Requirements for Economically and Environmental Sustainable Cage Fish Farming on the African Great Lakes

[1]Richard Ogutu-Ohwayo <ogutuohwayo@yahoo,con>, [1]Laban Musinguzi <labanmusinguzilaban@firi.go.ug>, [1]Vianny Natugonza<viannynatugonza@yahoo.com>, [1]Philip Rwezawula <philiprwezawula@gmail.com>, [1]Jessy Lugya <lugyajessy@yahoo.com>, [2]Robert Osinde <rosinde@lakeharvest.com>, [3]FridayNjaya<fnjaya@gmail.com>, [4]Stephanie Kamondo<nyfak2013@gmail.com>, [5]Christopher Aura <auramulanda@yahoo.com>, [6]Amon Paul Shoko<amon_shoko@yahoo.co.uk>, [7]Jose Halafojhalafo@yahoo.com

1National Fisheries Resources Research Institute (NaFIRRI), P. O. Box 343, Jinja, Uganda.
2Source of the Nile (SON) Fish Farm Ltd, P.O. Box 322, Jinja, Uganda;
3Department of Fisheries, P.O. Box 593, Lilongwe, Malawi;
4Rwanda Agriculture Board (RAB), P.O. Box 44 Kigali, Rwanda;
5Kenya Marine and Fisheries Research Institute (KMFRI), P. O. Box 1881, Kisumu, Kenya;
6Tanzania Fisheries Research Institute (TAFIRI), P.O. Box 9750, Dar es Salaam, Tanzania;
7IIP-Fisheries Research Institute, 389 Mao-Tsè-Tung Avenue, PO Box 4603, Maputo, Mozambique;

*Correspondence author: ogutuohwayo@yahoo.com

Abstract

Cage aquaculture is expanding on the African Great Lakes (AGL) and has potential to contribute to increasing fish production to provide the much-needed nutritious protein, employment, income and export earnings to bridge the gap in fish supply due to stagnation in capture fisheries. It however, needs technical guidance and regulation to avoid conflicts with other water uses, environmental degradation, and economic losses. We developed best management practices (BMP) from literature and experiences from existing farmers in the AGL region to guide farmers in increasing fish production from cage fish farming in a socially and environmentally sustainable manner while safe guarding the integrity of the water bodies. BMP in cage aquaculture require: Proper guidance before starting; Spatial planning; Selection of suitable and capable sites; Suitable farm plan; Appropriate cage design and installation; Application of appropriate production practices; Harvesting and Marketing strategies; Environmental monitoring; Adherence to appropriate policies and using competent manpower. The proposed BMP are adaptive, and will be improved from lessons learned from research and operations.

Key words: Adaptive research, cage aquaculture, culture practices, environmental monitoring, Africa.

Introduction

The African Great Lakes (AGL) including Albert, Edward, Kivu, Malawi, Tanganyika, Turkana, and Victoria are among the most important assets of the African Great Lakes Region (AGLR) (The Nature Conservancy, 2016). These lakes support high fish biodiversity especially of haplochromine cichlids that are the most diverse fish species on earth (Turner et al. 2001). The lakes are of immense economic value with capture fisheries producing *ca*. 1.5 million tons of fish per year, employing >350,000 fishers and supporting livelihoods of *ca*. 1.8 million people (The Nature Conservancy, 2016). The basins of the lakes have some of the fastest human population growth rates in the world (UN, 2017), and highest population densities in Africa (Kolding et al., 2008) many of whom depend on fish as a source of readily available high quality animal protein.

Inland fisheries in Africa, including those of the AGL face multiple social and environmental challenges (Hecky et al., 2010; Ogutu-Ohwayo et al., 2016). These have contributed to reduced fish catches, decline in fish species diversity and economic value. The catches of the large preferred food fishes on virtually all the AGL have declined and become dominated by small pelagic fish species. This trend is consistent with global decline and stagnation in fish production from wild fish stocks due to exploitation and environmental changes (Worm et al. 2006). Capture fisheries production alone can no longer meet both local and international fish demands. For instance, using Uganda as a proxy of this scenario, the country needs 600,000 tons of fish per year to raise the national *per capita* fish consumption about 10 kg to the 17 kg recommended by FAO and 400,000 tons to satisfy the regional and international markets. The current annual fish production level of 500,000 tons (400,000 from capture fisheries and 100,000 tons from aquaculture) leaves a deficit of 500,000 tons. Aquaculture is the only viable option to increase fish production to meet such deficits since capture fisheries cannot be increased further.

Aquaculture has become the fastest growing food industry in the world through adoption of new production systems and technologies such as cage fish farming (Tacon, 2001). Cage fish farming which involves rearing fish in an enclosure suspended in water while allowing free exchange of water between the enclosure and the host water body (Masser, 1988) is gaining momentum worldwide, including the AGL where it started around 2004 on Lake Malawi, Malawi (Gondwe et al 2011). Cage aquaculture systems are described in terms of fish density and cage volume either as Low Volume High Density (LVHD) or High Volume Low Density (HVLD) (Masser, 2012). Cage aquaculture has since its introduction in the AGLR demonstrated capacity to produce higher production of 60-80kg per m^3 of fish in LVHD cages and 20-40 kg per m^3 in HVLD cages compared to land-based pond fish farming s) which started around 1950s in the AGLR but can only produce a maximum of 2kg per m^3. Cage fish farming has other advantages including lower cost of construction of cages compared with land-based systems (such as ponds) targeting an equivalent production, higher fish survival rates, more efficient on-farm operations (such as handling, inventory and harvesting of fish), easier control of fish predators, more efficient utilization of feeds, lower susceptibility to extreme weather such as drought and floods and higher returns on investments (Beveridge, 1984).

However, cage fish farming poses social, economic and environmental challenges, including competition with other lake uses, pollution and nutrient enrichment of water bodies due to waste products with high organic content of phosphorus and nitrogen from uneaten feed, excreta, and dead fish (Rox et al, 1972; Liu et al. 2012), and disruption of biodiversity hotspots since most cages are sited in inshore areas which are the critical breeding and nursery areas for wild fish species. Because of these potential threats, and given that AGL are physically and ecologically dynamic and susceptible to environmental and climatic stressors (Hecky et al. 2010; Ogutu–Ohwayo et al., 2016), there is need for guidance on cage fish farming to safeguard the integrity of AGL.

Consequently, a team of experts from the AGL region have come together to develop BMP to support socially, economically and environmentally sustainable cage fish farming in the region. This is necessary because cage fish farming is expanding rapidly in the AGL region with limited guidance. The guidelines used by some of the farms have been adapted from elsewhere in the world and need to be tailored and tested to the AGL region and many farmers do not have readily available information to guide them in cage fish farming. There is, therefore need to produce materials that can be easily accessible to cage fish farmers in the region. The team has so far produced various cage fish farming guidelines including a mobile application, video documentaries, brochures and posters to guide cage fish farming in the region. This document provides further elaboration of this information. BMP in cage fish farming require:

a) Technical guidance on how to start cage fish farming;
b) Spatial planning, site suitability and capability assessments;
c) Farm plan and layout;
d) Cage fabrication and installation;
e) Production practices;
f) Harvesting and marketing strategy;
g) Environmental monitoring;
h) Appropriate policies, institutions and manpower.

These requirements are expounded here but are expected to evolve and be improved as more knowledge emerges from literature, adaptive research and experience from practicing farmers. Our recommendations so far are based on literature search, experience from established cage fish farms on the AGL and elsewhere, on-farm experiences, and our own research. Some of these BMP have been proposed, along with other practices, in various forms before (Beveridge, 1984), but we refocus them and translate them into readily available formats for application on the AGL. The BMP are therefore not exhaustive but are pertinent to the current situation (i.e. excitement about cage fish farming as well as stakeholder suspicion) in the AGL and are expected to improve as the industry grows. Improvement and adhering to the BMP with special care and diligence are critically important for socially, economically and environmentally sustainable cage fish farming on the AGL.

Technical guidance

Like any properly planned business, the very first step in cage fish farming is for a potential investor to obtain an enterprise budget prepared by an expert familiar with cage fish farming to provide an estimate of the expected investment including fixed and variable costs associated with setting up and operation of the farm and gross income based on several assumptions such as size of cages, stocking size, stocking density, size at harvest, Feed Conversion Ratio (FCR), feed costs and the selling price of fish. This helps the farmer in forecasting the costs and returns from the planned investment and facilitates informed decision before investing in cage fish farming.

After obtaining an enterprise budget the investor should consult technical personnel such as the local fisheries officer of their region for example a District Fisheries Office (DFO). The DFO will provide initial guidance on potential sites, the requirements for assessing suitability and capability of the proposed site, farm planning, cage types and sizes, production practices, applicable policies, relevant institutions, and suppliers of farm inputs.

Spatial planning, site suitability and capability

Cage fish farming should be preceded by spatial planning to define the areas that should be used for cage fish farming in relation to other lake uses and environmental factors of the water body. This helps in identifying those areas that can be designated to cage aquaculture. A farm should be sited in an area where it has minimal conflicts with other lake uses and environmental impacts (Price & Beck-Stimpert, 2014). The very high fish stocking densities used in cage fish farming require the farm to be located in an area with suitable environment for fish health and growth. Suitability and capability assessments of the site are therefore undertaken to identify the best areas for cage fish farming to reduce conflicts with other water uses and to safeguard the investment (Butsic et al. 2010; Bueno et al. 2013).

Experts from a competent technical institution, such as a Fisheries Resources Research Institute or university department should assess the suitability and capability of the proposed site and produce a report. Suitability involves assessing the landscape and the different uses in and around the proposed site for cage fish farming. A good landscape should be flat or with a gentle slope with adequate vegetation cover. The different uses to be assessed in the proposed site include; farming practices, navigation routes, landing sites, water extraction points, waste disposal points, fish breeding and nursery grounds, fishing grounds, recreational facilities, key biodiversity hotspots, hydropower plants and security installations. Suitability assessment involves a description of the site in relation to its location in relation to the above ‘no go’ areas that should not be considered for cage fish farm establishment, other water uses and their influence on surrounding social and natural environment, potential conflicts, surrounding land use patterns, accessibility, infrastructure, and presence of technical support services (Nath et al., 2000). Selection of the site should consider other water uses to limit undesirable consequences of cage fish farming, reduce conflicts among different water resource users and safeguard the investment (Subasinghe, 2009; Butsic et al. 2010; Bueno et al. 2013). Table 1 lists some factors that should be considered when setting up a cage fish farm and how far the farm should be from such areas.

Table 1. List of some ‘no go areas’ and proposed distances from the candidate sites. The distances given here are based on literature (Cross & Kingzett, 1992; Subasinghe, 2009; Bueno et al., 2013), and may change depending on local requirements of stakeholders. It is important, that the cage site is far enough to avoid conflict between the different uses

Establishment	**Distance**
Shore line	200 m
Areas of military or security interest	2 km
Published anchorages, where ships and boats anchor	500 m
Navigation channels for ships or other water transport	100 m
Marinas or mooring areas with structures to which vessels may be secured such as piers	500 m
Fish sanctuaries and Protected Areas (PA)	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	1.5-3 km
Landing sites	200 m
Weed hotspots (e.g. water hyacinth)	100 m
Recreational facilities	500 m

Sites that possess attributes that allow cage fish farming are considered suitable and are then assessed for capability to support cage fish farming.

Capability to support cage fish farming based on the extent to which key physical, chemical and biological water quality parameters can sustain cage fish farming (FAO, 1989; Cross & Kingzett, 1992). Good water quality around cage culture sites is important to maintain the water ecosystem as well as the health of the fish in the cages. The site should have good water circulation and environmental conditions. The minimum levels of key environmental parameters based on Swedish Environmental Protection Agency (2000) are: water depth (5-20 m), water transparency (>70 cm); wind velocity (≤10 knots), wave height (<1 m), current speed (10-100 cm sec^{-1}), temperature (27-30^{o}C), pH (6.5-9), dissolved oxygen (≥5 mg/L), biological oxygen demand (≥6 mgL^{-1}), CO_2 (<5 mg L^{-1}), total ammonia nitrogen (<0.01 mg/L), nitrate (0.1-4.0 mg/L), nitrite (< 0.2 mg/L), total phosphorus(<100 µg/L), chlorophyll-a (<75 µg/L), total suspended solids (<10 mg/L), Total Dissolved Solids (<40 mg/L), firm sediment substrate; conductivity (30-5,000 m Siemens/cm), salinity (2-3 ppt), alkalinity (120-400 ppm), hardness (30-180 mg/L), and fecal coliform(≤100 count per 100 ml).

During capability assessment, data should also be collected on biological communities in the proposed site including algae, zooplankton, benthic invertebrates, fish and aquatic macrophytes. This facilitates exclusion of critical habitats for fish, spawning and nursery areas, and species at risk or threatened in relation to the International Union for Conservation of Nature (IUCN) red list. Depending on the magnitude of investment especially medium to large farms with a planned production of 20 to 50 tons and above per year, an Environmental and Social Impact Assessment (ESIA) should be conducted and an Environmental Impact Statement (EIS) prepared and submitted to relevant environmental management authority for approval. After the site has been shown to be suitable and capable of supporting cage fish farming, it should be demarcated and its carrying capacity estimated based on the data collected on water quality and biological aspects. Decision support tools such as CADS framework (Halide et al., 2009) is employed to estimate carrying capacity. These assessments should be the basis for issuance of an operational permit to the prospective cage fish farmer by licensing authorities. The data collected during capability assessment forms the baseline for environmental monitoring of the site if a cage fish farm is established. If the ideal levels are not met, the site is not capable of supporting cage fish farming regardless of the results of the suitability assessment. Once the site has been found to be suitable and capable for cage fish farming, the perceptions and acceptability of the communities in the area to establishment of the cage fish farm to avoid conflicts.

If the site is found to be suitable and capable, the farmer can proceed to apply for an establishment permit from the regulatory authority responsible for fisheries management such as a Directorate of Fisheries Resources, obtain a water use permit from the authority responsible for water resources management such as the Directorate of Water Resources Management, and depending on the scale of production (>50 tons per annum in case of Uganda), obtain approval of the authority responsible for the environment.

Farm plan and layout

Once permission has been obtained from the responsible authorities, the farmer can proceed to prepare the plan of the farm. The plan of the farm should consider aspects highlighted under technical guidance, suitability, capability and biological assessment of the site. The layout of cages will depend on the type, (LVHD or HVLD), size, design and number of cages and exchange of water within and around cages. The plan should show: The boundary and size of the farm; Depth contours to provide inclination of the bottom of the lake; Predominant current direction to provide information on the water current and where the cage wastes are likely to be deposited to help in determining the area where the highest number of cages will be placed; Cage dimensions and number; Grid for attachment of cages and anchors to stop the cages from being carried away by water currents; Navigation pathways to allow feeding, sampling and other operations on the farm. The layout should also show land based support installations such as access roads, boat landing points, loading and storage facilities, clean water access points, net cleaning points, waste disposal areas, and sanitary facilities.

The farm should have a security plan to prevent fish escape and vandalism. Fish escape can be prevented by installing double layered cage bags, predation by fixing a cover net on top of the cage frame, theft and vandalism by constructing and attaching a floating security house to the cage grid and employing patrol guards. All workers should wear life jackets while on water, and divers who check cages under water should have proper diving kits. There should be provision for disposing off dead fish, and other structure used on the farm. There should be a decommissioning plan to restore the site as much as possible to its original conditions at the end of the operation. All foreign materials used on the farm should not be abandoned in the water or along the shoreline.

Cage, design, fabrication and installation

After the plan and layout of the farm has been determined, cage units are made. These may be of different shapes (rectangular, square or circular) depending on the farm plan. A cage (Figure 1) is the basic production unit in cage fish farming and consists of; Cage bag (to hold the fish), sinkers (to stretch the cage bag), a frame (on which the bag is attached), floaters (for keeping the unit afloat), feed barriers (to stop feed from floating out of the cage), cage cover (to keep away predators), and anchors (to secure the cage and stop it from being carried away by wind). Cages of less than or equal to 30 m^3 in size that hold a high number of fish per unit volume are categorized as Low Volume High density (LVHD) while those of more than 30 m^3 and that hold low number of fish per unit volume are categorized as High Volume Low Density (HVLD) cages. The sizes of cages used on AGL have evolved overtime from small rectangular LVHD cages as small as 2.5m by 2.5m width and 2.5 m depth to HVLD cages of up to 12 m width and 6 m depth.

The cages should be strong to withstand winds and currents, and hold fish securely to avoid escape to the environment. This is important because fish escapees can cause undesirable environmental effects (Naylor et al., 2005) and economic losses to the farmer. Escape of fish from cages is normally due to structural failures and weak cage materials (Jansen et al., 2010). The cages should therefore be made of materials that are strong, weather and fouling resistant, easy to repair, drag free, smooth in texture and non-abrasive to fish. The cage frame can be made from mild steel, galvanized iron, High Density polythene (HDPE) or Poly-Vinyl Chloride (PVC) tubes. The metallic frame cage is fabricated on land by a local welder and should be painted using anti-corrosive paint. Airtight plastic drums or jerry cans can be used as floaters of metallic frames but these are not required for PVC frames as these can float. The floaters are fitted on the frame using binding wires before the frame is deployed in water. Cage bags are made from durable nylon knotless netting material which can be bought as finished products or fabricated according to specifications.

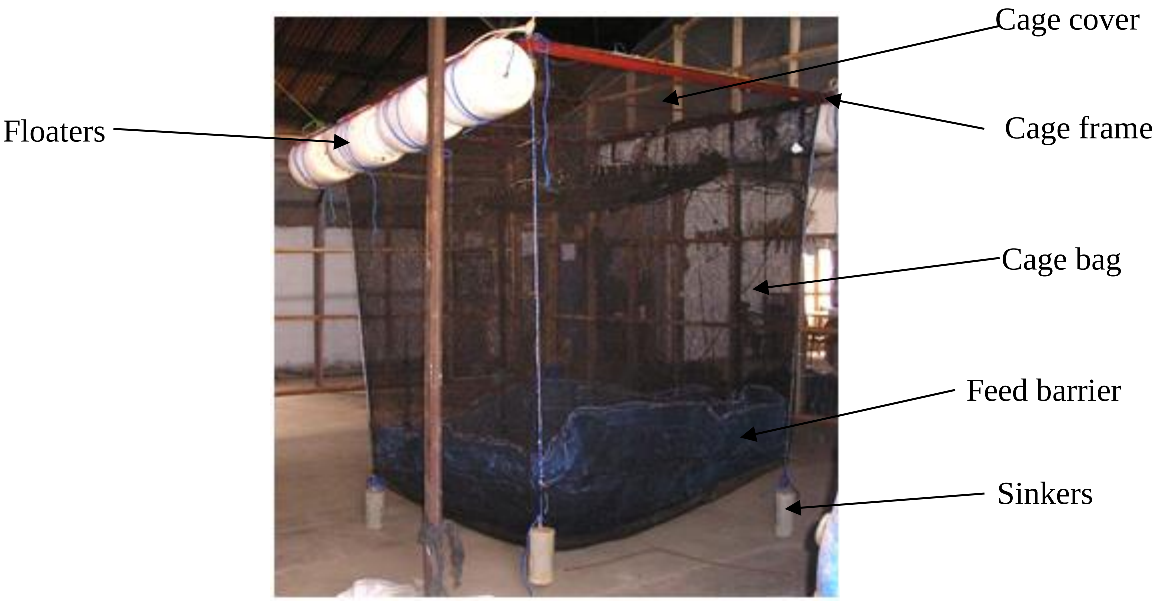

Figure 1 A typical floating cage structure with its components

There are two types of cage bags: nursery cages of a minimum mesh size 5mm for nursing juvenile fish of 1-3g to about 15-20g and grow out cages of 13 mm mesh for growing fish to harvest. The cage bag is fabricated to fit the shape of the frame and should be fixed to the frames on water. Double layered cage bags are recommended to avoid fish escape and to increase protection against predators. A net of 0.1 mm mesh is sewed along the top inner perimeter of the cage to cover about 0.5m to act as a feed barrier to keep floating feeds within the cage or at the bottom to keep sinking feeds in the cage. Sinkers for stretching the cage bag are made using sand, cement and gravel to make a concrete block of about 3-4 kgs with a metallic handle for attaching to the cage bag. These are used to stretch the cage bag to enable it stay open. Anchors for keeping the cages from being swept away by current or wind are also fabricated using cement, sand and gravel to make a concrete block of a minimum weight of 40kgs depending on the substrate.

After fabricating and assembling, the cage components are deployed into the water. Cages can be laid out in a grid or individually for large circular cages. Cages in grid lines are laid perpendicular to the direction of water current if the waves are moderate and parallel for relatively stronger waves. The perimeter of the farm should be marked using anchored buoys. There should be provision for direct access to each cage for feeding, sampling, grading and routine management. This can be achieved by providing walkways connecting grid lines using timber where a service boat cannot directly access each cage. Cages should be installed at a depth twice that of the cage bag to maximize exchange of water however the deeper the area the higher the mooring costs. During installation the anchor block of not less than 40 kg is attached to a mooring chain using shackles or using strong nylon ropes of about 24 mm diameter and placed diagonally to the cage, for single cages or to the gridline. Cages frames or grids with their floaters are moved and attached to ropes of the grid mooring system. The cage bags with their feed barriers, and sinkers are then fixed onto the frames. A cage cover is attached to the top of the cage to prevent fish escape and predation in a way that allows opening of the cover, for stocking, sampling, routine management and harvesting. At this point, cages are ready for stocking.

Production practices

The key production aspects to be considered in cage fish farming include: culture species; Fingerlings; stocking density; feeds and feeding; monitoring growth performance; water quality monitoring; health management; environmental monitoring; harvesting and marketing; and policies and manpower.

Culture species

The fish species to be cultured should be native or naturalized to the water body where cage fish farming is to take place to reduce chances of introducing non-native fish species. Adherence to this requirement is important to avoid negative impacts of fish species introductions such as those that decimated fish biodiversity, with severe environmental challenges in Lake Victoria (Barel et al. 1985; Ogutu-Ohwayo, 1990; Witte et al., 1992; Goudswaard et al. 2002; Hecky et al., 2010). A survey of the main farms operating in the AGL region shows that only endemic, native or naturalized fish species are so far cultured in cage fish farming in the AGLR (Table 2) and this

Table 2 An indication of the fish species cultured by selected fish farms on some African Great Lakes (*Froese & Pauly, 2017)

Name of farm (s)	Lake (Country of farm location)	Cultured species	Status
SON Fish Farm and Pearl Aquatic	Lake Victoria (Uganda)	*Oreochromis niloticus*	Introduced or naturalised in 1950s and 1960s
Mpende Fisheries	Lake Tanganyika (Zambia)	*O. tanganicae* (Günther)	Native*
Kivu Tilapia Farm	Lake Kivu (Rwanda)	*O. niloticus*	Native*
Lake Harvest Aquaculture, Kariba Harvest and Yalelo	Lake Kariba (Zimbabwe)	*O. niloticus*	Introduced*
Maldeco Fisheries	Lake Malawi (Malawi)	*O. karongae* (Trewavas)	Endemic*

should be adhered to. Tilapias are the most widely cultured species because they grow faster, can tolerate high stocking densities and easily accept formulated feeds. These include: Nile tilapia (*Oreochromis niloticus*) in lakes Victoria, Kivu and other lakes in Uganda; the Tanganyika tilapia (*Oreochromis tanganicae*) in Lake Tanganyika; and Tilapia shiranus (*Oreochromis shiranus*) in Lake Malawi/Nyasa/Niassa. Farmers should contact their local fisheries officials on the species permited for culture in a given water body to avoid introduction of invasive species.

Fingerlings

Fingerlings should be obtained from certified hatcheries to ensure that they are of good quality. Fingerling production and nursing should be carried out in controlled systems preferably in land based systems to reduce nutrient loading due to feed wastes, and fecal materials. This is because fingerlings are fed on feed in form of powder and crumbles which can causes high nutrient loading of aquatic systems (Wang et al., 2012) and are easily lost to the water due to limited stability. Fingerlings of an average weight of 1-3 g should be nursed to about 15-20g before being stocked in grow out cages. All male sexually reversed or sterile fingerlings are recommended in cage fish farming.

Fingerlings should be inspected for deformities, uniformity in color, and avoidance behavior at stocking as signs of good health. They should be graded to uniform size and Average Body Weight (ABW) determined. Excessive handling should be avoided to minimize stress. Fingerings should be stocked in the morning or late evening when the weather is cool to minimize mortalities and should not be fed 24 hours before and after stocking. Fingerlings should be acclimatized during stocking by allowing lake water to gradually mix with that in the packing material. Over stocking should be avoided to minimize stunting and susceptibility to disease.

Stocking density

Stocking density depends on site characteristics, target yield, and planned size at harvest. According to the pioneer cage fish farm on Lake Victoria (Source of the Nile, SON Fish Farm Ltd) with over ten years' experience, stocking density in nursery cages should be 400 fish per m^3. The target yield for LVHD cages should be 60-80 kg per m^3 and 20-40 kg per m^3 for HVLD cages for a planned size at harvest of 500g (0.5 kg). The number of fish to be stocked is determined by dividing the target yield by the planned size at harvest and allowing for a 10% mortality. For example, if you are aiming at a target yield of 40 km per m^3 and target size at harvest of 500g (0.5 kg) in HVLD cages which are commonly used, stocking density is calculated as follows:

Target yield = 40kg per m^3
Target size at harvest = 500g (0.5kg)
Number of fish per unit volume = 40/0.5 = 80fish per m^3
For a cage of 5x5x5m, Cage volume = 5x5x5=125m^3
The total number of fish (without mortality) = 80x125 = 10,000
Expected mortality = 10000x10% =1000
Total number of fish to be stocked = 10,000+1000 = 11,000 fish per cage

Feeds and feeding

Feeds and feeding practices play a major role in cage fish farming (Hassan, 2001) and contribute 60-70% of the cost of a cage aquaculture operation but are also the main source of nutrient enrichment and pollution to water bodies especially from uneaten feed (De Silva et al., 2010). Reduction of environmental challenges from cage fish farming due to enrichment of nutrients must start with feeds and feeding practices. These include minimizing uneaten feeds and increasing retention of nutrient especially phosphorous and nitrogen by cultured fish species (Hardy & Gatlin, 2002). Farmers should use water stable, extruded pelleted feeds, which are easily acceptable by the fish to minimize nutrient accumulation in water. The amount of feed used in relation to the amount consumed by the fish and the resulting fish growth should be monitored through regular sampling. Only adequate amounts of feed should be administered to the fish in cages, feed wastage should be minimized and the fish should be sampled at appropriate intervals to determine the average body weight (ABW) to facilitate adjustment of daily feed rations. Fish should be fed by response. Feed barriers should be used to retain floating feeds inside cages, or feeding trays should be installed on the cage floor to retain sinking pellets to avoid wastage and subsequent contamination of the environment. Feeds should be made with nutrient levels not in excess of the requirements of the cultured fish species, so that most of them are retained by the fish to avoid nutrient enrichment of water bodies (Hardy & Gatlin, 2002). Farmers should use feeds obtained from certified feed manufacturers to ensure that feeds have all the desired qualities. Fish should be fed on nutritionally complete feed and the texture, color, smell, signs of molds and expiry date of the feed must be checked before purchase and use of feeds. Feeds should be transported in clean vehicles, stored on racks off the floor, away from the wall in ventilated, leak and vermin proof building, with no other materials such as chemicals and should be used from the store on a first in first out basis, and feeding containers should be clean.

The amount of feed to be given to the fish should be estimated based on the average body weight (ABW) of the fish using a localized feeding chart (Table 3). Average food intake decreases with the weight of the fish it grows. Feeding response should be monitored as the fish are fed and administration of fish should be stopped when the fish are no longer responding. The size of pellets, crude protein (CP) content and the frequency of feeding varies as the fish grows:

Fingerlings of 1-3g are fed on crumbles of 1-2 mm of 40-45% CP four to five times a day until they are 15-20g, graded and transferred to grow out cages; In grow out cages, they are first fed on 2 mm pellets of 35-40% CP three to four times a day until they are 80-100g; From 80-100g, they are fed on 3-4 mm pellets of 30-35% CP two to three times until they are 250-280g; and Finally, on 5 mm pellets of 25-30% CP once or twice a day until harvest.

Table 3: Summary feeding chart

Average Body Weight (ABW) (g) of fish	Feeding rate (% ABW/Day)	Quantity of feed per fish g/day	Frequency of Feeding per day
<2	13-20	0.02-0.25	6
2-10	5 - 8	0.17-0.47	4
10-100	2-4	0.47-2.47	3
100-500	1-2	1.77-6.56	2
>500	1	5.95-10	1

Growth performance

Growth performance of the fish should be evaluated periodically if possible monthly by scooping a random sample of fish to determine Food Conversion Ratio (FCR), weight gain and daily growth rates.

- Weight gain = Final Body Weight – Initial Body Weight
- Food Conversion Ratio (FCR) = (Quantity of feed fed/Average Weight gain) *No of fish
- Daily growth rate = Weight gain/Time (number of days);
- Survival rate= (No of fish present/No of fish stocked) *100.

This should be used to adjust the feed ration, feed type, pellet size, and feeding frequency. Sampling should be done during cool weather (early mornings or late evenings) when the temperature is low.

Water quality monitoring

Water quality around and within the cages should be monitored regularly to determine deterioration in key water quality, as this is an important factor in fish growth and survival. Some of the key parameters to be monitored are: Temperature; DO; pH; and Total Ammonia Nitrogen (TAN). Deterioration in water quality can be shown by gasping behavior of fish.

Health management

The high concentration of fish in cage fish farming provides conducive conditions for the proliferation of disease causing parasites and pathogens, which can spread to wild fish populations (Peeler & Murray, 2004). The farmer should, therefore have a health surveillance plan and protocol to prevent disease outbreaks in farmed fish and the spread to the environment. Fish should be checked for any infection at stocking, and infected fish should be moved to a separate land based system and treated according to the syndrome. Farmers should look out for symptoms of poor health such as; gasping, abnormal swimming, loss of appetite, mortalities, presence of wounds, and parasites on the skin and gills. Equipment used to handle infected fish should not be used in non-infected cages without disinfection. Dead fish should be removed and should not be discharged directly into surrounding waters. There should be a separate cage to hold weak quarantined fish downstream the water current. Farmers should consult and inform extension workers and fish health experts about occurrence of any disease and get advice on prevention/treatment. 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. The nets should be periodically cleaned to remove fouling organisms and to enhance water exchange. Use of chemical antifoulants should be avoided because they can accumulate in fish and other aquatic biota and cause environmental impacts, antibiotic resistance and harm to consumers (Guardiola et al., 2012) and instead mechanical cleaning methods should be employed.

Harvesting and marketing

The ultimate aim of investing in cage fish farming is to generate income. The fish should be harvested and marketed once it has reached the desirable market size. Cage fish farming involves harvesting large quantities of fish at once. The markets should therefore be identified and confirmed before harvesting. The fish should not be fed two days before harvest. Harvesting can be done in total or partially by lifting the cage bag out of water and removing the fish using a scoop net. Farmers should have access to proper harvesting and storage facilities such as fish holding and storage tanks; Cold rooms; Live fish transport facilities (tanks & oxygen supply); and Post-harvest processing plants for gutting or filleting. The farmer should have access to cold chain storage and transport infrastructure that promotes hygiene and environmentally sustainable bulk distribution to minimize losses. Efforts should be made to create e-market chains using internet and mobile phones. Efforts should be made to create outlets for live/preserved fish sale at strategically important locations. Value addition can be done on the fish to increase revenue by generating products such as fillets, fingers and sausages.

Environmental monitoring

A competent institution should undertake environmental monitoring in and around the farm bi-annually by evaluating changes in the parameters taken during site capability assessment. The data generated should be compared with that collected during site selection and/or during ESIA to determine the impact of the farm on the environment and the changes occurring in the system. This is to safe guard the integrity of the aquatic ecosystem and adherence of the farm to good farming practices.

Policies and manpower

The farmers should follow applicable policies and regulations and seek guidance of relevant institutions. Applicable international, regional and national policies, standards, and regulations especially those of fisheries, water, navigation and environment should be adhered to. Some of the policies will, however need adjustment to make them appropriate for cage fish farming. Competent manpower should be used in management of a cage fish farm. Since cage fish farming is new in the AGLR, there will need to improve the capacity of people operating cage fish farms in the BMP.

Conclusions

This paper provides some advice that can be applied on the AGL to promote socially, economically and environmentally sustainable cage fish farming in the region. These BMP will help various stakeholders in cage fish, including farm owners and operators, fisheries managers, and regulatory agencies. It is important to emphasize that the BMP have been proposed from the current AGL practices along with other practices, in various farms elsewhere, and will need to be continually improved with new knowledge. They, therefore, do not constitute an exhaustive set of best practices but have been provided to support the rapidly growing cage fish farming sectors in the AGL. Adhering to these best practices with special care and diligence and improving them through adaptive research is critically important for socially, economically and environmentally sustainable cage fish farming on the AGL.

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