occurs for this species. These results concur with previous work on the spawning seasonality of *S. sutor* by Ntiba and Jaccarini (1990), who also found two distinct peak spawning seasons for *S. sutor* in Kenyan coastal waters. In contrast, the current findings differ from those of de Souza (1988), which showed that *S. sutor* spawns throughout the year in Kenyan inshore waters thereby agreeing with this present study.

Tanzanian populations of *S. sutor* exhibit a less protracted spawning season than populations in Kenya (Kamukuru, 2006).

5.4 Length-Weight Relationship of the Target Species

Length-weight relationship of *Siganus sutor* and *Leptoscarus vaigiensis* were analyzed for impacts of beach seine at Majoreni. The high r^2 values recorded in this present study (Figures 14 and 15) show that there is a very strong and positive correlation between total length and body weight of these two species in both seasons. The '*b*' values of the sampled two species were greater than 3.0 indicating a likelihood for positive allometric growth (Akinyi et al., 2018; Anam et al., 2019; Mrombo et al., 2019), meaning that the fish increase in relative body weight as total length increases. A study by Mbaru et al., (2010) on the length-weight relationship of 39 selected reef fishes in the Kenyan coastal artisanal fishery also found comparable results with *b* value of 3.290 for *S. sutor*, and 3.541 for *L. vaigiensis*. Therefore, the results of the length-weight relationship for *S. sutor* and *L. vaigiensis* of the beach at Majoreni indicate that these two fish species are healthy and in good condition. The good condition of these two species indicates that the impacts of beach seine on these species have not been harmful.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

Despite the beach seine fishing gear being illegal and destructive, it is still commonly used in Majoreni in south coast Kenya as depicted by the findings of this study. This study has shown that the existing efforts by the fisheries managers through the available government regulations such as the Fisheries Management and Development Act – No. 35 of 2016 and the revised Fisheries (Beach Management Units) Regulations of 2021 in place, it is still difficult to enforce the use of this fishing gear along the Kenya coast. The use of this gear can in part be regulated by observing the appropriate mesh size of the gear apart from imposition of a ban which has been very difficult to implement due to local community resistance as observed in Lamu area. The increase in mesh size of especially the cod-end of the gear could reduce the catch of small-size individuals and improve fisheries sustainability. Despite the effectiveness of this fishing gear, findings of this study indicate a lower catch productivity compared to other artisanal fishing gears that are more sustainable such as the hook and line, gill nets with the recommended mesh size, and basket traps.

The results of this study show that *Leptoscarus vaigiensis* and *Siganus sutor* together contributed 32.8% of overall total landings sampled over the study period. This is a confirmation that these two fish species remain a high target of the beach seine fishery. Improved management of this gear will therefore, help to reduce the exploitation of these commercial species. Despite being landed in higher numbers, the two species of *L. vaigeinsis* and *S. sutor* were also composed of higher abundance of immature and under size individuals adding more threats and pressure to the sustainability of these fish species. In terms of length at 50% maturity, findings of this study indicate that the beach seine gear was more exploitative to *L. vaigeinsis* compared to *S. sutor*. The gear landed larger individuals of *S. sutor* at 50% maturity than *L. vaigeinsis* which were landed at much more smaller size at 50% maturity.

Despite this gear showing negative impact to these two commercial fish species, there was still a very strong and positive correlation between total length and body weight of these two species was evident as indicated by the results of length-weight relationship. This means that the growth of these two species was still normal and in good condition despite the pressure imposed by this gear. However, this outcome needs to be confirmed.

Based on these conclusions, this study, therefore, recommends the following:

- Fisheries managers in consultation with Beach Management Units (BMUs) and beach seine fishers, undertake tests of beach seine modifications regarding limits on the length, height, and mesh sizes to technically improve beach seine gear to reduce catches of juvenile fishes;
- Fisheries managers in consultation with BMUs and beach seine fishers to implement a seasonal closure for beach seine fishing in Majoreni fishing grounds as a management measure to reduce the existing pressure on the two commercial fish species of *L. vaigensis* and *S. sutor*
- There is a need to support fishers to shift from using beach seines by providing them with alternative sustainable options to enable them to access pelagic fisheries resources in offshore waters to reduce pressure in near shore fishing grounds
- A longer-term study to be conducted to monitor the impacts of beach seines at Majoreni on the health condition of *Siganus sutor* and *Leptoscarus vaigiensis* using the length-weight relationship already explored in this present study and the length at 50% maturity to confirm the findings of this study for the two target fish species.

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LIST OF APPENDICES

Appendix 1. Beach seine species abundance by weight sampled at Majoreni fish landing site over the study period

No.	Species	Family	Weight (kg)	Relative abundance (%)
1	*Siganus sutor*	Siganidae	35.82	19.53
2	*Leptoscarus vaigiensis*	Scaridae	22.19	12.10
3	*Valamugil seheli*	Mugilidae	17.3	9.43
4	*Pomadysis multimaculatum*	Haemulidae	16.2	8.83
5	*Lutjanus argentmaculatus*	Lutjanidae	10.4	5.67
6	*Lethrinus lentjan*	Lethrinidae	8.8	4.80
7	*Tylosurus crocodilus*	Belonidae	7.1	3.87
8	*Parupenus barberinus*	Scaridae	6.2	3.38
9	*Siganus canaliculatus*	Siganidae	4	2.18
10	*Lethrinus nebulosus*	Lethrinidae	3.5	1.91
11	*Pristipoma plagiodesmus*	Haemulidae	3.2	1.74
12	*Plectorychus pictus*	Haemulidae	3.26	1.78
13	*Rastrelliger kanagurta*	Scombridae	2.48	1.35
14	*Lethrinus harak*	Lethrinidae	2.45	1.34
15	*Caranx heberi*	Carangidae	2.38	1.30
16	*Gerres oyena*	Gerreidae	2.14	1.17

17	*Lutjanus fulviflamma*	Lutjanidae	1.85	1.01
18	*Alectis ciliaris*	Carangidae	1.74	0.95
19	*Carangoides spp*	Carangidae	1.70	0.93
20	*Scolopsis bimaculatus*	Nemipteridae	1.60	0.87
21	*Parupeneus barberinus*	Scaridae	1.48	0.81
22	*Parupeneus cyclostomus*	Scaridae	1.26	0.69
23	*Parupeneus heptecanthus*	Scaridae	2.14	1.17
24	*Sphyraena barracuda*	Sphyraenidae	3.36	1.83
25	*Scarus rubroviolaceus*	Scaridae	1.10	0.60
26	*Epinephelus coioides*	Serranidae	1.00	0.55
27	*Scarus ghobban*	Scaridae	1.01	0.55
28	*Epinephelus malabaricus*	Serranidae	0.96	0.52
29	*Platycephalus crocodilus*	Platicephalidae	0.89	0.49
30	*Sphyraena putnamae*	Sphyraenidae	0.87	0.47
31	*Scarus russelii*	Scaridae	0.87	0.47
32	*Diagramma pictum*	Haemulidae	1.37	0.75
33	*Lethrinus harak*	Lethrinidae	0.83	0.45
34	*Scarus sordidus*	Scaridae	0.81	0.44
35	*Parascolopsis erioma*	Nemipteridae	0.81	0.44
36	*Hemiramphus affinis*	Hemiramphidae	0.79	0.43
37	*Lethrinus elongatus*	Lethrinidae	0.79	0.43

38	*Epinephelus merra*	Serranidae	0.78	0.43
39	*Hipposcarus haris*	Scaridae	0.76	0.41
40	*Calotomus carolinus*	Scaridae	0.70	0.38
41	*Plectorhinchus gaterinus*	Haemulidae	0.57	0.31
42	*Parupeneus bondanensis*	Scaridae	0.57	0.31
43	*Panulirus longipes*	Panuliridae	0.49	0.27
44	*Plectorynchus chubbi*	Haemulidae	0.59	0.32
45	*Sillago sihama*	Sillaginidae	0.45	0.25
46	*Epinephelus rogaa*	Serranidae	0.41	0.22
47	*Trichinotus blochii*	Carangidae	0.38	0.21
48	*Acanthunthrus teneti*	Acanthuridae	0.36	0.20
49	*Caranx ignobilis*	Carangidae	0.35	0.19
50	*Acanthunthrus xanthopterus*	Acanthuridae	0.30	0.16
51	*Tylosurus crocodilus*	Belonidae	0.26	0.14
52	*Bothus mancus*	Bothidae	0.25	0.14
53	*Gerres filamentosus*	Gerreidae	0.25	0.14
54	*Sphyraena jello*	Sphyraenidae	0.24	0.13
55	*Platax pinnatus*	Ephippidae	0.21	0.11
56	*Sigunus canaliculatus*	Siganidae	0.12	0.07
57	*Siganus stellatus*	Siganidae	0.11	0.06
58	*Cheilinus chlorulus*	Scaridae	0.08	0.04

59	*Plectorynchus flavomaculatus*	Haemulidae	0.08	0.04
60	*Siganus luridus*	Scaridae	0.08	0.04
61	*Leiognathas fasciatus*	Leiogathidae	0.08	0.04
62	*Sphyraena spp*	Sphyraenidae	0.07	0.04
63	*Scolopsis ghanam*	Nemipteridae	0.06	0.03
64	*Monodactylus argenteus*	Monodactylidae	0.06	0.03
65	*Plectorynchus quatrimaculatus*	Haemulidae	0.04	0.02
66	*Scolopsis vosmeri*	Nemipteridae	0.04	0.02
67	*Plectorhynchus erioma*	Haemulidae	0.03	0.02
			183.42	100