National Fisheries Resources Research Institute

and Directorate of Fisheries Resources

Guidelines for Cage Fish Farming in Uganda



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Summary

The rapidly increasing human population and the export market have increased the demand for fish in Uganda. However, production of high-value wild fish stocks has stagnated, leading to a *per capita* consumption of ca. 8 kg, which is below the 17 kg recommended by FAO for healthy living. Uganda, with a population of 35 million people, needs 0.6 million tons (Mt) to meet FAO *per capita* consumption, while the export market requires an additional ca. 0.4Mt per year. The current production of 0.4Mt from capture fisheries and 0.1Mt from aquaculture leave a deficit of 0.5Mt. This deficit can be met through expansion of aquaculture, the fastest growing food production industry in the world. Cage fish farming in Uganda has demonstrated in a period of only ten years that it can increase fish production by 150-300 kg m^{-3} compared to 2-10 kg m^{-3} from pond aquaculture, which started about sixty years ago. Cage fish farming, however, has socio-economic, environmental, and technical challenges that need to be addressed and effective cage culture operations require ideal conditions for optimal production. We reviewed literature and examined existing data to develop best practices for establishment and operation of cage fish farms. These practices involve assessment of site suitability and capability, zoning, estimation of carrying capacity, effective operational practices, and monitoring the impact of the operations. This information is important for supporting cage fish farmers and securing the environment, and should continually be refined with new knowledge. The National Fisheries Resources Research Institute (NaFIRRI) and the Directorate of Fisheries Resources (DiFR) are continually updating the information and has set up a facility for research and training. There is need for government to build a robust policy and legal framework to guide cage fish farming.

1. What and why cage fish farming

Cage aquaculture is the raising of fish in an enclosure suspended in water that allows free exchange of water between fish and the water body in which the cage is suspended. There are two cage fish farming systems, the Low Volume High Density (LVHD) and High Volume Low Density (HVLD) cages. The LVHD involves raising fish at high densities of 50-500 fish per cubic meter and can yield 150-300 kg m^{-3}. Conversely, HVLD production involves raising fish at low densities per unit volume ranging from 2-20 fish m^{-3}.

Aquaculture practices like cage fish farming have been necessitated by the increase in local and global demand for fish due to increasing human population and preference of fish due to its high quality protein (Tacon and Metian, 2013). This also corresponds with a period when global fish production from wild fish stocks has stagnated, with most fisheries fully exploited (Worm et al. 2006; FAO, 2014). In Uganda, this has been accompanied by a very low *per capita* fish consumption of 8 kg, which is below the 17 kg recommended by FAO. With a population of 35 million people, and one of the world's fastest population growth rate of 3% per annum (UBOS, 2014), Uganda needs about 600,000 tons of fish per year to meet the recommended FAO *per capita* fish consumption. In addition, the international and regional export markets require about 400,000 tons from Uganda, indicating that Uganda needs to produce at least one million tons of fish per year to sustain local, regional, and international markets. Currently fish production in Uganda is about 400,000 tons from capture fisheries and 100,000 tons from aquaculture, leaving a deficit of about 500,000 tons per year. Since production from capture fisheries is not expected to significantly increase, aquaculture is the only available option for meeting the deficit. Consequently, the Government of Uganda, under the Development Sector Investment Plan (DSIP II) and the Agriculture Sector Strategic Plan (ASSP) 2016 – 2020, has committed to increase aquaculture production to 300,000 tonnes annually by 2020.

Aquaculture has become the fastest growing food industry in the world mainly due to adoption of new production technologies (FAO, 2014). Cage aquaculture, which started in Uganda in 2006 using LVHD cages of about 62.5 m^{-3}, has been observed to have the capacity to produce 150-300 kg m^{-3} under good management practices compared to pond aquaculture, which has been the dominant aquaculture production system in the country since the 1950s which has achieved production of only 2-10 kg m^{-3}. Promotion of cage culture can therefore contribute to the required increase in fish supply in Uganda.

Cage fish farming has a number of advantages over other fish culture systems (Beveridge, 1984). It can achieve very high production in a limited volume of water. The cost of construction of a LVHD cage is about 1/10 that of a pond that produces the same yield of fish. Land ownership is not required. It does not require re-filling of water. Handling, inventory and harvesting of fish are 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. Fish grown in cages can be sold fresh, in good quality and it has high returns on investments over a short period of time.

However, cage fish farming takes place in water bodies that are used for other social and economic activities such as fishing, recreation, transport, water extraction, and sewage disposal. These uses have to be considered to avoid conflicts. Cage fish farming also has environmental challenges that can exacerbate existing environmental problems in most water bodies. Wastes products with high organic content of phosphorous and nitrogen compounds from uneaten fish feed, excreta, and dead fish can increase nutrient loading, reduce dissolved oxygen, produce algal blooms, disrupt aquatic biodiversity, and cause fish kills (Rox et al, 1972; Liu et al. 2012). The materials used in cage fish farming, and the chemicals and drugs used to treat infections can also affect the environment. Cage fish farming normally takes place in shallow areas that are breeding and nursery areas of wild fishes and can affect natural fish populations.

Despite the challenges posed by cage fish farming, Uganda has very high potential for cage fish farming with about 20% of its surface area covered by freshwater bodies comprising of five major lakes and >160 small lakes and rivers. The country has suitable climate with high temperatures up to 35°C, suitable native aquaculture fish species, especially the Nile tilapia (*Oreochromis niloticus*) and the African catfish (*Clarias gariepinus*). There are local ingredients for fish feed such as maize bran, soya bean and fish meal. There is a huge national, regional and international market for fish and increased interest in cage fish farming by local and international investors and development partners. There is also a policy, legal and institutional frameworks for regulation, research, and extension to support cage fish farming. Cage fish farming, which started as a pilot by the Source of the Nile (SoN) Fish Ltd on Lake Victoria in 2006, has expanded fast and there are >3000 cages on Lake Victoria and there are cages on virtually all suitable water bodies in Uganda. Cage fish farming has also started on most other African Great Lakes such as Malawi, Tanganyika, and Kivu. There is therefore need to address the challenges in order to tap into the opportunities provided by cage fish farming not only in Uganda but also in other parts of Africa.

There are success stories where cage aquaculture has had no significant effects on the environment, attributed to careful planning and management of cage fish farms and farming practices (Bueno et al. 2013). Effective planning and management of cage fish farming operations requires knowledge on sites selection, carrying capacity, optimal cage layout and design, good farming practices, and return on investments and environmental management. In addition, operation of cage fish farms requires skilled and technically competent farmers and managers who can effectively plan and manage the operations, such as proper feeding, which is responsible for water contamination by uneaten feeds. All these call for information to address the threats of cage fish farming and exploit the opportunities and development of capacity. This

paper has been prepared as a result of the high demand for information to guide cage fish farmers and secure the environment.

The National Fisheries Resources Research Institute (NaFIRRI) together with the Directorate of Fisheries Resources DiFR) are making efforts to address challenges of cage fish farming by providing guideline on site capability, suitability, zoning, production practices, and monitoring the environment to guide cage fish farmers. This booklet uses existing literature and data to provide information on best practices for site selection, production, monitoring and management, and on policies, legal framework and institutions framework to support cage fish farming. It will continually be updated in consultation with the different stakeholders.

2. Site selection

The first step in cage fish farming is to assess the suitability of the site proposed for cage fish farming. This involves a description of the site including identification of 'no go' areas, its location, and adjacent areas, an assessment of the suitability and capability of the area, zoning the area and determining its carrying capacity. The site suitability assessment should be undertaken by a competent technical institution such as the NaFIRRI. The report of the site suitability assessment will be required by the Directorate of Fisheries Resources (DiFR) as part of application of a license for cage fish farms.

2.1. Description of candidate sites

Candidate sites should be developed in the context of other sectors or uses, and should take into account their influence on surrounding social and natural environment (Subasinghe, 2009). Selection and zoning lead to identification of suitable and capable sites and provides guidance on effective planning. This safeguards the investments, limits the undesirable consequences of cage fish farming on the environment, and reduces conflicts among water resource users, which ultimately increase social and economic benefits from cage fish farming (Butsic et al. 2010; Bueno et al. 2013).

One of the initial steps in site selection is to identify 'no go areas', that should never be considered as candidate sites for cage fish farming and agree on how far the cage fish farms should be from these 'no go areas'. A list of these and their distance based on available knowledge are summarized in **Table 1**. This list as well as the distances indicated can change depending on circumstances.

Once the 'no go areas' have been identified, a description of the location and adjacent uses of the proposed cage site is made. This description forms the site suitability assessment. It includes extrinsic aspects of resource use such as potential conflicts, surrounding land use patterns, market conditions, infrastructure, and presence of technical support and considerations of the type of the planned cage fish farm system (Nath et al. 2000). Aspects recorded in this description include: Administrative units i.e. district, county, sub-county, village and nearest landing site; Coordinates (longitude and latitude); Category of water body such as lake, river and dam; Access road(s); Proximity to technical support services i.e. supplies of aquaculture inputs such as seed and feed, fish handling faculties and marketing; Shoreline description, including the slope, aquatic vegetation, bottom type of the water body at the proposed site; Average width and depth range of the water at the site, Direction of winds, water currents and flushing rates; Streams and rivers in or out of the site; Tenure and ownership of adjacent land. Information should also be provided on adjacent uses such as housing and settlements and other shoreline structure; power lines, crop cultivation and livestock grazing, waste water treatment structures, and industrial activities. After elimination of 'no go areas', defining distances of 'no go areas within', and

assessing the suitability, the site becomes a candidate site for cage fish farming. Its capability for cage fish farming is then assessed.

Table 1. The list of some no go areas and a definition and the distances of their proximity around candidate sites. The distances provided here have been based on a wide range of literature and may change depending on local requirements of stakeholders.

Establishment	**Distance**
Shore line	200 m
Areas of military or security interest	2 km
Published anchorages where ships and boats anchor	500 m
Marked navigation channels for ships, or other form of water transport	100 m
Marinas or mooring areas with structures to which vessels may be secured such as piers	500 m
Fish sanctuaries and Marine Protected Areas (MPA)	2 km
Cables, pipelines and drilling platforms	100 m
Parks, conservation and heritage or tourist sites	100 m
Gazetted fish breeding and nursery grounds	200-300 m
Water intake and extraction points	100 m
Fish migration routes;	500 m
Hydropower plants	1 km
Core Zones of Ramsar sites	2 km
Areas gazetted under the Lacustrine Statutory Instrument	1 km
Areas with high water depth and quality fluctuation	500 m
Important fishing grounds;	1 km
Effluent discharge and waste disposal points	500 m
River and stream mouths and sources	1.5 or 3 km
Landing sites	200 m
Weed hotspots (e.g. water hyacinth)	100 m
Recreational facilities	500 m

2.2. Site capability assessment

The capability of the candidate site is assessed on the basis of physical and chemical environment, pollutants and contaminants, biological communities. The physical, chemical and biological information obtained during the capability assessment also forms the baseline for environmental monitoring of the cage fish farm during operation of the farm.

Physical and chemical environment

A non-stressful water environment inside the cage is fundamental to good fish health and production performance. During assessment of the candidate site, information should be provided on levels of different physical and chemical characteristics of water at the site to demonstrate that they can support cage fish farming. The key physical and chemical conditions, and their ideal levels, are listed in **Table 2** and their description is summarized below. If these ideal levels are not met, the site should be deemed incapable for cage fish farming.

Table 2. Key ideal levels of physical and chemical factors for cage aquaculture

Variable	**Notes**	**Ideal levels**
Depth	There should be at least 2-3m depth under the cage to facilitate water exchange, avoid oxygen depletion, accumulation of uneaten food, faecal material and debris, and buildup of noxious gases such as hydrogen sulphide and methane from decomposition of wastes	5- 20 m
Water transparency	Depth of visibility in water is a measure of suspended and dissolved solids, sunlight and salinity. The greater the depth the lower the nutrient level, but the greater the potential for cage fish yield.	>70 cm
Sediment	The sediment at the site should be clear with no black layer with no signs of contamination. The ideal site should have a firm substrate with fine gravel and sand.	
Gradient	The cage site should slope from the shore leading to flat bottoms to reduce buildup of waste at the bottom of cages.	
Wind velocity	This determines the height of waves at a specific site on a water body. The higher the velocity, the higher the wave height and current speed	≤10 knots
Wave height	Wave height of a surface wave is the difference between the elevations of a crest and a neighboring trough. High waves deform and destroy cages leading to losses and escapes of fish	<1 m
Current speed	Currents bring fresh oxygenated water and remove waste from the cages. Stronger currents exert strain on the cage anchoring system and distort the cage structure.	10 to 100 cm/sec^{-1}
Temperature	Changes in water temperature affect fish metabolism, oxygen consumption, and ammonia and carbon dioxide production rates, Feed Conversion Ratio (FCR) as well as fish growth	27-30°C
pH	Both high and low pH slows fish growth and increases susceptibility to disease. Most fish species grow slowly at	6.5-9

Variable	Notes	Ideal levels
	pH levels > 6.5 and <9	
Dissolved Oxygen (DO)	DO influences growth, survival, behavior and physiology of fish.	≥5 mgL^{-1}
Biochemical oxygen demand (BOD)	BOD measures the total DO consumed by microorganisms for biodegradation of organic matter. High BOD levels are a sign of pollution from organic material such as sewage and can suffocate fish	≥6 mgL^{-1}
Carbon-dioxide (CO_2)	CO_2 in produced from respiration of animals and exists in water as bicarbonate or carbonates. It forms carbonic acid when dissolved in water leading to low pH which can be harmful to fish	<5 mgL^{-1}.
Total Ammonia Nitrogen	Ammonia is caused by deposition of uneaten food and debris, excretion wastes, sewage discharge and pollution.	<0.01mgL^{-1}
Nitrate	Accumulation of organic matter in the sediment provides an environment for nitrite generation where it is converted to ammonia. This can bind with hemoglobin to form methemoglobin which interferes with transportation of oxygen in the blood. Toxicity increases with low DO and decreases with increasing chloride concentration	0.1-4.0 mg L^{-1} (2 mg L^{-1} is optimal)
Nitrite	Nitrite affects fish by oxidizing haemoglobin to methemoglobin in the blood, hindering respiration and causing damage to the nervous system, liver, gills, spleen and kidneys.	< 0.2 mgl^{-1}
Total phosphorous	Total Phosphorus is the sum of reactive, condensed and organic phosphorous and is an important nutrient in fresh water bodies which can cause adverse environmental impacts when present in large concentrations leading to eutrophication.	<100 µg/L
Chlorophyll-*a*	This is an indicator of primary production.	<75 µg/L
Total suspended solids	Suspended solids are pieces of particulate matter > 0.45 µm. They make water turbid preventing good water exchange due to accumulation of suspended solids in the cage. Suspended solids act as substrate for growth of fouling organisms which affects water circulation. Suspended solids can clog the gills of fish leading to mortality. Visibility of fish will also be reduced leading to feed losses and impaired growth.	<10mgL^{-1}
Total dissolved	These are pieces of particulate matter <0.45µm	<40 mg L^{-1}

Variable	Notes	Ideal levels
solids (TDS)		
Conductivity	Conductivity is determined by presence of ions such as Ca2+, Mg2+, HCO, CO3-, NO3- and PO4- in water.	30-5,000 mSiemens/cm
Salinity	Salinity is defined as the total concentration of electrically charged ions (cations – Ca++, Mg++, K+, Na+ ; anions – CO3-, HCO3-, SO4-, Cl- and other components such as NO3-, NH4+ and PO4-). Salinity is a major driving factor that affects the density and growth of aquatic organism's	2-3 ppt
Alkalinity	This is the capacity of water to resist changes in pH, and is based on total concentration of bases such as carbonates, bicarbonates, hydroxides, phosphates.	120-400 ppm
Hardness	This is the measure of elements such as calcium, magnesium, aluminium, iron, manganese, strontium, zinc, and hydrogen ions. These are essential for metabolic reactions.	30-180 mgL^{-1}
Chloride	Chloride is a common component of most waters and is useful to fish in maintaining their osmotic balance.	60-100 mg L^{1-}
Faecal coliform	Coliform are bacteria belonging to Family Enterobacteriaceae. Presence of these is indicative of contamination of fecal material of human and other warm blooded animals. Information should be provided on occurrence of fecal coliforms and total bacteria count to ensure that fish farming does not occur in sites contaminated by fecal material that can lead to production of fish contaminated by bacteria that can cause diseases to consumers.	≤100 count per 100 ml

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Biological information

Biological data should be obtained on communities of phytoplankton, zooplankton, benthic invertebrates, fish and aquatic plants that grow in or near water, and are emergent, submerging, or floating. This information should be synthesized to determine whether the sites are critical habitats for fish, spawning and nursery areas, fish migratory corridors, and critical areas for fish food organisms and other sensitive or endangered species. Information should be given on presence of species at risk and those that are threatened in relation to the International Union for Conservation of Nature (IUCN) red lists. The species that may be at risk due to the proposed cage aquaculture operation should be identified and the site either excluded from cage fish farming or measures taken to mitigate the risks.

Pollutants and contaminants

A site selected for cage fish farming should be free of pollution and contamination by heavy metals and Persistent Organic Pollutants (POPs). Heavy metals and POPs are important as they persist and bioaccumulate through the food web, causing severe adverse effects to living organisms including man. The desired levels of selected heavy metals and POPs at sites selected for cage fish farming are presented in **Tables 3 and 4**. Sites with levels above those provided for the heavy metals and POPs should be excluded from cage fish farming.

Table 3. Desired concentrations of selected heavy metal contaminants in water (mg m^{-3}) and sediments (µg/g) at sites selected for establishment of cage fish farming and aquaculture parks. For each heavy metal, the concentrations is at the level it causes lowest influence to the environment (Adopted from: TNO, 2008a,b; Swedish Environmental Protection Agency, 2000; FAO 1999; Battsand Cubbage 1995)

Heavy metal	Sediments (µg/g)	Water (mg m^{-3})
Mercury	0.2	0.144
Lead	31	5
Nickel	16	13.4
Cadmium	0.6	10
Zinc	120	20
Iron	2	300
Copper	16	3
Chromium	26	50
Arsenic	6	5
Manganese	460	50
Selenium	-	10
Barium	60	1000
Silver	0.5	50
Thallium	-	13

Table 4. Desired concentrations of selected Persistent organic pollutants (POPs) and pesticides, including some of the dirty dozen provided in the Stockholm convention on POPs in sediments (µg/g) and water (µg/l) at sites selected for establishment of cage fish farming and aquaculture parks. For each, the concentrations is at the level it causes lowest influence to the environment (Adopted from: TNO, 2008ab; Swedish Environmental Protection Agency, 2000; FAO 1999; Batts and Cubbage 1995).

Persistent organic pollutant/pesticides	Sediments (µg/g)	Water (µg/l)
Aldrin	0.002	0.01
Chlordane	0.007	
DDT (total)	0.007	
Dieldrin	0.002	0.005
Endrin	0.003	0.005
Heptachlor	0.0003	
Toxaphene	-	0.002
Polychlorinated Biphenyls (total)	0.07	
Mirex	0.007	
Hexachlorobenzene	0.02	0.01
Endosulfan	-	0.1
Tributyltin	-	0.014
Pentachlorobenzene	-	1
Lindane	0.005	0.02
α-Hexachlorocyclohexane	-	10

2.3. Zoning and carrying capacity

After the site has been deemed suitable and capable, it should be demarcated to indicate the area of intensive use for cage fish farming and presented as polygons. A demonstration of layout of cages should be indicated depending on a target biomass and cage designs and considerations to allow good water exchange in cages to maintain dissolved oxygen at a safe level throughout the period of the culture. Decision support tools such as Cage Aquaculture Decision Support Tool (CADS_TOOL) that take into account site characteristics and other parameters from cage fish farming industry (Halide et al., 2009) should be used to determine maximum cage holding capacity and lay out for the site to maximize benefit from cage fish farming with minimal negative impacts on aquatic environment and ecosystem services.

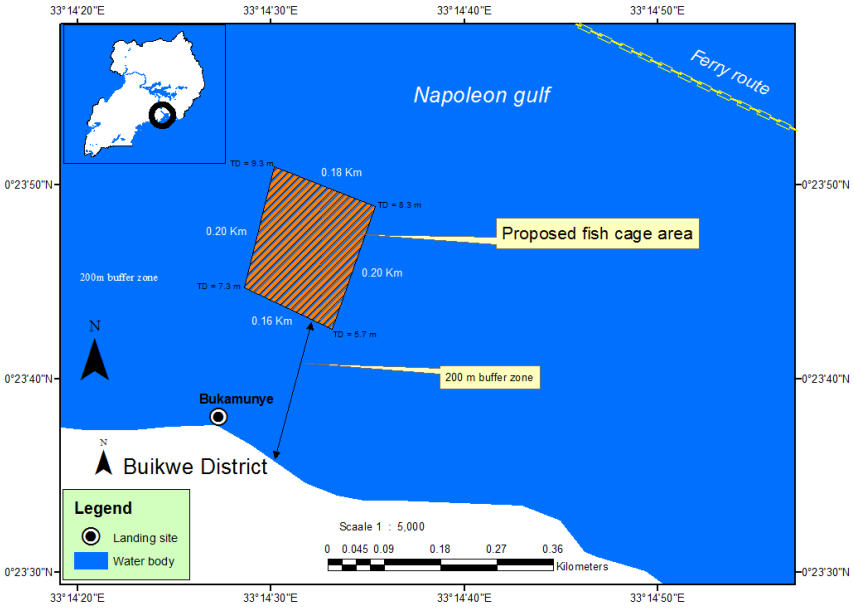

Figure 1. An illustration of cage site selection based the example of Napoleon Gulf (Lake Victoria)

2.4. Environmental and Social Impact Assessment (ESIA)

Large scale cage fish farms by law require an ESIA that has to be prepared and submitted to the National Environmental Management Authority (NEMA) for approval. An ESIA should be undertaken by a competent firm and submitted to NEMA for approval, following existing ESIA guidelines. It is incumbent upon the prospective farmer to ensure that an ESIA report is prepared and presented to NEMA for approval before applying for an operating license. The ESIA should be carried out in line with guidelines provided by NEMA but, in case of cage fish farms, the report should include information such as: Water rights and accessibility to water and other resources (fishers, navigation, industries); Production carrying capacity of the site; The impact on the natural environment, water quality and biodiversity; The impact on capture fisheries, transmission of diseases to wild populations, biodiversity, escapees of cultured species, and competition in the market place with capture fisheries products; Human health issues, such as waterborne diseases such bilharzia; Gender participation; Economic issues e.g. whether cage fish farming will reduce or increase poverty by disrupting established local socio-economic activities or displace alternative economic activities. An approved ESIA report together with the report of the site suitability assessment will form the basis for the DiFR in issuing a provisional operating license to carryout cage fish farming.

3. Production practices

Once an operational license has been issued by DiFR, the farmer is ready to set up the farm for production. The farm should maintain production information including: types and sizes of cages; species cultured; number of fingerlings stocked 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, boat, engine, sampling baskets and scales, fuel and personnel costs. These data are important for management, and will be valuable in cross-learning since cage fish farming is still a new venture in Uganda.

3.1. Lay out of the farm

The farm should have a site plan which should include: The cage fish farming facility and expected footprint i.e. the zone of maximum accumulation; The boundary; The cages and any other containment structures; The anchor blocks and mooring lines; Cage numbers and their dimensions; Navigation markers and potential navigation pathways around the farm; Buildings, offices; Walkways, utilities, cables, catwalks; Stores for fuel, chemicals, feeds; Access road to the site; Water lines that supply clean water to the farm; Mortality storage and net cleaning points; Depth contours from the low water mark; Predominant current direction; and Anchor blocks, mooring lines, marker buoys and shore attachments within the approved site plan.

The sizes of cages are defined during assessment of site suitability and carrying capacity assessment stage. The sizes of cages initially used in Uganda were of square from of 2.5m and depth of 2.5 m. However more farmers have shifted to slightly bigger cages of 5 m^2 frame but still of 2.5m depth. 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, and fouling resistant, easy to repair, drag free, smooth in texture and non-abrasive to fish. Auxiliary cage equipment include: Partially removable cover to prevent fish from jumping out or preventing predators from getting into the cages; Floating feedbox or ring cylinder 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 to retain the feeds; Steel bar, polyvinyl chloride (PVC) pipe or other rigid materials if a rigid frame is used to support the cage walls; Floats; Anchors and platforms/walkways.

The cages should be located in water with good circulation, protected from strong currents and high waves, away from stagnant water which can deteriorate fast and 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 located in an easily accessible area to facilitate routine maintenance and feeding and in a place where they can be easily monitored and security provided. The cage perimeter can be enclosed using a

chain link around the cages with an access gate. A dog can be kept inside to provide 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. Most cages are either rectangular, but circular or cylindrical cages are sometimes used. However, water exchange is better in rectangular than cylindrical cages of the same volume and mesh size. Some examples of the layout of cages on Lake Victoria is illustrated in Figure 1 below.



Figure 2. 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.

A typical cage structure with its components is illustrated in **Figure 3** and comprises of a cage frame, cage bag, floaters, feed enclosures or feed barrier, cage covers and sinkers. The 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. Floatation may be provided by plastic drums or jerrycans, sealed PVC pipe, styrofoam or bamboo frames. It has a cage bag which holds the fish. The mesh size of the cage bag is important in preventing escape of fish to the surroundings. Double case netting could be used to reduce the chances of escape of fish in case of damage.

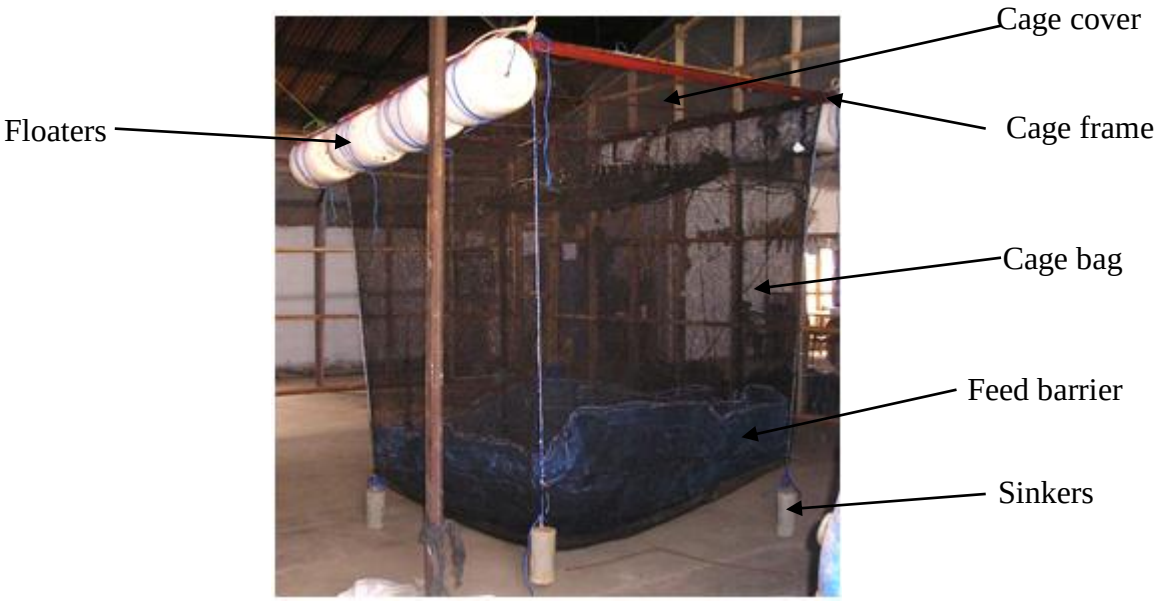

Figure 3. A typical cage structure with its components.

There should be a nursery cage and a production cage. The nursery cage should have a minimum mesh size of 8 mm square and a production cage of 13 mm square mesh size. The mesh size of the cage bag influences water exchange between the cage and the surrounding water and water exchange increases with mesh size, but decreases with increasing amount of solid space between openings. There should be anchors to stop the cages from being drifted away by wind. The best anchoring system comprises four concrete blocks which are heavy enough to stop drifting of the cage with an iron loop into which the ropes is connected to each corner of the cage frame. 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 movements above the cage. 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 in weight and weather resistant. 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 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 of the cage. Floating feed enclosures should be placed in the center of cages. Where sinking feeds are used, the feed enclosure should be at the bottom of the cage. Other inputs required in operation of a cage fish farm include items like a canoe, outboard engine, life jackets, sampling baskets, measuring boards, fuel to facilitate movements from the shore to the cages, and labor for management of cages.

3.2. Culture species

Nile tilapia (Figure 4) is the most widely cultured and recommended species for cage culture. It it grows fast, and can tolerate high stocking densities. It is are locally available in virtually all water bodies in Uganda, although it requires research to improve seed quality and growth performance. Cultured fish experience considerable stress as a result of handling right from the stocking to harvest, and efforts have to be made to reduce this as it affects the fish. During the growth period, fish disturbance should be kept to the minimum. Stress reduces feed consumption and affects growth.



Figure 4. Nile tilapia

3.4. Seed (or fry) and stocking density

Most cage fish farmers obtain their seed from commercial seed producers. It is recommended the seed are obtained from certified seed producers. All male juveniles sexually reversed using hormones are best for cage culture but mixed sex Nile tilapia can be reared in cages without the problems 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 as they grow faster and acquire more uniform size at harvest. Fry for stocking should be of high quality, disease free and uniform size.

Juveniles of not less than 1 g should be stocked in a juvenile cage at a density of 1000-2500 fish m^{-3}, reared for 8 weeks, graded and stocked in production cages at a density of 150-300 fish m^{-3}. and reared for 6-7 months to 350-600 g and harvested depending on market demands. Sites with good water exchange can have higher stocking densities, while those with poor water exchange should use lower stocking densities. Survival rates in well-placed and well-managed cages are typically 80-95%. 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 cool temperature of 20 to 22° C.

3.5. Feeds and feeding

Feeds play a major role in cage fish farming, but are also the main source of nutrient enrichment or pollution to water bodies. Farmers are advised to use feeds certified by a relevant mandated institution for desired quality, absence of bacteria and other contaminants that are likely to affect the environment and health of fish and consumers. The feeds used should be water stable, extruded and pelleted, and easily acceptable by the fish. 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 constituents of the different nutrients for different developmental stages are summarized in **Table 5**.

Table 5. 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(200)	750(1500)	1500(300)

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+)
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 Council - 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

Correct amounts of feed should be provided to the fish daily using weighed feed based on feeding ration tables. 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 6)**. 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.

Fish should be fed twice a day by dividing the daily ration into two portions respectively and giving each portion at a time. 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.

Floating rings should be used to retain floating feeds inside cages. Feeding trays may be built inside cages or placed on the cage floor to retain sinking pellets. The amount of feed given to fish should be adjusted depending on the average body weight of the fish obtained from regular sampling.

Table 6. 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

3.6. Monitoring growth performance, survival and feed utilization

Fish should be sampled at least once every four weeks to determine average body weight, calculate and monitor the Feed Conversion Ratios (FCR) to 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. 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 5.** Daily growth rates of 2 to 3 g have been recorded in cages in Lake Victoria where average water temperature is 26ºC (Veverica et al. 2009). Nile tilapia fry of brood stocks from Lake Victoria have been reported to 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).

Efficiency in converting feed mass into increases in weight of the fish is determined from the Feed Conversion Ratio (FCR). FCR is the mass of the input divided by the output. Hence the smaller FCR is the higher the efficiency. The 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.

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. Overall survival rate can be 80% to 95% depending on cage management.

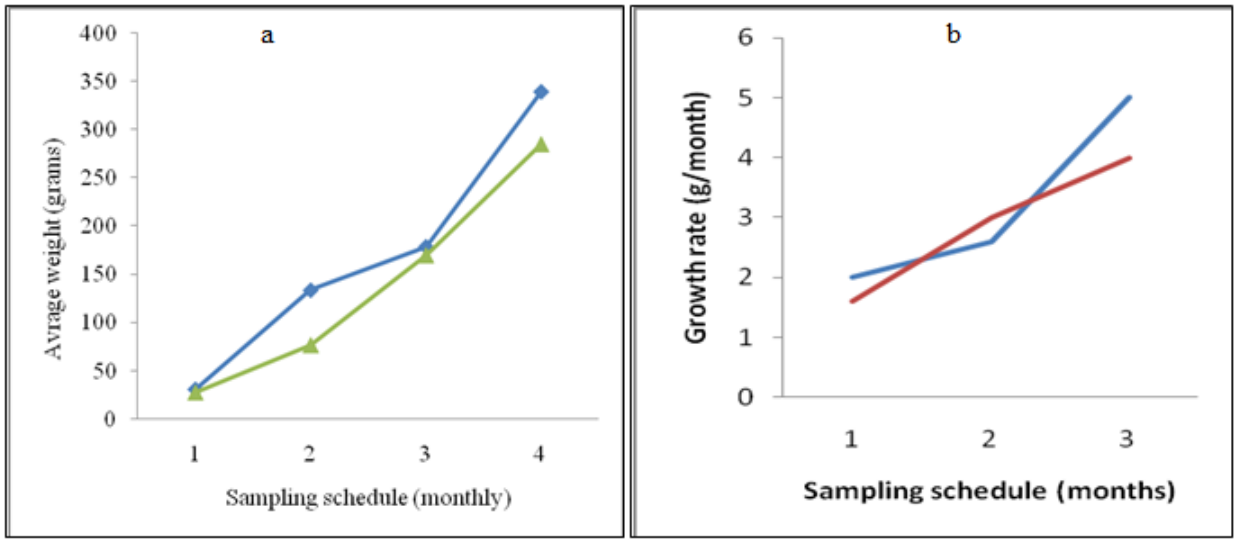

Figure 3. Growth performance of Nile tilapia

3.7. Yield and production economics

Fish from cages is normally harvested at an average weight 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. 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 (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}. The price at which the fish is sold per kg should be recorded.

The estimated yield under varies between 80 and 300 kg. m^{-3} depending on site quality and management. (i.e ~1200-4600 kg from the 2.5x2.5x2.5: 15.6 m^3 cage). The estimated cost of inputs per cage are: The cage (Shs 1,200,000 - US$ 340; Seed (Shs 950,000/= - $270); Feed (assuming FCR of 1.5 would require 1875 kg) which at an estimated cost of Shs 3,000 per kg is Shs 5,625,000/= ($1,610). If we provide for US$ 300 for other costs, the total cost of production

per cage is ~US$ 2,500. At a selling price of US$ 2.5 per kg, the expected gross minimum income at selling is about US$ 3,000, providing a net profit of about US$ 500 per cage.

4. Monitoring and Management

4.1. Site security

There should be a facility security plan to ensure that farmed fish do not escape in the wild. This can be achieved 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. The cages should be checked regularly for damage. 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.

4.2. Fish health

Farmers should minimize risk of diseases transmission by buying fingerlings from certified disease free sources. Farmers should develop 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: 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. Infected fish should be moved to a separate cage and treated according to the syndrome. Equipment used to handle infected fish should not be used in non-infected cages without disinfection. Dead fish should be taken away and should not be discharged directly into surrounding areas. There should be a separate cage to hold weak fish downstream the water current. Farmers should consult and inform extension workers and research institutes about the disease and treatment. Farmers should collect infected fish or their parts such as gills and injured parts as samples, preserved in alcohol, formalin or ice boxes and send them to the laboratory for examination. Farmers are advised not to use chemicals and drugs as much as possible and in case of disease, guidance should be sought from competent authorities.

4.3. Waste management

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

4.4. Environmental monitoring

There should be periodic environmental monitoring of the farm by a competent authority in line with environmental monitoring plan included in the approved proposal for setting up of the farm. 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. As indicated earlier, data on environmental variables and biological communities collected during the site capability assessment will form the baseline for environmental monitoring. The information collected should also be compared with NEMA standards. Farmers should maintain the data collected and associated reports generated. Environmental monitoring should be in the form of a recognized and independently audited environmental management system. Any negative changes in environmental data, which cannot be mitigated, may necessitate closure and relocation of the farm. 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.

4.5. Decommissioning of the farm

The farmer should have a decommissioning plan for the farm. 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.

5. Policies and institutions

Cage culture has social and environmental concerns, and there is need for clear policies and institutions to regulate its development especially relating to water, fisheries, and environment. There are international, regional and national policies, regulations and institutions which, although not specifically addressing cage culture can be adapted and improved to address issues related to cage culture.

The International and regional institutions through which cage culture can be supported include the UN, FAO, AU and EAC. The international and regional policies, and legal instruments that can be applied or improved to support cage culture include: The FAO - Code of Conduct for Responsible Fisheries (CCRF); The EAC Protocol for sustainable development of the LVBC, 2004; The convention for the establishment of the LVFO; and the EAC Protocol on environment and natural resources management; and the EAC Regional Aquaculture strategic plan.

There are a number of national institutions that have a stake in the development of cage aquaculture in Uganda including: Directorate of Fisheries Resources (DiFR); National Environmental Management Authority (NEMA); Directorate of Water Resources Management (DWRM); National Fisheries Resource Research Institute (NaFIRRI); and Universities and other tertiary institutions such as the Fisheries Training Institute (FTI); and Local governments. Some of the key national policies and regulations include:Water Act;The Fisheries Act Fish and (Aquaculture) Rules; National Environment Management Act; EIA Regulation; The national Environment (Wetlands, River Banks and Lake Shores) Management; National Water and Sewerage Corporation Statute; and Local government Act, 1997. Some of these will however need some amendments to specifically address issues of cage culture. Farmers and prospective farmers, and managers should familiarize themselves with these policies, utilize them and ensure compliancy.

6. Conclusions and recommendations

Cage culture is new and developing fast, and has potential to increase fish production and create wealth in Uganda. The challenges associated with cage fish farming can be addressed through good management. There are some guidelines that can be applied to promote best practices in cage fish farming. There also some policies that can improve to guide cage fish farming. There are research and management institutions that can improve the guidelines, train and supervise cage fish farming. What is needed is for the different institutions and farmers to work together to make this a reality and to continually review and improve the process.

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