AGA 4531 INTRODUCTION TO AQUACULTURE

3. Fish Culture systems

1. Fish ponds

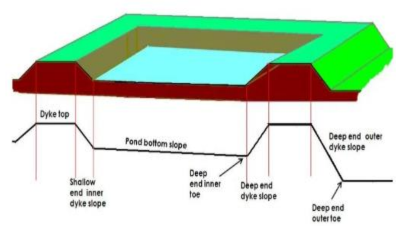
According to FAO, https://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e01.htm

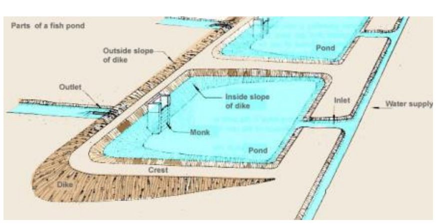
- A fish pond is defined as an artificial structure used for the farming of fish. It is filled with fresh water, is fairly shallow, and is usually non-flowing.
- Fish production requires earth ponds, which contain and renew fresh water, and can accommodate the storage, farming, and harvest of fish.

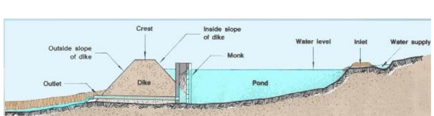
Features of a fish pond

Although there are many kinds of fish ponds, the following are the main features and structures associated with them in general:

- **Pond walls or dikes,** which hold in the water;
- **Pipes or channels,** which carry water into or away from the ponds;
- **Water controls,** which control the level of water, the flow of water through the pond, or both;
- **Tracks and roadways** along the pond wall, for access to the pond;
- **Harvesting facilities** and other equipment for the management of water and fish.





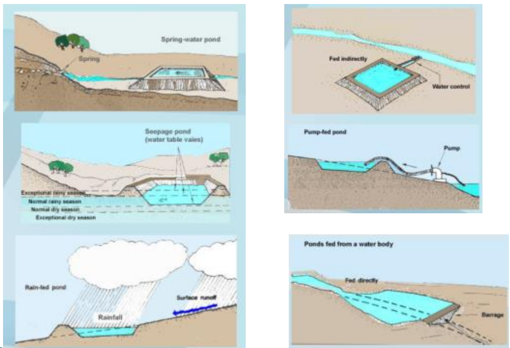


Classification of ponds

Ponds are classified according to:

1. According to the water source

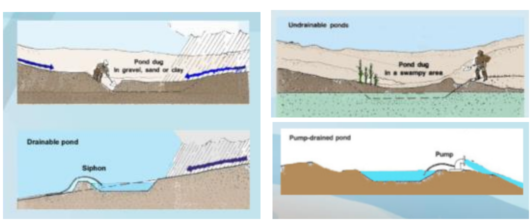
- <u>Spring-water ponds-</u> supplied from a spring either in the pond or very close to it
- <u>Seepage ponds</u> – are supplied from the water table by seepage into the pond
- <u>Rain-fed ponds</u> are supplied from rainfall and surface runoff.
- <u>Ponds can be fed from a water body</u> such as a stream, a lake, a reservoir or an irrigation canal.
- <u>Pump-fed ponds</u> are normally higher than the water level and can be supplied from a well, spring, lake, reservoir or irrigation canal, by pumping.



https://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e01.htm

2. According to the means of drainage

- Undrainable ponds cannot be drained by **gravity***. They are generally fed by **groundwater** and/or surface runoff, and their water level may vary seasonally
- Drainable ponds are set higher than the level to which the water is drained and can easily be drained by **gravity***. They are generally fed by surface water such as **runoff***, a spring or stream, or are pump-fed.
- Pump-drained ponds may be drainable by gravity to a certain level, and then the water has to be pumped out



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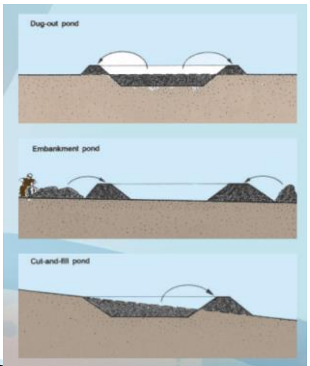
3. According to the construction materials

- Earthen pond -entirely constructed from soil materials
- Walled ponds –usually surrounded by blocks, brick or concrete walls. Sometimes wooden planking or corrugated metal is used.
- Lined ponds – are earthen ponds lined with an impervious material such as a plastic or rubber sheet

Imasiku Jimmy on facebook

4. According to the construction method

- **Dug-out ponds** are constructed by excavating soil from an area to form a hole which is then filled with water. They are usually undrainable and fed by rainfall, surface runoff* or groundwater.
- **Embankment ponds** are formed without excavation by building one or more dikes above ground level to impound water. They are usually drainable and fed by **gravity*** flow of water or by pumping.
- **Cut-and-fill ponds** are built by a mix of excavation and embankment on sloping ground. They are usually drainable, and water, which is impounded within the dikes, is fed by gravity or by pumping.



Lined earthen diversion pond constructed by above ground embankments (dykes), the pond will be supplied by borehole water and is completely drainable

5. According to the use of the pond

- Spawning ponds for the production of eggs and small fry;
- Nursery ponds for the production of larger juveniles;
- Brood ponds for broodstock rearing;
- Storage ponds for holding fish temporarily, often before marketing;
- Fattening ponds, for the production of food fish;
- Integrated ponds which have crops, animals or other fish ponds around them to supply waste materials to the pond as feed or fertilizer;
- Wintering ponds for holding fish during the cold season.

https://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e01.htm

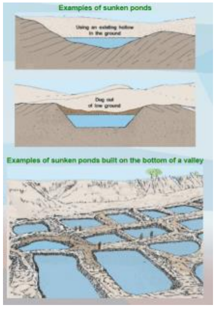
Scadoxius farm Kasama

Three basic pond types

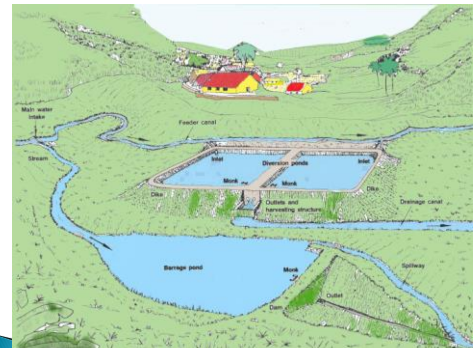
There are many types of ponds but they can be conveniently grouped into three basic types depending on how the pond fits in with the features of the local landscape.

- Sunken ponds: The pond floor is generally below the level of the surrounding land. It is directly fed by groundwater, rainfall, and/or surface runoff
- Barrage ponds: are created in the bottom of a valley by building a **dam** across the lower end of the valley. They may be built in a series down the valley.
- Diversion ponds: fed indirectly by gravity or by pumping through a diversion canal (which becomes the **main feeder canal**), from a spring, stream, lake or reservoir. The water flow is controlled through a water intake. There is an inlet and an outlet for each pond.

(see https://www.fao.org/fishery/docs/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e01.htm



Sunken pond (excavated) fed by ground water seepage in Chief Magodi area Eastern province



Advantages and disadvantages of the three basic types of pond

Type	*Advantages*	*Disadvantages*
Sunken pond	No need for dikes except for flood protection No water body to supply water Little skill required for construction	Water level can greatly vary seasonally Requires more work to excavate Undrainable; uncontrolled water supply, unless pumped; pumping may be expensive Low natural productivity of groundwater Pond management difficult
Barrage pond*	Simple to design for small streams Construction costs relatively low unless there are flood defence problems Natural productivity can be high, according to quality of water supply	Dike needs to be carefully anchored Need for a spillway and its drainage canal No control of incoming water supply (quantity, quality, wild fish) Cannot be completely drained except when incoming water supply dries out Pond management difficult (fertilization, feeding) as water supply is variable Irregular shape and size
Diversion pond**	Easy control of water supply Good pond management possible Construction costs higher on flat ground Can be completely drained Regular pond shape and size possible	Construction costs higher than barrage ponds Natural productivity lower, especially if built in infertile soil Construction requires good topographical surveys and detailed staking out

* If the barrage pond is built with a diversion canal, some of the disadvantages may be eliminated (controlled water supply, no spillway, complete drainage, easier pond management), but construction costs can greatly increase if the diversion of a large water flow has to be planned.
** Relative advantages will vary according to the arrangement of the ponds (see Section 16), either in series (pond management is more difficult) or in parallel (both water supply and drainage are independent, which simplifies management).

CAGE SYSTEMS

2. Fish Cages

- Aquaculture farming systems in Zambia include cages, ponds, circulation tanks, and dams
- On Lake Kariba, intensive cage fish farming was introduced in the late 1990s using *Oreochromis niloticus*. Currently, over 100 cages have been recorded on the lake compared to only three recorded in the late 1990s

A cross section of Yalelo fish cages inside lake victoria

- In Zambia there are 13 commercial fish farmer with 263 cages producing about 14, 586 MT
- Accounting for about 23% of Aquaculture production

- There are 636 small scale cage famers with 636 cages producing about 5073 MT of fish
- Accounting for about 8% of total Aquaculture production

Advantages and disadvantages of cages

Advantages	Disadvantages
• Cage construction is simple, easy and cheaper, • Observation of the stock is easy in cages • Use of existing water bodies no land required • High quality production per unit area or volume • Fish in cages are protected from predators and competitors. • Increase fish production of the water bodies and reduced fishing pressure on natural fish stocks	• Fish are confined in cage and could not have free access on natural food • Fish in cage must be fed by the farmer to a much higher extent with high quality and expensive fish feed • High stocking density creates a stressful environment for the fish and damages the immune system. • Poaching is easy because fish are confined in a small area, Predators can be attracted to the cages; • Security and high protection to be provided.

Species of choice in cages; Tilapia

Tilapia species are chosen based on presence in the receiving waters

Biological Characteristics of Nile Tilapia (Oreochromis niloticus)

- Native to Africa,
- Growing rapidly,
- Ease breeding (in both artificial and natural habitat),
- Accepts a wide range of feeds including planktons from natural sources,
- High disease-resistance,
- Tolerance to poor water quality and low dissolved oxygen levels.

Choosing the right cage site

1. Physical and biological considerations
- Culturable species
- Water Depth
- Water quality
- Current (gentle flow about 4cm/s).
- Traffic (avoid transport routes)
- Shelter from winds and waves
- Availability of fingerlings
- Natural food
- Type of soil/substrate
- Pollution

Recommended water quality characteristics for cages

Parameter	Value
Dissolved oxygen	>4 mg/l
Salinity	15 – 30ppt
Electrical Conductivity	90 – 110 µScm⁻¹ expected range in Lake Victoria (except heavily polluted Murchison bay)
Ammonia-nitrogen (NH_3-N)	< 0.5 ppm
Hydrogen ion index (PH)	7.0 – 8.5
Nitrate (NO_3-N)	< 200 mg/l
Nitrite (NO_2-N)	<4 mg/l
phosphate	<70 mg/l
Chemical oxygen demand (COD)	<3 mg/l
Biological oxygen demand (BOD)	<5 mg/l
Biological criteria	
Bacteria count (E. coli)	<3000 cell/ml

Adopted from MAAIF2016

Depth	Stationary cage	Min >4m, max <8m
	Floating cage	Min >5m, max <20m
Physical criteria		
Current velocity		Min >10cm/sec, max <100cm/sec
Total Suspended Solid (TSS)		<10mg/l
Water temperature		27 – 31ºC
Secchi Depth		> 0.5m

Adapted from MAAIF, 2016.

2. Economic and social factors

- Quantity and quality of available manpower;
- Social and religious customs;
- Consumer habits;
- Availability and cost of construction materials and equipment;
- Transportation and communication facilities;
- Security of tenure;
- Peace and order (Security)
- Industrial and agricultural planning in the area;
- Accessibility and nearness to markets.
- Distance from protected/ established areas

3. Technical consideration for cage site selection

- Impact on environment and biodiversity
- Introduction or disrupt disease and parasite cycles, change the aquatic flora and fauna, and alter the behavior and distribution of local fauna.
- Cage fish culture is recommended to be practiced in deeper lakes, large and medium water reservoirs or irrigation dams, leaving aside small and shallow water bodies because small and shallow waters are generally rich in nutrients and the sunlight penetrates down to the bottom resulting in a high rate of primary production.
- Cage culture involves high input of nutrients in the form of feed. This coupled with the high rate of deposition of fish excretory matters results in a high rate of nutrient input to the system that causes eutrophication. This will lead to the disruption of natural ecosystem processes and cause irreparable damage to the system.
- Small reservoirs do not have sufficient depth for the cages to remain afloat during the lean season. If water level recedes and goes beneath the critical level, the crop will be destroyed. Therefore, the water body at cage site should have at least 5 m depth round the year.

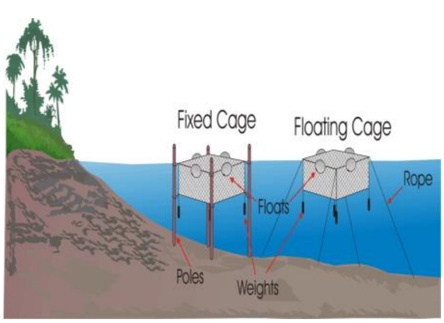
CAGE DESIGN AND CONSTRUCTION

Type of cages

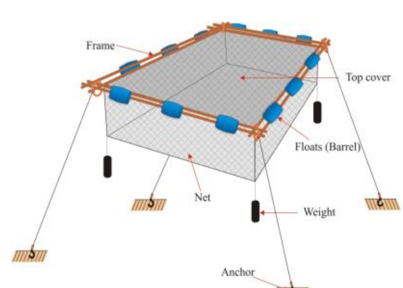
- Four basic types of cage are described as fixed, floating, submersible and submerged cages.
- Only fixed and floating cages are recommended in Zambian water bodies while submersible and submerged are marine cages.

Floating cages

A floating cage module consists of (a) net cages that will contain the fish stocks and exclude predators, (b) flotation system, (c) mooring system, and (d) module frame with working platform. Net cages are tied securely to the frame but move freely

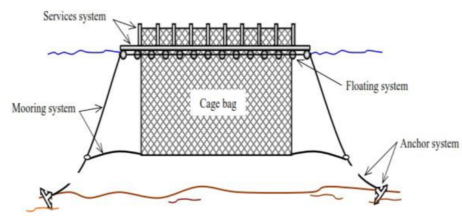


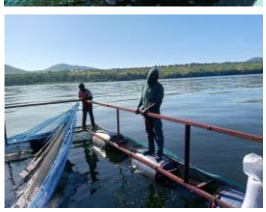
Components of cages



Frames should be made of angle bars

Weak frames will be damaged by the strong winds





Cage can be built in several types and sizes; however most of them present the following common components:

1. Floating system
2. Mooring system
3. Anchor system
4. Cage bag
5. Services system

1)Floating system

- Important part of the cage that gives the shape of the cage,
- Provides buoyancy and holds the cage at the surface of the water,
- The buoyant force varies depending on size and materials used;
- The minimum suitable level is 0.50m above the water surface,
- The assembly can be by connectors, stitching or tying.

Different floating frame of the cages

Common materials to build a flotation frame:

- Metal or plastic drums
- High density polyethylene (HDPE) pipes
- Rubber tires and metal drums coated with tar or fiberglass.

2) Services system

- This is a space or catwalk along the cage frame required for providing operating and maintenance services, such as feeding, cleaning, monitoring or grading.
- Farmers should use the floating system without additional floats or buoyancy to make catwalks.

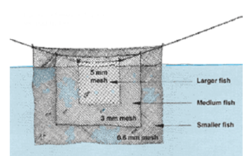
- A catwalk can be made of pieces of woods tied together on floating frame by connectors or strong cord to form a smoothen and fixed floor.
- Its size depends on the cage design, minimum is 0.50m of width

With service system

Without service system

Raft for transport and management of cages

3) Cage bag



The function of the net bag is:

- ✓ to contain and protect the fish,
- ✓ to provide fish habitat.

The net is normally flexible and made of synthetic netting of nylon or polythene fibers reinforced with polythene ropes.

Different mesh size of net bag according to the fish size

The net bag should be kept stretched vertically with weights at the bottom of the cage or fastened by rope to the framework depending of the type of cages.

- The flexible net bags are the most used.
- A conical bottom allows for mortalities to collect in one point.
- A mortality collector aids significantly in the removal and management of mortalities.
- Nets should be adequately weighted to maintain the shape of the net.

Netting materials:

Suitable net material for construction of cages:

- Material should be durable with high breaking strength and resistance to abrasion
- The material should not be very heavy to make handling very easy
- Cages net of synthetic fibres are convenient as they can be easily folded, installed, removed and are also light to handle

4) Mooring system:

- Help to hold the cage in the suitable position according to the direction and depth designed
- Helps to maintain the shape of the cage
- Join the cage at the anchor system.

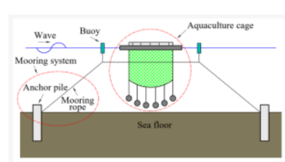
Technical consideration for mooring system:

- *A mooring system must be powerful enough to resist the combination of currents, wind and waves forces without moving or breaking up.*
- *The materials used in the mooring systems could be the steel lines, chains, reinforced plastic ropes and mechanical connectors.*
- *The mooring force capacity depends on both the material and size,*
- *Attachment to the system is by metallic connectors and ties.*
- *Multiple attachment points to each cage to prevent stress on the cage structure.*
- *Even tension between all the mooring points.*
- *Horizontal force better than downward pull – use a float*

5) Anchor system

The anchor holds the cage and all its components into the bottom bed. There are basically three types:

- Pile anchors
- Dead weight anchors
- The mooring anchor



- Pile anchors: buried piles at the bottom by a pile hammer from a barge on the surface, effective for a small space, expensive to buy, and difficult to install,
- Dead weight anchors: concrete blocks, hard sac of sand, rock or gravel, fairly consistent in holding power and should resist at least their own weight in water and in soft seabed conditions, may hold more than three to five times their own weight under any condition, Anchors that get their strength by engaging with the seabed.
- The mooring anchor; hold into the bottom bed made of steel and should slip easily into the bottom bed without disturbing the soil, anchors are joined to the mooring system usually by chains and metallic connectors.

6) Nets of protection

- Additional nets of protection should be installed to prevent the predation from birds and an early detection of fish theft.
- Predator nets add extra weight and drag on the cage system, thus they should only be installed if predators are problematic.

Net cover to prevent birds' entries

Wire mesh cage protector

Site selection for cages

Case study – Luapula

Considerations (Revision)

- Physical and biological considerations
- Economic and social factors
- Technical considerations

Identification of suitable location in Luapula

Mukwakwa

Kashikishi

Nchelenge Boma

Ntoto

Site selection criteria of different sites

Site	Nchelenge Boma	Kashikishi	Ntoto	Mukwakwa
GPS	-9.345972 28.731048	-9.315582 28.730562	-9.257298 28.779529	-9.079363 28.932948
In shore area	Available area about 500 m from shore	Busy area for boats and harbor nearby	Available area about 500 m from shore	Available at more than 2 Km from shore
On shore land	Non-available: land occupied by buildings	Non-available land occupied by building and a harbor	Available land adjacent to the shore	Non-available: occupied by settlements
Population density	Low: area for office buildings	Very high	Very low	High
Displacement of people	Well established buildings on shore which cannot be demolished	Well established buildings on shore which cannot be demolished	No buildings on shore and very little displacement of villagers	Well established settlement on shore and massive displacement would be needed
Access roads	Limited access to the site	Limited access to the site	Very good access though roads need to be worked on	Limited access to the site
Access to Powerlines	Nearby	Nearby	Longer distance to Powerlines	Nearby
Suitability for fish cages	Suitable	Suitable	Very Suitable	Less suitable
Suitability fish ponds and support structures	Not suitable	Not suitable	Very suitable	Not suitable

Figure 3: Comparison of settlements around proposed cage farming sites: A **Mukwakwa,** B **Kashikishi,** C **Nchelenge boma and** D **Ntoto village site.**

Table 2: Site selection matrix for cage location at Ntoto

Parameter	GPS	Dissolved Oxygen (mg/L)	Salinity (ppm)	pH	Temp (°C)	Conductivity (µS/cm)	TDS (ppm)	Secchi disk (cm)	Depth (m)
Standard / Sites		> 5mg/L	< 5 ppm	6.0 -9.0	24 -35 °C	<150 µS/cm	<500 ppm	> 20 cm	> 4 m
Location A	-9.257415 28.778515	8.2	0.04	8.3	25.9	73.9	36.6	80	2.8
Location B	-9.257449 28.777716	8.0	0.04	8.1	24.3	74.3	37.2	70	2.9
Location C	-9.257645 28.777274	8.0	0.04	8	24.2	73.9	36.6	70	4
Location D	-9.257872 28.776773	8.0	0.04	8	24.2	73.9	36.6	70	4.5
Location E	-9.258156 28.776242	7.9	0.04	7.7	24.4	74.1	37.1	70	5

A Novatek outlet which stocks fish feeds at Kashikishi will be the nearest source of fish feeds before establishment of a feed mill

Ntoto site was too busy with Chisense fishing

Ntoto site had a lot of population and activities

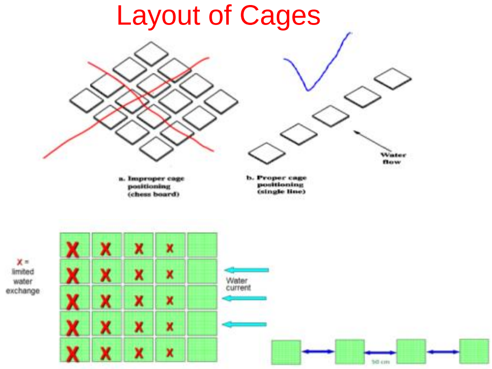
Catfish

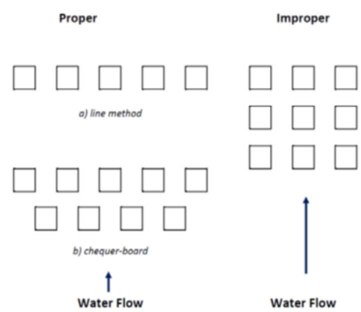
imbowa

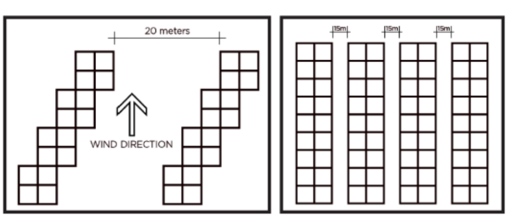
Cage positioning

- In large-scale tilapia farming, fish cage modules can be arranged in rows either diagonally or parallel to each other.
- This way, order is maintained, water flow is not impeded too much, and operations can be done with ease — boat movements, harvesting fish, inspecting and repairing the net cages, etc.

Layout of Cages





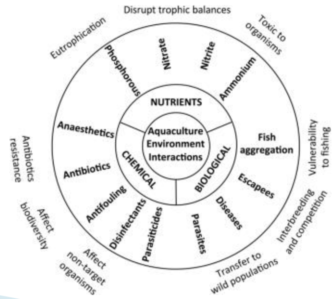


Arrangement of fish cage modules in rows that are diagonal (top) and parallel (above) to each other

Environmental impact of Aquaculture

With increasing intensity the aquaculture will pose an environmental impact from both cage and pond culture systems

Environmental Impact of Aquaculture



CONSUMPTION HAZARDS OF AQUACULTURE PRODUCTS

- **Endocrine Disrupting Compounds (EDCs)**: organic contaminants, can cause adverse effects on the hormonal systems of organisms.
- **Heavy metals:** mainly derived from land urbanization, land reclamation, petrochemical industries and mining activities
- **Microplastics:** synthetic plastic particulates with a diameter size of 100 nm–5 mm. It is commonly detected in the aquatic ecosystem, particularly the coastal, estuarine, and aquaculture water systems
- **Antibiotics:** may cause an environmental threats and antimicrobial resistance to living organisms.

Case study

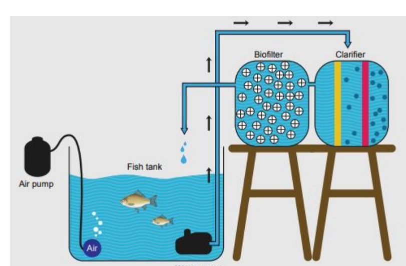
Lake Victoria: Abandoned Fish Cages Slowly Turning Into 'Floating Museums

- In 2021, there were an estimated 5,300 fish cages in the Kenyan side of Lake Victoria – according to data from the Kenya Fisheries.
- Today, some of these fish cages, dot the waters of Lake Victoria like floating museums – with some owners forced to abandon the projects all together.
- Despite the venture promising rich alternative for many fishermen, and fish farmers, cage fish farming in Lake Victoria has continued to be affected by a wide range of challenges like the high cost of production, inadequate supply of quality fish feeds and the theft of fish from the cages.

https://www.citizen.digital/wananchi-reporting/lake-victoria-abandoned-fish-cages-slowly-turning-into-floating-museums-n332487

WHAT IS RAS?

- Aquaculture system where the culture water is purified and reused continuously.
- A recirculating aquaculture system is an almost completely closed circuit. Waste products; solid waste, ammonium and CO2, are either removed or converted into non-toxic products by the system components.
- The purified water is subsequently saturated with oxygen and returned to the fish tanks.
- It is however not possible to design a fully closed recirculating system. The non-degradable waste products must be removed and evaporated water must be replaced. Still some recirculating systems are capable of reusing 90% or more of the culture water.
- Best option for locations close to or in cities, with limited land and water but good availability of electricity.



Basic Recirculating aquaculture system set up

ADVANTAGES OF RECIRCULATING AQUACULTURE SYSTEM

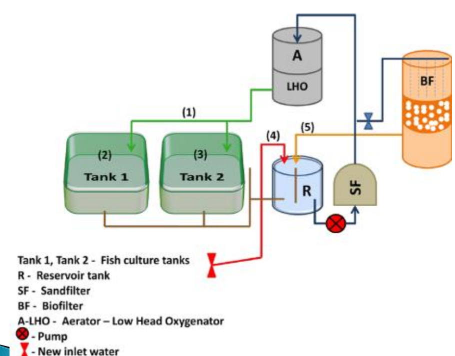
The advantages of farming in RAS are:
- Fully controlled environment for the fish
- Low water use
- Efficient energy use
- Efficient land use
- Optimal feeding strategy
- Easy grading and harvesting of fish
- Full disease control

CONSTRAINTS OF RECIRCULATING AQUACULTURE SYSTEMS

- Necessity for electricity 24/7
- Good water source, preferably borehole
- Good fish feed quality, preferably high protein and fat extruded diets with high digestibility
- Technically skilled staff able to work in a medium tech environment
- Good electricity backup which can run up continuously for a week or more

BASIC COMPONENTS OF A RAS SYSTEM

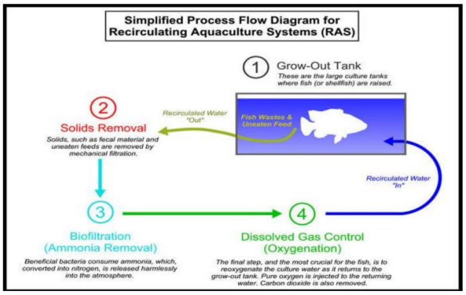
A basic RAS consists of the following components:
- Fish tank
- Mechanical Filter
- Biological Filter
- Pump tank
- Pump
- Aeration devices
- Other items if needed (e.g. UV-C light, oxygenation devices, feeders, monitoring, etc.)



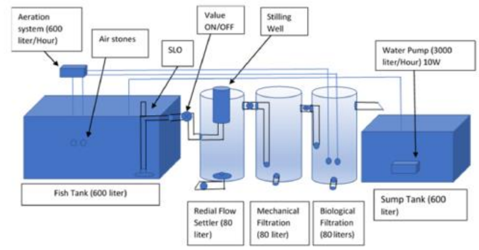
Basic principle of RAS

- The basic principles are based on water treatment technology, which continuously removes waste products and reproduces optimal water quality for fish.
- Other facilities can be added, like oxygenation with pure oxygen, ultraviolet light or ozone disinfection, automatic pH regulation, heat exchange, denitrification, etc.

In the filters, the fish wastes is removed from the water
- first using a mechanical filter that removes the solid waste and then through a biofilter that processes the dissolved wastes.
- The biofilter provides a location for bacteria to convert ammonia, which is toxic for fish, into nitrate, a more accessible nutrient for plants. This process is called nitrification.



Backyard RAS design



RAS unit process design. *Notes: SLO = solid lifting outlet.*
Source: Authors.

Benjamin et al 2022. Feasibility Study of a Small-Scale Recirculating Aquaculture System for Sustainable (Peri-)Urban Farming in Sub-Saharan Africa: A Nigerian Perspective

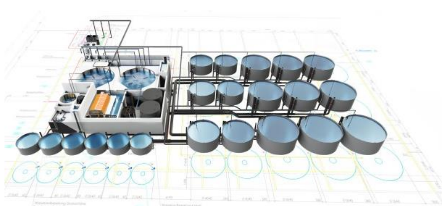
Another Backyard RAS

RAS prototype implementation

African Catfish yield of the RAS in one production cycle of 4 months. Stocked @ 78kg/m³

Benjamin et al 2022. Feasibility Study of a Small-Scale Recirculating Aquaculture System for Sustainable (Peri-)Urban Farming in Sub-Saharan Africa: A Nigerian Perspective

Commercial RAS systems



https://www.asc-aqua.org/explained-what-is-ras-aquaculture/

Profitability of RAS

- With RAS, the key parameters determining profitability are price, yield, fingerling costs, feed, and initial investment.
- Due to the lower cost of sludge disposal and the higher fish density of RAS compared to conventional fish farming, RAS can achieve higher fish yields and profits.

Other factors affecting profitability are;

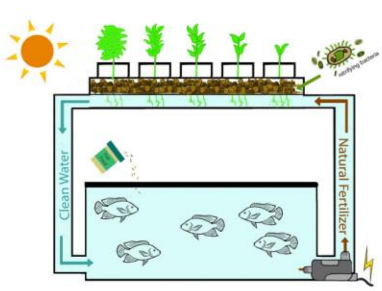
- Efficient use of energy
- Efficient use of land
- Optimal feeding strategy
- Easy grading and harvesting of fish
- Complete control of the disease

Backyard RAS systems can be easy to install and user-friendly

AQUAPONICS

What is Aquaponics?

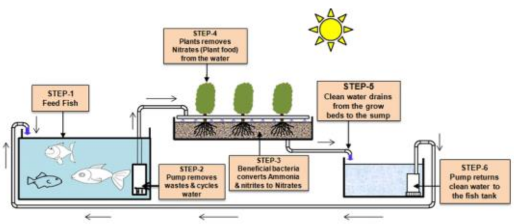
- Aquaponics is a sustainable method of food production combining aquaculture (raising aquatic animals) and hydroponics (cultivating plants in water).
- In this circulating system, fish waste acts as a natural fertilizer for plants, plants then take up those nutrients and return clean water to the fish.



Why Use Aquaponics?

- Aquaponics systems operate with little environmental impact to produce high quality, hormone-free fish and organic vegetables, without the use of artificial fertilizers, harmful pesticides, and dangerous herbicides.
- Aquaponics emphasizes water conservation. Generally, aquaponics uses 90% less water than conventional vegetable gardens and 97% less water compared to standard aquaculture methods. Additionally, the recirculating system keeps waste out of watersheds.
- Aquaponics is a versatile and adaptable method of sustainable farming. Systems can be built on just about any scale and designed to fit in almost any space – talk about efficient land use!

Mechanism



The Nitrogen Cycle - The Magic of the System

Nitrogen is an essential nutrient for plant growth and is abundant in a healthy aquaponics system. Nitrifying bacteria convert ammonia and ammonium (found in fish waste) into nitrates, a form of nitrogen that plants can use as fertilizer. You will find three forms of nitrogen and two main types of bacteria in an aquaponics system:

Forms of Nitrogen:

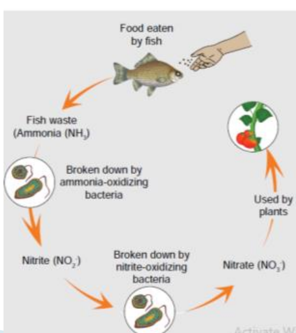
1. Ammonia/Ammonium
2. Nitrites
3. Nitrates

Bacteria:

1. Nitrosomonas
2. Nitrospira

Remembering the name of the bacteria is less important than knowing their functions. The first set of bacteria essentially consumes the ammonia/ammonium produced from fish and converts it into nitrite. The second set of bacteria consumes the nitrites and produces nitrates - the most accessible form of nitrogen for rapid plant growth!

The Nitrogen flow in an aquaponic system



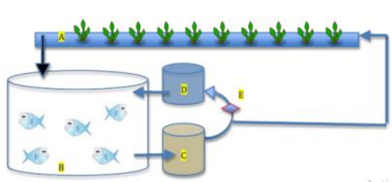
Aquaponics methods

There are three primary growing methods in aquaponics:

- Nutrient Film Technique (NFT)
- Ebb & Flow
- Raft or Deep Water Culture (DWC)

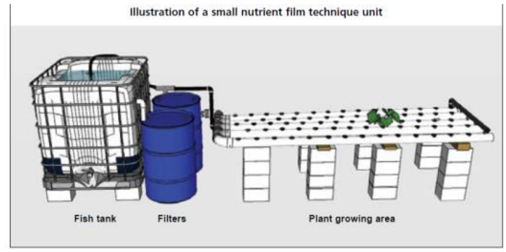
a. Nutrient film Technique (NFT)

A. NFT Grow Channel
B. Fish Tank
C. Mechanical Filter / Solids Removal
D. Biological Filter
E. Gate Valve (To direct flow to grow channels)

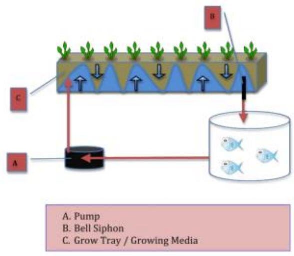


The main advantage of the NFT system is that the plant roots are exposed to a continuous supply of water, oxygen, and nutrients. A downside of NFT is that it has less buffering against interruptions in the flow, e.g. power outages, but overall it is a very productive technique.

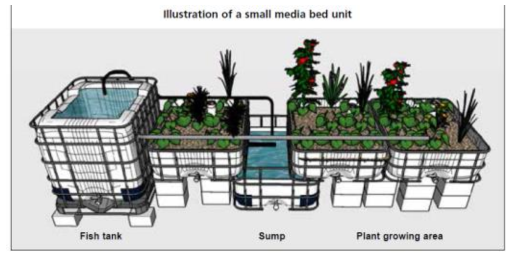
Illustration of a small nutrient film technique unit



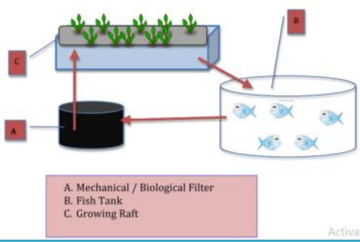
Grow bed/ Ebb and Flow



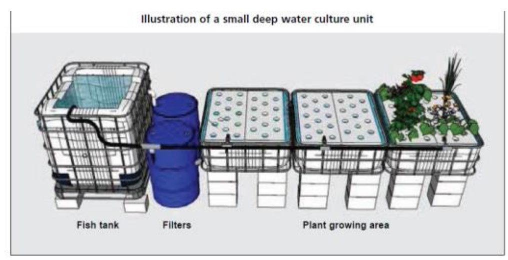
The growing area is a wide deep container with sufficient surface area. This container is filled with gravel, LECA, or other soil-less growing medium where the vegetables can be planted. The water pump is controlled by an adjustable timer which is used to circulate water to fill the tub in an "ebb-and-flow" manner



Raft / deep water system



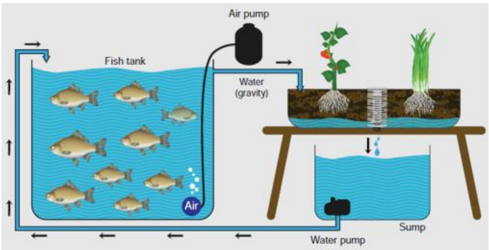
Raft or Deep Water Culture (DWC) is the most frequently used technique for large scale, commercial aquaponics. With this technique, the plants are grown on perforated rafts, usually made of Styrofoam or similarly buoyant material, which float in dedicated water tanks. The roots of the plants are often bare and constantly in the water.



- Fish Tanks
- Grow Trays or NFT Channels
- Growing media
- Plumbing
- Biological Filter
- Mechanical Filter
- Water Pump
- Water Heater (if needed)
- Air pump / Diffusers
- Net Pots (for NFT)
- Lighting (if indoors)

Major benefits of aquaponic food production:

- Sustainable and intensive food production system.
- Two agricultural products (fish and vegetables) are produced from one nitrogen source
- (fish food)
- Extremely water-efficient.
- Does not require soil.
- Does not use fertilizers or chemical pesticides.
- Higher yields and qualitative production.
- Organic-like management and production.



- Higher level of biosecurity and lower risks from outer contaminants.
- Higher control on production leading to lower losses.
- Can be used on non-arable land such as deserts, degraded soil or salty, sandy islands.
- Creates little waste.
- Daily tasks, harvesting and planting are labour-saving and therefore can include all
- genders and ages.
- Economical production of either family food production or cash crops in many locations.
- Construction materials and information base are widely available.

Major weaknesses of aquaponic food production:

- Expensive initial start-up costs compared with soil vegetable production or hydroponics.
- Knowledge of fish, bacteria and plant production is needed for each farmer to be successful.
- Fish and plant requirements do not always match perfectly.
- Not recommended in places where cultured fish and plants cannot meet their optimal temperature ranges.
- Mistakes or accidents can cause catastrophic collapse of system.
- Daily management is mandatory.
- Energy demanding.
- Requires reliable access to electricity, fish seed and plant seeds.

CURRENT APPLICATIONS OF AQUAPONICS

- **Domestic/small-scale aquaponics**

The main purpose of these units is food production for subsistence and domestic use, as many units can have various types of vegetables and herbs growing at once.

- **Semi-commercial and commercial aquaponics**

Owing to the high initial start-up cost and limited comprehensive experience with this scale, many commercial ventures have failed because the profits could not meet the demands of the initial investment plan.

- **Education**

Aquaponics is being used as a vehicle to bridge the gap between the general population and sustainable agricultural techniques, including congruent sustainable activities such as rainwater harvesting, nutrient recycling and organic food production, which can be integrated within the lesson plans.

Commercial aquaponics

http://www.globalaquaponics.net/aquaponics-belongs-hands-aquaculturists/

Integrated Aquaponics -Agric systems are flexible

Fish waste water can be used for veggies which in turn can support the fish

BIOFLOC SYSTEMS

- Biofloc technology was initially developed by an Israeli professor **'Yoram Avnimelech'** but was commercially applied on Indonesian and Malaysian shrimp farms from where this technology spread worldwide.
- Biofloc technique primarily aims on purification of aquatic environment and recycling of nutrients through heterotrophic Bacteria by maintaining C:N ratio.
- Moreover feed can be regenerate by microbial activity, thereby reducing feeding expenses, which means, higher production in less cost. Furthermore it also enables high stocking density and easy management of fishes within less water space.

What are biofloc?

- Bioflocs are aggregates of aquatic organic detritus and microbes comprising of phytoplankton, zooplankton, autotrophic and heterotrophic bacteria, diatoms and fungi.

Difference between traditional aquaculture and biofloc technique

	Traditional aquaculture	Biofloc technique
1	High feed requirement per no of fish grown. About 75% of feed is lost to environment and only 25% contribute to the size development.	Low feed requirement per no of fish grown. Feed is regenerated by processing flocs.
2	Large area requirement for same no of fish in comparison with Biofloc technology	Higher stock density
3	Sometimes accumulation of toxic nitrogenous waste exceeds the algal removal capacity which can lead to high fish mortality.	Efficient management of toxic nitrogenous waste
4	Frequent water exchange is required	Zero or limited water exchange
5	No interaction with microbes for constructive purpose	Use of Heterotrophic bacterial culture for waste management
6	No artificial aeration is required	Artificial aeration is done with aerators

Advantages of Biofloc Farming

- **Higher Productivity**
- **Eco friendly sustainable system**

Nitrogen waste is efficiently converted into protein feed having double benefits of water conservation and waste management.

- **Controls diseases and reduces pathogen transfer**

Probiotics present in the mixture kills harmful microbes. Moreover disease and pathogens of one container will not spread to other container which restricts the loss of whole culture.

- **Zero or limited water replacement**
- **Reduced feed cost**

Feed cost is ultimately reduced by (30-50%) due to dual positive factors of effective utilization of feed and regeneration of lost feed.

- **Easy harvesting**

Limitations of Biofloc technology

- **Higher setup cost**
- **Requirement of technical skills**
- **Need of constant power supply and energy costs**
- **Requirement of Supplements**

To maintain the C:N ratio, alkalinity, and other factors, we must add respective supplements such as sugar molasses, liming material etc.

- **Requires start up period**

Biofloc technology requires a startup period for bacteria to be active and function properly.

Setup and mechanism

In **Biofloc technique** fish is reared on small heighted tanks about **4 m** in diameter with approximately capacity of 600 fish. A culture of **heterotrophic bacteria** is also grown along them. The setup also requires aeration and mixing mechanism to balance oxygen supply and for proper functioning of heterotrophic bacterial culture.

- Heterotrophic bacterial cultures grown along with fish performs the task of recycling nutrients. Bacteria consumes unutilised protein feed and nitrogenous waste which in turn increases their own protein content. We can recollect these proteins from aggregates known as **flocs** and utilize them again as fish feed.
- **Heterotrophic Bacteria** also converts harmful ammonia into non toxic nitrates and usable proteins. In fact in traditional pond farming, when we provide protein feed to fishes they can utilise only about 25% of it for their direct body growth. While the remaining 75% goes to water and contributes to unwanted aquatic weed or algal growth. The accumulation of wasted feeds and nitrogenous waste in water degrades its oxygen level and a need for water replacement arises in conventional aquaculture.

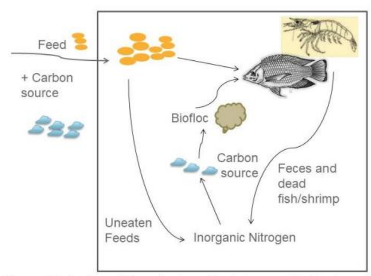


Figure 1. Mechanisms of the production and maintenance of bioflocs in ponds and tanks. Adapted from Crab et al. (2012)

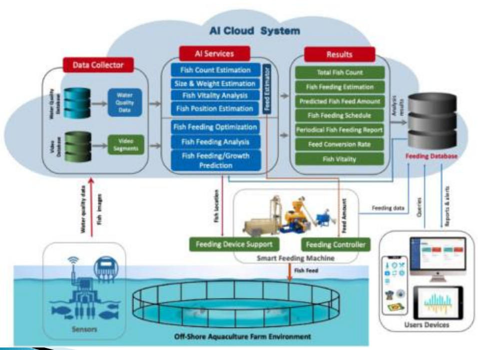
Use of AI in Aquaculture

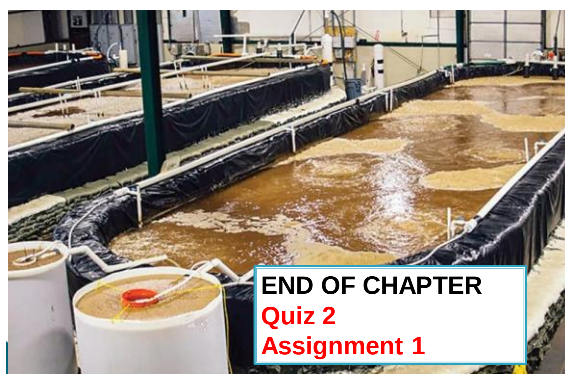
- Aquaculture plays a crucial role in meeting the growing global demand for seafood, but it faces challenges in terms of fish growth and health monitoring.
- AI technologies, such as machine learning and computer vision, have shown immense potential in analyzing large volumes of data collected from fish farms.
- By leveraging AI algorithms, fish farmers can gain valuable insights into fish growth patterns, feeding behavior, and environmental factors affecting fish health.
- These systems employ various sensors, cameras, and data analytics tools to continuously collect real-time data on water quality, temperature, oxygen levels, and fish behavior.

- AI algorithms analyze this data to identify deviations from optimal conditions and provide timely alerts to farmers, allowing them to take appropriate actions such as adjusting feeding schedules, modifying water parameters, or administering treatments as needed.
- Furthermore, AI-based models can assist in optimizing feed management and reducing wastage.
- Another significant aspect of AI in fish farming is disease detection and prevention. Through image analysis and pattern recognition, AI algorithms can identify early signs of diseases, parasites, or abnormalities in fish appearance and behavior.
- This enables prompt disease diagnosis and targeted treatment, reducing the need for excessive use of antibiotics and chemicals while improving fish welfare.

10 Applications of AI in Aquaculture

- Automated Feeding System
- Remote Monitoring and Maintenance
- Growth Statistics
- Temperature Optimization
- Water Quality Regulation
- Consistent Aeration
- Human-less Filtration
- Predictive Measures
- Big Data Analytics





END OF CHAPTER
Quiz 2
Assignment 1