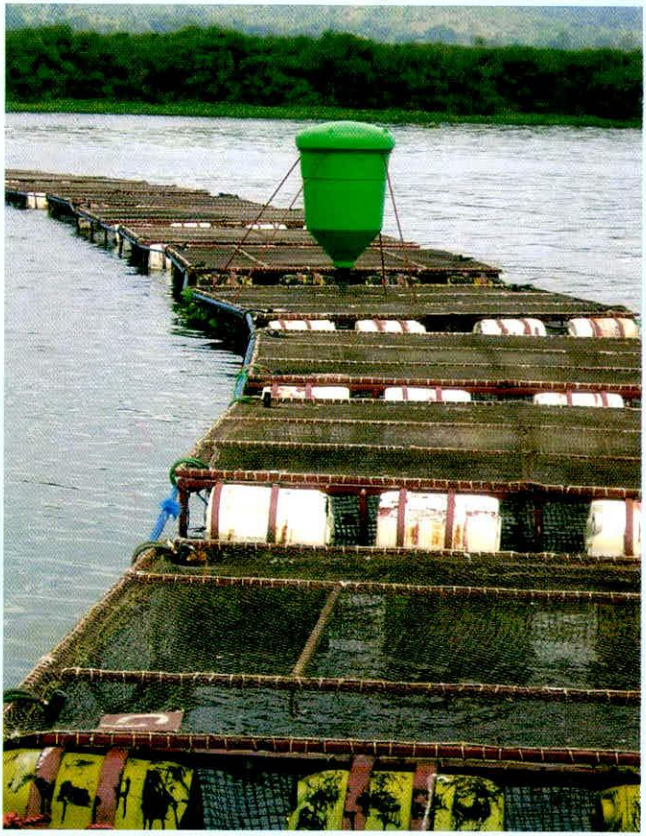
AQUACULTURE IN UGANDA

POLICY BRIEF NO. 1 OF 2012



Framework for Cage Fish Culture Development in Uganda

NARO

NaFIRRI

National Fisheries Resources Research Institute

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ABBREVIATIONS AND ACRONYMS

ABW	Average Body Weight
NaFIRRI	National Fisheries Resources Research Institute
DO	Dissolved Oxygen
EIA	Environmental Impact Assessment
FAO	Food Agricultural Organisation
FCR	Feed Conversion Ratio
LVHD	Low Volume High Density
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
NRC	National Research Council
USAID	United States Agency for International Development
SON	Source of the Nile

PREFACE

The mandate of the National Fisheries Resources Research Institute (NaFIRRI) is to conduct basic and applied research of strategic and national importance in Aquaculture, Capture Fisheries, Water Environment, Socio-economics and Marketing, and any emerging issues in the fisheries sector.

The Institute's Management Committee recognized that the geographical mandate for fisheries is quite large with up to 20% of the country's surface covered by open water in form of lakes, rivers and wetlands all conducive for both capture and aquaculture fisheries. The Institute's Scientific Committee analysed the diversity of stakeholder needs and recommended that scientists should incorporate development of Policy Briefs in their research activities. This approach would enhance uptake of research products through dissemination of non-jargon products that can guide sustainable utilization of the fisheries that have come to be associated with fish exports, livelihoods and the preferred health benefits.

It is a major concern that fish production predominantly from capture fisheries has drastically declined and the country cannot meet national, regional and international market demands. Despite its long history dating to the early 1950s, fish farming in Uganda has not developed beyond small wilder subsistence scales. According to the National Development Plan (NDP), fish farming in the country presents immense opportunities for socio-economic development in terms of livelihood, income and employment.

This Policy Brief seeks to demystify the practice of cage culture by outlining what the practice requires and how an average Ugandan fish farmer can take up profitable commercial fish farming. The information in the brief was prepared by William Wandera Owuli and Richard Ogutu-Ohwayo through a consultative research process that addressed key issues in Uganda's emerging cage fish culture farming.

Dr John S. Balirwa
Director of Research

EXECUTIVE SUMMARY

In comparison to the traditional earthen pond fish farming, cage fish culture is a new fish farming practice in Uganda. Unlike pond fish farming, cage fish culture relies on artificial structures (i.e. the cages) of various sizes that are suspended in a water body such as a lake, river or reservoir. Cage culture is practiced in many countries around the world, and in Africa, it is practiced in many countries around the world, and in Africa, it is practiced in Egypt and Zimbabwe. Cage culture has great potential to rapidly transform fish farming in Uganda to commercial scales.

Through USAID support to NaFIRRI, research findings from pilot Low Volume High Density (LVHD) cage culture studies demonstrated that the practice was environmentally and commercially viable in many water bodies of Uganda. Recommendations have been made to introduce the use of small (2m x 2m x 2m) to medium-sized (5m x 5m x 4.5m) cages that are within the means of an average Ugandan commercial fish farmer. After thourough environmental impact studies, larger cages may also be used in large and deeper water bodies such as Lakes Victoria and Albert.

Cages allow for high density production and mainly used for 'fattening' or raising fish quickly from juveniles to table or market sizes using high quality feeds and that cages can be done in many water bodies in the country. Of particular focus and interest are the over 160 minor lakes and thousands of communal reserviors that can be targeted specifically for cage based fish production. However, the research established that there is clear need for Government to map out areas for locating of the cages especially in the large water bodies so as to ensure that cage based fish production does not affect the ecological and environmental integrity of these natural water bodies. The research found that the most suited and appropriate species for cage culture is the Nile tilapia but the cages can also be used to culture and produce other species. The research established that Uganda needs less than 1% of her water surface to produce the amount of fish equivalent in weight to its natural fisheries production potential of 800,000 tonnes annually.

INTRODUCTION

The demand for fish in Uganda and worldwide is increasing due to increasing human population and health concerns. Fish is preferred over beef because of its high quality protein with essential amino acids and fatty acids with lower cholesterol levels in blood and reduce incidences of high blood pressure and heart diseases. According to FAO, the per capita fish consumption should be 15 kg.

According to FAO, 50% of the global wild fish stocks were fully exploited and 25% were over-exploited by the end of the 20th century and yet the human population was increasing and had reached the 6 billion mark. In Uganda, capture fisheries production has been declining to the extent that *per capita* fish consumption is currently only 8kg which is much below that recommended by FAO. With an estimated population of 33 million people, the local demand for fish to meet the FAO requirements is about 500,000 t annually. In addition, Uganda's raw materials for International trade are about 200,000 t annually and the demand from the regional market is about 200,000 t annually. This means that Uganda need to produce about 900,000 t of fish annually to meet its national, regional and international demands. Fish production from capture fisheries is about 400,000 t annually leaving a deficit in fish supply of about 500,000 t annually. Capture fisheries have been declining and this source is not expected to produce more fish. If Uganda has to avoid importation of fish, then the only available option for increasing fish production is through aquaculture.

Aquaculture production systems include ponds, cages, tanks raceways and pens. Pond culture which has been the dominant system of aquaculture production has been practiced in Uganda since the 1950s. However, this system of pond based fish culture is suitable for extensive to medium density production, and has had limited impact in commercialization of aquaculture in the country. Production from ponds is 2-10 kg m^{-3}. Concrete tanks can produce 25-40 kg m^{-3} but this is not much practiced in Uganda. The highest production of up to 300 kg m^{-3} can be realized from Low Volume High Density (LVHD) cages of 4-8 m^{-3} under good management and some fish farms such as the Source of the Nile (SON) are engaged in LVHD cage fish farming. Experimental trials are also ongoing in various small lakes in western Uganda and along the Nile, and results are promising.

APPROACHES AND RESULTS

This research work involved a review of scientific and technical literature on cage based fish culture technology, and assessment of the natural and socio-economic potential of this technology. The research also reviewed secondary data on aquaculture production from the pilot cage culture facilities at Jinja; the requirements of key targeted species for cage based fish production – the Nile tilapia; the feed requirements and implication for management; the physiochemical parameters for optimum performance of fish production in cages; and preliminary production and operational costs of cage fish production.

The potential for cage culture

Uganda has great potential for cage culture in water bodies such as Lakes Victoria, Albert, Edward, numerous crater lakes and River Nile. The country has suitable climate with high temperatures of 25-35°C which are suitable for optimum fish growth. Suitable aquaculture fish species comprising of the Nile tilapia *(Oreochromis niloticus)* and the catfish *(Clarias gariepinus)* are available in the country. There are huge international, regional and national markets for fish. The national policy environment has high support for aquaculture. There are local inputs for feed formulation such as maize bran and Mukene *(Rastrineobola argentea)*. There is increased interest in aquaculture development by the private sector and some local industries have started producing feeds suitable for cage culture. The country has an institutional framework for conducting research and providing advice in aquaculture and there is increased private sector and donor interest and support for aquaculture development in Uganda. There is therefore need to tap this potential to increase fish supply using the most effective aquaculture production systems such as cage culture.

Advantages of cage culture

Advantages of cage culture over other fish culture systems include:

a) Relatively low investment. The cost of construction of a (LVHD) cage is about 1/10 that of a pond which produces the same yield;

b) Cage culture permits high stocking densities in a small volume of water;
c) Land ownership is not required;
d) Does not require re-filling of water;
e) Handling, inventory and harvesting of fish is easier;
f) Fish populations are controlled as breeding of fish does not occur in cages;
g) Fish competitors and predators can easily be controlled;
h) Survival rate of fish is high;
i) Feeds are efficiently utilized;
j) Allows total harvesting and re-investing of the resources;
k) Observation, sampling and harvesting are easy;
l) Fish grown in cages can be sold fresh and in good quality; and
m) Requires less labour.

Disadvantages

There are some disadvantages of cage culture which include:
a) Requirement of Environmental Impact Assessment (EIA);
b) The need for supply of good quality seed (fry);
c) Requirement of high quality nutritionally complete feeds;
d) Vandalism, poaching and damage to the cage remain potential threats;
e) Water bodies are public property and there may be conflicts between cage farming and other users; there can be potential conflict between cage fish farmers and fishers;

Key issues

The key issues that should be considered as part of the process of promoting cage culture in Uganda include:

a) EIA;
b) Site selection;
c) Water characteristics and quality;
d) Cage design and size;
e) Species selection and fingerlings (seed);
f) Feeds and feeding;
g) Sampling;

h) Growth (performance) rate;
i) Harvesting;
j) Marketing;
k) Other operational costs (e.g. security, canoe, boat, outboard engine, life jackets, labor)
l) Initial capital investments; and
m) Policy and operational requirements.

Environmental Impact Assessment (EIA)

The inputs into cage culture such as feeds, seed/fry, chemicals and drugs and products such as dead fish, residues of uneaten feeds and cage materials, fish feaces, and other wastes may have negative impacts on the water environment and other aquatic organisms including wild fish and this has to be addressed through an EIA. The EIAs should consider;

a) Water rights and accessibility to water and other resources (fishers, navigation, industries, etc);
b) The impact on the natural environment, water quality and biodiversity;
c) The impact on capture fisheries, harvesting of wild juveniles for stocking transmission of diseases to wild populations, biodiversity, escapees of domesticated cultured species, and competition in the market place with capture fisheries products;
d) Human health issues such as waterborne diseases e.g. bilharzias;
e) Gender participation;
f) Economic issues. Whether cage culture reduces or risks increasing poverty by disturbing established local socio-economic activities; and
g) Whether it displaces alternative agricultural activities and at what cost.

Site selection

The following criteria should be considered during cage site selection:

a) Water with suitable current flow;
b) There should be no direct access by livestock or large numbers of livestock in the watershed;
c) The site should not have a highly erodible watershed or one that allows the accumulation of large amounts of organic debris or silt;

d) The sediment at the site should be of firm substrate with fine gravel, sand and clay. Sloping areas from the shore leading to flat bottoms are most suitable because the waste build up at the bottom is easily eliminated;
e) The site should not be prone to problems of aquatic weeds, surface algal scums, over populations of wild fish, or oxygen depletion problems;
f) The site should be near the shore and easily accessible for routine management;
g) The site should be sheltered and protected from strong wind and waves. Wave height of <1m and wind velocity of ≤10 knots are recommended; and
h) The site should be located away from navigation routes, landing sites and fish breeding areas.

Water characteristics and quality

Water quality characteristics are important in cage culture, the most relevant include water depth, currents, temperature, pH, DO, transparency, chemical, physical and biological characteristics. Poor water quality affects the fish, promotes disease and parasite outbreaks and can cause fish kills.
A non-stressful water environment inside the cage is fundamental to good fish health and production performance.

a) **Water depth:** Cage depth is normally about 2-2.5 m. There should be at least 3m depth under the cage to facilitate water exchange, avoid oxygen depletion, accumulation of uneaten food, faeces and debris, disease infection and build up of noxious gases such as hydrogen sulphide from decomposition of wastes.
Water depth of at least 5m and <20 m is recommended.

b) **Water current:** Currents bring fresh oxygenated water and remove waste from the cages. Minimum current of 10 $cm.sec.^{-1}$ and a maximum of <100 $cm.sec.^{-1}$ are recommended for high stocking densities. Stronger currents exert strain on the cage anchoring system and distort the cage structure. The rectangular raft of the cage should be in a direction parallel to the current to minimize strain on the anchoring system. In weak current areas, the raft can be positioned against the current for better water flow.

c) **Temperature:** Water temperatures of 27-30°C are ideal for fish growth. Changes in water temperature affects fish metabolism and activity, oxygen consumption, ammonia and carbon dioxide production rate feed conversion ratio (FCR) as well as fish growth.
Strong winds affect temperature by bringing cooler water from the bottom to the surface and reducing the heating of the surface waters.

d) **pH:** The desirable range of pH is between 6.5 and 9.0. pH outside this range slows fish growth and increases susceptibility to disease.

e) **Dissolved oxygen [DO]:** Solubility of oxygen in water decreases with increasing tem perature. DO of $\geq 5 mg.L^{-1}$ is recommended and should not fall below $3mg.L^{-1}$

f) **Ammonia:** Ammonia is caused by deposition of uneaten food and debris, sewage discharge and industrial pollution. The recommended level of ammonia in fish culture should be $\leq 0.01 mg.L^{-1}$.

g) **Transparency:** Depth of visibility in water is a measure of nutrient enrichment and optimum fish yield for wild stocks. The greater the depth the lower the nutrient level, but the greater the potential for cage fish yield. The recommended water transparency for cage culture is ≥40 cm.

h) **Suspended solids:** Turbid water prevents good water exchange due to accumulation of suspended solids in the cage. The suspended solids act as substrate for growth of fouling organisms which affecrs water circulation. Suspended solids can also clog the gills of fish leading to mortality. Visibility of fish will also be recuced leading feed losses and impaired growth. The level of suspended solids for cage culture is $<10mg.\ L^{-1}$.

i) **Alkalinity:** The optimum range of alkalinity is 120-400ppm.

Cage design and size

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, inexpensive and readily available. A typical cage is illustrated in **Figure 1.**

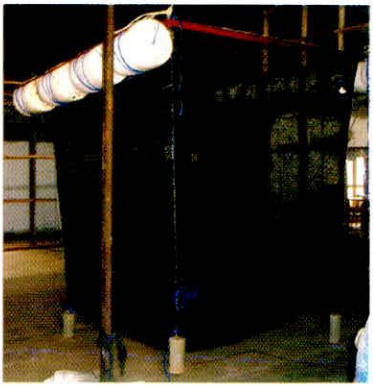

Figure 1. Structure of typical cage

a) **Mesh size:** Water exchange between a cage and the surrounding water is influenced by the cage mesh size. Water exchange potential increases with increasing mesh size, but decreases with increasing amount of solid space between openings. A 13mm square mesh is considered the minimum standard mesh size for production cages and an 8 mm square mesh size for nursery cages.

b) **Cage shape:** 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 cage than a cylindrical cage of the same volume and mesh size.

c) **Cage size:** Cages can be as large as 100 to1000 m^3 or more. Performance per unit volume of cage is however higher and economically more efficient in small (LVHD) cages of 4 to 8 m^{-3}. Fish yields in small cages vary greatly because of differences in production technology and environmental quality. The optimum yield is between 150 $kg.m^{-3}$ and 300 $kg.m^{-3}$.

d) **Cage frame:** Cage frames are made of metallic bars or PVC pipes or other rigid material. However, metallic frames are recommended because they are stronger and long lasting. Floatation may be provided by metal or plastic drums/jerrycans, sealed PVC pipe, or Styrofoam. Bamboo frames have also been tried out.

e) **Feed enclosure:** This is a structure specifically installed in the cage to prevent feed loss and optimize feeding in LVHD cages. A model enclosure for floating feeds is a ring or a box positioned in the top center of the cage that has 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; and only one meal should be given at a time.

f) **Cage covers:** Cage covers are needed on cages to protect fish 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, inexpensive, weather resistant and impervious to light.

g) **Cage anchors:** Cages should be placed in at least 5m of water. The best anchoring system comprises four 0.3 m^3 concrete blocks with a 6.4mm (¼") iron loop tied to ropes connected to each corner of the floating cage frame (see Fig. 1).

h) **Cost of cage:** The approximate cost of making a cage of 8 m^{-3} is given in **Table 1.**

Table 1: Construction costs in Uganda Shillings for a 2x2x2 m (8 m^3) cage as at October 2012

Item	Description	Quantity	Unit cost (Ug.Shs)	Item amount
Frame	Angle bar (20ft)	4	45,000	180,000
	⅜" bar (20 ft)	6	25,000	150,000
	¾" flat bar (20 ft)	2	20,000	40,000
Floats	Plastic jerrycan (20 litre)	6	5,000	30,000
	Plastic barrel (250 litre)	2	80,000	160,000
Nets	13 mm (or ¾") stretched mesh	25 metre	12,000	300,000
Ropes	8 mm diameter roll	1	100,000	100,000
	6 mm diameter roll	1	50,000	50,000
Anchors	1 kg concrete block with iron loop	4	15,000	60,000
	15 kg 2 blade concrete block with iron loop	2	50,000	100,000
Welding			50,000	50,000
Cage cover	Shade cloth 2x2 metre	4 metre	10,000	40,000
	Chicken mesh	4 metre	3,500	14,000
Labour		1	100,000	100,000
Total				1,374,000

Source: ARDC Kajjansi



Figure 2. Cages laid out in the lake



Figure 3. Seven –month old Nile tilapia (+400g) harvested from cages

Species selection, seed and stocking density

a) **Species selection:** The desired fish species should have fast growth rate, be tolerance to crowded conditions, and of high market value. Nile tilapia is the recommended species for cage culture in Uganda. However, catfish *(Clarias gariepinus)* can also perform well in cages. These species are locally available in Uganda but there is need to improve their seed quality and growth performance through research.

b) **Stocking density:** Stocking density depends on the quantity and quality of the feed to be used, water quality, species to be cultured, expected yield and average size desired at harvest. A minimum stocking density of 100 fish.m^{-3} is recommended, but densities can be as high as 300-600 fish.m^{-3}.

c) **Monosex (all male Tilapia):** Mixed sex tilapia can be reared in cages without the problem of breeding and stunting since the breeding requirements for tilapia are not available in cages. Mixed sex tilapia will result in variable sizes at Harvest. All male tilapia are recommended for stocking because they grow faster and will have more or less uniform size at harvest. These should be obtained from a certified source.

d) **Size at stocking:** Fingerlings for stocking should be graded to ensure uniformity in size at stocking to ensure uniform size at harvest. The recommended fingerling size for stocking is 15 g. This size of fish will be retained by a 13 mm mesh net.

e) **Price of fingerlings:** The price for the recommended size for stocking varies with production but ranges between UShs. 100-250/= per fish.

f) **Initial Biomass (B) of stocked fish:** This depends on the average body weight (ABW) at stocking and the number of fish (N) stocked. It is derived from the formula: B=ABW*N.

g) **Conditioning of fingerlings:** Fingerlings should be conditioned and trained to feed vigorously before stocking in grow-out cages by holding them in hapas off food for 1-3 days followed by training them to feed rapidly for 1-2 weeks; stocking them into conditioning cage; and finally into a growing cage.

Feeds and feeding

Feed quality: 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 is shown and different developmental stages of fish require feeds of different quality **(Table 2).** Feeds should be purchased from credible feed manufacturers like Ugachick.

Table 2. Summary of Tilapia nutrient level requirements.

Nutrient level	Fish Size Class				
	Fry (0-0.5g)	Fingerling (0.5-10g)	Juvenile (10-50g)	Grower (50g+)	Broodstock (500g+)
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); NRC (1983); Millikin (1982)

[1]Digestible carbohydrate

[2]Available phosphorus

[3]Suggested minimum dietary vitamin levels required to prevent deficiency signs. 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

Feed quantity: The correct amount of feed is weighed daily. Feeding rate tables are used to adjust daily ration. The fish should be sampled every 4 weeks to determine their average body weight to facilitate calculation and adjustments in 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) obtained from 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.

Table 3: A feeding chart showing recommended daily feeding rates for Tilapia of different sizes.

Fish weight (g)	Feeding rate (% Body weight)	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

Feeding frequency and time: Fish should be fed two or three times a day by dividing the daily ration into two or three portions and giving each portion at a time. Fish less than 25 g should be fed at least three times a day. Fish may not eat all the feed in a particular portion due to water quality and weather conditions. It is advisable to feed fish by response. Preferred feeding time is 8:00 am to 4:00 pm.

Feed prices: An indication of feed prices based on those produced by Ugachick as of 23rd August 2010 are given in **Table 4.**

Table 4: Prices of Ugachick floating feed as at 23rd August 2010

Feed type	Cost	20 kg/bag	30 kg/bag	50kg/bag
45% Crude protein (CP)	Cost/bag	104,900	157,200	262,000
	Price/kg	5,245	5,240	5,240
35% "	Cost/bag	49,200	73,800	122,900
	price/kg	2,460	2,460	4,097
30% "	Cost/bag	27,200	40,800	68,000
	price/kg	1,360	1,360	2,267
25% "	Cost/bag	23,500	35,300	58,700
	price/kg	1,175	1,177	1,957
20% "	Cost/bag	18,500	27,800	46,300
	price/kg	925	927	1,543

Source: Ugachick Poultry Breeders Ltd.

Growth performance

Fish in the cages should be sampled every 4-6 weeks to examine growth performance and adjust feeds. Fish are starved for about 24 hours before sampling in order to reduce stress. Sampling is done by lifting one side of the lid and throwing a cast net. The fish are placed in a bucket containing water. The process is repeated several times to catch enough fish. The fish are then collected in a mesh basket and either weighed as a batch or individually and returned to the cage. Average weight of the fish is then obtained. Handling fish should be done carefully to reduce stress and injury. Fish should be weighed regularly to monitor growth rates, FCR and facilitate adjustments of the amount of feed.

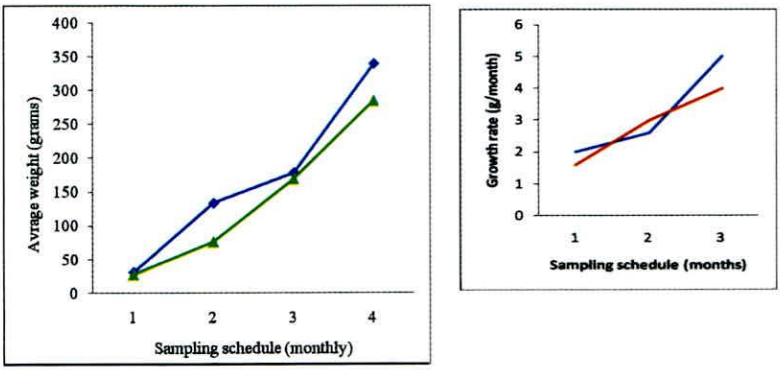

Figure 4: Growth of mixed sex tilapia in 2 cages over 3 months (Source Kajansi ARD)

An indication of the growth performance of Nile tilapia is given in **Figure 4.** The daily growth rates of 2 to 3 g are observed in cages in Lake Victoria where water temperature averages 26°C (Veverica, et.al. 2009). Tilapia fry from Lake Victoria broodstocks had highest experimental growth rate performance of 0.11g/day as compared to Lake George strain which had 0.04g/day (Mpalampa, 2000). However, Tilapia fry from Lake Victoria broodstocks showed very slight difference in growth rate performance as compared to Lake Albert strain (Odur, 2001) and Lake George Tilapia has the lowest growth rate.

Harvesting: Cage fish is normally harvested at aa average weight i.e. ≥400g after 6-7 months growth period. The requirements for harvesting include dip nets, mesh baskets, buckets, and tank. 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.

Total fish yields: Total fish yields (Y) are determined from the total Biomass (B) at harvest and the volume (V) of the cage. The formula below is used: $Y = B/V$. For example, if $B = 1200$ kg and $V = 6$ m^3; then $Y = 1200/6 = 200$ kg. m^{-3}.

Survival rates: There is need to calculate survival rates of the fish in cages. This is expressed as a percentage of the number of fish stocked to the number harvested. This is obtained from the record of mortalities throughout the production cycle and the fish harvested. For business plan, survival rate is estimated at 80% but these can be >95 depending on cage management through the production period.

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

Marketing: Fish may be harvested and marketed on the farm, local markets and restaurants. They may be sold fresh, smoked or deep-fried. The amount per kilogram of fish depends on market and any value addition but Nile tilapia is normally preferred fresh. The price of Tilapia ranges between UShs 3500 – 8000/= per kg.

Other inputs and operational costs

A number of other inputs are required in management of a cage fish farm. These include items like: personnel costs; cages; a canoe, outboard engine, life jackets and fuel to facilitate movements from land to the cages; and labor for management of cages.

Security is very important after the cages have been installed and stocked. Security concerns include; predators such as otters and birds, theft and cages being carried away by wind. Predator control is achieved by using strong nets and proper covering of the top of the cage. Theft can be controlled by involving the community in cage culture operations, hiring a guard. Cages should be properly anchored to avoid being carried away by wind.

Investment requirements (Enterprise Budget)

The investments required to operate an 8m-^{3} cages, stocked with Nile tilapia at a stocking density of 400 fingerlings m-3, operated for a period of 7 months which is close to SON operations and estimate the break-even price and the number of cages one would need to invest in to get profit are in **Table 5.** Once this Table has been fully developed, we should be able to advise on how many cages Uganda would need to produce e.g. 100,000t of fish. We would also be able to estimate other input such as the fry and feed requirements. The unfilled gaps show that not many practitioners have quantified costs of a full cycle of operations.

Table 5. Partial investment costs (Enterprise budget)

Item	Unit	Qty	Unit Cost	Total cost
Office space				
Canoe (wooden or fibre glass)	units	1		
Outboard engine	units	1		
Life jackets	units	2		
Cage size 2*2*2 (8 m^{-3})	units	1	1,374,000	1,374,000
Fish stocking density (400 fingerlings m^{-3})	pcs			
Number of fingerlings stocked	pcs	3200	200	
Initial weight of fingerlings at stocking (15 g)	g			
Initial total weight stocked (15x3200 g)				
Feeds (35% protein) (for two months)	kg	500		
Feeds (30% protein)	kg	2380		
Food Conversion Ration (FCR – 1.8)				
Fish survival rate (80%)				
Final weight of fish at harvest average (500 g)				
Fish yield (1600 kg)				
Selling price. kg-1 of fish (Shs 3500)				
Operation and maintenance – Fuel per day				
Operation and maintenance – Oil per day				
Operation and maintenance – Security per month				
Operation and maintenance – Labor (list key personnel and their monthly salary)				

CONCLUSIONS AND RECOMMENDATIONS

1. Uganda can significantly increase fish supply using cage based fish culture technology using less than 1% of the country's water surface with minimal and reversible environmental impacts.
2. Adoption and popularizing cage culture in Uganda will require establishment of cage culture demonstration facilities on appropriate water bodies and some of the minor water.
3. Nile tilapia is most suitable and appropriate fish species for cage based fish culture and production owing to its good culture and economic characteristics.
4. Uganda should urgently invest in industrial production of quality formulated fish feeds to support high density environmental friendly fish production through cage aquaculture.
5. Some of the 160 minor lakes and thousands of communal water reservoirs can be targeted specifically for cage culture development as they offer minimal environmental and ecological challenges.
6. Cage fish culture should in the short-to-medium term focus on Low Volume High Density cages.

POLICY AND OTHER CONSIDERATIONS

a) The requirement by NEMA is for the investor to pay for the EIA and this will be mandatory in cage culture. However, to provide an incentive for cage culture Government and development partners may have to develop modalities to reduce this cost to the investor.

b) The most suitable areas such as shallower inshore areas of 5 to 20 m depth are also the most productive areas of capture fisheries especially in large lakes like Victoria, Albert and Edward. This may cause conflict with capture fisheries and there is need for clear guidelines on location of cages.

c) Lakes Victoria, Albert and Edward, and River Nile which are suitable for cage culture are shared by more than one country and there may be need for appropriate protocals to permit cage culture in these international waters.

d) Some of the materials for construction of cages may not be available on the local markets and may be expensive which may make cage culture prohibitive. There is also need to use materials which will not degrade the environment. Government will need to identify suitable materials and provide appropriate incentive to promote cage culture.

e) There is need for large quantities of high quality fingerlings for stocking large commercial cage culture establishments. Government, Development Partners and the private sector should partner to assist in initially setting up regional centers to supply adequate quantities of high quality fingerlings.

f) Production of adequate quantities of quality feeds is crucial to development of cage culture. Currently, there is only one establishment (Ugachick) producing feeds suitable for cage culture and there is need to support and encourage other investors to produce suitable feeds. Also some of the ingredients for feeds especially Mukene have high demand for domestic consumption and alternative protein sources for feeds should be identified.

g) Marketing of fish which is a highly perishable product will require good infrastructure. An option is to have cage culture parks or desig nated cage culture areas and cooperatives among farmers to facilitate marketing of their products. Government may need to set up these cage culture parks.

h) There will be need for research in the above policy requirements to provide farmers knowledge on best practices to maximize benefits from cage culture. Government will therefore need to invest in research.

i) The current fisheries policy does not specifically emphasize cage culture. Also, The Fish (Aquaculture) Rules, 2003 does not adequately address the requirements of cage culture and both the policy and the Aquaculture Rules will need review to emphasize cage culture.

j) There is limited human resources capacity both in research and fisheries management institutions and at different levels of governance to address issues of cage culture and this will require improvement.

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