

## Comparative Study of Growth Performance and Viability of Four Marine Fish Species under Cage Culture

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### Abstract

*This study set out to investigate and compare the growth performance and viabilities of four 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 four marine species: rabbit fish (*Siganus vermiculatus Valenciennes, 1835*), red snapper (*Lutjanus argentimaculatus*), milk fish (*Chanoschanos*) and groupers (*Epinephelus fuscoguttatus*). The experiment consisted of 16 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 groupers had the highest final body weight ( $242 \pm 10.2$  g), whereas rabbit fish had the lowest final weight of  $101 \pm 3.63$  g. One-way ANOVA showed that groupers mean weight differed significantly from the milk fish, red snapper and rabbit fish right from the second to the sixth month ( $F= 80.61$ ;  $p<0.0001$ ). The final mean length for each species also show that groupers had the highest final mean total length ( $26.1 \pm 0.40$  cm) follow by milk fish ( $24.1 \pm 0.53$  cm), rabbit fish ( $19.5 \pm 0.52$  cm) and lastly by red snapper ( $17.5 \pm 0.22$  cm). The variation in final mean length was significant between species ( $F= 82.35$ ;  $p<0.0001$ ). Percent Weight Gain (PWG) was 290.3% for groupers, 168.6% for milk fish, 125.6 for rabbit fish and 65.03% for red snapper. The initially high PWG of 57.1% declined to only 15.1% for grouper in the first month to only 15.1% in the fifth month. The Specific Growth Rate (SGR) was also highest for the grouper (0.89%) as compared to milkfish (0.65%), 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 red snapper ( $b=1.7$ ;  $R^2=0.811$ ), rabbit fish ( $b=2.8$ ;  $R^2=0.895$ ) and the grouper ( $b=2.7$ ;  $R^2=0.966$ ). The best Feed Conversion Ratio (FCR) was obtained in the grouper. Relatively poor FCR were obtained in all the four species with the highest value for the red snapper ( $92.3 \pm 8.35$ ), rabbit fish ( $52.8 \pm 11.2$ ), milk fish ( $38.9 \pm 2.68$ ) and grouper ( $20.4 \pm 1.99$ ). The grouper had low mortality and high survival (98%) as compared to milk fish (81%), snapper (91%) and rabbit fish (93.5%). On economic viability, groupers were found to be more viable compared to other three since they had higher market value per piece of KSh. 40 as compared to KShs. 20 for the red snapper, KSh. 22 for rabbit fish and KShs. 25 for milk fish. Based on the results of growth rate, feed conversion ratio, survival and economic viability, it is concluded that groupers is the best candidate for culture as compared to the other three test species. It is recommended that intensive pilot culture of groupers be undertaken in cages to develop an enterprise budget and business plan for commercial investment to improve livelihoods of the coastal community and at the same time, open up the opportunities for further research on nutrition, husbandry and further research on growth requirement of groupers.*

**Key Words:** Growth Performance, Cage Culture, Viability

## INTRODUCTION

### Background Information

Populations in numerous countries around the world are increasingly suffering from hunger, malnutrition and lack of crucial 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. Boyd (1999) and Gordon (2000) 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 (Boulton *et al.*, 2014). 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%. On overall, the Kenya fisheries sector contributes only 0.5% to Kenya's Gross Domestic Product (GDP) unfortunate circumstance given the large water resources (Fisheries Department, 2012). This is partly due to the inability of the country to exploit the marine resources, the Lake Victoria fisheries and the small scale and limited aquaculture development.

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%. 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. Aquaculture provides a source of subsistence and livelihood to the fish farmers and the local community (Ngugi and 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 (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 (Boyd, 1999). 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 Oyieng *et al.* (2013), 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 give farmers at the coast another fish species that can be cultured with economic gains.

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 has calls for urgent action to solve the eminent crisis of depleted fish stocks and malnutrition population. Apart from the highly pressured capture fisheries, fish farming has the potential to generate sufficient fish to the national population and source of income to fish farmers (FAO, 2005).

According to Mbugua (2008), commercial fish farming is influenced by demand, cost of production and financial returns at the end of the culture period. Demand of fish and preferences go hand in hand. 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 rabbit fish (*Siganus vermiculatus* Valenciennes 1835), snappers (*Lutjanus argentimaculatus*), milkfish (*Chanoschanos*) and the grouper (*Epinephelus fuscoguttatus*) 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 four potential culture species and assess 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.

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.

## **MATERIALS AND METHODS**

### **Study Area**

The study was carried out in the Kenyan Coast (South Coast) at Makongeni Village, Kinondo location, Diani division, Msabweni district, Kwale County. The research was conducted from April to Nov 2012. The coastal belt of Kenya experiences a tropical monsoon climate dominated by two seasons, the Southeast monsoon (SEM) prevailing

from April to September and the northeast monsoon (NEM) from October to March. The two seasons are characterized by distinct differences in physical and chemical conditions of the coastal waters (McClanahan, 1988). The SEM is associated with strong winds, low air and water temperatures, low solar radiation and heavy rains, with the lowest tides occurring during the night. During the NEM, these conditions are reversed with the lowest tide occurring during the day. The tides are mixed semidiurnal, with tidal ranges of about 4.0 m.

### **Experimental Design**

The experiment consisted of 16 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, flumes and polyethylene twine. The net cages were hung on wooden frames and were kept afloat by plastic drum and anchored on mangrove trees using polyethylene twine. 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. One raft to fit a net cage had a size of 3.6 m by 1.4m; all the nets used were made of polyethylene material. 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 of 3.8 mm to prevent fouling more rapidly.

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 spoilt 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.

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. After stocking, the fish were reconditioned for one month after which feeds were introduced. A formulated diet of fishmeal and maize bran at a ratio of 1:2 to make a meal of 30% protein was used to feed the fish. The fish were fed at 3% of their body weight twice a day, resulting in a daily ration of 6% of the body weight.

A mosquito seine net was used to seine inside the cages to get fish. After collection the length and weight of the fish was taken. This was conducted in triplicates and bi-weekly. The length was measured in centimeters and weight in grams by use of a fish measuring board and an electronic scale of a capacity of 5 kg by 1g.

The data generated was entered in an excel spreadsheet for storage and management. This data was then analysed using MINITAB version 14 software. The monthly weight was analysed for Percept Weight Gain (PWG) using the formula:

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

where;

$$W_2 = \text{Mean final fish weight}$$
$$W_1 = \text{Mean initial fish weight}$$

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

$$\text{SGR (\%)} = \frac{\ln W_2 - \ln W_1}{\text{Days}} \times 100$$

Where;

$$W_2 = \text{Mean final fish weight}$$
$$W_1 = \text{Mean initial fish weight}$$

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 and Helfrich, 2009):

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

Where;

$$\text{TFI} = \text{Total feed ingested (g)}$$
$$\text{WG} = \text{Weight gain (g)}$$

The 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 using the following relationship:

$$\text{Log } W = \text{Log } a + \text{Log } TL$$

Where;

$$W = \text{Fish weight (g)}$$
$$TL = \text{Total Length (cm)}$$

While the condition factor Kn was calculated as follows

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

Where;

$$W = \text{Fish weight (g)}$$
$$TL = \text{Total Length (cm)}$$

This result was then represented in regression graphs for each fish. Mortalities were determined at each sampling date by counting the remaining fish in the cages. However, in the cage, 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 ponds as a percentage of the stocked fish. The economic value was then calculated using the number harvested and the average market.

## RESULTS

The highest final body weight was that of groupers ( $242 \pm 10.2$  g), followed by that of milk fish ( $150.4 \pm 4.80$ g) and red snappers ( $125 \pm 7.02$  g). Rabbit fish had the lowest final weight of  $101 \pm 3.63$ g. The statistical analysis revealed that the body weight of the four fish species during six months was significant ( $F = 80.61$   $P < 0.0001$ ). On pair wise comparison (Table 1), the final weight of red snappers did not vary significantly from that of rabbit fish but varied significantly from all the other species. It was also observed that the final weight of groupers contributed much to the variation between the four species.

The comparison of body weight of the four species during the six months revealed that in the first month the mean body weight was not significantly different from each other. During second and third months, the means body weights of milk fish, red snappers and rabbit fish were not significantly different from each other but the groupers showed significantly higher value. During fourth month until the sixth month, only rabbit fish and red snappers did not vary significantly from one another.

Table 3. Monthly average fish weight  $\pm$  SEM (g) during the study period (different letters show significant variation)

Fish Type	June	July	August	September	October	November
Milk Fish	56.0 $\pm$ 2.45 <sup>a</sup>	64.8 $\pm$ 2.44 <sup>a</sup>	76.0 $\pm$ 1.3 <sup>a</sup>	94.8 $\pm$ 5.30 <sup>b</sup>	116.4 $\pm$ 6.08 <sup>b</sup>	150.4 $\pm$ 4.80 <sup>bc</sup>
Red	61.2 $\pm$ 3.01 <sup>a</sup>	66.4 $\pm$ 3.67 <sup>a</sup>	70.2 $\pm$ 2.99 <sup>a</sup>	78.8 $\pm$ 5.32 <sup>a</sup>	92.8 $\pm$ 3.20 <sup>a</sup>	125.0 $\pm$ 7.02 <sup>b</sup>
Snapper	55.4 $\pm$ 1.63 <sup>a</sup>	61.4 $\pm$ 1.40 <sup>a</sup>	75.0 $\pm$ 0.894 <sup>a</sup>	79.8 $\pm$ 1.85 <sup>a</sup>	108.2 $\pm$ 5.8 <sup>a</sup>	101.0 $\pm$ 3.63 <sup>a</sup>
Rabbit Fish	62.0 $\pm$ 2.21 <sup>a</sup>	97.4 $\pm$ 5.01 <sup>c</sup>	127.8 $\pm$ 14.5 <sup>c</sup>	175.2 $\pm$ 8.18 <sup>d</sup>	210.2 $\pm$ 7.39 <sup>d</sup>	242.0 $\pm$ 10.2 <sup>d</sup>
Groupers						

### Monthly Fish Length

The highest mean final length of fish (Table 2) was for the groupers ( $26.1 \pm 0.4$  cm), followed by milk fish ( $24.1 \pm 0.534$  cm) and rabbit fish ( $19.5 \pm 0.524$  cm). Red snappers had the lowest mean final length ( $17.5 \pm 0.224$  cm). The variations between the four species in final total length was significant ( $F = 82.35$ ,  $p < 0.0001$ ). During the first three months of study, the milk fish had the highest average length but this changed during the fourth month when the groupers grew past milk fish in length (Table 2). The red snappers were however shorter from month one all the way to the last month.

Table 4. Monthly average fish length  $\pm$  SEM (g) during the study period (different superscript letters show significant variation)

Fish Type	June	July	August	September	October	November
Milk Fish	19.6 $\pm$ 0.25 <sup>d</sup>	20.4 $\pm$ 0.37 <sup>d</sup>	21.4 $\pm$ 0.4 <sup>c</sup>	22.0 $\pm$ 0.45 <sup>b</sup>	23.3 $\pm$ 0.62 <sup>c</sup>	24.1 $\pm$ 0.53 <sup>c</sup>
Red Snapper	13.2 $\pm$ 0.58 <sup>a</sup>	14.8 $\pm$ 0.37 <sup>a</sup>	15.6 $\pm$ 0.19 <sup>a</sup>	16.5 $\pm$ 0.22 <sup>a</sup>	17.1 $\pm$ 0.19 <sup>a</sup>	17.5 $\pm$ 0.22 <sup>a</sup>
Rabbit Fish	14.9 $\pm$ 0.19 <sup>b</sup>	15.6 $\pm$ 0.19 <sup>b</sup>	17.0 $\pm$ 0.16 <sup>b</sup>	17.2 $\pm$ 0.23 <sup>a</sup>	18.5 $\pm$ 0.52 <sup>b</sup>	19.5 $\pm$ 0.52 <sup>b</sup>
Groupers	16.4 $\pm$ 0.43 <sup>c</sup>	18.1 $\pm$ 0.33 <sup>c</sup>	20.8 $\pm$ 1.06 <sup>c</sup>	23.6 $\pm$ 0.43 <sup>c</sup>	25.2 $\pm$ 0.26 <sup>d</sup>	26.1 $\pm$ 0.40 <sup>d</sup>

### Percent Weight Gain

Table 3 shows that the groupers had the highest final percent weight gain (290.3%) followed by milk fish (168.6%) and 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. The monthly percent weight gain of groupers on the other hand reduced every month from 57.1% during the first month to 15.1% during the last month. The monthly percent weight gain for rabbit fish and red snappers were oscillating.

Table 5. Monthly and overall percent weight gain (%) of the four studied fishes during the study period

Sampling	Milk Fish	Red Snappers	Rabbit Fish	Groupers
June	15.7	8.4	10.8	57.1
July	17.3	5.7	22.2	31.2
August	24.7	12.3	6.4	37.1
September	22.8	17.8	35.6	20.0
October	29.2	8.8	15.5	15.1
Overall	168.6	65.03	125.6	290.3

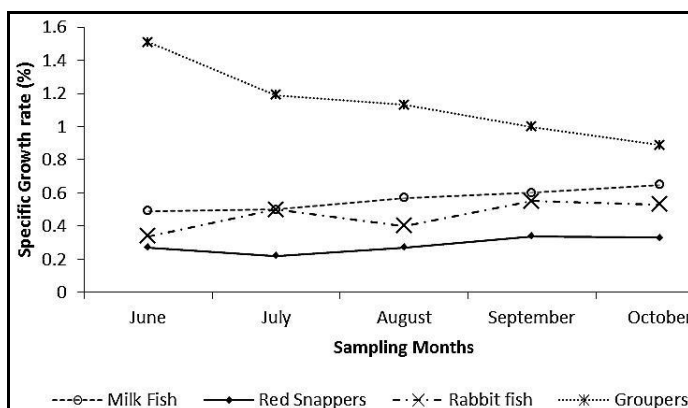


Figure 1. Specific growth rates of fishes sampled during the study period

## Specific Growth Rate

On specific growth rate (Fig. 2), groupers showed the highest value (0.89%) followed by milk fish (0.65%) and rabbit fish (0.53%) whereas red snappers had the lowest specific growth rate of 0.33%. The specific growth rate for milk recorded a monthly increase while that of groupers showed a monthly decline. Rabbit fish however 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.

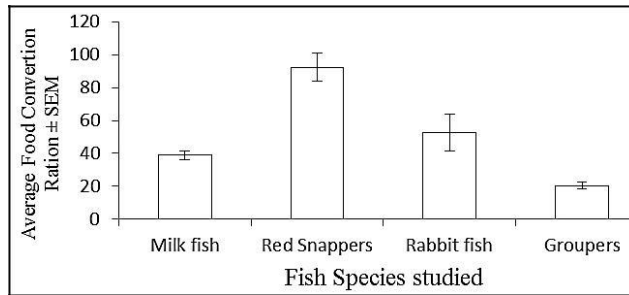


Figure 2. Length-weight relationship for the four fish species during the study period

## Length-Weight Relationship

Figure 3 below shows regression outputs for the length-weight relationships for the four species studied. Groupers had the highest  $R^2$  value of 96.6% showing that the data fitted well in the linear regression model. The lowest  $R^2$  value was with milk fish which was 80%. Generally all the four species fitted well in a linear regression model.

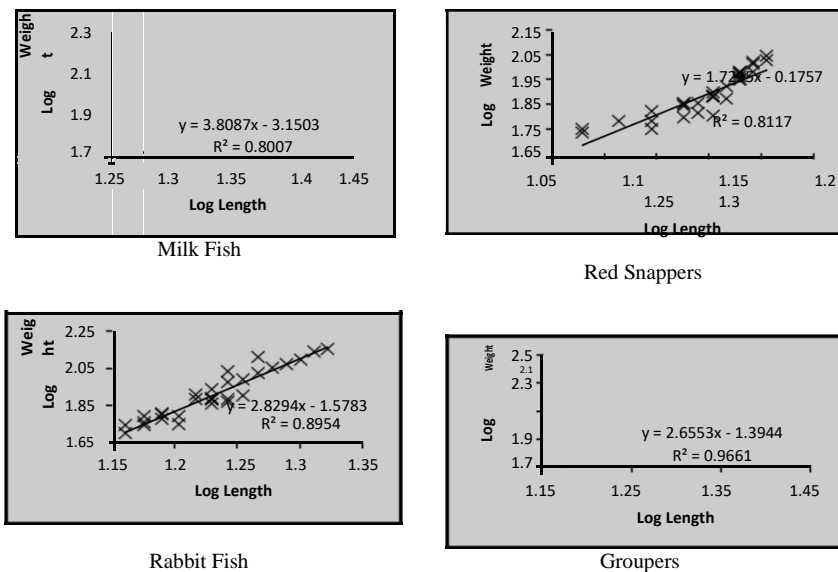


Figure 3. Food Conversion Ratio (FCR) for the four species studied

## 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 three species showed negative allometry and none had an isometric growth (Table 4).

Table 6. Growth 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	1.723	1.005539	0.811	Negative allometry
Rabbit Fish	2.829	1.021429	0.895	Negative allometry
Groupers	2.655	1.013369	0.966	Negative allometry

## Feed Conversion Ratio

The worst FCR values was obtained in the red snappers ( $92.3 \pm 8.35$ ), followed by rabbit fish ( $52.8 \pm 11.2$ ) and milk fish ( $38.9 \pm 2.68$ ). A relatively lowest FCR was obtained for the groupers ( $20.4 \pm 1.99$ ). The overall mean values of FCR for all the four fish species were significantly different from each other (Fig. 3). The ANOVA test results gave an F value of 8.59 and p-value of 0.036.

## Fish Mortality

The mortality (Fig. 4) was highest during the month of June, which was the first month. The number however reduced during the subsequent months and was even zero for groupers during the fourth and fifth months. Considering individual species, milk fish recorded higher mortality during the study period (38 individuals) followed by red snappers (18 mortality) and rabbit fish (13mortality) whereas groupers had the lowest number of mortality (4 individuals).

Based on the mortality, the grouper had about 98% survivorship which was the highest among the four species followed by rabbit at 93.5% and red snapper that recorded 91% survivorship. Milk fish had the lowest percent survivorship at 81%.

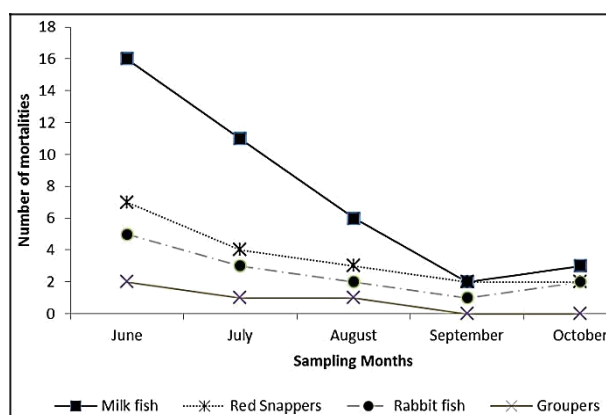


Figure 4. Monthly fish mortality for the four species during the month of June to October

### Economic Value

Red snappers had the highest market price of Shs. 200 Kg<sup>-1</sup> on average, while milk fish and groupers attracted prices of Shs. 165 Kg<sup>-1</sup> each on average. Rabbit fish on the other hand was selling at average price of shs. 175 Kg<sup>-1</sup> (Table 5). However, based on the final weight, groupers were found to sell for Shs. 40 a piece which was twice the price of a piece of red snapper due to size difference.

Table 7. Estimated Economic values of the four fish species after the growth period

Species	Final weight	Price/Kg (KSh.)	Value/piece (V)	Number (N) (Stocked –	Total value
Milk Fish	150.4g	165	25	162	4,050
Red	101g	200	20	182	3,640
Rabbit Fish	125g	175	22	187	4,114
Groupers	242g	165	40	196	7,840

Even though factors like feeding and feed types, water quality variables, and fish type determine the rate of growth (Zaikov, 2006), for this study, all factors were constant except fish type. The groupers gained higher body weight and maximum total length over the entire study period, followed by milk fish. The overall growth pattern of fingerlings also remained highest for groupers. In groupers, the higher mean body weight encountered at the end of the culture suggests better growth performance as compared to the other three species. Under the conditions of the present study, the discrepancy in growth performance between the four 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 groupers further supports the idea that it has better growth performance as compared to the other three 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).

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 this study is concerned, the better (lower) feed conversion ratio was observed for the groupers 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 (Bhijkajee & Gobin 1997; Bailey *et al.*, 2000).

This result therefore points at the groupers having the best efficiency in term of feed conversion among the four species followed by rabbit fish and milk 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 four species and reared under similar conditions. It is also known that nutritional requirements may differ between species (Boyd, C. E. (1999) but the crude protein levels required to sustain acceptable growth remains generally between a specified range (Craig & Helfrich 2009). The FCR of 20 for the snapper is still quite high as compared 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 snapper in order to develop consistent grow-out requirements and feeding practices or regimes.

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 (Le Cren, 1951; 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 whereas the rest showed negative allometry growth. 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 little stress during culture compared to other test species.

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 takes more time to acclimatize (Tuncer, 1988). The highest percent survivorship was observed in groupers where only four individuals died in the entire six month period. In contrast, a total of thirty eight fish mortality was observed in milk fish which was the highest among the four species. High survivorship is among the qualities of a good species for aquaculture production (Zaikov, 2006).

Based on percent survivorship results, the groupers are considered superior among the four species studied thus a better candidate for aquaculture in this region. However this is not a standalone quality to qualify it, the economic returns also plays a major role in the life of farmers hence has to be considered (Rothuis, 2011; FAO, 2008). In economic terms, the value of one piece of groupers after six months could sell for KSh. 40 considering the market price per kilogram. Considering the quantity available after six months of cage culture, groupers stocked could fetch over KSh. 7,800 which is twice that of red snapper and significantly higher than the other two fish species considered in this study.

## **CONCLUSIONS AND RECOMMENDATIONS**

### **Conclusions**

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

- i) The groupers had the highest SGR followed by milk fish which recorded the best length-weight relationship.
- ii) The FCR was however lowest for the groupers bringing the issue of production cost in relation to output though it exhibited hardiness because it had the smallest number of mortality.
- iii) The market price for groupers at the time of the study was highest. The higher price coupled with high survivorship rate makes groupers a better candidate for aquaculture in the Kenyan Coast. Similar observations have been made by Hassin *et al.* (1997) and Glamuzina *et al.* (2000) for groupers from the Mediterranean.
- iv) Grouper is most promising candidate for intensive cage based aquaculture because of its high market value, excellent taste, as well as rapid growth rates.

### **Recommendations**

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

- i) Intensive production of groupers should be promoted in the Kenyan coast to boost the economy of the coastal community.

- ii) A further study should be conducted to determine ways of improving the welfare of groupers which may eventually improve its efficiency in food conversion.

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## **BIO-DATA**

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