A BRIEF ON FISH CAGE FARMING IN LAKE VICTORIA, KENYA AS GUIDANCE ON DECISION MAKING FOR POLICY DIRECTION

PREPARED BY:
Dr. Christopher M. Aura (Ag. Deputy Director, FWS)
KENYA MARINE AND FISHERIES RESEARCH INSTITUTE (KMFRI).

DATE: 17TH SEPT. 2020

Introduction
Cage culture has presented itself as a new socioeconomic frontier with good prospects for income in Lake Victoria, besides conserving declining wild fish stocks. Whereas there is an increase in adoption of cage culture in Lake Victoria owing to prospects of better income, the sustainability of this technology within the lake remains uncertain. With rise in cage culture investments, concerns on environmental degradation arise, since it brings about discharge of particulate and dissolved nutrients such as uneaten waste feed, fecal matter, and excretory products which are bound to negatively impact the fishery environment by causing anoxic conditions in sediments underlying the cages thus changing the abundance and composition of biotic communities. Furthermore, the haphazard installation of cages could spell doom for the lake ecosystem.

Using satellite and GIS technologies, in 2019 the same portion of the lake was found to contain 4,357 fish cages covering 62,132 m² (Hamilton, Aura et al., 2020). When sustainably managed, cage technology has the potential to provide significant contribution to national fish production, increased job opportunities, enhanced food security and incomes for both rural and urban dwellers in light of the blue economy. Therefore, the brief gives suggests suitability locations of cage culture based on sound scientific findings to help management and authority agencies in making policy decisions and development guidelines of cage culture that will be essential to the sub-sectors value chain.

Policy advices

Suitability map and carrying capacity
- Using bathymetric data, optimal water quality parameters, suitability mapping sites for cages was undertaken for Lake Victoria, Kenya (Figure 1).
- The most suitable sites location for fish cage culture consist of 191.30 km² or 4.67% of the lakescape.
• The Suitability sites location have an area extent of about 171.10 km² or 4.17%.
• Thus, the entire lakescape potential area extent for cage culture suitability is (191.30 km² + 171.10 km²) about 362.40 km² or 8.84%.
• Therefore the carrying capacity of the lake is at 362.40 km² or 9%.
• Using satellite, and GIS technologies, in 2019 the portion of the lake that was found to contain 4,357 fish cages covered 62,132 m² or 0.0621 km² (Hamilton…Aura et al. 2020, Bulletin of Marine Science, 96(1):71–93. 2020).
• In this case, 0.0621 km² ≈ 4,357 fish cages, 362.40 km² that is available for cage culture can be calculated for 2 by 2 by m cages in proper locations – but larger ones are preferred.
• Fairly inaccessible areas (constraints) for cage culture farming due to prevalence of water hyacinth (hotspots), demarcated fish breeding grounds and moving islands cover a surface area of about 459 km² (Appendix 1).
• The area unsuitable for cage culture is 3,737.50 km² or 91.16% of the lake, consisting of 2,753.00 km² or 67.15% of least suitable sites and 984.5 km²; or 24.01% of wholly unsuitable sites which could be vital for wild fishing, navigation and transport, water abstraction, among others.

Characteristics of cage culture suitability sites as per the map and best management practices
• A depth of 0 – 4 metres is likely to be affected by land use activities, hence allocated unsuitable cage culture site hence cages in such locations should be removed. These sites also form sheltered bays and breeding grounds of fish hence unsuitable for cage culture encroachment.
• A depth of 4 – 6 metres is assigned least suitable because of the proximity to unsuitable sites as well as less water circulation for Dissolved Oxygen (DO) exchange which may cause fish kills; but small-sized cages with less intense cage culture is the best option.
• A depth of 6 – 12 metres is most suitable with high water currents for removal of wastes. In such areas, high volume with high density fish cages and stocking is required alongside to minimize future negative occurrences and emergence of diseases and fish kills. Such areas are suitable for fish feeds which take longer period to float and therefore provide sufficient time to be accessible to fish.
• A depth of more than 12 metres (unsuitable) may have strong currents that can damage the cage culture structure. However, high volume with high density fish cages and stocking is required in such areas. Fish spend a lot of energy swimming against the currents that could be otherwise be used for growth.
• Primary parameters for cage culture suitability that could be measured periodically to ascertain environmental changes are shown in Appendix 2 and 3 alongside their optimum levels, beyond which, the establishment may be deemed a threat to the environment.
Figure 1. Cage culture suitability map for Lake Victoria, Kenya.

Characteristics and basic guidelines for cage culture (to be spelt out in EIA reports)
1. **The farm should have a site map which should include:**
   a) The boundary as determined by GPS coordinates;
   b) The cage fish farming facility and expected Zone of Maximum Accumulation (ZMA);
   c) Location of the cages, layout and any other containment structures;
   d) Dimensions and number of cages;
   e) Navigation markers and potential navigation pathways around the farm;
   f) Buildings, offices and staff living quarters if available;
   g) Access road, walkways, utilities, cables, catwalks;
   h) Stores for fuel, chemicals, feeds etc.;
   i) Water lines that supply clean piped water to the farm;
   j) Mortality storage and net cleaning points;
   k) Depth contours from the low water mark;
   l) Predominant current direction;
   m) Anchor blocks, mooring lines, marker buoys and shore attachments

2. **Cage design and size**
   - Cages can be rectangular, square or cylindrical in shape and can range in size from 1m³ to several hundreds of cubic meters based on location and carrying capacity. Small cages are easier to manage than large cages. Performance per unit volume of cage is higher and economically more efficient in small (LVHD) cages.
   - Cage structures should be strong enough to withstand strong winds and currents and hold the fish securely. The materials for construction of cages should be durable, strong, light in weight, rot and weather resistant (not degradable in the water), rustproof, fouling resistant, easily worked and repairable, drag free, smooth in texture and non-abrasive to fish. The materials should allow complete exchange of water.
   - There should be auxiliary cage equipment including: completely or partially removable cover to control predators and prevent fish from jumping out; a floating feed box or ring cylinder with wire mesh cover can extend 40cm below and 20cm above the water surface to retain floating feeds; or solid or fine mesh tray (covering 20% of the cage bottom) with 5 to 15cm raised sides if sinking feeds are used; Steel bar or Polyvinyl Chloride (PVC) or High Density Plastic Ethylene (HDPE) pipes or other rigid materials used to support the cage walls; Floats; Anchors and Platforms/walkways.
   - The cages should be located in waters with good water exchange (10 – 100cm/sec), protected from strong currents and high waves (especially LVHD cages). Stagnant water of poor quality may stress or even kill the fish. It is preferred that cages are in rows, spaced at least 2 m apart. The water should be deep enough to allow the cage bottom to be at least 2 - 3m above the bottom sediments and should be located in an accessible area to facilitate routine maintenance and feeding.
   - The cages should be placed where they can be monitored and security provided. A surveillance system can be installed on the cages for monitoring and security purposes. Hired guards and/or other forms of security such as guarding dogs can also be deployed.
3. Species type for culture and stocking
- The desired fish species for cage fish farming should have fast growth rate, be tolerant to crowded conditions, and of high market value. **Nile tilapia** is the recommended species for cage fish farming in East Africa. However, the African catfish can also perform well in cages. These species are native to the region although they require improvement of seed quality and growth performance through research.
- Seed (fingerlings) should be obtained from authorized certified hatcheries and approved research centers e.g. Kenya Marine and Fisheries Research Institute (KMFRI) or those approved by the Department responsible for Aquaculture Management and Development. Seed production centres will be certified and monitored by the Departments responsible for Aquaculture Management and Development.
- Harvesting of fries or fingerlings from the lake by farmers should be banned as this may interfere with wild fisheries.
- Generally, a recommended stocking rate for LVHD cages is 120-150 fish per m$^3$ and for HVLD cages 70 – 100 fish per m$^3$. Stocking density depends on the quantity and quality of the feed to be used, water quality, water temperature, the species to be cultured, expected yield and average size desired at harvest. High stocking densities in low volume cages usually results into fish kills and death.
- Farmers should use floating feeds evaluated by a mandated competent institution for feed quality as per National Bureau of standards. The feeds must be free of bacteria and other contaminants likely to affect the environment, health of fish and consumers. The feed should be nutritionally complete with all essential nutrients including proteins, lipids, vitamins, minerals and carbohydrates.
- Survival rates of the fish in cages should be monitored. 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 at harvest. Survival rate can be 80% to 95% depending on cage management.
- Harvesting of fish in cages should be done depending on the size preferred in the market. Fish for processing preferably be taken live to the processing factory without allowing any of the farmed fish into the wild or vice versa; Farmers and owners of cage culture facilities must keep and provide on an annual basis records for all their production at harvest to the relevant authorities; and all handling and transportation of fish or fish products out of cage fish facilities must be according to established national, regional and international Hazard Analysis and Critical Control Points (HACCP) procedures.

4. Other best management practices in EIA reports
- Every fish cage farm shall have an effective bio-security program incorporating:
  a) Disease monitoring, prevention, and management of disease out breaks;
  b) Cleaning and disinfection between production cycles; and
  c) General security precautions.
• A Bio Security Plan should be adaptable, be reviewed at the end of each production cycle and should include:
  a) Checking weak fish and bathing them in fresh water to check for parasites. If there are parasites, all fish should be bathed and the cage changed;
  b) Separating infected fish and moving them to a special quarantine tanks on land;
  c) All equipment used to handle infected sick fish should be disinfected before further use;
  d) Treating sick fish properly according to the infection and changing the net at the same time;
  e) Taking dead fish away and bury or burn them on land;
  f) Not selling sick fish or using them in feed;
  g) Aerating the cages to increase Dissolved oxygen (DO) in water and bottom;
  h) Acting quickly to stop spreading disease;
  i) Consulting and informing other farmers about a disease outbreak and treatment;
  j) Consulting and informing extension workers and research institutes;
  k) Collecting the infected fish or their parts such as gills and injured parts as samples, preserved in alcohol, formalin or ice boxes and sending them to a laboratory for disease pathogen detection.

• There should be a waste management plan including disposal of dead fish, processing products and solid waste in accordance with national laws. Waste water should not be discharged directly into natural water without dilution or neutralization. Waste water should be kept in drum/tanks for few days to allow oxygenation to neutralize the chemical and drug before discharge. The CA should carry out inspections to ensure compliance with the set requirements.

• Every enterprise should have an environmental monitoring plan which involves activities to evaluate the influence of the activities of the enterprise on the sites, considering potential effects of the siting and operation of farms on sensitive aquatic organisms and habitats. Data should be collected prior to establishment of the farm and periodically (quarterly, biannual, and annual) after establishment of the farm on environmental variables and biological communities.

Conclusions and Recommendations

- With the current boom in cage culture, it necessitates the need to create a balance between the lake management and the cage culture farming.
- To realize profitability in cage farming, the farmers are advised to place their cages in the suitable sites described herein.
- Proper site selection is critical as it may considerably affect construction costs, operating costs, growth and survival rates of the fish and durability of the cages. Therefore, requires one to have good knowledge of the critical habitats in the locations where cages are to be mounted.
- The cages installed in shallow areas (≤ 4 m depth), fish breeding and nursery grounds and water hyacinth hotspots should be moved to deep waters (6 – 12 m).
with good water exchange and mixing. The movement should be guided in a manner to protect navigation, protection of breeding zones and fishing to avoid conflicts with other stakeholders. Thus Environmental Impact Assessment (EIA) reports should clearly specify the GIS location and the depth values of cages to be installed, as well as the size of the cages and materials used.

- Farmers should be encouraged to form cooperative units for collection of enough capital to install and sustain high volume with high density fish cages and stocking in deeper areas for maximum profits.
- Furthermore, with an estimated carrying capacity of 25,427 cages in proper locations over an average of cycle of 6 months, the lake has the potential to approximately produce 10,000 tonnes; a potential for blue growth.
- The significance of sound science combined with mapping and GIS will help management agencies in making sound judgment for better investment, EIA and development guidelines of cage culture.
- Periodical water quality assessments by the farmer and Competent Authorities are recommended to help in undertaking any corrective measure in case of potential change in lake environment. This should be done alongside cleaning cage netting regularly to avoid fouling and clogging thereby leading to fish deaths.
- There is need to recommend use of floating feeds to avoid excessive accumulation of uneaten feeds thus bringing about water pollution. Farmers should further be trained on the use of extruded pellets i.e. floating pellets since they have water stability and will not disintegrate.
- Investors should be advised to develop business plans for their cage enterprises to track their investments in order to make necessary adjustments to maximize profits. Furthermore, they should be encouraged to insure their cage culture investments against risks and losses.
- After regulations are put in place as a matter of urgency, investors should also be advised to consult Kenya Marine and Fisheries Research Institute (KMFRI), the Kenya Fisheries Service, and National Environment Management Authority (NEMA) on regulations and guidelines before engaging in Cage culture in the lake in order to be guided on where to locate their cages.
Appendices

Appendix 1. A map showing (a) demarcated fish breeding grounds (potential areas for protection at river mouths and sheltered bays), and (b) water hyacinth and moving islands hotspots of Lake Victoria, Kenya that are deemed as constraints to potential suitability of cage culture. Constraints, in this case, would imply areas where cages cannot be installed to give room for breeding and recruitment of fish. Water hyacinth and moving islands have been associated with destroying of cage culture installations.
**Appendix 2.** Selected and common biophysical variables employed in the cage culture suitability sites classification in relation to existing literature.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Recommended Level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Ammonia Nitrogen</strong></td>
<td>Ammonia is caused by deposition of uneaten food and debris, excretion wastes, sewage discharge and industrial pollution. The recommended level of ammonia in fish culture should be &lt;0.01mgL⁻¹. The suitable time to measure ammonia is when water current is slow. Sewage discharge and industrial pollution are the main sources of high ammonia content. Sites of effluent deposition to the lake should be avoided.</td>
<td>Not more 0.3–2 mg L⁻¹</td>
</tr>
<tr>
<td><strong>Nitrate</strong></td>
<td>The optimal level is 2mgL⁻¹. 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.</td>
<td>0.1-4.0 mg L⁻¹ (2 mg L⁻¹ is optimal)</td>
</tr>
<tr>
<td><strong>Nitrite</strong></td>
<td>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 of the fish.</td>
<td>&lt; 0.2 mg l⁻¹</td>
</tr>
<tr>
<td><strong>Total phosphorous</strong></td>
<td>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</td>
<td>&lt;100 µg/L</td>
</tr>
<tr>
<td><strong>Chlorophyll-a</strong></td>
<td>This is an indicator of primary production</td>
<td>&lt;75 µg/L</td>
</tr>
<tr>
<td><strong>Total suspended solids</strong></td>
<td>Suspended solids are pieces of particulate matter larger than 0.45μm. 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 also clog the gills of fish leading to mortality. Visibility of fish will also be reduced leading to feed losses and impaired growth.</td>
<td>&lt;10mgL⁻¹</td>
</tr>
<tr>
<td><strong>Total dissolved solids</strong></td>
<td>These are pieces of particulate matter smaller than 0.45μm.</td>
<td>&lt;40 mg L⁻¹</td>
</tr>
<tr>
<td><strong>Conductivity</strong></td>
<td>Conductivity is determined by presence of ions such as Ca²⁺, Mg²⁺, HCO⁻, CO₃⁻, NO₃⁻ and PO₄⁻ in water</td>
<td>30-5,000 mSiemens/cm</td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>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 population</td>
<td>2-3 ppt</td>
</tr>
<tr>
<td><strong>Alkalinity</strong></td>
<td>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.</td>
<td>120-400 ppm</td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>This is the measure of elements such as calcium, magnesium, aluminium, iron, manganese, strontium, zinc, and hydrogen ions. These are essential for metabolic reactions</td>
<td>30-180 mgL⁻¹</td>
</tr>
<tr>
<td><strong>Chloride</strong></td>
<td>Chloride is a common component of most waters and is useful to fish in maintaining their osmotic balance</td>
<td>60-100 mg L⁻¹</td>
</tr>
<tr>
<td><strong>Fecal coliform</strong></td>
<td>Coliform are bacteria belonging to Family Enterobacteriaceae. Presence of these is indicative of contamination of feacal material of human and other warm blooded animals. High levels of these may cause typhoid fever, hepatitis, gastroenteritis, dysentery and eat infection</td>
<td>≤100 count per 100 ml</td>
</tr>
</tbody>
</table>

(Adopted from: Aura et al., under review in Journal of Lakes and Reservoirs: Research & Management)
Appendix 3. List of biophysical and chemical variables that should be available for monitoring by the farmer and the Competent Authorities (CA).

<table>
<thead>
<tr>
<th>Water quality Parameters</th>
<th>Monitoring frequency by farmer</th>
<th>Monitoring frequency by CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td>Monthly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Dissolved oxygen.</td>
<td>Monthly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Temperature</td>
<td>Quarterly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>Quarterly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Quarterly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Turbidity</td>
<td>Quarterly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>Biannually</td>
<td>Biannually</td>
</tr>
<tr>
<td>Trace metals</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Organic matter</td>
<td></td>
<td>Biannually</td>
</tr>
<tr>
<td>Total carbon</td>
<td></td>
<td>Biannually</td>
</tr>
<tr>
<td>Sulfide</td>
<td></td>
<td>Annually</td>
</tr>
<tr>
<td>Macro invertebrates</td>
<td></td>
<td>Biannually</td>
</tr>
<tr>
<td>Plankton</td>
<td></td>
<td>Biannually</td>
</tr>
<tr>
<td>Fish communities around the cage</td>
<td></td>
<td>Biannually</td>
</tr>
</tbody>
</table>