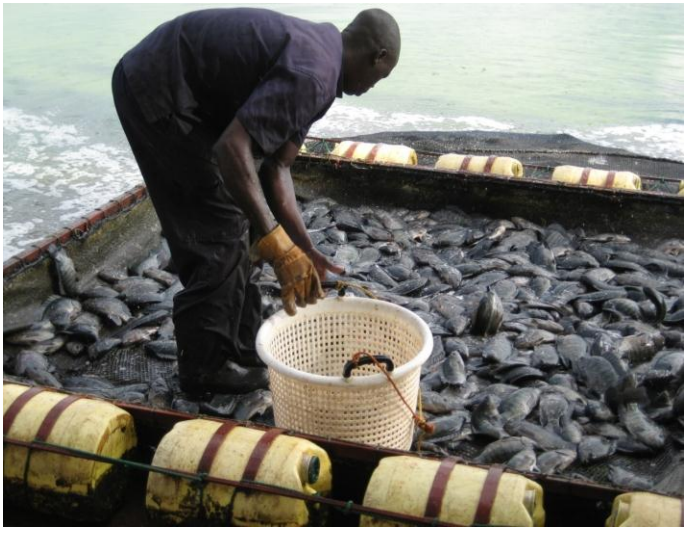
Operational Manual for Cage Fish Farming in Uganda









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Summary

These guidelines have been prepared to guide operation of cage fish farms in Uganda to ensure optimal benefit to farmers with minimal impact on the environment and other lake uses. Increased demand for fish by the rapidly increasing human population, export demand, and reduced fish production from capture fisheries has reduced *per capita* of consumption of fish in Uganda to as low as 8 kg, which is below the 17 kg recommended by FAO and 25 kg recommended by the WHO for healthy living. With a population of 35 million, Uganda needs about 600,000 tons of fish annually to meet the recommended FAO *per capita* fish consumption. In addition, regional and international export markets each require about 200,000 tons of fish annually from Uganda, indicating that Uganda needs to produce at least one million tons of fish annually to meet its demands. Current annual fish production in Uganda is about 500,000 tons (400,000 tons from capture fisheries and 100,000 tons from aquaculture), leaving a deficit of about 500,000 tons annually. Production from capture fisheries has stagnated and is not likely to meet the deficit. The deficit can therefore be met from aquaculture which is the fastest growing animal production system in the world and is considered a major remedy to increase fish supply amidst dwindling wild fish stocks. The government of Uganda has committed itself under the Agriculture Sector Strategic Plan (ASSP) 2016 – 2020 to increase aquaculture production by at least 300,000 tonnes annually by 2020. Aquaculture in Uganda has mainly been through earthen ponds but cage fish farming which started in 2006 is becoming more productive than pond aquaculture. This is due to attributes such as higher production per unit volume of up to 300 kg m^{-3} compared to 2-10 kg m^{-3} for pond fish farming), efficient utilization of feeds, and relatively lower start-up investment which offer opportunities to address the limitations that have undermined the contribution of pond fish farming to fish production in Uganda. However, cage fish farming presents environmental challenges as feeds, chemicals, veterinary drugs, excretion waste products, fish escapes, and diseases have potential to contaminate the natural environment and resident organisms. Cage fish farming can also result into conflicts among multiple water resource uses such as fishing, recreation, transport, water extraction and hydro power generation. There is therefore need for guidelines to guide operation of cage fish farms. These guidelines have therefore been developed to guide operation of cage fish farm in Uganda in line with international codes of practice for aquaculture. They provide basic information on setting up the cage fish farm, production practices, facility security, fish health management, waste management, environmental monitoring, and decommissioning of the farm, plus some information on the enterprise budget.. The guidelines periodically be improved from the lessons learnt in implementation of the process.

1. Introduction

1.1. Background

Local, regional and global demand for food fish is increasing due to increasing human population and preference for fish as a high quality protein with omega-3 fatty acids and micronutrients (Tacon and Metian, 2013; FAO, 2014). However, global fish production from wild fish stocks has generally stagnated, with most fisheries already fully exploited or over-exploited (Worm et al. 2006; FAO, 2014). In Uganda, this has been accompanied by a decline in *per capita* fish consumption to as low as 8 kg which is much below the 17 kg recommended by FAO and 25 kg recommended by WHO. With a population of 35 million people which is growing at one of the world's fastest growth rates of 3% per annum (UBOS, 2014), Uganda needs about 600,000 tonnes of fish annually to meet the local demand for fish to meet the recommended FAO *per capita* fish consumption. In addition, the international and regional export markets each require about 200,000 tons of fish annually from Uganda, indicating that Uganda needs to produce at least one million tons of fish annually. Current, annual fish production in Uganda is about 500,000 tones, comprising of about 400,000 tons from capture fisheries and about 100,000 tons from aquaculture, leaving a deficit of about 500,000 tons. Since production from capture fisheries is not expected to significantly increase, aquaculture is the only available option for increasing fish production to meet the deficit. Consequently, government has under the Agriculture Sector Strategic Plan (ASSP) 2016 – 2020 committed itself to increase aquaculture production to 300,000 tonnes annually by 2020 to reduce the fish supply deficit.

1.2. Potential for cage fish farming in Uganda

Aquaculture is the fastest growing food industry in the world (FAO, 2014) which has largely been achieved through adoption of new production systems and technologies. Pond aquaculture has been the dominant aquaculture production system in Uganda since the 1950s but cage aquaculture in lakes and other water bodies by local and foreign investors started in 2006, and has increased to over 1750 cages on Lake Victoria alone. The upsurge in cage fish farming is mainly due to its very high potential compared to pond aquaculture. Since its establishment >60 years ago, pond aquaculture has been able to achieve production of only 2 - 10 kg m^{-3}. On the other hand, cage aquaculture which started in the country in 2006 using Low Volume High Density (LVHD) cages of 8 - 18 m^3, has been observed to have the capacity to produce up to 300 kg m^{-3} under good management practices within a growth period of 6-8 months.

Cage fish farming has a number of advantages over other fish culture systems (Beveridge, 1984). They include: Very high production in a limited volume of water; Relatively low investment (the cost of construction of a LVHD cage is about 1/10 that of a pond producing the same yield of fish); Land ownership is not required; Does not require re-filling of water; Handling, inventory and harvesting of fish is easy; Breeding does not occur in cages; Fish predators can be controlled; Survival rate of fish is high under good management; Feeds are efficiently utilized; It

allows total harvesting and re-investing of the resources; Observation, sampling and harvesting are easy; Fish grown in cages can be sold fresh, in good quality and even alive; and requires relatively less labor. A basic enterprise budget using the Nile tilapia as the cultured fish species over a culture period of six months in LVHD cages of 2.5x2.5x2.5m (15.625m^3) is given in annex **Table 1**, indicates high returns on low investments over a short period of time, demonstrating that cage fish farming has higher potential to increase fish production and create wealth among fish farmers in Uganda.

Table 1. Enterprise budget for 10 units of Low Volume High Density (LVHD) cages

Gross Receipts	Unit	Quantity	Unit Cost	Total Cost (UShs)	Total cost (USD)
Gross Receipts of tilapia at harvest	Kg	16,875	8,500	143,437,500	54,747
Variable Costs:					-
Nile tilapia fingerlings	No	18,750	250	4,687,500	1,789
Feeds	Kg	25,313	2,850	72,140,625	27,535
Labor	months	6	1,200,000	7,200,000	2,748
Food/Fish Baskets	No	10	20,000	200,000	76
Feeding accessories	Assorted	10	10,000	100,000	38
Total Variable Costs (TVC)				84,328,125	32,186
Net Returns Above TVC				59,109,375	22,561
Fixed Costs (FC):					
Cage (2.5X2.5X2.5) m	No	10	2,200,000	22,000,000	8,397
Mooring and technical services		1	500,000	500,000	191
Boat	No	1	2,500,000	2,500,000	954
Life jackets	No	4	70,000	280,000	107
Multi parameter meter	No.	1	4,000,000	4,000,000	1,527
Weighing Scales	No	2	1,000,000	2,000,000	763
Placement of the cages in lake		10	250,000	2,500,000	954
Total Fixed Costs (TFC)	UGX			33,780,000	12,893
TFC Amortarised over 10 year	UGX			3,378,000	1,289
Total Costs (TC)	UGX			118,108,125	45,079
Insurance - per annum	UGX			3,012,188	1,150
Professional Management	UGX			5,905,406	2,254
Net Returns Above TC - Run 1	UGX			16,411,781	6,264
Net Returns above TC per cage - Run 1	UGX/Cage			1,641,178	626
Net Returns less TFC Run 1				50,191,781	19,157
Net Returns less TFC Run 1/cage				5,019,178	1,916
Net Returns (Amortarised FC)	UGX			46,813,781	17,868
Net Returns per cage Amortaritsed	UGX/Cage			4,681,378	1,787
Cost of installing, running 1 cage for 6months				12,702,572	4,848
Cost of installing, running 1 cage for 6months				9,662,372	3,688
% profit (Run 3) / cage				40	
% profit (Run 3) / cage				48	

Notes: The projections are for operating ten cages (15.6 m^3 each), stocked with Nile tilapia fingerlings of 20 g at a stocking density of 280 fish m^{-3} with a survival rate of 90%, fed with pelleted diet of 30% crude protein, with a food conversion ratio of 1.5, harvested twice a year at 0.5 kg, producing 120 kg m^{-3} i.e. a production period of six months, assuming cage frames last for ten years and the nets last 5 years. 1$ = 2620 Uganda shillings).

About 20% of the surface area of Uganda is covered by freshwater bodies including five major lakes (Victoria, Albert, Edward, Kyoga and George), over 160 small lakes, rivers such as the Nile and numerous dams which provide substantial potential for cage fish farming. Other suitability attributes include: suitable climate with high temperatures up to 25-35^oC; Availability of suitable native aquaculture fish species especially the Nile tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepinus*); High national, regional and international markets for fish; Availability of local ingredients for fish feed formulation such as maize bran, soya bean, fish meal,; increased interest in aquaculture by local and international investors; and Availability of a policy, legal and institutional frameworks for regulation, research, and extension to support cage fish farming.

1.3. Socio-economic concerns

Cage fish farming takes place in water bodies that are public property and are used for other social and economic activities such as fishing, recreation, transport, water extraction for domestic and industrial use, and sewage disposal. These uses have to be addressed to avoid conflicts with cage fish farming.

1.4. Environmental concerns

Inputs in cage fish farming [feeds, seeds, chemicals, cage materials] and products [dead fish, uneaten food, feaces and other wastes] can affect water quality. Cage fish farming can lead to introduction of diseases. Cages are set up in shallow near shore areas that are normally breeding and nursery areas and areas of high natural fish species diversity which can affect natural fish populations. Escapes from the cages can interbreed and adulterate wild stocks. The materials used can foul the environment if not properly disposed of. Chemicals and drugs used to treat parasites and diseases can affect the environment.

Cage fish farming can alter physical, chemical and biological conditions of the aquatic environment such as dissolved oxygen (DO), nitrate, Chla, bacterial, algal and invertebrate communities and can increases in turbidity, BOD, Organic-N, total-P and organic content of sediments under cages in the farm area (Rox et al, 1972).

1.5. Purpose of the guidelines

Therefore, effective cage fish farming requires proper guidelines for establishment and operation of cage fish farms o ensure that the farms are established, operated and managed in a manner that are in line with an Ecosystem Approach to Aquaculture (EAA) which is a

requirement for all aquaculture interventions worldwide. This approach requires that aquaculture operations are sustainable and consider all other uses of the ecosystem where they occur, taking into account their influence on surrounding social and natural environment (Subasinghe, 2009).
In order to fulfill these requirements the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) is addressing the socio-economic and environmental concerns of cage fish farming through: Development of guidelines for establishment of cage fish farms and aquaculture parks; Characterizing and mapping sites suitable for cage fish farms and aqua-parks; Developing an operational manual for cage fish farming; Establishing a site for research and demonstration in cage fish farming; Developing an operational manual for monitoring impacts of cage fish farms; Monitoring ecological and environmental impacts of cage fish farming.

This document provides some guidelines for operation of cage fish farms in Uganda including:

a) The site plan of the fish farm including types of cages, their design, layout, and inputs;
b) Production practices including selection of the fish species to be cultured, seed production and acquisition, stocking density, and feeds and feeding;
c) Performance, yield;
d) Harvesting and marketing of cultured fish;
e) Site security, fish health and waste management
f) Environmental monitoring of the site;
g) The decommissioning plan at the end of the operations; and
h) An indication of an enterprise budget.

The guidelines will be updated as new information on cage fish farming emerges.

2. Site plan of the fish farm

2.1. Site plan of the farm and future expansion

The farm should have a site plan which includes:

a) The cage fish farming facility and expected footprint i.e. the zone of maximum accumulation;
b) The boundary;
c) The cages and any other containment structures;
d) The anchor blocks and mooring lines;
e) Cage dimensions and number of cages;
f) Navigation markers and potential navigation pathways around the farm;
g) Buildings, offices and staff living quarters if available;
h) Walkways, utilities, cables, catwalks;
i) Stores for fuel, chemicals, feeds etc;
j) Access road to the site;
k) Water lines that supply clean piped water to the farm;
l) Mortality storage and net cleaning points;

m) Depth contours from the low water mark;
n) Predominant current direction;
o) Anchor blocks, mooring lines, marker buoys and shore attachments

2.2. Cage design and size

Cages range in size from 1 m^3 to hundreds of cubic meters. They can be rectangular, square or cylindrical in shape. Small cages are easier to manage than large cages, and usually provide higher economic return per unit volume.

Cage structures should be strong to withstand strong winds and currents and hold the fish securely. The materials for construction of cages should be strong, light in weight, rot and weather resistant, rustproof, fouling resistant, easily worked and repairable, drag free, smooth in textured and non-abrasive to fish.

There should be auxiliary cage equipment including: Partially removable cover to prevent fish from jumping out or predators from getting into the cages; Floating feed box or ring cylinder with wire mesh cover extending 40 cm below and 20 cm above the water surface to retain floating feeds, or solid or fine mesh tray (covering 20 % of the cage bottom) with 5 to 15 cm raised sides if sinking feeds are used; Steel rebar, polyvinyl chloride (PVC) pipe or other rigid materials if a rigid frame is used to support the cage walls; Floats; Anchors and platforms/walkways. Examples of layout of the cages currently practices in Uganda is shown in **Plates 1**



Plate 1. A typical layout of cages. Top left cages without an enclosure and bottom - cages with an enclosure of a chain link and a gate for security.

The cages should be located in water with good circulation protected from strong currents and high waves, away from stagnant water where poor water quality may stress or kill the fish. The cages should be in rows spaced at least 2 m apart. The water should be deep enough to allow the cage bottom to be at least 2-3 m above the bottom sediments and should be located in an easily accessible area to facilitate routine maintenance and feeding.

The cages should be in a place where they can be easily monitored and security provided using hired guards and other forms of security such as guarding dogs. Alternatively, the cage parameter could be enclosed using a chain link with an access gate can be installed around the cages and a dog kept inside to improve security.

The materials used for cage construction should be durable, strong and light, allow complete exchange of water, and should not stress or injure fish, should be resistant to fouling, not degradable in the water, and readily available.

Cage shape influences water exchange. Most cages are either rectangular or square, but circular or cylindrical cages are sometimes used. Water exchange is greater in a square or rectangular than cylindrical cages of the same volume and mesh size.

Cages can be of sizes up to 1000 m^3 or more. Performance per unit volume of cage is higher, most economical, and efficient in small Low Volume High Density (LVHD) cages of 2x2x 2 to 3x3x3m (8 to 25 m^3).

2.3.Structure and components of a cage

A typical structure with its components is illustrated in **Plate 2** and comprises of a cages frame, cage bag, floaters, feed enclosures or feed barrier, cage covers and sinkers.

Cage frame: Cage frames should be made of metallic bars or PVC pipes or other rigid materials. However, metallic frames are recommended because they are stronger and last longer.

Floaters. Floatation may be provided by plastic drums or jerrycans, sealed PVC pipe, Styrofoam or bamboo frames.

Cage bag. The cage bag is the one which holds the fish. The mesh size of the cage bag is important in preventing escape of fish to the surroundings and for this reason, a double case netting could be used to reduce the chances of escape of fish in case of damage. There should be a nursery cage and a production cage. A nursery cages should have a minimum mesh size of 8 mm square and a production cage 13 mm square mesh size. Water exchange between a cage and

the surrounding water is influenced by the mesh size of the cage bag. Water exchange increases with increasing mesh size, but decreases with increasing amount of solid space between openings.

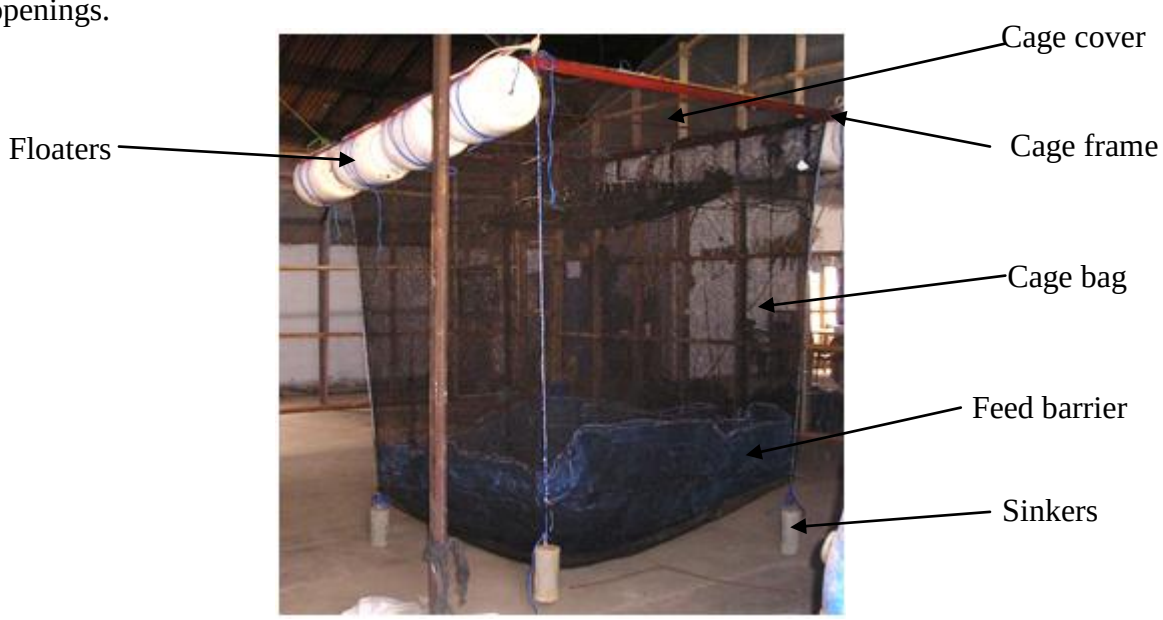

Plate 2 . A typical cage structure of a cage with its components.

Cage anchors: Since cages are placed in water to allow at least 2-3 m below the cage bottom, there should be anchor to stop the cages from drifting away by wind. The best anchoring system comprises four 0.3 m^3 concrete blocks with a 6.4 mm iron loop tied to ropes connected to each corner of the cage frame.

Cage covers: There should be covers over the cages to protect fish from jumping out of the cage and from predators such as otters, birds and theft. These should be opaque to block sunlight from entering the cage, and to restrict fish vision of objects and movement above the cage. Predatory birds are not as attracted to opaque-covered cages as they are to open top cages. The opaque cover material should cover the entire cage surface, excluding the floating feed container at 10 – 15 cm above the water surface. The ideal cage cover material should be light weight and weather resistant.

Feed enclosure: This is a structure installed in the cage to prevent loss of feed and optimize feeding in LVHD cages. A model feed enclosure for floating feeds is a ring or a box positioned in the top center of the cage with an open bottom and removable top cover. It should extend 40 cm below and 10 cm above the water surface. Its purpose is to prevent loss of floating feed while allowing the fish free access to the feed. Water surface area inside the feed container should be 20 - 25% of the total cage surface area. Floating feed enclosures should be placed in the center of cages. Demand feeders may be used as trickle feeders. However, where sinking feeds are used, it should be at the bottom of the cage

2.3. Other inputs

Other inputs are required in management of a cage fish farm include items like a canoe, outboard engine, life jackets, sampling baskets, measuring boats, fuel to facilitate movements from the shore to the cages, and labor for management of cages. These should be provided as part of the investment plan for the farm.

3. Production practices and data

The farm should maintain production information including: the species cultured; number of fingerlings stocks and their initial weight; stocking density; the types of feeds used; feeding rates; Survival rate; Growth performance; Weight of fish at harvest; Total quantity of fish harvested; Selling prices and other operational costs such as fuel and personnel costs. This data is important for management and can be used in cross-learning since cage fish farming is new in Uganda.

3.1. Culture species

The desired fish species for cage fish farming should have fast growth rate, be tolerant to crowded conditions, and of high market value. The Nile tilapia (Pates 3) is the recommended species for cage fish farming in Uganda. However, the African catfish can also perform well in cages. These species are locally available in Uganda although they require research to improve seed quality and growth performance. Introduction of none native species is prohibited and introduced fish species should only be used in cage fish farming in any water body in Uganda after approval by DiFR.



Plate 3. Nile tilapia is the most cultured and recommended fish species for cage culture

3.2. Seed (fry) for cage culture

Seed should be obtained from commercial or own hatcheries. It is recommended that brood stock (if operating a hatchery) and fingerlings should be obtained from suppliers certified by DiFR. In addition to mono-sex (all male) Nile tilapia**,** mixed sex Nile tilapia can be reared in cages without the problems of breeding since breeding requirements for tilapia are not available in cages and any eggs or fry produced go through the meshes to the surrounding water. Mixed sex tilapia however results into more variable sizes at harvest. All male tilapia are recommended for stocking because they grow faster and acquire more uniform size at harvest.

Fingerlings should be conditioned and trained to feed vigorously by holding them in hapas without food for 1-3 days followed by training them to feed rapidly for 1-2 weeks, stocking them into conditioning in nursery cages and before finally stocking them into growing cages. A nursery period of 1-1.5 months is necessary to grow small fingerling (<5 - 6 cm) to about 10 cm before stocking in grow out cages. Survival of fingerling depends on many factors but this can be improved by not stressing them during handling, transport and stocking.

3.3. Stocking density and size

The minimum recommended stocking density for Nile tilapia and the African catfish is 80 fish per cubic meter. The smallest recommended fingerling size for stocking is 15 g. This will be retained by a nursery cage of 13 mm mesh size net. Survival rates in well placed and well managed cages are typically 80-95%. The carrying capacity of a body of water limits the weight of fish that can be cultured. Stocking more fish than the carrying capacity will result in increased stress, disease, and mortality, and reduce feed conversion efficiency, growth rate, and ultimately profits. Generally, a 1,000 m^2 of water surface area is needed to support 400 kg of fish.

Stocking density depends on the quality and quantity of the feed, water quality, the species to be cultured, expected yield and average size desired at harvest. Temperature affects fish mortality after stocking. Nile tilapia survival is best when stocked at 20 to 22° C. Fingerlings should be stocked after attaining the recommended size of 15 g that is efficiently retained by a 13 mm mesh net nursery cage. A minimum stocking density of 50 fish m^{-3} is recommended, but densities can be as high as 300-600 fish m^{-3} depending on management practice. Sites with good water exchange can have higher stocking densities, while those with poor water exchange should use lower stocking densities. Fingerlings for stocking should be graded to ensure uniformity in size at stocking and harvest.

3.4. Feeds and feeding

Feeds play a major role in cage fish farming but are also the main source of nutrient enrichment or pollution which cage fish farming poses to water bodies. Farmers are advised to use feeds evaluated by a relevant mandated institution for desired quality, absence of bacteria and other

contaminants, likely to affect the environment and health of fish and consumers. The feeds used should:

a) Have a Veterinary Health Certification;
b) Be water stable and easily acceptable by the fish;
c) Be dry extruded and pelleted; and
d) Proper feeding technology should be applied with regards to quantity and feeding method.

Fish should be fed daily on high quality feed in correct amounts. The feed should be nutritionally complete with all essential nutrients including proteins, lipids, vitamins, minerals and carbohydrates. The ideal constituent of the different nutrients for different developmental stages are summarized in **Table 2**.

Table 2 Summary of nutrient level requirements for Nile tilapia at different culture stages

Nutrient	Fish Size Class and nutrient levels				
	Fry (0-0.5 g)	Fingerling (0.5-10 g)	Juvenile (10-50 g)	Grower (50g+)	Brood stock (500 g+)
Crude protein (% min)	45	35-39	30-37	30-35	35-37
Amino acids (% min)					
Arginine	1.6	1.2	1.1	1.1	1.2
Histidine	0.6	0.5	0.4	0.4	0.5
Isoleucine	1.2	0.9	0.8	0.8	0.9
Leucine	1.5	1.2	1	1	1.2
Lysine	2	1.6	1.4	1.4	1.6
Methionine	0.9	0.7	0.6	0.6	0.7
Cystine	0.29	0.27	0.26	0.24	0.26
Phenylalanine	1.4	1.1	1	1	1.1
Tyrosine	0.97	0.9	0.85	0.81	0.85
Threonine	1.5	1.2	1	1	1.2
Tryptophan	0.3	0.2	0.2	0.2	0.2
Valine	1.1	0.9	0.8	0.8	0.8
Crude lipid (% min)	8	7	7	6	5
Carbohydrate (% max)[1]	30	35	40	40	40
Crude fibre (% max)	1.5	2	3	4	4
Major minerals					
Calcium (% max)	2.5	2.5	2	2	2
Phosphorus (% min)[2]	1	0.8	0.8	0.7	0.8
Magnesium (% min)	0.08	0.07	0.07	0.06	0.07
Vitamins (IU/kg min)[3]					
Vitamin A	3000(6000)	2500(5000)	2000(4000)	1500(3000)	3000(6000)
Vitamin D_3	1500(3000)	1250(2500)	1000(2000)	750(1500)	1500(3000)
Vitamins (mg/kg min)					
Vitamin E	120(240)	100(200)	80(160)	60(120)	120(240)
Vitamin K	10(12)	8(10)	6(9)	5(6)	10(12)
Vitamin B12	0.015(0.03)	0.0125(0.025)	0.01(0.02)	0.0075(0.015)	0.015(0.03)
Vitamin C)[4]	300(900)	250(750)	200(600)	150(450)	300(900)

Source: Jauncey, 1998; National Research Counsil - NRC(1983); and Millikin, (1982): [1]Digestible carbohydrate, [2]Available phosphorus, [3]Suggested minimum dietary vitamin levels required to prevent deficiency. Values in parentheses indicate suggested dietary vitamin levels taking into account processing, storage and leaching losses. [4]These vitamins should be added separately to the diet and not included in the form of a multivitamin premix; vitamin C should be added in fat coated form so as to minimize losses through diet processing and leaching

The correct amounts of feed should be provided to the fish daily using weighed feed based on feeding rate tables to adjust daily ration. Fish should be sampled every four weeks to determine their average body weight to facilitate calculation and adjustments of the daily ration. The amount of feed per day per cage depends on: the average body weight of the fish (ABW); the number of fish (N); the percentage body weight (%BW) of feed that should be provided to the fish, obtained from standard feeding charts (**Table 3)**. The quantity of feed (F) to be administered is derived from the formula: F = ABW*N*%BW or F = Biomass (B)*%BW where B= ABW*N.

Table 3.. A feeding chart showing recommended daily feeding rates for Nile tilapia of different weight.

Fish weight (g)	Feeding rate (%BW)	Quantity of feed /fish/day (g)
1	11.0	0.11
2	9.0	0.18
5	6.5	0.33
10	5.2	0.52
15	4.6	0.69
20	4.2	0.84
30	3.6	1.08
60	3.0	1.8
100	2.5	2.5
175	2.5	4.38
300	2.1	6.3
400	1.5	6
500	1.5	7.5

Source: SRAC No. 281

Fish should be fed two or three times a day by dividing the daily ration into two or three portions respectively and giving each portion at a time such as 9:00 am, 1:00 pm and 4:00 pm. Fish less than 25 g should be fed at least three times a day. Fish should be fed by response. Preferred feeding time is between 8:00 am to 4:00 pm. Adequate supplies of good quality feed must be available.

Non-filter feeding fish confined to cages have limited access to natural foods and need a nutritionally complete diet on a daily basis using proper feeding considerations. Floating rings

are used to retain floating feeds inside cages. Feeding trays may be built inside cages or placed on the cage floor to retain sinking pellets. Other important considerations and recommendations for feeding fish in cages are as follows:

a) Time to feed should be in the early morning (7-8h) or in the late afternoon (4-5h)
b) Feeding should be in the centre of cage or in many places at the same time.
c) Feeding should be based on the demand by the fish.
d) Feeding should be by observation of the fish and should be stopped once the fish stop feeding to prevent the residue of food waste that can lead to contamination.
e) The health of fish should be checked regularly for disease outbreak.
f) The amount of feed given to fish should be adjusted in depending on the average body weight of the fish obtained from regular sampling.
g) The net should be changed immediately when there is disease outbreak, net is torn or too much fouling.
h) The fish should be graded regularly (at least once a month) to reduce competition and ensure uniform growth.

3.5. Growth performance, yield and marketing

Growth performance: Fish should be weighed regularly to determine average body weight, calculate monitor the FCR to facilitate progress in production, estimate growth rate, guide adjustment of the amount of feed according to the new ABW, check efficiency of feeds, and check health of the fish. This should be done every 4-6 weeks. The fish should be starved for about 24 hours before sampling in order to reduce stress. Sampling should be done by lifting one side of the lid and a sample of the fish collected using a cast net and placed in a bucket containing water. The fish should then be weighed as a batch, counted and returned to the cage and the average weight calculated. An indication of the growth performance of Nile tilapia is illustrated in **Figure 1.** Daily growth rates of 2 to 3 g have been recorded in cages in Lake Victoria where average water temperature is 26°C (Veverica et.al. 2009). Nile tilapia fry of brood stocks from Lake Victoria have a higher growth rate performance of 0.11g/day compared to Lake George strain with 0.04g/day (Mpalampa, 2000). The Nile tilapia fry from Lake Victoria brood stocks have slight differences in growth performance compared to those from Lake Albert (Odur, 2001).

Survival rates: Survival rates of the fish in cages should be monitored during the culture period. This is expressed as a percentage of the number of fish stocked to the number surviving at any one time. The overall survival rate is obtained from the record of mortalities throughout the production cycle to harvest. Overall survival rate can be 80% to 95% depending on cage management.

Feed Conversion Ratio (FCR): Feed Conversion Ratios (FCR) is calculated as: Weight of feed used/ (final weight of fish – initial weight of fish). It should normally vary between 1.5-2.3 depending on feed quality, growing conditions and management.

Harvesting: Fish from cages is normally harvested at an average weight of 350-600 after 6-8 months growth period. Harvesting is done by concentrating fish in the cage and then removing the fish using dip nets, or the entire cage is detached and towed to the shore to remove the fish.

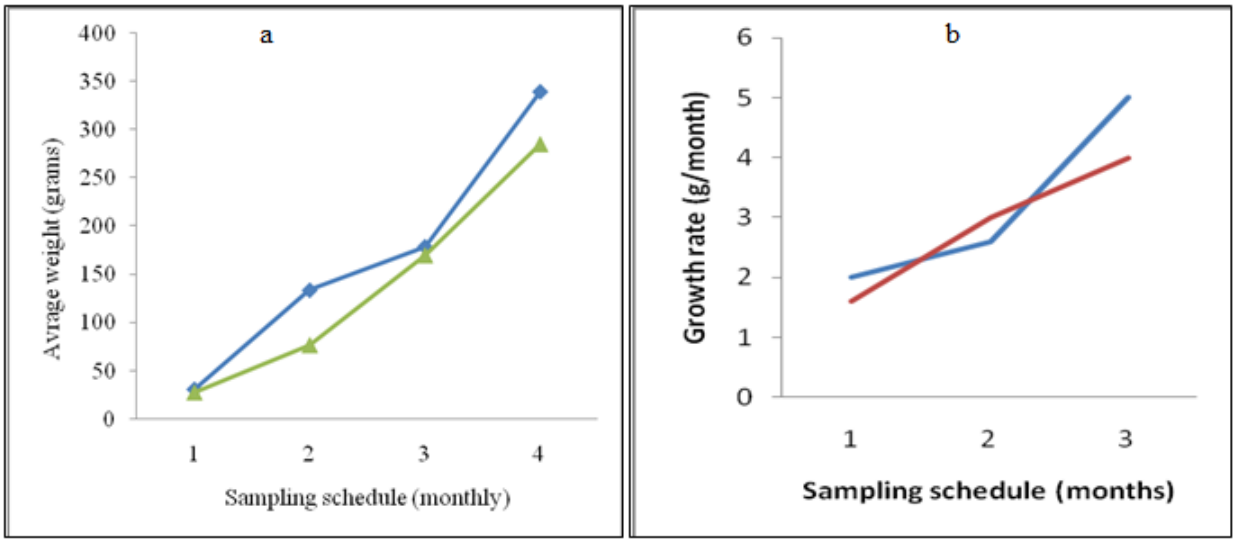

Figure 1 Growth (a) and growth rate (b) of mixed sex tilapia in 2 cages over 4 months (Source: Kajansi Aquaculture Research and Development Centre - ARDC)

Yield: Fish yields in small cages vary greatly depending on production technology and environmental quality and management practice. The optimum yield is between 150 to 300 kg m^{-3} over a growth period of about 8 months. The yield of fish (Y) in a production cycle is determined from the total Biomass (B) of the fish at harvest and the volume (V) of the cage and expressed as Y = B/V. For example, if B = 1200 kg and V = 6 $m^{3;}$ then Y = 1200/6 = 200 kg m^{-3}.
Marketing: The price at which the fish is sold per kg should be recorded.

4. Facility security plan

There should be a facility security plan to ensure that farmed fish do not escape in the wild. This can be reduced by constructing cages with double netting and precautions taken to minimize escapes while transferring, harvesting and grading fish. The specifications for cage construction and the nets to be used should be provided including net strengths, and farmers should use the cages with highest strength available. There should be a plan to monitor predators such as otters and birds, theft and wind, which can also lead to fish escape. There should be regular diving to check the status of cage nets. Predator control can be achieved by using strong nets and proper covering of the top of the cage. Theft can be controlled by hiring guards or using dogs. Cages should be properly anchored to avoid being carried away by wind.

5. Fish health management plan

Farmers should minimize risk of diseases transmission by importing/buying fingerlings from certified disease free hatcheries/sources and tested dangerous disease pathogen.

Farmers should develop and document a Veterinary Health Plan (VHP) and a Bio security Plan (BP). The VHPs and BPs should be reviewed at the end of each production cycle. This should include:

a) Checking weak fish and bathing them in fresh water to check for parasites. If there are parasites, all fish should be bathed and the cage changed;
b) Infected should be moved to a separate cage;
c) Equipment used to handle infected fish should not be used in non-infected cages without disinfection;
d) Sick fish should be properly treated according to the syndrome;
e) Dead fish should be taken away and should not be discharged directly into surrounding areas;
f) Not selling sick fish or using them to feed others;
g) Aerating the cages to increase DO in water and bottom;
h) Having a separate extra cage to hold weak fish downstream the water current;
i) Acting quickly to stop spreading disease;
j) Treating the fish and changing the net at the same time
k) Consulting and informing other farmers about the disease and treatment;
l) Consulting and informing extension workers and research institutes;
m) Collecting the infected fish or their parts such as gills and injured parts as samples, preserved in alcohol, formalin or ice boxes and sent to laboratory for disease pathogen detection.

Farmers are advised to use limited chemicals and drugs as much as possible. In case of disease, guidance should be sought from the DiFR and National Drug Authority (NDA).

6. Waste management plan

The waste generated by the farm should be managed in accordance with the waste management in the approved proposal. This should include disposal of dead fish and other processing products. Waste water should be kept in drum/tanks for few days allow oxygenation to neutralize the chemical and drug. Waste water should only be discharged into natural water after dilution or neutralization.

7. Environmental monitoring plan

Environmental monitoring of the farm should be undertaken in line with environmental monitoring plan included in the approved proposal for setting up of the farm. Environmental monitoring should be carried out by a competent authority. This should include evaluating the influence of the activities of the enterprise on the sites, considering potential effects of the siting and operation of farms on sensitive aquatic organisms and habitats. Data on environmental variables and biological communities as indicated in **Annex 1**. should be collected at the time of setting up the farm updated and periodically. Farmers are expected to facilitate the monitoring

activities which should be undertaken by competent agencies such as NaFIRRI. These activities are expected to be quarterly, biannual, and annual and farmers should maintain the data collected on water quality variables during their operations. Environmental monitoring should be in the form of a recognized and independently audited environmental management system.

Existing cage fish farming enterprises requiring expansion or renewal of operating license will have to provide a report detailing monitoring interventions during operations. This report should highlight interventions undertaken to mitigate any negative impacts noted during the monitoring process and any others aimed at preventing undesired consequences. It should also highlight any noticeable changes that have occurred since the beginning of the operations.

8. Decommissioning plan

At the time of closure of the farm, the farmer should remove all materials and equipment and all structural and support features at the farm. Efforts should be made to restore the site to its natural conditions as provided in decommissioning plan provided during setting up of the farm.

9. Enterprise data and budget

The cage fish farmers should maintain data of their cage fish farming operations. This data is required on different variables indicated in enterprise budget **(Table 1)** and others indicated in **Annex 2** (data requirements may change with time). This data is critical in evaluating performance of the cage fish farming thus providing a basis for justifying the occurrence of cage fish farming on the water bodies. Farmers are expected to provide this data to sector relevant agencies such as DiFR and NaFIRRI for utilization in research, management decisions and other activities to promote the sector. These institutions will be expected to keep the data from specific farms confidential and only use it for general analysis and advise to the specific farms.

10. Bibliography

Beveridge, M.C.M. 1984. Cage and pen fish farming. Carrying capacity models and environmental impact.FAO Fish. Tech. Pap. (255): 131 p.

FAO, 2014.The State of World Fisheries and Aquaculture. Opportunities and challenges. Rome, Italy.

Jauncey, K. 1998. Tilapia feeds and feeding. Institute of Aquaculture, University of Stirling, Scotland. Pisces Press Ltd, Stirling, Scotland. 48p.

Millikin, M.R. 1982. Qualitative and quantitative nutrient requirements of fishes: A *review. Fish*.,80,655-686.

Mpalampa, A. 2000. The comparative growth rate performance of *Oreochromis niloticus* from Lake George and Lake Victoria in ponds. Diploma dissertation. Fisheries Training Institute, Entebbe, Uganda.

NRC (National Research Council). 1983. Nutrient requirements of warm water fishes and shellfishes. National Academy Press, Washing D.C., 102 p.

Odur, R.A. 2001. Comparative study of *Oreochromis niloticus* strains from Lake Victoria and Lake Albert. Diploma dissertation. Fisheries Training Institute, Entebbe, Uganda.

Rox L.E., Carrroll J.H., Doyle DW. 1972. Effects of Caged catfish culture on water quality and community metabolism of a lake. Proceedings of Olkahoma. Academic Science 52:10-15.

Subasinghe, R. 2009. Aquaculture development: the blue revolution. In Fisheries, Sustainability and Development, pp. 281-302. Stockholm, Royal Swedth Academy of Agriculture and forestry.

Tacon, A. G. J. and Metian, M. 2013. Fish Matters: Importance of Aquatic Foods in Human Nutrition and Global Food Supply. Reviews in Fisheries Science, 21(1), 22-38.

Veverica, K. et.al. 2009. High density tilapia culture in locally-made low volume cages in Uganda. In: Presentation at World Aquaculture Society meeting in Vera Cruz, Mexico.

Worm, B., Barbier, E.B., Beaumont, N. et al. 2009. Impacts of Biodiversity Loss on Ocean Ecosystem Services. *Science*, 314, DOI: 10.1126/science.1132294.

Annex 2. List of variables on which data should be obtained for monitoring purposes

Parameter	Monitoring frequency
Water quality	Quarterly
PH	Quarterly
Dissolved oxygen.	Quarterly
Temperature	Quarterly
Suspended solids	Quarterly
Nutrients	Quarterly
Turbidity	Quarterly
Total nitrogen	Biannually
Trace metals	Annually
Organic matter	Biannually
Total carbon	Biannually
Sulfide	Annually
Macro invertebrates	Biannually
Plankton	Biannually
Fish communities	Biannually

Annex 2. Required enterprise data that should be obtained by farmers

Item/variable	Unit	Qty	Unit Cost	Total cost
Office space				
Canoe (wooden or fibre glass)	Number (N)			
Outboard engine	N			
Life jackets	N			
Cage size (m^{-3})	N			
Fish stocking density	fingerlings m^{-3}			
Number of fingerlings stocked	N			
Initial weight of fingerlings at stocking	g			
Initial total weight stocked	kg			
Feeds (35% protein)	kg			
Feeds (30% protein)	kg			
Other feeds	kg			
Fish survival rate	(%)			
Final weight of fish at harvested average	g			
Fish yield	Kgm^{-3}			
Selling price of fish	Ugshs kg^{-1}			
Operation and maintenance – Fuel per day	Litres (L)			
Operation and maintenance – Oil per day	L			
Operation and maintenance – Labor (list key personnel and their monthly salary)				