

In the Face of Poverty Mangrove Wetlands are Lifelines: Viability Indicators in Silvofishery Initiatives along the Kenyan Coast Assessing Polyculture of Milkfish (*Chanos chanos*) and Mulletts (*Mugil mugil*)

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ABSTRACT

Milkfish (*Chanos chanos*) have been grown in polyculture with mulletts (*Mugil cephalus*) in marine coastal ponds to increase productivity by more efficiently utilizing ecological resources within an aquatic environment and reduction of risks. Little attempts have been made to culture the two together in East Africa. The study was aimed at identifying the growth rate of milkfish and mulletts during the wet (long rains) and dry seasons (short rains) in Kenya; assess variability in pond water quality during peak spring and neap tides; and, assess milkfish and mullet fingerling occurrence over the year. The culture was done in three earthen ponds (each 0.018ha) constructed in the sandy flat behind the mangrove forest, in Kwetu and Majaoni, Mtwapa creek, and Makongeni, Gazi bay. The first culture cycle was July–December 2005 (dry-short rains) and second culture cycle being March–August 2006 (wet-long rains).

Stocking was done at 4 fish/m² and a polyculture ratio of 5 milkfish: 1 mullet with an organic manure fertilization (poultry manure) of 25kg in sacks floated on the pond and replaced after every three weeks. Fish sampling was done once every month. Basic water quality parameters (temperature and oxygen) were measured twice a week while other water parameters and nutrient analysis were done four times during the experimental period at peak neap and spring tides. Milkfish and mullet fingerling collection was done for six days in a month during spring tide using a “mosquito-mesh” seine net and push net along the mangrove channels where the water remains stagnant at low tide and during the incoming water. One way ANOVA indicated that milkfish growth rate was significantly lower in wet (0.52 ± 0.18 g/day) than dry (1.21 ± 1.0 g/day) seasons ($P < 0.001$), and similarly for mullet between wet and dry (0.15 ± 0.04 vs. 0.29 ± 0.15 g/day, $p < 0.05$). Pond water temperature varied between 27.1 ± 1.3 to 31.2 ± 2.1 °C (morning and

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evening respectively) during dry season and 25.7 ± 1.2 to 28.2 ± 1.9 °C in the wet season. Fingerling availability in 2005 - 2006 was analysed with repeated ANOVA and indicated significant difference in milkfish ($P < 0.001$) and mullet ($P < 0.001$) abundance between months; the occurrence of the two fish species also differed significantly at $P < 0.001$.

INTRODUCTION

Fish farming accounts for more than one-quarter of the total fish directly consumed by humans, using about 220 finfish and shellfish species (Naylor et al., 2000). Tilapia, milkfish, catfish, carps and marine molluscs contribute 80 % of the global aquaculture output amounting to 29 million tonnes in 1997 (Naylor et al., 2000). Ninety percent of the world's aquaculture is undertaken in Asia, with China producing two – thirds of the world total while Europe, North America and Japan, which produce only 10% consume the bulk of the seafood traded internationally (Naylor et al., 2000).

Milkfish aquaculture has a long history in Nauru (Pacific Ocean) where fry were caught in the surf and transferred to brackish water Ponds Island's interior which caused mortality of most fry but a large number survived (Spennemann, 2002). Schuster (1960) reported that milkfish have been recorded in the Red Sea, the Aden Gulf, the California Gulf, and off the coast of East Africa. Milkfish culture can be traced back about 700 years in Indonesia (Ronquillo, 1975), and at least 400 years in Philippines (Ling, 1977). At present milkfish occurs near continental shelves and around oceanic islands throughout the tropical indo-pacific. Mulletts (*Mugil cephalus*) are temperate and tropical euryhaline (Tucker and John, 1998).

Chanos chanos belongs to a monotypic gonorynchiform family and is most closely related to the freshwater Ostariophysi (Bagarinao, 1994). Milkfish populations show high genetic variation but low genetic divergence, similar to other commercially important teleosts. The natural life history of milkfish is one of continual migration. Adults are relatively large (to 1.5 m or 15 kg), long-lived (to 15 years),

pelagic and schooling. They spawn offshore near coral reefs or small islands. The eggs, embryos and larvae are pelagic and relatively larger than those of most marine species. Larvae ≥ 10 mm long and 2-3 weeks old move inshore via a combination of passive advection and active migration. Passing shore waters and surf zones, they settle in shallow-water depositional habitats such as mangrove swamps and coral lagoons, where they spend a few months as juveniles. A fishery on inshore larvae supports the centuries-old aquaculture of milkfish in Southeast Asia. The mullet (*Mugil cephalus*) is under family mugilidae which are schooling, very omnivorous and eat detritus and a wide range of organic material. The suitable temperatures for spawning range between 23 to 28°C while suitable salinity ranges are 17 to 36 ppt (Tucker and John, 1998). In Florida the mullets spawn offshore and larvae start drifting to shallow coastal areas while adults are found in the shallow coastal and estuaries. *Mugil cephalus* are extremely active omnivores and almost constantly swimming and feeding over wide areas.

The development of mariculture in Africa has experienced several setbacks including high cost of labour per unit output (Christensen, 1995); lack of documentation on possible impacts to the environment; appropriate technology; facilities, infrastructure and government policies. Despite that, the demand for marine fisheries production is increasing with the expansion of tourism and increase in human population (Anon, 1997).

Milkfish have been grown in polyculture with mullets in marine coastal ponds (Joseph, 1982). The underlying goal of polyculture involves increasing productivity by more efficiently utilizing ecological resources within an aquatic environment inclusive reduction of the risks i.e. mullets are especially susceptible to ectoparasites and scale loss (during handling) leading to vibriosis (Tucker and John, 1998). This type of aquaculture is attempted by stocking species with different feeding habits and different habitat preferences (Lutz, 2003). Synergism is often seen in polyculture systems where some species perform better in presence of other species.

From the biological, environmental and economic sustainability points of view, it is now becoming clear that it is more advantageous to farm herbivorous rather than carnivorous fish because of the lower amount of fish meal required as well as conversion efficiency (Mmochi et al., 2002). However despite the debates on the issue, farming of herbivorous finfish and filter feeders has a better chance of solving the world's food problems and protecting the environment.

The success of milkfish as a cultured food fish species may be attributed to its ability to tolerate extremes of environmental conditions; temperature, salinity, dissolved oxygen, ammonia, nitrite, crowding and starvation. Low temperatures (23°C) decrease survival, activity, food intake, and growth and development of milkfish while high temperatures (up to 33°C) have the opposite effect (Villaluz and Unggui, 1983). Milkfish tend to show signs of hypoxia at 1.4mg/l while 50% mortality occurs around 0.1 to 0.4 mg/l at 31 to 34°C (Gerochi et al., 1978). Tolerance limits to salinity vary with age (Duenas and Young, 1983) with larger fish being more efficient at handling osmotic stress than smaller ones (Ferraris et al., 1983). Milkfish can tolerate high ammonia levels of 21 to 20ppm, far above the normal values (around 1ppm) recorded in ponds (Jumalon, 1979; Cruz, 1981). Gill damage due to ammonia is reversible ten days after exposure in ammonia-free water. The juvenile can also tolerate high levels of nitrite- 675ppm (Almendras, 1987), thus eliminating ammonia and nitrite toxicity as main factors of mass kills in milkfish ponds.

In consideration of the above attributes, and research studies in Kenya and Tanzania, this research came up with a silvofisheries (polyculture of milkfish and mullets) program to look at innovations on community mariculture which can be easily adoptable; cheap; accessible; sustainable and of less environmental impacts to the environment. The water supply to the earthen culture ponds depended on the tidal cycle of seawater with no artificial aeration or water input. Several water quality parameters were

monitored and assessed regularly during spring and neap tides. The objectives of this study were: to monitor the variations of the main water quality parameters in the culture pond at spring and neap and relate them to fish production; to monitor growth rate and yield of milkfish and mullets during the rainy and dry seasons; to assess if there is any seasonal variability in milkfish and mullets fingerling abundance.

METHODS

Study Site, Pond Design and Preparation

The study was carried out in three replicate ponds in three sites along the Kenyan coast: Kwetu Training Centre - Mtwapa creek, Majaoni youth group-Mtwapa creek and Makongeni Baraka conservation group-Gazi bay (Fig. 1). Three replicate ponds of 0.018ha were used for the trials – one from each site. Waste pipes with elbows were placed at the gate sites for filling in water and draining of ponds while other waste pipes with screens were placed on the dykes relatively higher as overflows during high spring tides and occasionally during heavy rain floods (Fig. 2). Pond design and preparation took place from February to May 2005 and for the second phase, January to February 2006. After completion of pond construction, ponds were cured through drying and water flushing in preparation for stocking. One week prior to stocking, water was let into the pond through screens at the gate and overflow pipes.

Water Quality and Fertilization

Water temperature, pH, salinity and dissolved oxygen were taken in situ. While water samples were collected for chl-a, BOD, Ammonia, Nitrites, Phosphates, calcium, particulate organic matter and total suspended matter in the laboratory. Water samples were taken at 3 points along a transect in each of the culture ponds and mixed to get a sub-sample for laboratory analysis. The parameters that were measured in the field involved measuring at three points along a transect to obtain an average. Water quality status is quite eminent in aquaculture ponds.

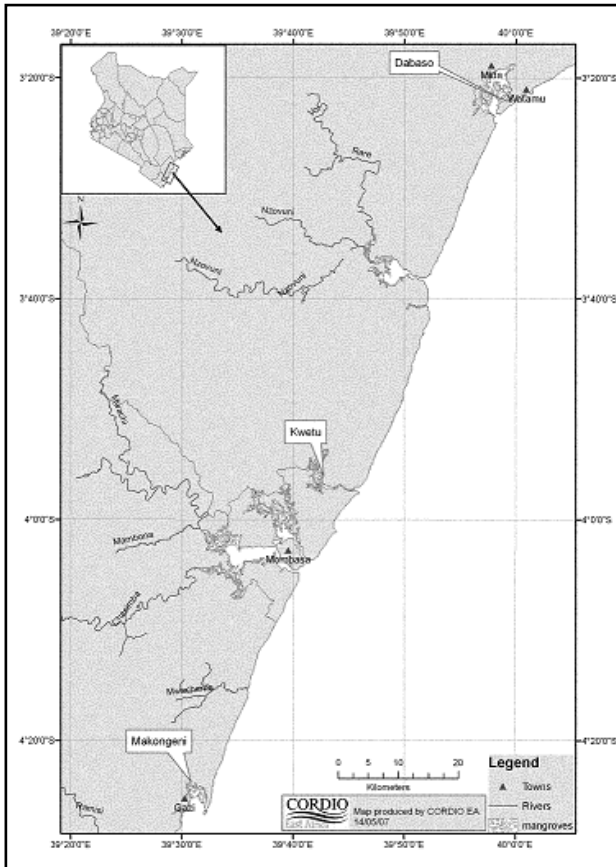


Figure 1. Map of Kenya coast showing the study sites where polyculture trials were carried out (Mtwapa creek and Gazi bay).



Figure 2. A pond at Majaoni showing stand pipe for draining the pond and overflow pipes to relieve the pond of extra water at spring high tides and increase water exchange in the culture ponds.

Temperature of the pond was monitored on a daily basis (morning; 0800 hours to 0930hours and evening; 1400hours to 1600hours) for a period of seven months in the first culture cycle-2005 and five months in the second culture cycle-2006. Dissolved Oxygen and Biological Oxygen Demand were measured three times during the experimental period in the morning and evening while other parameters were measured twice at spring and neap tides in the course of the field experiment. Costly water quality parameters were minimized since the results were targeted to help the local people who may not have the equipment and technology/know-how to use them. Whenever any stress was observed on the fish; sensitive water quality parameters (Dissolved oxygen) were assessed to ascertain if they were within the tolerance levels.

The culture facility (pond) was designed to allow in water at high spring tide to enrich the pond with planktonic materials and nutrients from the ocean water to develop the required lablab (benthic algal mat) for milkfish and mullets. During neap tide, four sacks of chicken manure weighing 25kgs each were floating in the pond to release nutrients for primary productivity in the pond and production of the benthic algal mat. The manure could also act as direct food for milkfish and mullets which were the target species under culture. No application of artificial fertilizer was made and manuring was reduced to three week intervals to reduce input of excess nutrients into the ocean.

Pond Stocking and Fish Sampling

Fish fingerling collection took place for a period of 2 months (April – June 2005) for the first cycle and March - April 2006 for the second cycle due to unavailability of the seeds. The culture period was programmed to be between six and seven months in the two trials. During the first cycle, a total of 692 milkfish and 124 mullets were stocked per pond with similar stocking in the second cycle. Milkfish and mullet fingerlings of between 2-8cm total length with an average weight of 5-9g/fish were selected for

Table 1. Average water quality parameters as recorded in the ponds at spring and neap tides and average quality of the open sea

Water quality parameters	Pond water		Surrounding Ocean
	Neap tides	Spring tides	
Chlorophyll-a ($\mu\text{g/l}$)	0.925 \pm 0.740	1.733 \pm 0.580	0.75 \pm 0.32
Calcium (mg/l)	0.019 \pm 0.020	0.0347 \pm 0.010	0.015 \pm 0.01
Total suspended matter(g/l)	0.0367 \pm 0.004	0.0398 \pm 0.004	0.0456 \pm 0.13
Particulate organic matter(g/l)	0.0335 \pm 0.004	0.0366 \pm 0.003	0.0426 \pm 0.06
Dissolved oxygen(mg/l)	5.75 \pm 2.530	6.592 \pm 3.580	5.25 \pm 2.36
BOD (MgO_2/l)	0.7587 \pm 0.367	0.9622 \pm 0.693	0.2 \pm 0.34
Salinity (ppt)	27.382 \pm 0.120	34.667 \pm 3.270	32.58 \pm 0.11
pH	8.0783 \pm 0.065	7.445 \pm 0.022	7.52 \pm 0.12
Ammonia-N (mg/l)	1.243 \pm 0.780	0.5311 \pm 0.086	0.214 \pm 0.02
Phosphate (mg/l)	1.718 \pm 0.140	0.0382 \pm 0.008	0.153 \pm 0.04
Nitrite-N (mg/l)	0.0723 \pm 0.034	0.0196 \pm 0.003	0.017 \pm 0.21

stocking. However, a number of other fish entered in with the tide as eggs through the screens but were removed with hook and line and at sampling.

Sampling was limited to two times during the capture period. This was mainly due to inadequate techniques of capturing milkfish and mullets, lack of efficient sampling tools, and the fear to cause frequent discomfort to the fish as a result of very muddy bottom. The proportion of sampling in terms of numbers could not be obtained since few fish were able to be caught at any one time and constant

movements in the waters could not be made due increased turbidity with each movement.

Harvesting

Harvesting was done after 7 months in the first cycle and 5 months in the second cycle. The whole pond was drained of all the water in order to allow for effective harvesting to take place. All the harvested fish were grouped into their respective species (milkfish and mullets) then separated into sizes and measured for both total length and wet weight (Fig. 3). Harvested fish were then sold to the local people at a reasonable price to create awareness on the potential for fish culture and mangrove conservation.

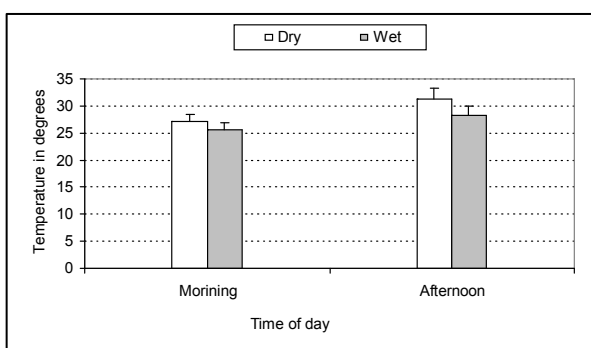


Figure 3. Temperature variations in the culture ponds during wet and dry seasons in the three replicate pond sites along the coast of Kenya.

RESULTS

Pond Water Quality

A survey of the physical chemical parameters was done in the sea water around the replicate culture ponds to assess if there were any significant difference between pond water and open sea water quality in sites and tides. No significant differences in open water quality were observed in the 3 replicate ponds ($p = 0.478$). Table 1 gives a summary of average water quality

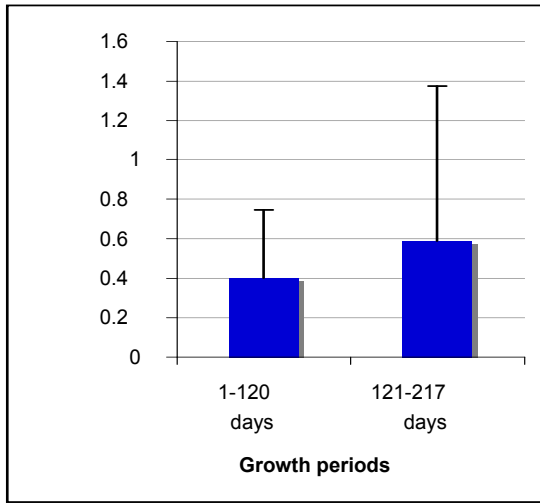


Figure 4. Growth trend of milkfish in an earthen pond during the wet season over a period of 217 days.

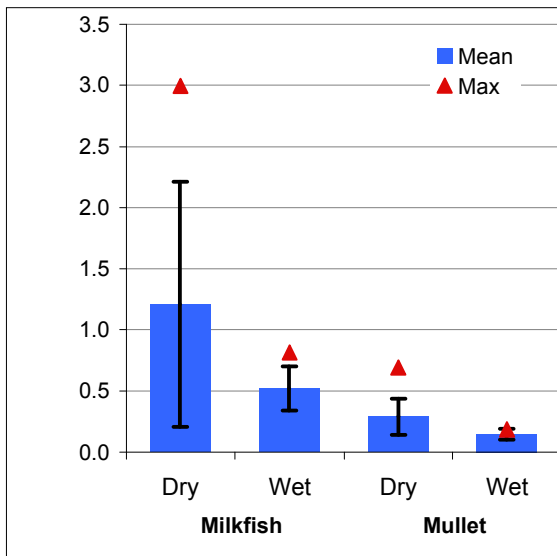


Figure 5. Growth rate (g/day) of milkfish (*Chanos chanos*) and mullet (*Mugil cephalus*) during different growing seasons (wet and dry) along the coast of Kenya.

Table 2. Harvesting size (mean, standard deviation and maximum, in grams) of milkfish and mullet per culture cycle during the period 2005-2006.

Season	Parameter	Milkfish	Mullet
Wet	m ± sd (g)	81.3 ± 28.1	28.7 ± 6.9
	max (g)	117.8	30.4
Dry	m ± sd (g)	262.5 ± 218.1	62.9 ± 31.9
	max (g)	650.5	150.2

parameters recorded in the ponds (neap and spring tides) and sea.

Wet months indicated lower mean temperatures compared to dry months however not significantly different ($p = 0.078$). One way ANOVA indicated significantly lower morning temperatures in the pond water compared to the afternoon ($p = 0.05$) (Fig. 3). Pond water was generally neutral at neap tide pH 7.4 equivalent to that of the open sea pH 7.5 while it became more alkaline at spring tide pH 8.1.

On average, dissolved oxygen was reasonably high ranging between 5.8-6.6mg/l in neap and spring tides (Table 1). ANOVA results showed that salinity of water was significantly higher at spring tides (34.7ppt) compared to neap tides (27.4ppt) ($p = 0.05$).

Chlorophyll-a was highly influenced by spring tides in the pond increasing to almost double that recorded in the neap tides a concept justifying the importance of water exchange in the culture ponds and the dependence on the natural productivity of the mangrove system. Low levels of suspended organic matter and particulate organic matter were recorded in the pond systems, which lead to the low BOD recorded in the ponds (Table 1).

Fish Growth Rate and Harvesting Size

Milkfish growth was consistent over the study, averaging 0.4 g/day in the first 120 days and almost 0.6 g/day from 121-217 days (Fig. 4). However variation in growth rate among individuals was very high: of the 7 individuals sampled, 2 fish with starting

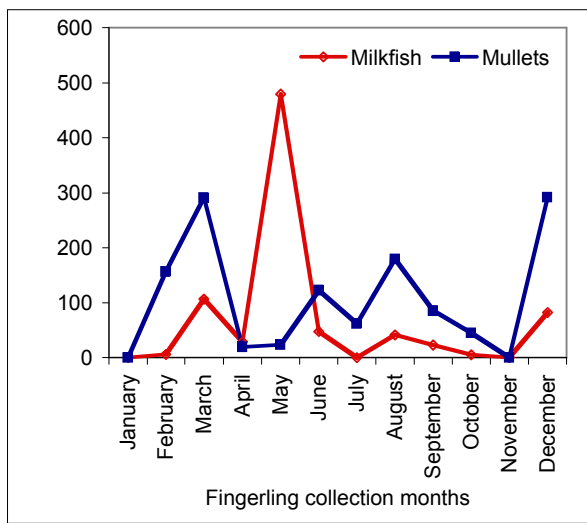


Figure 6. Number of milkfish and mullet fingerling collected from 2005-2006.

weights of 24.8 and 25.3g grew to 80 and 370g, respectively, over 217 days, while 5 fish from 2.8 – 5.4g initial weight grew to 34 – 115.3g over the same period.

Both milkfish and mullet fish were observed to be active during mid afternoon in hot sunny days. The average growth rate for mullet fish was comparatively lower than milkfish ($p = 0.05$). The dry season provided the highest significant growth rate for both milkfish (1.21g/day) and mullets (0.29g/day) compared to the wet season ($p = 0.05$) (Fig. 5). The average weight of milkfish harvested during the dry season differed significantly from that of wet season ($p = 0.05$) however, with a higher standard variation in the dry season (Table 2). The same trend was recorded for mullets but with relatively small standard deviations between the individual fish weights. The maximum weight attained by the both milkfish and mullets varied in the wet and dry seasons.

Fingerling Occurrence

The survey made for two years (2005-2006) indicated that milkfish occurrence could be only reliable twice in a year between March and June with a peak being

recorded in May. A relatively small collection peak was found in December. Hardly any fingerling collection for milkfish could be made in January and February while a few were collected between July and October (Fig. 6). Mullet fish fingerling abundance was observed to be more abundant throughout the year with limited occurrence between April and June and in November. The abundance of the milkfish and mullet fingerlings varied between and within sites with no significant difference ($p = .089$).

DISCUSSION

Culture Species and Fingerling Capture Strategy

Milkfish (*Chanos chanos*) and mullet (*Mugil cephalus*) were targeted for culture in this trial due to their tolerance to a wide range of water quality factors, simplicity of feeding habits and adaptability to crowding. The ability for crowding helps to capture many species at a small point unlike the territorial ones (Rice and Devera, 1998). In small scale aquaculture, culture of species that are tolerant to a wide range of water quality factors help to reduce culture expenses; implying that it is best to select species that are tolerant to fluctuations and extremes of water quality like milkfish and mullets (Swift, 1985).

All the seed stocked were readily obtained from the wild through seining but not from hatcheries. Even in South East Asia where hatchery technology has been developed (Lee and Liao, 1985), most of the culture of this species is based on collection of larval and juvenile fish from a capture fishery (Villaluz, 1986). Mosquito nets being cheap and available locally were used to seine milkfish and mullet fingerlings along the mangrove channels both at low and high tides during spring tides. Occasionally the milkfish and mullet fingerlings were found in the pools of water within the intertidal area at low tide and scooped with hand nets for stocking.

Water Quality

Conversion of wetlands into aquaculture ponds has resulted in increase of nutrients and organic wastes, leading to general deterioration of water quality (Mmochi et al., 2002). The water quality problem is associated with both physical and chemical factors such as high or low dissolved oxygen, high concentration of nitrogenous compounds (ammonia-N and nitrate-N) and high levels of hydrogen sulphide.

Temperature and Salinity

Milkfish do not inhabit areas of the Pacific Ocean influenced by cold currents but they do occur in seas affected by warm ocean currents. Their distribution coincides with coral reef areas where the water is warm (more than 20°C), clear and shallow (FAO, 1987).

Temperature was not observed to be a problem in the milkfish and mullet culture ponds since it varied from 24°C to 33°C during wet and dry seasons. It was significantly higher during the dry season (27.1°C - 31.2°C) compared to wet season (25.7°C - 28.2°C). Therefore temperature was not a limiting factor to growth as argued by Roberts (1964). Based on the argument by Rice (2003) that warm water fish species grow best between 25 and 32°C, the recorded water temperature in this study was appropriate for fish growth.

Higher salinity influences solubility of oxygen in water, resulting in decreased dissolved oxygen saturation in the water. Fish get adapted to specific salinity regimes and become stressed when there are rapid changes (Rice, 2003). In the current study salinity was significantly high at spring (mean 34.7ppt) compared to neap tides (mean 27.4ppt). This was a clear indication of the tolerance needed for the culture species for effective culture process. The recorded salinity level falls within the range of salinity in the marine environment and was not expected to cause any stress in growth of cultured fish and mainly tolerant species like milkfish and mullets (Lee and Liao, 1985). However, it has been pointed out that a salinity difference of only 5mg/l (ppt) can be lethal to some fish (Boyd, 1990; Rice, 2003). This might have

been the cause of the fish kill that occurred in the present study two days after heavy rains during wet season that reduced salinity significantly to 25ppt.

pH and Chlorophyll-a

Most fish can survive normally in a pH range of 6.5 to 8.7 (Rice, 2003) while extremes of pH can be directly harmful to the fish or increase the toxicity of a number of naturally occurring ions or metabolic wastes such as ammonia. In the current study, pH levels were within the fish culture levels (7.0 to 8.5) while increasing as the day matures. There was a clear difference in pH between neap (8.07) and spring (7.44) with higher values being recorded at neap in the mornings and afternoons. There was a general increasing pH from morning to evening which is associated to photosynthesis during the day that used up carbon dioxide thus facilitating the release of carbonate ions from calcium carbonate (Boyd, 1992), but the levels were okay for milkfish culture. The levels compared well with the values found in the mangrove channels (7.52) where no fish were being cultured however, the afternoon pH was comparatively low compared with the ones recorded by Mirera (2000) in the Tilapia ponds where artificial fertilizers were used. Waters that are in the range of pH 6.7 to 8.0 at day break and 9.0 to 10.0 by late afternoon are considered the best for fish production.

Chlorophyll-a, is an indicator of primary productivity in the pond. High chlorophyll-a, indicate good primary productivity in the ponds to warrant high fish production. Mean values at neap were lower (0.93 µg/l) than spring (1.73 µg/l). The recorded results in these research study were higher compared to those by Mirera (2000) at Sagana in his studies of phosphorus fertilization where a high correlation was observed between fish standing crop and chl-a. Consequently, they were much lower than those recorded by Boyd (1992) at Auburn University. Measurement of chlorophyll-a levels in water within the mangrove channel (0.75 µg/l), revealed that the pond had higher levels and hence likely to be more productive.

Dissolved Oxygen

Dissolved oxygen is one of the critical parameters of concern with any kind of aquaculture system, therefore calling for proper monitoring of its dynamics in small scale pond aquaculture where aerators are not applicable. Dissolved oxygen levels in this study were between 5.75 and 6.59mg/l which did not have any significant difference with the surrounding sea water. However, mortalities (fish kill) were observed following two days of rainfall in the Kwetu and Majaoni ponds during the wet season that was associated to stratification of water forcing fish to gulp for air on the surface in the early morning which was hardly enough (less than 0.9mg/l) due to still air (Rice, 2003). Dissolved oxygen (DO) levels were relatively high in the pond in the early morning of spring high tide (2.85 -4.1mg/l) and afternoon (7.5-8.3 mg/l). The neap tide dissolved oxygen variation was between 3.25 -3.75mg/l in the morning and 8.6 – 11.15mg/l in the afternoon. While the morning values were similar to those obtained by Mirera (2000) in his phosphorus experiments, afternoon values were far much lower in the current study which explains the difference of artificial and organic fertilization.

More dissolved oxygen was recorded in the ponds during spring tides than at neap tides which could be a result of temperature, salinity, chlorophyll-a and atmospheric pressure (Batiuk, 2002). According to Boyd (1990) and Rice (2003), an artisanal fish pond should have sufficient oxygen levels to support fish all the way to the bottom. However, fish selected for culture in artisanal ponds should be tolerant to low dissolved oxygen a case which was observed for milkfish and mullets in the current study.

Nitrite and Ammonia-N

The level of nitrite (toxic component of nitrogen) in the culture ponds was relatively low (0.0196 - 0.0723mg/l) compared to what is expected in aquaculture ponds. This can be associated to the fact that no feeding was used during this experiments which could have increased the amount of nitrogen in the water (Darborow et al., 1997). Significantly higher

nitrite levels were recorded in neap tides compared to spring tides possibly because of reduction in water level by evaporation or higher amount of organic matter in the system due to higher lablab accumulation and decomposition (Neori et al., 1989; Hall et al., 1992). The nitrite levels were also well controlled within limits since there was no much variation in pH which is a contributory factor to their increase.

Total Ammonia Nitrogen (TAN) is composed of toxic (unionized) ammonia-NH₃ and non-toxic (ionized) ammonia-NH₄ but only a fraction of the TAN is in the toxic form. Dangerous short term levels of toxic un-ionized ammonia which are capable of killing fish over a few days start at about 0.6mg/l. The total ammonia nitrogen (TAN) recorded in this study were ranging between 0.53 – 1.24mg/l far below the individual toxic component of un-ionized ammonia (0.5 -2.0mg/l). However, there were significant differences in ammonia nitrogen between spring and neap tides indicating the importance of water exchange in a pond systems to help in pond self regulation. The amount of ammonia excreted by fish varies with the amount of feed put into the pond, increasing as feed rate increases. Ammonia also enters the pond from bacterial decomposition of organic matter such as uneaten feed or dead algae and aquatic plants (Darborow et al., 1997) which could have been the main contributory factors in this study since no feed was used.

Phosphates and Calcium

Phosphates were observed to be significantly higher during the neap tides (1.72 mg/l) compared to spring tides (0.038 mg/l). This was associated to the dilution effect of water from the open ocean at spring tides while higher neap tide values could be a result of phytoplankton breakdown and release of phosphates from the sediments (Welch, 1980). The available phosphate levels were above the required values for earthen culture ponds 0.001-0.05ppm (Knud-Hansen, 1998). Hence an indication that soluble reactive phosphorus was not limiting in the pond. Meaning

that nitrogen was well utilized in these ponds due to availability of phosphorus, since nitrogen full use may be hindered by deficit of phosphorus.

Calcium concentration in the pond was similar both at spring (0.035mg/l) and neap (0.019mg/l) tide. The difference could be associated to water replenishment in the pond during spring high tides leading to increase in calcium.

Total Suspended Solids and Particulate Organic Matter

Total suspended matter and particulate organic matter are important factors in limiting primary productivity in the culture ponds if their level is too high. The two parameters were noted to be low and of less consequence in the fish culture trials. The values were observed to be low at both spring and neap tides (0.03 to 0.05). Higher levels of total suspended matter was during spring signifying the particles coming in with tidal water and uplift of settled materials at the bottom of the pond due to falling of tidal water from inlet pipes. The result indicated low impact of these factors on primary productivity in the pond, hence, less likely impact on fish yield.

Dynamics of Fish Growth

Milkfish take food mainly from the substrate. They ingest the surface layer of the substrate together with the associated micro-and meio-fauna (Blaber, 1980). Pond reared milkfish feed mainly on either lablab (a complex mat of blue green algae, diatoms and associated invertebrates) or lumut (mainly filamentous green algae). The study observed that milkfish and mullet growth rates were significantly higher during the dry season compared to wet season. This observation is supported by Guanzon et al (2004) who found out that production of milkfish was higher during the dry season. Growth rates of milkfish were positively correlated with temperature and salinity, while net production rates were positively correlated with temperature and rainfall, but were inversely correlated with dissolved oxygen.

The higher growth rate of milkfish and mullets in

the dry season is due to abundance of lablab which is the main feed item. It has been observed elsewhere that Lablab is equivalent to the benthic algae (FAO, 1987) and leads to high milkfish production compared to the other methods (Lumut and plankton). Lumut (filamentous green algae especially *Enteromorpha* sp. and *Chaetomorpha* sp) yields are below 400kg/ha, while lablab method yields average 1000 to 2000kg/ha possibly why the milkfish growth in the present study was high in the dry season with abundant lablab unlike in the rain season with abundant lumut. During the rainy season, lablab disintegrates and lumut and/or plankton becomes part of the main natural food base and yet their support to faster fish growth is limited (Banno, 1980).

It was observed that milkfish intensified feeding during mid-afternoon in a hot sunny day when lablab started peeling off the pond bottom to float fostering active surface feeding by fish. The observation was also echoed by Kumagai et al., (1985) and Chiu et al., (1986) "Feeding activity peaks at midday and in the afternoon when dissolved oxygen, water temperature and digestive enzyme activity are highest".

Studies carried in Asia suggest that harvesting of milkfish is done usually when the fish have reached an average of 300 to 800 g body weight. While pond yields have reportedly ranged from 50 to 500 kg/ha/year (Bardach et al., 1972). The present study harvested milkfish at an average of 82g during the wet season and 263g in the dry season with some of the fish having individual weight of up to 650g concurring well with studies recorded by Mwaluma (2003). Mulletts were harvested at a relatively lower average weight of 29g and 63g during wet and dry season respectively. There was a generally uniform growth of milkfish during the wet season suggesting that feed availability and water quality parameters impacted all fish sizes equally.

Fingerlings Occurrence

The spawning cycle of milkfish has been observed to be seasonal and varies with localities. Based on the annual occurrence patterns of milkfish fry, the

breeding season of milkfish has been described to be long near the equator and becomes progressively shorter with a single peak at higher latitudes in the northern hemisphere (Kumagai, 1984). Kenya being near the equator, the present survey indicated that milkfish occurrence could be only reliable twice in a year between March and June with a peak in May and a relatively small peak in December while mullet fish occurrence was throughout the year with limited occurrence between April and June when milkfish abundance is expected to be highest. Observations in the Philippines indicate that, milkfish fry occur practically throughout the year with the peak season being April-July and October-November (Villaluz, 1986) while Indonesia has two milkfish fry seasons: April-June and September – December (Chong et al., 1984) that ties well with observations made in the current study. The observations on milkfish fingerling occurrence along the coast of Kenya is also supported with records of FAO (FAO, 1987).

Both milkfish and mullet fingerlings in this study were collected during periods of spring high tides. The fish were seined with push nests in the mangrove channel water pools at low tide. In Philippines, milkfish were observed to enter a mangrove lagoon fortnightly with the high tides of spring tide periods where they grow into juveniles before leaving the area with the high tides (Kumagai et al., 1985). The observations also concur with those of Kumagai, (1987) that fry were collected during the new and/or full moon period because intense spawning occurs during the quarter moon period however; total fry catch showed annual fluctuations due to such factors as climate and fishing efforts.

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