A STUDY ON GROWTH PERFORMANCE AND VIABILITY OF THREE MARINE FISH SPECIES UNDER CAGE CULTURE IN THE KENYAN COAST

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DECLARATION

Declaration by the candidate

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DEDICATION

This thesis is dedicated to my beloved husband and children for their positive contribution in my life.

ABSTRACT

This study set out to investigate and compare the growth performance and viabilities of three different marine fish species for commercial cage culture. The study was carried out in Makongeni village along Kenya coast from April 2012 to November 2012 with three marine species: maze rabbit fish (*Siganus vermiculatus* Valenciennes, 1835), red snapper (*Lutjanus argentimaculatus*) and milk fish (*Chanos chanos*). The experiment consisted of 12 floating cages, four cages for each species and each cage holding a total of 50 juvenile fish of weight between 50-70 gm, reared for six months. Monthly variations of mean weight for each species in each of the cages show that milkfish had the highest final body weight (150.4 ± 4.8 g); whereas rabbit fish had the lowest final weight of 101 ± 3.63 g. The final mean length for each species also show that milk fish had the highest final mean total length (24.1 ± 0.53 cm) followed by rabbit fish (19.5 ± 0.52 cm) and lastly by red snapper (17.5 ± 0.22 cm). The growth parameter were L_∞ of 45.53, 37.96 and 20 cm for milkfish, rabbit fish and red snapper respectively while the corresponding growth constant (K) were 0.398, 0. 526 and 0.729 respectively. The growth performance index was highest for milkfish ($\varnothing=1.71$ and $\varnothing'=2.92$) while the Specific Growth Rate (SGR) was also highest for milkfish (0.65%) as compared to rabbit fish (0.53%) and red snapper (0.33%). The length weight relationship showed a positive allometric growth for milk fish ($b=3.8$; $R^2=0.800$) and negative allometric growth for both red snapper ($b=1.7$; $R^2=0.811$) and rabbit fish ($b=2.8$; $R^2=0.895$). The best Feed Conversion Ratio (FCR) was obtained in milk fish (4.45 ±0.65) and highest in red snapper (10.56 ± 1.12). Rabbit fish on the other hand recorded an FCR of 6.04 ± 0.71. Milkfish had high mortality and low survival (81%) as compared to rabbit fish (93.5%) and snapper (91%). Milk fish were found to be more viable compared to other two at a net profit of KShs. 914.00. Based on the results of growth rate, feed conversion ratio, survival and economic viability, it is concluded that milkfish is the best candidate for culture as compared to the other two test species. Intensive pilot culture of milk fish should be undertaken in cages, develop an enterprise budget and business plan for commercialization with parallel research and development of suitable feeds.

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LIST OF ACRONYMS AND ABBREVIATIONS

EEZ	Exclusive Economic Zone
ESP	Economic Stimulus Programme
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed Conversion Rate
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GoK	Government of Kenya
K	Condition Factor
LWR	Length-Weight Relationship
PWG	Percent Weight Gain
SEAFDEC	South East Asia Fisheries Development Centre
SEM	Standard Error of the Mean
SGR	Specific Growth Rate
SSR	Sum of Squared Residuals

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Populations in numerous countries around the world are increasingly suffering from hunger, malnutrition and lack of protein in their diet (FAO, 2008). Since capture fisheries cannot be expanded beyond its natural productivity, aquaculture is becoming an important source of animal protein for human consumption and a considerable economic factor, supplying secure, year round employment to many people. Over the last 50 years, aquaculture has become a worldwide industry. FAO (2013) observed that aquaculture production has realized over 40% growth over the previous two decades. The importance of aquaculture has become even more apparent at present, with higher demanding pressure from an ever-increasing world population.

Kenya has large and several natural water resources which include springs, wetlands, water reservoirs, temporary water bodies, lakes, rivers and marine waters that provide a huge potential for not only the wild fisheries but also aquaculture development (Rothuis *et al.,* 2011). The vast water resources favor the culture of a wide variety of aquatic species both marine and freshwater (GoK, 2010). According to GoK (2007), aquaculture presently accounts for about 2.5% of total fish production in Kenya, inland capture fisheries accounts for 93% and marine capture fisheries 4.5%. Overally, the Kenya fisheries sector contributes only 0.5% to Kenya's Gross Domestic Product (GDP), which is an unfortunate circumstance given the large water resources (Fisheries Department, 2012). This scenario is partly due to the inability of the country to exploit the marine resources and the small scale and limited aquaculture development (GoK, 2010).

According to FAO (2005), aquaculture in Kenya was at its infancy stage but had the potential to change the estimated natural fish production three-fold. At present (FAO, 2013), fisheries production is estimated to support the livelihood of over half a million Kenyans either directly or indirectly and this can increase to about 3 million Kenyans if exploited sustainably to its potential. Over 90% of the total fish production is derived from Lake Victoria while the Indian Ocean contributes about 5% (FAO, 2013). This insignificant marine fish production is due to the inability to invest in the exploitation of the vast existing potential in the 200 nautical mile Exclusive Economic Zone (EEZ).

According to Mbugua (2008), for quite a long time there has been an un-receptive perception of aquaculture as an economic activity in Kenya. This has made it difficult to promote its commercialization since most potential investors are not convinced that aquaculture can be a profitable enterprise. Despite these perceptions, fisheries industry has been recognized as a key player in the economic and social development of Kenya (FAO, 2013). Aquaculture provides a source of subsistence and livelihood to the fish farmers and the local community (Ngugi & Manyala, 2009). Fisheries industry earns revenue to the Government of Kenya in terms of foreign exchange with a high potential to 12% annual increase. Due to the potential for aquaculture growth, the Government of Kenya has recognized the ability of this industry to steer economic growth and is actively identifying and mitigating the challenges facing the sub-sector (GoK, 2009a).

A number of reports and documents (Pillay, 1997; Hishamunda & Ridler, 2004; Mbugua, 2008; GoK, 2009a) observe that aquaculture can play a key role in provision of protein food and reduction of fishing pressure in capture fisheries. Aquaculture in Kenya is therefore receiving more attention which has led to gradual change from rearing of fish for only subsistence purpose to small-scale commercial culture (Hishamunda *et al*., 2009). The aquaculture industry is transitioning from the rural subsistence enterprise to a more commercial profit-oriented aqua-business. In order to achieve this, aquaculture needs to be expanded by increasing the number of farmers in the country and species under domestication.

According to Mwamunye *et al*., (2012), one of the obstacles to Economic Stimulus Programme (ESP) in aquaculture performance is the limited number of domesticated marine species which are highly treasured by the coastal community. The purpose of this project was therefore to recommend to farmers at the coast fish species that can be cultured with economic gains.

1.2 Statement of the Problem

Due to the increased population, education and awareness, the demand for white meat is so high in Kenya that it cannot be met by the present production from capture fisheries (Mbugua, 2008). This has contributed to increased demand for fish to improve the overall health of the Kenyan society. In an attempt to meet this demand, the Kenyan population has relied on capture fisheries which are not only insufficient but also declining (FAO, 2010). This situation calls for urgent action to solve the eminent crisis of depleted fish stocks and malnutrition population which this study was designed to address.

1.3 Justification

Apart from the highly pressured capture fisheries, fish farming has the potential to produce enough fish for the national population and be a source of income to fish farmers (FAO, 2010). According to Mbugua (2008), commercial fish farming is influenced by demand, cost of production and financial returns at the end of the culture period.

Fish farmers along the Kenyan coast are constrained by knowledge and skills on the important commercial fin fish which can grow best in cages and generate income (GoK, 2009b). Species such as maze rabbit fish (*Siganus vermiculatus* Valenciennes 1835*)*, the mangrove red snappers (*Lutjanus argentimaculatus*), and the milkfish (*Chanos chanos*) appear to have considerable potential and have been recommended for feasibility studies for cage culture in an attempt to determine their performance (Ariyaratne, 2000). This study therefore seeks to evaluate the growth performance of each of the three potential culture species and access their potential for cage-based mariculture in order to uplift the living standard of marine fish farmers and provide the much needed white meat for increasing human population.

1.4 Objectives of Study

1.4.1 Overall objective

The overall objective of the study was to assess the growth performance and viability of Milk fish (*Chanos chanos* Forsskal, 1775), mangrove red snappers (*Lutjanus argentimaculatus*, Forsskål), maze rabbit fish (*Siganus vermiculatus* Valenciennes 1835*)* for cage-based mariculture in Kenya.

1.4.2 Specific objectives

The specific objectives of the study were to:

i) Estimate the monthly growth rates of the three fish species under cage culture.

ii) Determine length-weight relationship and condition factor for each of the three species

iii) Determine the Food Conversion Ratio for each of the three fish species.

iv) Determine the monthly mortalities and the economic value for each fish species at the end of culture period

v) Compare the growth performance and economic viability of culturing the three species.

1.5 Research Hypothesis

H_{01}: There is no significant variation in growth rates between the three fish species.

H_{02}: The condition factors for the three species do not differ significantly.

H_{03}: The food conversion ratios do not vary between the three species.

H_{04}: There are no significant differences in fish mortalities between the three species studied.

H_{05}: There are no significant differences in the economic values of the three species.

CHAPTER TWO

LITERATURE REVIEW

2.1 Ecology and Biology of the Fishes

2.1.1 Rabbit fish

Rabbit fishes or spine foots are perciform fishes in the family Siganidae **(**Kuriiwa *et al.*, 2007). The 28 species are in a single genus, *Siganus*. Rabbit fishes are native to shallow waters but *S. luridus* and *S. rivulatus* have become established in the eastern Mediterranean via Lessepsian migration. The largest rabbit fish grows to about 53 cm, but most species only reach 25 to 35 cm (9.8 and 14 in). All have large dark eyes and small, somewhat rabbit-like mouths which gives them their name. Most species have either bright colors or a complex pattern (Fishbase, 2004).

Another unusual feature among rabbit fishes is their pelvic fins, which are formed from two spines, with 3 soft rays between them. The dorsal fin bears 13 spines with 10 rays, while the anal fin has 7 spines and 9 rays; the fin spines are equipped with well-developed venom glands. All rabbit fish are diurnal, some live in schools while others live more solitary life among the corals. They are herbivorous, feeding on benthic algae in the wild (Froese & Pauly, 2006). Many Rabbit fishes are fished for food hence, their potential for culture as food fish, and the more colorful species especially the fox fish are often kept in aquaria where they are fed on algae and a variety of fresh vegetables.

2.1.2 Red snappers

The red snapper's body is very similar in shape to other snappers, such as the mangrove snapper, mutton snapper, lane snapper, and dog snapper (Halwart & Moehl, 2006). All feature a sloped profile, medium-to-large scales, a spiny dorsal fin and a laterally compressed body. Red snappers have short, sharp, needle-like teeth, but they lack the prominent upper canine teeth found on the mutton, dog, and mangrove snappers (Froese & Pauly, 2006). They reach maturity at a length of about 39 cm. The common adult length is 60 cm, but may reach 100 cm. The maximum published weight is 22.8 kg, and the oldest reported age is 57 years (Ameer & Mohamed 1992; Emata *et al.,* 1994). Coloration of the red snapper is light red, with more intense pigment on the back. It has 10 dorsal spines, 14 soft dorsal rays, three anal spines and eight to 9 anal soft rays. Juvenile fish (shorter than 30–35 cm) can also have a dark spot on their sides, below the anterior soft dorsal rays, which fades with age.

Red snapper is one of the commercial important species in India but culture of this species has not been established yet (FAO, 2013). Red snappers are usually cultured in floating net cages and pens in South East Asian countries (Biswas *et al*., 2012; Halwart, Soto & Arthur, 2007; Ameer & Mohamed 1992; Bensam, 1993). Red snapper are stocked at 5 fish m^{-2}, and take about 18 months to reach the preferred market size of 1,000 gm while typical production rates are 20 t ha^{-1} per cropping season (Biswas *et al*., 2012). Red snapper are usually fed on moist pellet feed, dry floating pellet, or trash fish. FCRs range from 2.2:1 to 2.5:1 for moist pellet and from

7:1 to 9:1 for trash fish. Red snapper are graded one month after stocking, when the fingerlings have reached 12 cm TL (Liao *et al*., 1995).

According to Liao *et al*. (1995), the main diet for red snapper in the nursery phase is the shrimp *Acetes chinensis* and chopped trash fish. Red snapper fingerlings produced during summer in temperate regions are usually sold directly to grow out farmers, but fry produced in autumn are usually stocked in nursery ponds for over-wintering and sold the following spring for higher prices. Red snapper are tolerant of low oxygen conditions, with a lethal oxygen concentration of 1.2 mg L^{-1} for fingerlings of 5.2 g at 30°C and 25 ppt. The body colour of red snapper darkens when the fish are fed artificial feeds and cultured at low salinity (10 ppt). Dark-bodied fish attract lower market prices. Body color can be improved by supplementing the feed with shrimp heads, xanthophylls or astaxanthin for two-to-three weeks before harvesting (Liao *et al*., 1995).

Mortalities in the nursery and grow out phases may be caused by *Amyloodinium ocellatum* and *Trichodina* sp. dense diatom or dinoflagelate blooms can cause bubble disease, impede gill function and may lead to high mortality (Rottman *et al*., 1992).

2.1.3 Milk Fish

Milkfish have a generally symmetrical and streamlined appearance, with a sizable forked caudal fin. They can grow to 1.70 m (5 ft 7 in) but are most often about 1 metre in length. They have no teeth and generally feed on algae and invertebrates. Milkfish aquaculture first occurred around 800 years ago in the Philippines and spread in Indonesia, Taiwan and into the Pacific. Traditional milkfish aquaculture relied upon restocking ponds by collecting wild fry. This led to a wide range of variability in quality and quantity between seasons and regions. In the late seventies, farmers first successfully spawned breeding fish. However, they were hard to obtain and produced unreliable egg viability. In 1980 the first spontaneously spawning happened in sea cages. These eggs were found to be sufficient to generate a constant supply for farms.

Fry are raised in either sea cages, large saline ponds (Philippines) or concrete tanks (Indonesia, Taiwan).

Milkfish reach sexual maturity at 1.5 kilograms, which takes 5 years in floating sea cages, but 8-10 years in ponds and tanks. Once 6 kilograms (13 lb) is reached (8 years) an average of 3-4 million eggs will be produced each breeding cycle. This is mainly done using natural environmental cues. However, there have been attempts using gonadotrophin-releasing hormone analogue to induce spawning (Duray, 1996). Some still use the traditional wild stock method. This involves capturing wild fry using nets.

Milkfish hatcheries, like hatcheries for many other fish species contain a variety of cultured and target species (SEAFDEC, 1995). For example rotifers, green algae and brine shrimp. They can either be intensive or semi-intensive. Semi-intensive methods are more profitable with it costing $6.67 US per 1000 fry in 1998, compared with $27.40 per 1000 fry for intensive methods. However, the experience required by labour for semi-intensive hatcheries is higher than intensive (Kühlmann, 1998).

Milkfish nurseries in Taiwan are highly commercial and have densities of about 2,000 individuals L^{-1}. Indonesia achieves similar densities but has more backyard-type nurseries. The Philippines have integrated nurseries with grow-out facilities and have densities of about 1,000 individuals L^{-1}. According to FAO (1997) the leading countries in production of farmed milkfish are Indonesia, the Philippines and Taiwan which produced about 157,000, 151,000 and 63,000 t respectively in 1995. Production of farmed milkfish occurs on a much smaller scale in some Pacific islands; for example in 1995, Guam 25 tones, and Kiribati 50 tones. Milkfish production increased continuously until the late 1980's but declined during early 1990's mainly because of deterioration of spawning grounds (coral reefs), nursery grounds (mangrove areas) and fry collecting grounds (sandy coast lines) (SEAFDEC, 1995). Moreover, many pond owners then changed to shrimp farming.

As for climate and environmental tolerance: Milkfish, except for spawning adults and the early larval stages, have very wide ranges of environmental tolerance (Chang *et al.* 2006; Pillay & Kutty, 2005; Bagarinao, 1991). Most juvenile stages tolerate low temperatures of 14 to 18 °C and high temperatures of 38 to 41 °C. In the Philippines wet season (May to October), milkfish pond temperatures range from 25 to 34°C, salinities from 15 to 25 ppt and dissolved oxygen from 4 to 11 ppm. In the dry season (November to April) there are similar fluctuations, but temperatures stay below 30°C from November to December and peak in February and March, sometimes exceeding 35°C and with concurrent salinities up to 40 ppt (Sumagaysay, 1994). Milkfish, except for spawning adults and early land stages, are remarkably euryhaline and tolerate all salinities from freshwater to hyper-saline lagoons. The pH preferred by milkfish is around 8.0 and more acidic waters such as ponds that are affected by acid sulphate sorts can depress growth and survival. Milkfish fry are still mainly caught from shallow inshore waters. Historically, catches of wild fry have been huge:

reaching over 1 billion annually in the Philippines and 700 to 800 million in Indonesia. However, artificial propagation and hatchery operations are being developed to avoid the unpredictable nature of supplies of fry from the wild (Duray, 1996).

During the 1980's, the first spontaneous maturation of hatchery-bred milkfish in captivity was observed after 3.5 to 5.5 years of rearing spawners in net cages (Hilomen-Garcia, 1997). Subsequent efforts have been made to induce spawning using gonadotropin-releasing hormone analogues (GnRH-A). In the Philippines, hatchery-bred fish have spawned spontaneously in net cages and concrete tanks, producing 50,000 to 956,000 eggs per spawning (Emata, 1995). Milkfish farming in Taiwan is now based almost entirely on hatchery-raised fry. Hatchery production stabilizes the supply of fry and can promote increased production of milkfish. According to Emata (1995), a milkfish hatchery needs larval rearing tanks, culture tanks for rotifers (*Brachionus*) and green algae (*Chlorella*), and hatching tanks for brine shrimp (*Artemia*). Milkfish eggs are collected from broodstock cages and hatching occurs after 14-16 hours (at 28-29°C) after collection. Hatching tanks have about 300 eggs per liter for maximum hatching success.

To obtain an optimum survival of 30-40%, larval rearing tanks are stocked at a density of 30 larvae per liter, with moderate aeration (23-33°C, 30-40 ppt) (Emata, 1995). A 'green water' technique is used, with *Chlorella* added in the morning, before feeding the larvae. Starting on day 2 until day 21 larvae are fed with rotifers. From day 15 to day 21, additional *Artemia nauplii* are added. Water exchange in the rearing tanks is 30% from day 2 until 14, 50 - 70% from day 15-21. Rearing milkfish larvae to fry in ponds involve drying the ponds, liming and fertilizing with1 to 3 t.ha-1 of chicken manure or 0.5 to 1.0 t.ha-1 of rice bran to develop natural foods. The water depth is gradually increased to 30 cm before stocking fry at 30 to 50 per m^2 (Sadovy, 2000). Post larvae begin to feed shortly after the eyes have become fully pigmented and before the yolk is completely reabsorbed. Unfed larvae all die about 150h from hatching at rearing temperatures of 25 to 27 °C. Postlarvae and fry are particulate, visual feeders on small live prey such as rotifers (*Brachionus*), cladocerans (*Moina*), harpacticoid copepods (*Tisibintra*) and brine shrimp (*Artemia*) (Chiang, Sun & Yu, 2004). When milkfish larvae are about 2 weeks old, they can take artificial feed. Milkfish fry from artificial rearing on day 21 are at about the same developmental stages as wild caught fry.

Fry grow to 5 - 8 cm fingerlings in 4 to 6 weeks and the fingerlings are day-time feeders and take food mainly from the bottom (Lee, 1995). The kinds of food ingested vary with location and fish size. Juveniles from natural habitats feed mainly on cyanobacteria, diatoms and detritus along with filamentous green algae and invertebrates such as small crustaceans and worms (Sadovy, 2000). Milkfish tend to ingest the top layer of bottom sediments, with its associated micro - and meiofauna, as mullet do. Much of this material is detritus, rich in bacterial protein, fungi, and protozoans.

Adult milkfish graze on surfaces and on floating algae and, like the juveniles, are opportunistic omnivores. Grow out of milkfish is evolving from traditional low intensity systems in shallow ponds based on natural food supply to more intensive systems in pens and deeper ponds with supplemental feeding (Chiang, Sun & Yu, 2004; Lee, 1995; Kühlmann, 1998). The former include the culture of algal mats and their associated biota. Traditional shallow ponds yield around 800 kg ha^{-1} yr^{-1} from three crops, whereas more intensive modular ponds can yield up to 200 kg ha^{-1} yr^{-1} from six to eight crops. Using semi-intensive ponds, fertilized with chicken manure (2 to 3 t ha^{-1}) and inorganic fertilisers (100 kg ha^{-1} ammonia phosphate, 10 kg ha^{-1} urea) and stocking densities up to 7,000 fish ha^{-1} in combination with supplemental feeding at 4 % body weight have yielded 1,160 kg ha^{-1} per crop (Sumagaysay & Borlongan, 1995). In the Philippines, growth rates are much higher in the wet season than in the dry season (Kühlmann 1998). Adult milkfish spawners can be kept on a diet of commercial pellets with about 42 % protein, given at 1.5 to 2 % of body weight twice daily, presented on a feeding tray.

Milkfish are normally farmed in monoculture but there is some polyculture to utilize ecological food niches more efficiently like with crustaceans (*Penaeus indicus*, *Penaeus monodon*, *Scylla serrata*) or fish (*Oreochromis mossambicus*; *Megalops cyprinoides*) (Gapasin & Duray, 2001; Chiang, Sun & Yu, 2004). The preferred market size for milkfish in Asia is about 300 - 400 g, meaning fish of less than one year old. Milkfish do not reach sexual maturity until 5 - 7 years of age. Milkfish is mainly sold whole, fresh or frozen. It has very limited market acceptability outside the main countries for production, because of its many fine bones. Producers of milkfish do not usually sell fish directly to consumers, but instead deliver fish through co-operatives, brokers, dealers, collectors or wholesalers, and retailers. The majority are sold at auctions, through dealers, brokers, wholesalers or co-operatives to other dealers, and then to retailers. Milkfish are also processed by marinating, smoking, or canning for export to Asian minorities; for example, to the USA.

The introduction of milkfish hatchery technology will continue to have a positive net economic impact on farmed milkfish production, employment, and income, while removing the livelihoods of some wild fry collectors. If the production efficiency of intensive and semi-intensive (Cho & Bureau, 2001) systems can be improved, farmed milkfish production is likely to increase by 100%. There is also scope for wider consumption of value-added products, such as canned milkfish.

While milkfish is important, however, its production has been hindered by various problems in recent years. Among the most critical of these is the limited supply of fry. Milkfish production comes mainly from aquaculture and the availability of fry for stocking determines to a large extent the achieved levels of national production. In the past decade or so, the supply of fry, which comes mainly from the wild, has been declining rapidly (Ahmed *et al*., 1999). In contrast, the demand for fry has been growing steadily, brought about by the gradual intensification of culture practices and the shift in production toward milkfish farming in reaction to the decline of the prawn industry. Milkfish *(Chanos chanos* Forsskal) remains one of the cheapest sources of protein for developing countries in Southeast Asia, particularly in the Philippines. The unpredictable supply of wild fry, the only source of seed for the milkfish farmer, contributed largely to the slow growth of the milkfish industry. Research on the best means to acquire wild fry was, therefore, given emphasis.

The open sea cage culture has been expanding in recent years on a global basis and it is viewed by many stakeholders in the industry as the aquaculture system of the millennium. Halwart and Moehl (2006) observe that cage culture is a relatively complex system from technological, biological, ecological, economic and social perspectives. It is risky, (e.g. cages placed on lagoons at the sea if not properly anchored, can be swept by water through currents and be deposited in the open sea) and requires significant skill and adaptive learning at small scale level. This makes entry for the poor difficult and they will require much support if they are to succeed. This requires the government of Kenya and nongovernmental organizations (NGO’s) to support cage culture in Kenya for its success especially if it would benefit small scale farmers. Cage culture allows intensive exploitation of water bodies with relatively low capital investment (Beveridge, 2008). Cage culture can be established in any suitable body of water, including oceans, lakes, ponds, mining pits, streams or rivers with proper water quality, access and legal authority which makes it possible to exploit underused water resources to produce fish (Beveridge, 1996). Relative to the cost of pond construction and its associated infrastructure (electricity, roads, water wells, etc.), cage culture in an existing body of water thus is inexpensive to construct and manage. Cage materials are not especially expensive and many kinds of cages can be constructed with little experience. Because it is relatively cheap to manage and yields high production in a small area, it is a better area of government intervention to boost small scale farmers (Maser, 2008).

There can be two ways of raising fish in cage systems, that is either be intensive or semi-intensive system. This is a system whereby fish are stocked at high densities and are fed on complete diets and in semi-intensive fish rely on both natural productivity of water and supplementary feeds (Maser, 2008). Cage culture is used widely in fish seed production in countries such as Thailand, Malaysia, and Indonesia where it has been successful (Ariyaratne, 2000). In Kenya, marine farmers depend on seeds from the wild thus fry brought near the shores through currents are caught by hand nets or through seining. The fry are then stocked in cages and fed with both live and artificial feeds to juvenile stage after which are supplied to farmers. The choice of a species for culture depends mainly on its availability, legal status, growth rate (Huchette & Beveridge, 2003) and its coping capabilities to environmental conditions. According to Masser (1997) the most important decision in determining which species one should culture in cages is whether there is market for the species selected; whether the market is local or must the fish be transported for long distances; whether the market is a live market or a processed market; and the size preferred in the market. Therefore it is very crucial for all potential producers to evaluate markets to establish the best species to be cultured.

Despite multiple advantages of cage culture, it has several limitations such as risk of 1oss from poaching, which sometimes lead to a loss of the whole stock if poachers use herbs to get fish (Fishbase, 2004). Cages are damaged by predators; for example mud crabs will tear the nets in attempt to get fish (Masser, 2008). Water quality can also be a problem since the stock wholly depends on external water from the water body e.g. low oxygen; dependence of fish on nutritionally-complete diets, algal brooms and greater risk of disease outbreaks (Huchette & Beveridge, 2003; Masser, 2008). In water bodies which are also utilized by the public, cage culture is faced by many competing interests and its legal status is not well defined (GoK, 2009b). On the other hand sufficient conditions for cage culture are not offered by all water bodies e.g. in open sea where there are alterations of waves and water currents (Bagarinao, 1991)

The total biomass i.e. weight or number of fish stocked in a cage measuring 1 m^3 or of fish occupying a space of 1 m^3 of a cage from fingerling size to harvest size is also defined as the stocking density of a cage (Mokoro, 2008). Cages can support high stocking densities (of about 100 fish per m^3 while at the same time preventing occurrence of a build-up of waste metabolites inside the cage, due to a continuous exchange (FAO, 1996). These is more effective in large water bodies like the sea where is continuous exchange through water currents. However, water exchange is less frequent in large cages, and therefore the stocking rate must be reduced accordingly (Huchette & Beveridge, 2003).

Overstocking (more than 100 fish per $m^{3)}$ contributes poor feed consumption and also results into excess feed left uneaten which results in the deterioration of water quality in the cage system. This is so due to the fact that high stocking densities of above 100 fish per m^3 increase competition for space thus increased stress which eventually results to poor feeding efficiencies (Youssouf *et al.*, 2007). Mokoro (2008) noted that overstocking leads to poor growth and mortalities due to limited space in cage system. On the other hand, under stocking of fish in the cage culture system can also result to failure in maximizing production (Youssouf *et al.*, 2007). Space is not fully utilized and leads to failure to optimize profit and in some cases the initial investment might not be recovered.

2.2 Length-Weight Relationship

Data on the length and weight of fish have commonly been analyzed to yield biological information. The length-weight relationship (LWR) is very important for proper exploitation and management of the population of fish species. LWR has a number of important applications in fish stock assessment (Morey *et al.,* 2003). To obtain the relationship between total length and other body weight are also very much essential for stabilizing the taxonomic characters of the species. Froese (2006) stated that LWR provides valuable information on the habitat where the fish lives. Length and weight data are a useful and standard result of fish sampling programs. Furthermore, standing crop biomass can be estimated (Mansor *et al.,* 2010) and seasonal variations in fish growth can be tracked this way (Pervin *&* Mortusa, 2008)

However, the length-weight parameters of the same species may be different in the population because of feeding, reproduction activities and fishing etc. Therefore, data on functional LWR of fish species is important for fish stock assessment and parameters a and b can be used for length-weight conversion (Froese, 2006). At the same time, the relationship of length-weight estimates condition factor of the fish species and fish biomass through the length frequency. In fisheries science, the condition factor is used in order to compare the “condition”, “fatness” or wellbeing of fish. It is based on the hypothesis that heavier fish of a particular length are in a better physiological condition. Condition factor is also a useful index for monitoring of feeding intensity, age, and growth rates in fish (Mansor *et al.,* 2010). It is strongly influenced by both biotic and a biotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Anene, 2005).

The lack of information on this relationship between the four species under culture systems propelled this study, which is aimed at bridging this gap and also provide useful information to the potential fish farmers of the Kenyan coast.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The study was carried out on the Kenyan South coast at Makongeni Village, Kinondo location, Diani division, Msambweni district, Kwale County (Figure 1). Research was conducted from April to November, 2012. The coastal belt of Kenya experiences a tropical monsoon climate dominated by two seasons, the southeast monsoon (SEM) prevailing from April to October and the northeast monsoon (NEM) from November to March. The two seasons are characterized by distinct differences in physical and chemical conditions of the coastal waters (Lutjeharms, 2006). The SEM is associated with strong winds, low air and water temperatures, low solar radiation and heavy rains. During the NEM, these conditions are reversed (Trenberth *et al.,* 2000). The tides are mixed semidiurnal, with tidal ranges of about 4.0 m.

3.2 Experimental design

The experiment consisted of 12 floating cages at a stocking rate of 50 juvenile fish of between 50-70gm which were reared for six months. Each cage required a netting material, floaters, anchors, frames and polyethylene twine. The cages were hanged on wooden frames, kept afloat by plastic drum and anchored on mangrove trees using polyethylene twine (Fig. 2). Metal stands were also used to anchor the net cages above the sea bed. The metal stands were useful in fastening the net cage and preventing it from being swayed from side to side by water currents. The economic life of the nets used in the study range from two to five years according to the manufacturer. The mesh size of the net was 3.8 mm to prevent fouling more rapidly.

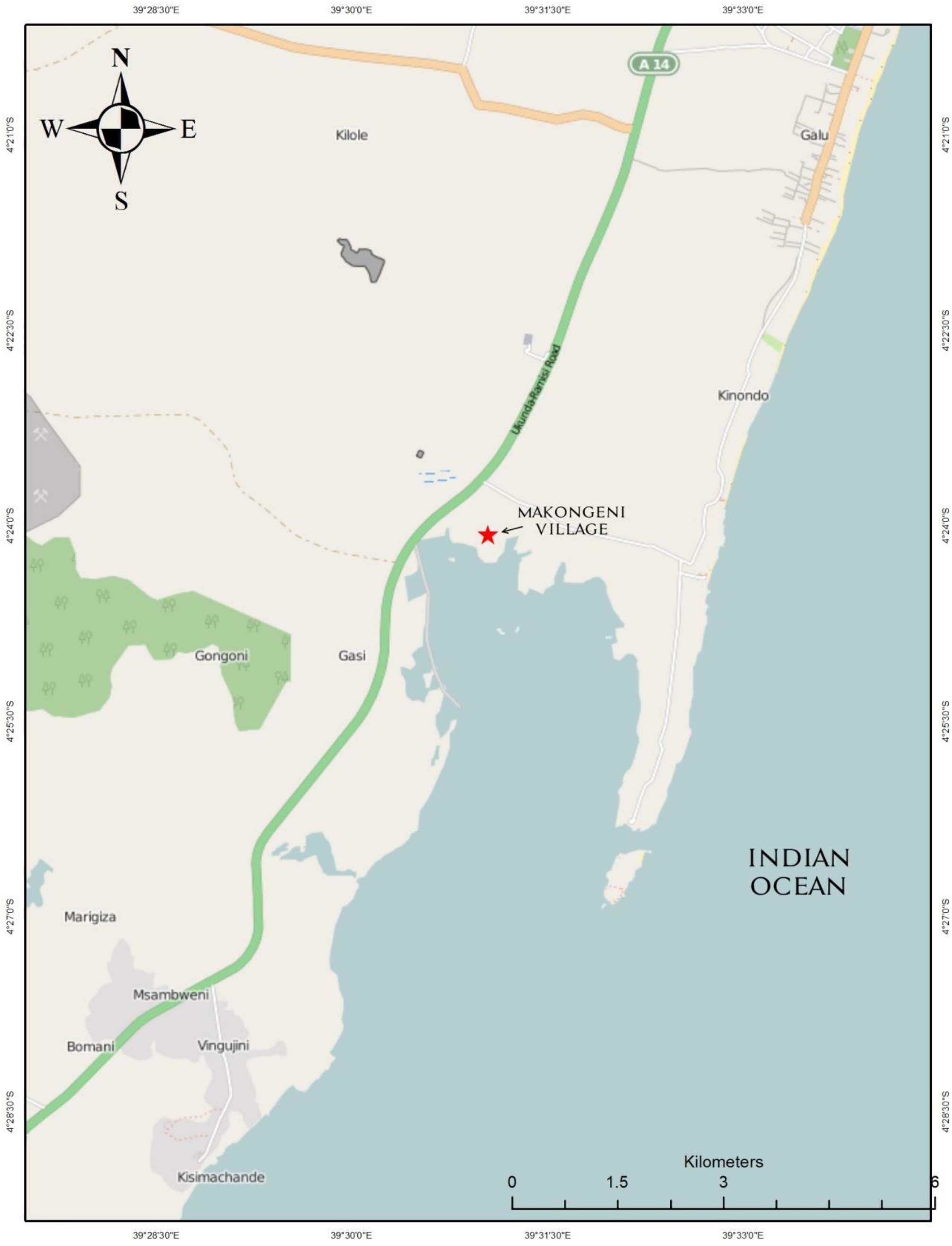


Figure 1: Map of the study area

(Source: google maps)

The cage - nets were cleaned regularly to prevent excessive fouling and to prevent net breakage and heavy losses of fish. The method of cleaning nets involves fish transfer, drying the nets for about 2 days, manually removing the dead fouling agents, dipping in sea water for some hours, inspection and mending of the tone ones. When nets were in use, care was taken to ensure that there were no loose knots or holes in the net which would allow the fish to escape.

Figure 2: Cages used during the study period

(Source : Author, 2012)

3.3 Seed collection and feeding

Seeds were collected from the wild through trap method, seining and hook and Line at the lagoon near the shore and transferred to the cages using a raft which has net-cage to hold the juvenile fish. The collected seed were transferred into basins and the sea water immediately diluted with freshwater to kill other organisms. The seed were then sorted to remove other species of fish that were also captured. The cages were stocked and not fed for one month during the acclimatization period.

A formulated diet of fishmeal and maize bran at a ratio of 1:2 to make a meal of 30% protein was introduced during the second month. Feeding of the fish was done twice a day, at 3% of their body weight resulting in a daily ration of 6% of the body weight. The fish were reared for a period of six months.

3.4 Fish sampling

Sampling was done every month from all cages using a seine net. At every sampling, a total of 30 fish samples were collected. After collection the fish were put in a basin containing water from which the length and weight of each fish was taken. The length was measured in centimeters and weight in grams using a fish measuring board and an electronic weighing balance.

3.5 Data analysis and Presentation

Data generated was entered in an excel spreadsheet for storage and management. This data was then analysed using both Microsoft Excel spreadsheet and further by MINITAB version 14 software.

The monthly weight was analysed for Percent Weight Gain (PWG) using the formula:

$$PWG\ (\%) = \frac{W_2 - W_1}{W_1} \times 100$$

where;

W_2 = Mean final fish weight

W_1 = Mean initial fish weight

Growth in wet weight of the fish was expressed as the Specific Growth Rate (SGR, % day^{-1}) using the formula below (Schram *et al.*, 2009):

$$SGR\ (\%) = \frac{\ln W_{2} - \ln W_1}{Days} \times 100$$

Where;

W_2 = Mean final fish weight

W_1 = Mean initial fish weight

Days = duration of culture in days

Food Conversion Ratio (FCR) was further computed from the results to show the efficiencies of these species in converting feed into body weight. This was calculated as follows (Craig & Helfrich, 2009):

$$FCR = \frac{TFI}{WG}$$

where;

TFI = Total feed fed (g)

WG = Weight gain (g)

Data on length and weight was log-transformed and used to determine the length-weight relationship and the condition factor of each fish using regression analysis. The condition factor K_n was calculated as follows

$$K_n = W/(aTL^b)$$

where,

W = Fish weight (g)

TL = Total Length (cm)

a = The initial growth index (y intercept)

b = The slope (growth exponent)

Mortalities were determined by counting the number of dead fish every day and summed monthly from every cage stocked. However, in the cages, survival was determined at the end of the experiment by completely draining the cage and counting the remaining fish (taking into consideration any fish that died during weighing exercise) and percent survival calculated based on the number of fish remaining in the cages as a percentage of the stocked fish using the formula below:

$$\%\,Survival = \frac{n}{N} \times 100$$

A modified Fabens (1965) method for estimating L_∞ and K by predicting length at second reading (L_r') based on the length at first reading (L_m) was used. The growth parameters were estimated by minimizing the Sum of Squares of Errors (SSE), i.e., the squared differences between the observed lengths at second reading (L_r) and the predicted lengths (L_r') using the Newton-Raphson iteration method and the following equation:

$$SSE = \sum_i (L_{ri} - L_{ri}')$$

where the predicted length at second reading (L_{ri}') is given by

$$L_{ri}' = L_{mi} + (L_\infty - L_{mi})(1-e^{(-K\Delta ti}),$$

and

$$\Delta t_i = t_r - t_m$$

The estimated growth parameters were then used to determine the length-based growth performance index ($\varnothing'$) using the relationship:

$$\varnothing' = \log_{10}(K) + 2 \cdot \log_{10}(L_\infty).$$

and the weight based version:

$$\varnothing = \log_{10}(K) + 2/3 \cdot \log_{10}(W_\infty).$$

where,

$$W_\infty = a\, L_\infty^{b}$$

Where n is the total number after six months while N is the initial number stocked. The economic value was then calculated by getting the product of the number of fish harvested per species and the average market price. The profit for each fish species will be calculated as follows;

Profit = Sales – Cost of production

whereas;

Sales = Pieces harvested × Average price a piece

Cost of production = Labour + Feeds

CHAPTER FOUR

RESULTS

4.1 Growth rates of the three fish species

4.1.1 Monthly growth in fish Weight and Length

The highest final body weight was that of milk fish (150.4 ± 4.80g) followed by the red snappers (125 ± 7.02 g). Rabbit fish had the lowest final body weight of 101 ± 3.63g (Table 1). The highest mean final length of the fishes (Table 1) was observed in the milk fish (24.1 ± 0.534 cm) and rabbit fish (19.5 ± 0.524 cm) as compared to the red snapper (17.5 ± 0.22). During the first three months of study, the milk fish had the highest average length as compared to the red snapper and rabbit fish.

Based on the growth parameters, L_∞ and K, the growth patterns of each of the fish type was reconstructed using the relative age (t') in years showed that milkfish and rabbit fish reaches a relatively larger size but takes a longer time as compared to the red snapper (Fig. 3). Direct comparison of the growth performance in length and weight indicate that better growth in milkfish in both length ($\varnothing$=1.71) and in weight ($\varnothing$'=2.92) as compared to rabbit fish ($\varnothing$=1.65; $\varnothing$'=2.88) and red snapper ($\varnothing$=1.24; $\varnothing$'=2.46) (Table 2).

Table 1: **Monthly mean fish weight ± SEM (g) and mean fish length ± SEM (cm) during the study period**

Fish type	**N**	**Mean weight (g)**					
		June	**July**	**August**	**September**	**October**	**November**
Milk Fish	120	56.0 ± 2.45	64.8 ±2.44	76.0 ± 1.3	94.8 ± 5.30	116.4 ± 6.08	150.4 ± 4.80
Rabbit Fish	120	55.4 ± 1.63	61.4 ± 1.40	75.0 ± 0.894	79.8 ± 1.85	108.2 ± 5.8	101.0 ± 3.63
Red Snapper	120	61.2 ± 3.01	66.4 ± 3.67	70.2 ± 2.99	78.8 ± 5.32	92.8 ± 3.20	125.0 ± 7.02

Fish type	**N**	**Mean length (cm)**					
		June	**July**	**August**	**September**	**October**	**November**
Milk Fish	120	19.6 ± 0.25	20.4 ± 0.37	21.4 ± 0.4	22.0 ± 0.45	23.3 ± 0.62	24.1 ± 0.53
Rabbit Fish	120	14.9 ± 0.19	15.6 ± 0.19	17.0 ± 0.16	17.2 ± 0.23	18.5 ± 0.52	19.5 ± 0.52
Red Snapper	120	13.2 ± 0.58	14.8 ± 0.37	15.6 ± 0.19	16.5 ± 0.22	17.1 ± 0.19	17.5 ± 0.22

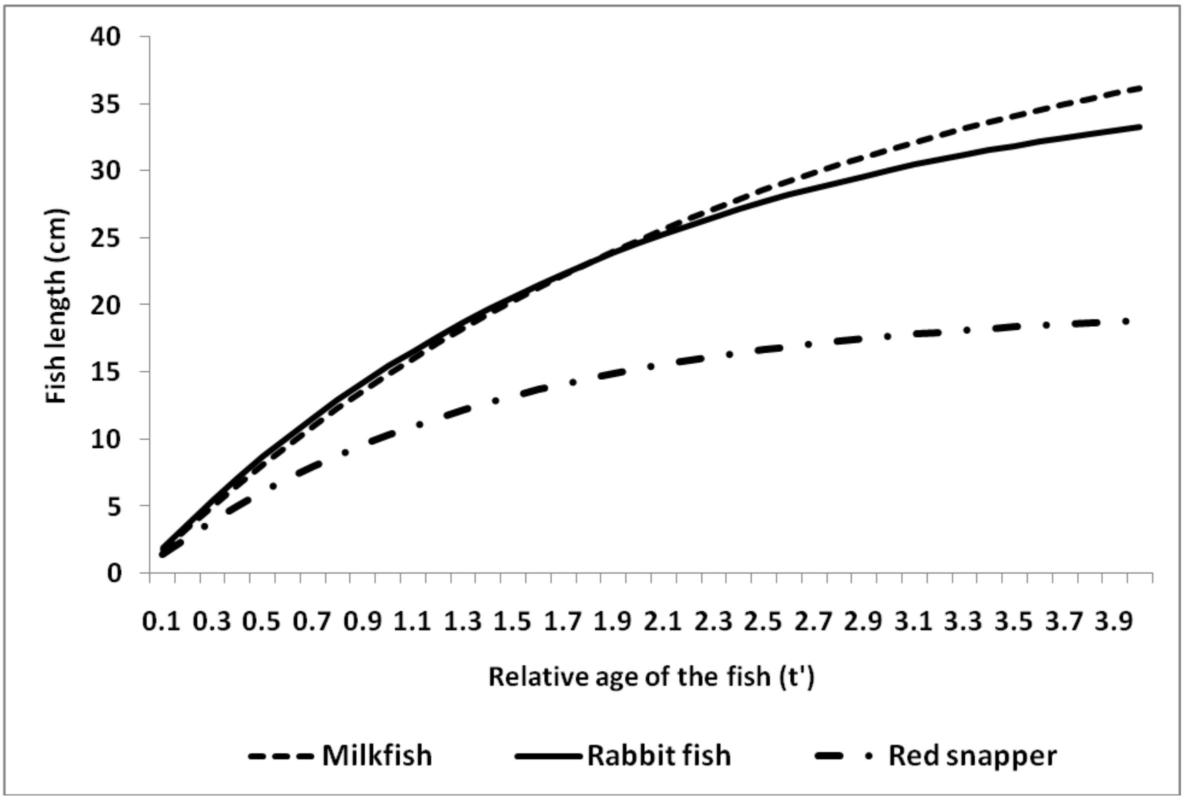


Figure 3: Specific growth rates of the fishes during the study period

Table 2: Growth parameters (L_∞ and K) based on the Fabens (1965) method

	a	b	K	L_∞	W_∞	∅	∅'
Milkfish	0.0007	3.808	0.398	45.53	1,461	1.71	2.92
Rabbit fish	0.0264	2.829	0.526	37.96	776	1.65	2.88
Red Snapper	0.6683	1.723	0.729	20.00	117	1.24	2.46

4.1.3 Percent Weight Gain

Table 3 shows that milk fish (168.6%) had the highest weight gain as compared to rabbit fish (125.6%). The red snappers had the lowest percent weight gain (65.03%). The monthly percent weight gain of milk fish increased every month from 15.7% during the first month to 29.2% during the last month of study.

Table 3: Monthly and overall percent weight gain (%) of the four studied fishes during the study period

Sampling Months	Milk Fish	Red Snappers	Rabbit Fish
June	15.7	8.4	10.8
July	17.3	5.7	22.2
August	24.7	12.3	6.4
September	22.8	17.8	35.6
October	29.2	8.8	15.5
Overall	168.6	65.03	125.6

4.1.4 Specific Growth Rate

Milkfish recorded the highest specific growth rate (0.65%) followed by rabbit fish (0.53%) whereas red snappers had the lowest specific growth rate of 0.33% (Fig. 4), The specific growth rate for milk fish recorded a monthly increase while that of Rabbit fish exhibited an oscillatory trend in monthly specific growth rate. The red snappers though had the lowest specific growth rate showed a monthly increase from the month of stocking.

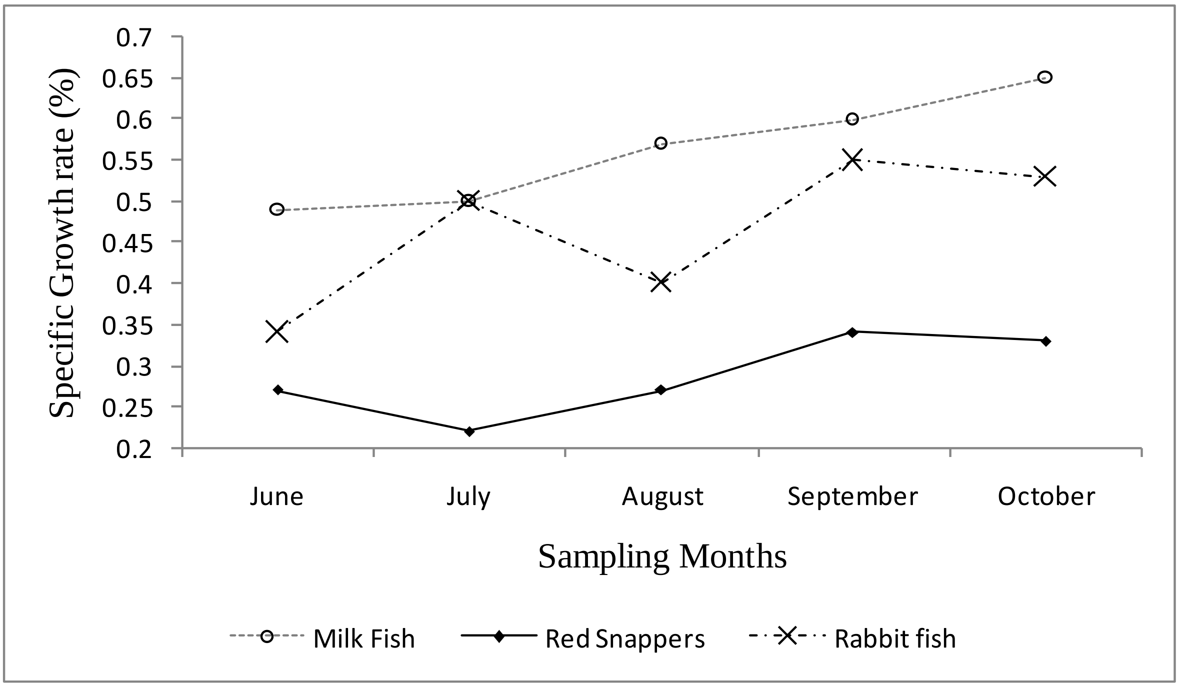


Figure 4: Specific growth rates of the fishes during the study period

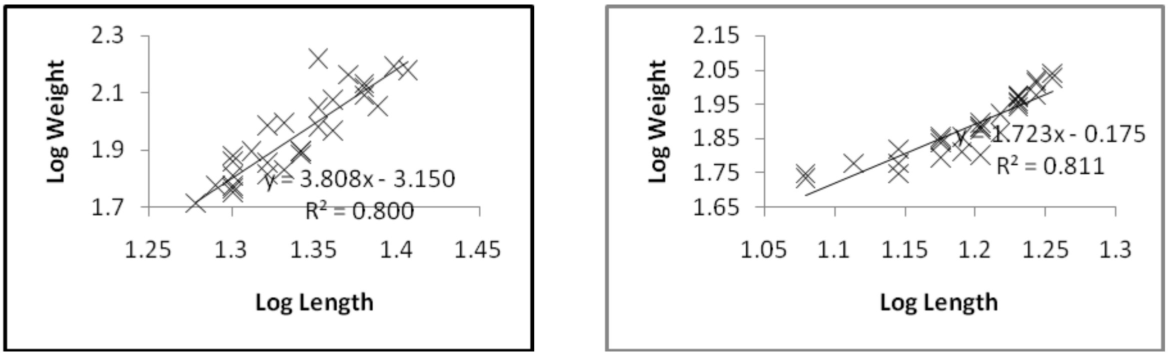
4.2 Length-Weight Relationships

Figure 5 shows regression outputs for the length-weight relationships for the four species studied. The length-weight relationships of the species under study were best described by the following logarithmic equations:

Milkfish: Log W=3.808•Log L - 3.150

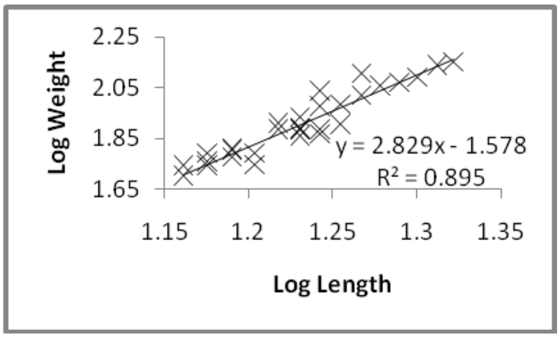
Red Snapper: Log W=1.723•Log L - 0.175

Rabbit fish: Log W=2.2829•Log L - 1.578



Milk Fish

Red Snappers



Rabbit Fish

Figure 5: Length-weight relationship for the four fish species studied during the study period

4.3 Growth Patterns and Condition Factor

Growth patterns in fish are predicted by considering the value of the growth exponent in a length-weight relationship. The pattern is isometric when the exponent b is 3; any deviation from this shows allometry in the growth of fish which can be negative ($b < 3$) or positive allometry ($b > 3$). From this study, only the milk fish depicted a positive allometry while the other two species showed negative allometry and none had an isometric growth (Table 4).

Table 4: Length exponent and Growth patterns of the four fish species studied

Fish Species	b	K_n	R^2	Growth pattern
Milk Fish	3.808	1.527148	0.800	Positive allometry
Red Snappers	1.723	1.005539	0.811	Negative allometry
Rabbit Fish	2.829	1.021429	0.895	Negative allometry

4.4 Feed Conversion Ratio (FCR)

The highest FCR value was obtained in the red snappers (10.56 ± 1.12), followed by rabbit fish (6.04 ± 0.71) while milk fish had the lowest (4.45 ± 0.65) which was the best among the three (Fig. 6).

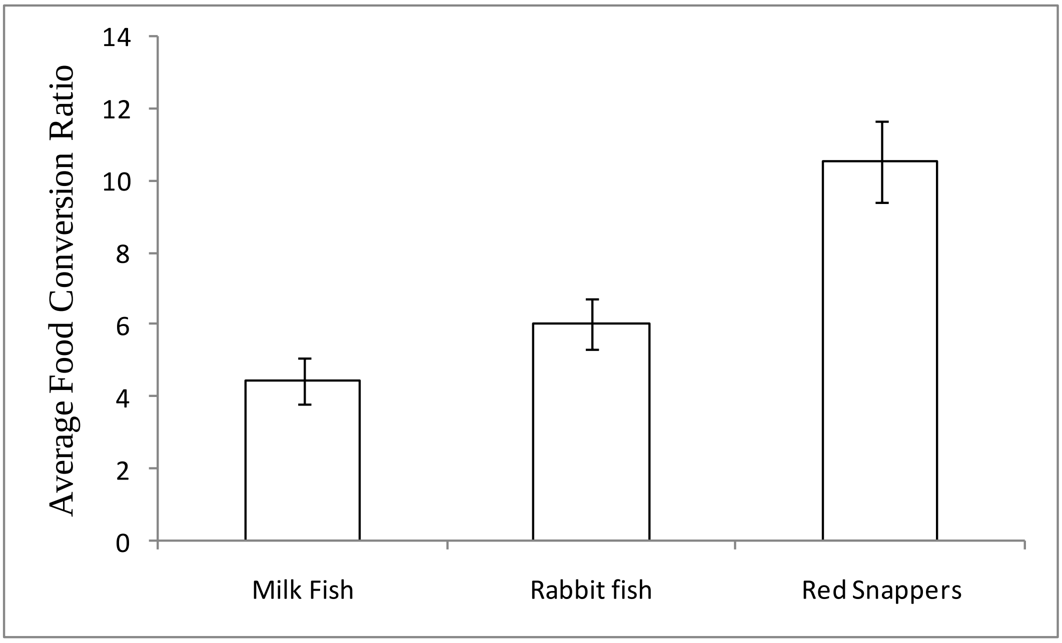


Figure 6: Food Conversion Ratio (Mean ± Standard error) for the species studied

4.5 Monthly Fish Mortality

For all the three species, mortality (Fig. 7) was highest during the month of June, which was the first month. The number however reduced during the subsequent months. Considering individual species, milk fish recorded higher mortality during the study period (38 individuals) followed by red snappers (18 mortality) whereas rabbit fish had the lowest number of mortality (13 individuals). Based on the mortality, rabbit fish had the highest percentage survival (93.5%) and red snapper recorded 91% survivorship. Milk fish had the lowest percent survivorship at 81%.

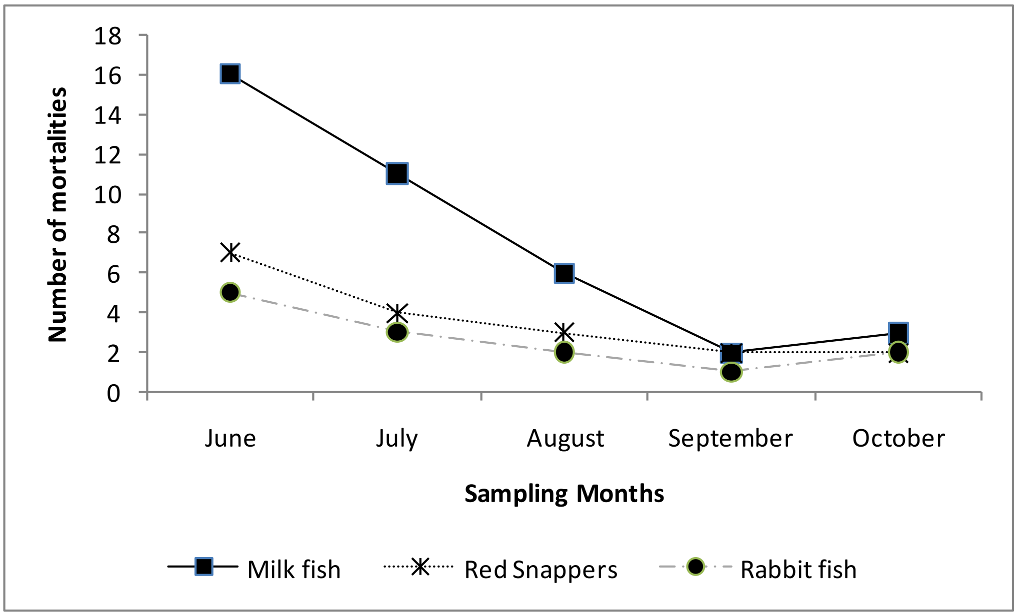


Figure 7: Monthly fish mortality for the four species during the month of June to October.

4.6 Economic Value

Red snappers had the highest market price of Shs. 200 Kg^{-1} on average, while milk fish and Rabbit fish attracted prices of Shs. 165 Kg^{-1} and shs. 175 Kg^{-1} (Table 5). However, based on the final weight, Milkfish were found to sell for Shs. 25 a piece which was the highest price a piece among the three species due to size difference. On profitability, the Rabbit fish could yield a profit of slightly over sh. 1,000 which was the highest while the red snapper only had a profit of sh. 549.10.

Table 5: Estimated Economic values of the four fish species after the growth period.

Species	Final weight	Price/ Kg (KSh.)	Unit price (Ksh.)	(N) (Stocked- Mortalitie	Total value (Ksh.)	P. Cost (Ksh.)	Profit (Ksh.)
Milk Fish	150.4g	165	25	162	4,050	3135.40	914.60
R. Snappers	101g	200	20	182	3,640	3090.90	549.10
Rabbit Fish	125g	175	22	187	4,114	3112.50	1001.50

CHAPTER FIVE

DISCUSSION

5.1 Growth Performance

Even though factors like feeding and feed types, water quality variables, and fish type determine the rate of growth (Zaikov, 2006), for this study, the feeding and water quality parameters were constant while the fish type varied. The milk fish gained higher body weight and maximum total length over the entire study period. The overall growth pattern of fingerlings also remained highest for milk fish. In milk fish, the higher mean body weight encountered at the end of the culture suggests better growth performance as compared to the other two species. Under the conditions of the present study, the discrepancy in growth performance between the three fish species was not about other external variables but fish type since all the species were subjected to similar conditions. The faster growth rate obtained in the length of milk fish further supports the idea that it has better growth performance as compared to the other two species. Faster growth is a desirable trait in aquaculture since it yields good production and hence can be profitable in terms of food and income (Zaikov & Hubenova, 2008).

Comparison of growth in different fish species has always posed a challenge to fish biologists according to Munro and Pauly (1983) and Pauly and Munro (1984). The authors therefore developed an index for direct comparison based on the growth rate for weight ($\varnothing$) and length ($\varnothing$'). This study employed this method of comparison which is based on the premise that fishes and invertebrates that grow very fast reach smaller sizes as compared to fishes that grow slowly but reach larger sizes. Judging from the results of growth comparison, both milkfish and rabbit fish would attain far much larger sizes for similar growth period or relative age as compared to the red snapper. For example both milkfish and rabbit fish would attain about 20 cm TL in one year as opposed to about 12 cm TL for the red snapper. Since marketability of farmed fish is dependent on size, the highest economic potential would be attained by growing milkfish and rabbit fish as compared to the red snapper. the larger fish.

5.2 Feed Conversion Ration

Feed Conversion Ratio (FCR) is a measure of an animal's efficiency in converting feed mass into increased body mass. Specifically FCR is the mass of the food eaten divided by the body mass gain over a specified period of time. As far as th/is study is concerned, the better (lower) feed conversion ratio was observed for the milk fish while the red snappers had the highest ratio. Enhancement in FCR suggests efficient food utilization through the extraction of more nutrients from the food and converting it into flesh (Bhikajee & Gobin 1997; Bailey *et al*., 2000).

This result therefore point at the milk fish having the best efficiency in terms of feed conversion among the three species followed by rabbit fish while red snappers had the lowest efficiency. Animals that have a low FCR are considered efficient users of feed (Al-Ahmed, 2004). However, comparisons of FCR among different species may be of little significance unless the feeds involved are of similar quality and suitability. During this study similar feeds were used for all the three species and reared under similar conditions. It is also known that nutritional requirements may differ between species (Boyd, 1999) but the crude protein levels required to sustain acceptable growth remains generally between a specified range (Craig and Helfrich 2009). The FCR of 4.45 for the milk fish is quite high as comparable to other species such as *Oreochromis niloticus* having values of 2-4 (Al-Ahmed, 2004). Since the cost of feeds is the most prohibitive factor in aquaculture (GoK, 2009a), it is desirable that more emphasis be laid on the nutrition of the milk fish in order to develop consistent grow-out requirements and feeding practices or regimes.

In terms of selection for good growth, both milkfish and rabbit fish qualify as potential candidates for cage culture. Feeds is known takes about 60-70% of production costs in aquaculture but fortunately, milkfish exhibited slightly better FCR though the values obtained are still far much above economically viable range. This means that the feed quality has to be improved considerably and a feeding regime developed for optimum cost effectiveness. On the basis of FCR, rabbit fish may not qualify as a good candidate since it would be un-economical to feed it in cages.

5.3 Length-Weight Relationship and Condition Factor

Length-weight relation parameters and condition factor provide basic information to the producer with an evaluation of the specific conditions under which organisms are growing (Araneda *et al*., 2008). Length-weight relationship (LWR) of fish also plays a significant role in studying the growth, rate of feeding, metamorphosis, fatness, onset of maturity, gonadal development and general well-being of the fish population (Koutrakis & Tsikliras, 2003; Pauly, 1993).

Further, it helps in establishing the biomass and in converting one variable to another as is often required during regular samplings for culture operation. Whereas, condition factor (K) is a quantitative parameter estimated based on length-weight data, which indicates the state of well-being of the fish for determining the present and future population success by its influence on growth, reproduction and survival (Biswas *et al*., 2011). From this study, all the species showed allometric growth. Milk fish had the highest value of b and showed a positive allometry and the rest negative allometry. This is an indication that the growth of these fish species under culture system is non proportionate in terms of weight gain and increase in length though an exception could be with rabbit fish whose *b* was closer to 3. Biswas *et al*. (2011) obtained a slope (b value) of 2.8 for milk fish in India and treated it as isometric growth on the basis of its closeness to 3. The b value in this study which is 2.829 thus meets that criteria and the fish can be described as having proportionate growth in terms of weight gain and increase in length**.**

Condition factor usually vary from one species to another. A lower condition factor however shows poor welfare or presence of stress factors in a system. From this study, the K values were all above 1 with milk fish recording the highest value of 1.53 while the lowest was red snappers (1.006). This finding indicates that milk fish had better condition during culture compared to other test species.

5.4 Survivorship and Economic Value

Fish mortality is influenced by water quality status and the ability of fish to resist stress factors. Fishes that acclimatize faster tend to have higher survivorship as compared to the weak ones that take more time to acclimatize (Boeuf & Payan, 2001). The highest percent survivorship was observed in rabbit fish where only 13 individuals died in the entire six month period. In contrast, a total of thirty eight (38) fish mortality was observed in milk fish which was the highest among the three species. High survivorship is among the qualities of a good species for aquaculture production (Zaikov, 2006).

Based on percent survivorship results, all the three species recorded higher survivorship but rabbit fish are considered superior among the three species studied thus a better candidate for aquaculture in this region since it had the highest. However this is not a standalone quality to qualify it and the economic returns also plays a major role in the life of farmers hence has to be considered (Rothuis *et al.,* 2011; FAO, 2008). In economic terms, the value of one piece of milk fish after six months could sell for KSh. 25 considering the market price per kilogram. Considering the quantity available after six months of cage culture, the milk fish stocked could fetch over KSh. 4,000 and a profit of about Ksh. 914 which is lower than that of rabbit fish at a profit of slightly above Ksh. 1,000.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the analysis of SGR, FCR and PWG, and results obtained in the cage culture experiments, it is concluded that:

i) Milkfish had the highest SGR and growth performance hence has a high potential for cage culture

ii) Both milkfish and rabbit fish exhibited relatively better growth performance based on $\varnothing$ and $\varnothing$’but rabbit fish had poor FCR.

iii) The FCR was lowest for milk fish which is an indication of feed efficiency, though the values obtained are still above optimum and the fish registered high mortalities bringing the issue of hardiness.

iv) The market price for rabbit fish was highest with low production as compared to high production of milk fish at relatively lower prices thereby resulting in slightly higher net profit in rabbit fish.

6.2 Recommendations

Based on the results and conclusions from this study, the following are recommended;

i) Piloting of cage culture of milk fish and rabbit fish in the Kenya Coast to develop a small scale production system.

ii) Comparison of the growth performance on different feed formulations should be carried out to determine the nutritional factors that may improve growth.

iii) Development of nutritionally balanced and lows feeds for cage culture of milkfish since it has more promising growth characteristics.

iv) A complete bio-economic analysis, enterprise budget and business plan should be developed during the piloting phase to facilitate any future investment of milkfih cage culture.

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