D - 5.1-5.2 DESIGN OF HATCHERY AND OPERATIONAL PLAN

DESIGN OF HATCHERY
AND OPERATIONAL PLAN

Promoting Community-Based Climate Resilience

in the Fisheries Sector Project

Submitted to:

THE NATIONAL FISHERIES AUTHORITY

Prepared by:

TIL-AQUA INTERNATIONAL BV

Date and Version :

07-11-2020 report V1 FINAL

Content

List of figures

1 PART I. SUMMARY

A. Overview

In this report Twickenham Park 2 is completely destined as tilapia hatchery; the spawning, incubation, swim-up and quarantine are considered as the indoor part of the hatchery.

Twickenham Park 2 is set up as a tilapia advanced fry production unit. Since the introduction of the reproduction method, based upon classic spawning ponds, in the fifties of last century this method hasn't changed.

The biological and technical assessment of the hatchery site has revealed several shortcomings resulting in the strong decline in fry production. Leaking ponds, silt, water quality, bio-security and environmental issues are some of these shortcomings.

The way of collecting only free swimming larvae from a spawning pond is a method that is used in the past in most tilapia-hatcheries, but is no longer the best and most efficient way of production. This method has been improved in the last decades, and a more modern way of working is actively collecting eggs and larvae from the mouth of a female by flushing them out of the mouth of the breeding females.

Survival from harvested swim-up fry to advanced fry for sales is quite poor. This mortality is caused by many different factors such as the condition of the ponds (leaking, siltation, growth of filamentous algae), but also management and water quality are important factors contributing to the low survival rate. A more controlled environment is developed nowadays by artificial incubation and the deployment of small so-called swim-up systems based on recirculation technology.

This modern way of producing 5 million advanced fry is laid down in a design with an extensive operational management description and a business plan with full attention to bio-security and environmental aspects.

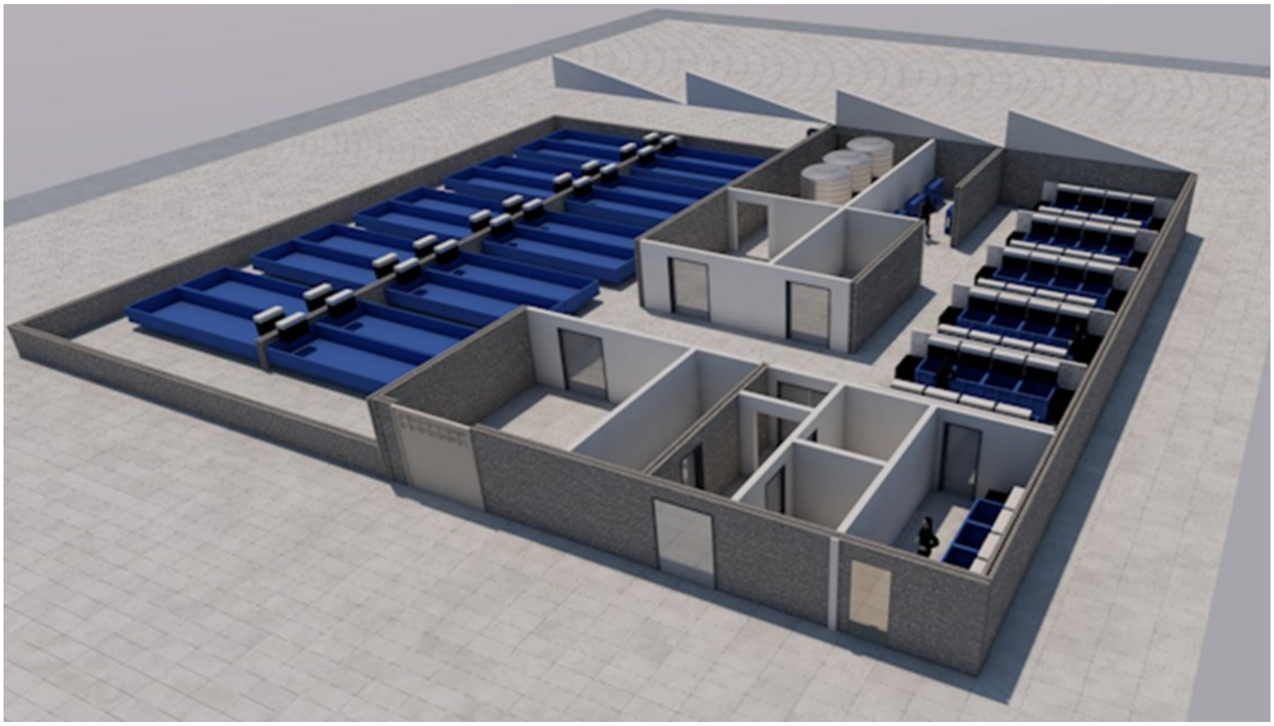
The fenced hatchery is modular in design and comprises:

- 2 lined ponds for growing new parent stock; outdoors
- 2 quarantine units
- 20 spawning units (RAS) with small bio-towers covered by shade nets
- 4 incubation units (RAS) with sedimentation tank; indoors
- 20 swim-up units (RAS) with sedimentation tank and bio-towers; indoors
- 2 lined ponds for fingerling and juvenile production; outdoors

This modular, modern 5 million advanced fry hatchery can be easily doubled or even tripled in Twickenham Park 2.

For spawning, quarantine, incubation and swim-up, the water supply comes from a borehole via a reservoir, water treatment unit and header tanks. An electricity supply of solar panels for daytime is advised for this unit and a generator needs to be installed as a backup.

A broodstock plan with a Tilapia Improvement Program is included in the report and is situated in a fenced part of Twickenham Park 2, completely separated.



Spawning and indoor part of the hatchery

Financial overview.

Summary Fish Farming

HATCHERY		advanced fry (0,5g)	fingerling (5 g.)
Annual fish production	kg	**2500**	**1,500**
	pieces	5,000,000	300,000
		kg fraction 63%	kg fraction 38%
Annual fry sales		**18,800,000**	**12,000,000**
Annual operating expenses		9,840,632	5,904,379
Annual taxs and interest		3,560,370	2,136,222
Net profit after tax & interest		**5,398,998**	**3,959,399**
Annual production costs		costs per fry	per fingerling
broodstock or seed		0.3	3
feed		0.2	2
electricity and water		0.4	4
labour		0.6	6
other		0.1	1
depreciation and interest		0.6	6
corp tax		0.5	5
Cost price of production		**2.8**	**27**

PROPERTY		
Needs	JMD	%
Building and infrastructure	26,340,000	55%
Hatchery system	14,696,000	31%
Broodstock system	3,920,000	8%
Fixed assets	**44,956,000**	
Working capital	3,080,000	6%
Financing needs	**48,036,000**	100%

PROPERTY			
Contribution	JMD	%	
Shareholders' equity	-	0%	
Loan capital, bank long term	22,478,000	47%	50%
Other funds	-	0%	
Equity privat capital, operation	25,558,000	53%	
Financial contribution	**48,036,000**		

B. Disclaimer

This report is prepared for the sole purpose of providing The National Fisheries Authority with information regarding the development of a modern, bio-secure and well-equipped hatchery of appropriate capacity. The drawn conclusions are based on the gathered information and although reasonable care was taken to ensure the reliability of this report, no warranty is made by Til-Aqua International and/or Holland Aqua BV as to its accuracy or completeness. They accept no liability for any damage resulting from the use of the results of this study, or for the application of the advice it contains.

THIS REPORT HAS A CONFIDENTIAL STATUS

2 PART II. Technical approach and methodology

2.1 Objective and scope of work

Subject of the underlying report is the design of the upgraded hatchery at Twickenham Park 2. It is part of a larger assignment, which includes (1) a situation analysis and plan for seed production in Jamaica, (2) an upgrade of the existing hatchery owned by the Fisheries Division and (3) the development of a climate resilient fish farm.

This upgraded hatchery must meet the increasing demand for high-quality advanced fry.

The implementation of the outcome of this assignment aims to promote community-based climate resilience in the fisheries sector whit the objective to strengthen fisheries and aquaculture policy and regulations, strengthen the livelihoods of fishers and fish farmers and reduce vulnerability of fish farming communities to climate shocks.
The research scope is limited to tilapia as this is the dominant cultured fish species in Jamaica. The scope is limited to the biological and the technical design. The preparation of the plot, with appropriate measures if soils need to be excavated are a the next step activities of the construction and installation companies.

2.2 Technical approach and research methodology

This study contains a technical design, an operational plan and a business plan. Research methods include governmental expert interviews, desk research, field research and hatchery visits.

For the technical design of the hatchery, the consultant has evaluated the biological and technical assessment of the actual hatchery. Based on this assessment, the consultant has drawn up technical design specifications for the new hatchery facility.

The adjoining operational plan includes information regarding production capacity, biosecurity, an electricity and water management plan, waste treatment, a broodstock production plan and a Tilapia Improvement Program.

The financial business plan is defined based on calculations for investments, cost price and turnover. Calculations are based on a 3-5 years scope.

2.3 Relation to the subprojects

The upgrade of the hatchery is related to two other projects: (1) A situation analysis and plan for seed production in Jamaica and (2) Design specifications of a climate resilient tilapia farm and operational plan. Both the development of the fish farm and the upgrade of the hatchery include design specifications and preparation of a business, management and operational plan.

3 PART III D-4.1 DESIGN OF HATCHERY (RE-DESIGN AND UPGRADING)

3.1 Site assessment

3.1.1 Biological assessment of the hatchery site

Twickenham Park was set up to refine the production systems used by farmers. It is still in use by the aquaculture division, only now as a hatchery. Multiple species are cultured at the facility; besides tilapia also Pangasius and koi-carps, Colosoma sp. and goldfish. No major tilapia diseases have been noted in the last decade, so no major risks like Streptococcus, Tilapia Lake virus or Franciscella have been recorded on Jamaica. The many other fish species can be of risk with regard to bringing in diseases. The borehole water has a high contamination of coliform bacteria, which can be a threat to the small larvae. The young fry do not have a well-developed immune system yet, and are more vulnerable to infections. There is no treatment of the water before entering the ponds or tanks, and there is no waste management for the wastewater from the farm.

The production method has not been changed significantly since the start of tilapia production. The way of collecting only free swimming larvae from a spawning pond is a method that is used in the past in most tilapia hatcheries, but is no longer the best and most efficient production method. This method has been improved in the last decades, and a more modern way of working is actively collecting eggs and larvae from the mouth of a female by flushing them out of the mouth of the breeding females.

Survival from harvested swim-up fry to advanced fry for sales is quite poor. At the hatchery different numbers of mortality are mentioned, varying from 10% to 60% from harvest to advanced fry for sales. This mortality is caused by many different factors; the condition of the ponds (leaking, siltation, growth filamentous algae), but also management and water quality are important factors contributing to the low survival rate. Based on Til-Aqua's experience, a mortality rate of 60%-75% is fairly common in hatcheries using the described hatchery method in combination with the use of methyltestosterone for sex reversal. Due to the hormone treatment, the immune system of the fry is suppressed. From experience in other farms (in Africa, South America etc.) who work with fry collection from ponds, the harvested fry are often infected with parasites (of which Gyrodactylus and Trichodina are the most common ones). Due to the stress of the collection process and the handling of the fry, the infection spreads quickly, causing high mortalities during the first days of rearing of fry.

There is no structural control of parasites, and there is only a preventative treatment with salt before sales. This preventative treatment with salt is called the "hardening process". The mortality during the "hardening process" in the concrete tanks ("Wetlab") is estimated at 4%-5%. This hardening process with salt is actually an (unintended) preventative treatment against parasites.

Wastewater from the hatchery and ponds is flushed directly into a wastewater canal flowing into the NIC Canal that runs into the Rio Cobre. There is a high risk of escapees from the spawning ponds into the NIC Canal and the Rio Cobre when the ponds are drained, or when there is heavy rainfall and water is flowing out through the overflow pipe. Especially the sex reversed fry are a high risk for the environment, as they can be ecologically disruptive to the local fish population. The sex reversed males are morphologically males, but still genetically female. When these sex reversed males mate with a normal female, they will produce only female offspring, resulting in an overpopulation of female tilapia.

The wastewater from the nursery ponds, where the fry are fed with feed with methyltestosterone, will contain hormones, causing a risk of contamination to the environment when the hormone is flushed into the NIC canal. With the drainage of the sex-reversal nursery ponds, hormones are flushed out into the environment as well, influencing native species that are present in the Rio Cobre.

It is unclear how dead fish are disposed of in the current hatchery, there is no clear collection point. It is advised to have a special collection place where dead fish can be stored until disposal, or buried in a deep pit. Dead fish should never be flushed out with the wastewater.

3.1.2 Technical assessment of the hatchery site

The government hatchery has been in use for decades. There has not, however, been any significant upgrade in the last decades. Groundwater is available, which is pumped up through a borehole with a depth of 190ft (57m). The capacity of the borehole is at least >40m^3/hour. This is more than enough for a large modern hatchery (a modern hatchery with a capacity of 5 million fry/year, using RAS systems, will need only 40m^3 water per day). Most ponds at the site of the hatchery are leaking and only a few are lined (see figure 1).

Figure 1 Overview of ponds

There are no aerators available, and the production method can be classified as extensive. After each cycle, a pond is drained and dried by the sun and wind. However, the sludge remains in the pond at the bottom and is dried as well. This has resulted in siltation of the ponds, a thick layer of mineral rich sediment in the ponds, sometimes causing an abundant growth of (filamentous) algae and suspended solids/silt. There have not been any structural improvements to the ponds in the last decade. No additional ponds have been upgraded with a liner to solve the problem of the leaking ponds.
The water supply from the well is organised through open canals to all the ponds (see figures 2 and 3).

Figure 2 Overview of the water supply of the total site


Figure 3 Water canal from borehole to the ponds

There is no structural refreshment of the ponds and concrete tanks. The pump from the borehole is running only during working hours between 8.00h and 16.30h. The rest of the day the pump of the borehole is not running, meaning there is no refreshment water available during night time or on the weekend.

The farm has no back-up generator in case the power supply fails. Without aerators or any water pumping except the pump for the borehole, an emergency generator is not essential with the current way of working. Upon modernisation of the hatchery, however, an emergency generator will become an essential part of the equipment.

There are 5 concrete tanks available where the fry are fed a feed with methyltestosterone. These concrete tanks are flow-through systems without any filtration. The wastewater is not treated at any moment, and all wastewater is flushed into a canal flowing into the Rio Cobre. There is no hygiene barrier for visitors entering the facility. Only Twickenham Park 2 of the site, the part north of the road, is completely fenced, but within the facility there are no hygienic barriers to prevent the spread of any contamination.


Figure 4 Concrete tanks

3.1.3 Design criteria, inclusive client requests

The Fisheries Division wishes to upgrade the existing facility into a climate resilient modern tilapia hatchery. To meet the market demand for tilapia fingerlings for the upcoming years, the total production of the hatchery should be 5 million advanced fry/year. To take the effect of a changing climate into account when re-designing a hatchery, first the effect of climate change on a fish farm and hatchery should be clear.

Due to climate change, it can be expected that there will be larger temperature differences, and larger variations in rainfall. This can cause flooding during heavy rains (and pollution due to (polluted) water running from surrounded terrain), but it can also cause dry spells with almost no rain, making fresh water more scarce. The prospect of climate change is also more chances of hurricanes and heavy storms in the Caribbean area. A proper (re)design for a modern hatchery should therefore take into account that water quality should be manageable, and that the usage of water per kg of fish production is limited, making sure that dry periods are not influencing the production. It is therefore advised that when modernising the hatchery, the step is taken to switch to recirculating aquaculture systems (RAS). The trend of using RAS technology for farming fish is not only taking place in countries where water is getting more scarce. Even in Scandinavian countries where there are large salmon farms using cages, more and more companies switch to (indoor) RAS systems for the production of fish. The use of RAS systems gives a total control of the environment of the fish, reducing risks of external influences like diseases, or extreme weather conditions.

The actual climate on Jamaica would make it possible to place all RAS systems outdoors. However, the systems would be exposed to (increasingly more extreme) weather conditions. It is therefore strongly advised to place all RAS systems indoors. The Twickenham Park facility might function as a place for education for other fish farmers. The small RAS systems are extremely well suited for educational purposes, and can be used by small farmers as well. When production needs to be expanded, it is easy to place more, identical systems. Most of the ponds at the site are leaking and have not been in use for many years. It is advised to upgrade these ponds so that they can be used again.

The design should take into account that less labour is needed for the production of the fingerlings, as the current way of seining the ponds for free swimming larvae is a very labour-intensive exercise. As the current survival rate of the fry from swim-up until advanced fry is only between 40-60%, the survival rate needs to be improved. The new design and management plan should also take into account the improvement of the broodstock. The current broodstock is poor in quality (both in growth and in larvae production). Biosecurity of the total farm needs to be upgraded as well.

3.1.4 Actual hatchery capacity and specifications

There are 3 spawning ponds for tilapia broodstock, of which 2 spawning ponds of 800m^2 (0,2 acres) are in use. These 2 ponds produce about 200,000 fry/month together at the moment. With fry collection once/twice a day, during 5 days/week, this results in 20 fry collection moments/month. With 2 ponds in use, this means only 5,000 fry are collected on average during each fry collection. If fry are collected twice a day, the number of collected fry is even half this number. This way of collecting swimming fry from a broodstock pond is very traditional, but quite inefficient. The production per square meter is only 125 fry/m^2/month. For expanding the production (if more broodstock is available), more broodstock ponds could be taken into production. Most of the ponds, however, are leaking, and no good additional spawning ponds are available at the moment, limiting the production of fry. Also additional spawning

ponds would take a lot of additional work, as each extra pond would need to be seined daily in order to collect the fry.
After the fry collection the fry are stocked in concrete tanks with 6,000-9,000 fry/m^2. The tanks are 6,9m^2 each, meaning a total number of 40,000-65,000 fry are stocked per concrete tank. After 4 days, the fry are collected from these concrete tanks and transferred to nursery ponds of 450m^2, where they are stocked for 28 days until they reach an average weight of 0,3-0,5 gram. In 2017, the production of advanced fry was almost 2 million. At this moment it is only around 1 million advanced fry/year.

Most of the ponds of the farm are leaking and non-functional. The current production method brings forth, due to many factors, a high mortality rate of 40-60%, which cannot be easily solved within the current production method. Due to the fact that the fry are collected swimming free in the ponds, the fry can be infected with parasites. There is no parasite check when the fry are transferred to the concrete tanks.

3.2 Design, functional and technical specifications

A design is made for a modern tilapia hatchery that is capable of producing 5 million advanced fry/year. A modular system has been chosen, using small RAS systems called swim-up systems. The benefit of using RAS systems is that the culture environment of the fish is controlled in these systems, meaning the production is more stable and more under control compared to outdoor production in ponds. The benefit of using smaller systems is that they can also be used by other (smaller) farms, and it is relatively easy to expand production by adding more systems. The systems are designed to use a minimum amount of electricity and a minimum amount of water compared to flow-through systems and ponds. In addition, they are easy to manage, and create the possibility to improve management procedures such as grading and parasite treatment of the fry.

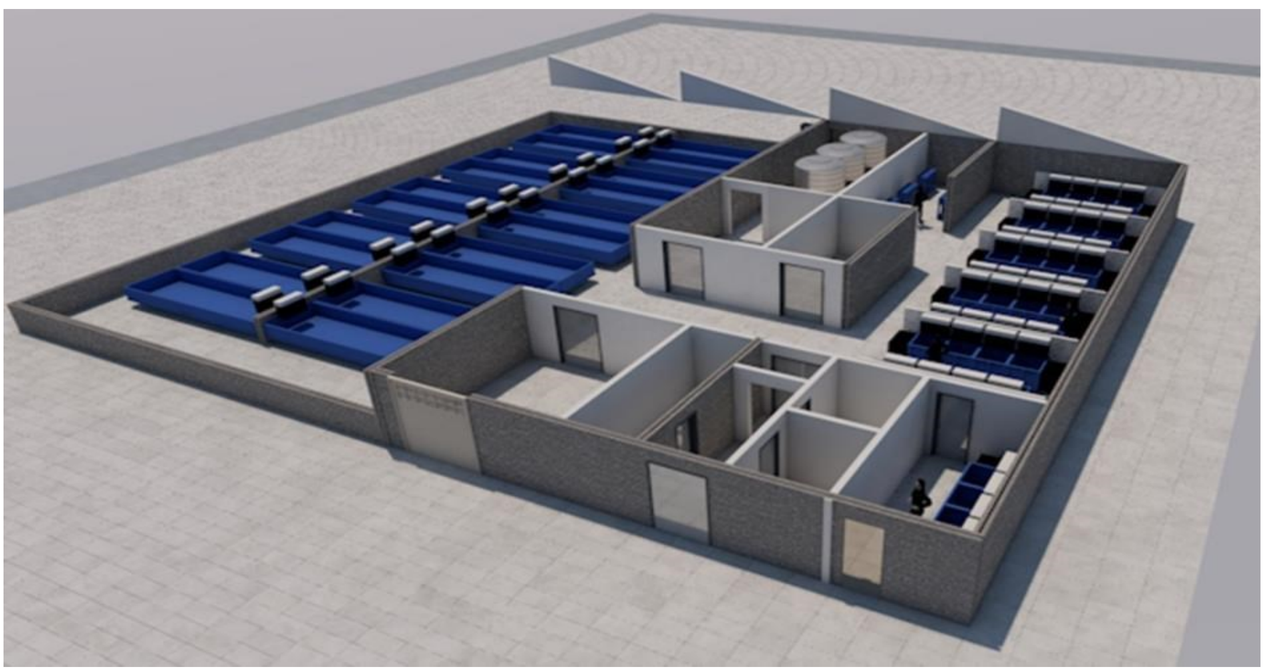


Figure 5 Artist impression of the layout of a modern hatchery for the production of 5 million advanced fry/year

The risk of pollution from the hatchery to the environment can be tackled by the implementation of a biological treatment, by running the water through a helophyte filter (also called reed bed filter).

3.2.1 Strategic seed production capacity goals

The new hatchery should be climate resilient, a robust design that can operate independently of weather conditions. This is why a design has been chosen with small RAS systems that can be placed in an indoor environment. The goal of the Fisheries Division is to produce enough advanced fry for the market, and to have no waiting list for orders. The calculated expected total demand for advanced fry is 5 million advanced fry/year. This is the minimum amount that needs to be produced, with an option to expand production to >10 million advanced fry/year. This expansion is projected in figure 6.

Figure 6 Floorplan of the site with the expansion from 5 to 10 and 15 million fry/year in purple. In yellow an area is reserved for a genetic improvement program.

Besides the production of 5 million advanced fry/year, there is also the possibility to sell larger fingerlings of >5 gram, and sell broodstock of the improved strain to other multipliers of tilapia on Jamaica.

3.2.2 Hatchery (re)design functional and technical specifications

Spawning

In tilapia farming, only natural breeding is possible. The fish will be allowed to spawn of their own volition while the eggs laid by the female tilapia will be fertilized by the male, who discharges sperm over the eggs. The female will collect the fertilized eggs in her mouth, and breeds the eggs in her mouth for around 6-10 days. After hatching, the newly hatched fry will continue to shelter in her mouth for another 4-7 days before the fry will begin to swim freely in schools in the culture environment (tank or pond).

The collection of only free swimming larvae is a labour-intensive and inefficient method. The modern way of fry production is the collection of eggs directly from the mouth of the female. This way the production per female and per square meter of spawning area is much higher compared to harvesting only free swimming larvae. Also, when free swimming larvae are collected from a spawning pond, the breeding broodstock are disturbed once or twice a day during their spawning. This will stress the broodstock. In addition, not all free swimming larvae will be collected.

When eggs are collected from the females, all females are checked for eggs every 10 days, to be in time before the females release the larvae. The broodstock are disturbed only once every 10 days, and the rest of the days the broodstock can be left to spawn, resulting in a much higher production. To facilitate the harvesting a fine-mesh net (a 'hapa') with the broodstock is hung in a (concrete) tank. This way the people that need to collect the eggs and larvae do not need to enter the water. This is better for workers, and better for the fish and the ponds. There is a smaller risk of contamination and no risk of damaging the liner of the pond. For the purpose of checking all the females for eggs, the spawning broodstock are kept in special spawning hapas which have a tiny mesh size that prevents any larvae that are released by a female to swim out of the hapa. This way all larvae and eggs that are produced during a 10 day cycle can be collected.

The spawning hapas should be placed in concrete tanks, and should be covered with a (shade) net to prevent too much direct sunlight, which can cause an algae bloom, and to prevent predation by birds (that can catch fish as well as spread diseases), or by rodents like rats entering the water. The tanks should be equipped with a small trickling filter for extra aeration, making sure the oxygen level and water quality of the spawning tank is always optimal. During cloudy days the growth of algae that produce the oxygen and break down the ammonia is reduced due to limited sunshine. Also there is no oxygen production during the night, causing a reduction in oxygen concentration during the night. A small trickling filter can compensate this, making the systems independent of weather conditions. The hapas should not be too large, otherwise the collection of eggs takes too much time per hapa, stressing the broodstock, but also stressing the eggs and larvae that are collected. A good size is approximately $20m^2$ (8.0 x 2.50 x 1,1 meters (LxWxH)). Males and females in a ratio of 1 male to 2 or 3 females are stocked in the spawning tanks with a density of 750-1,000 gram fish/m^2. With a starting weight at the moment of production of 250 gram/fish this would mean 1 set of broodstock (1 set = 1 male and 3 females) per m2, and 60-80 fish per hapa. The collection of eggs from 1 hapa with 80 fish would take half an hour. The average production of such a hapa is 5,000-10,000 eggs/larvae each harvest (about 10,000-20,000 eggs per month with harvesting every 10 days).

Figure 7 Example of spawning hapas in a concrete tank

Figure 8 Example of spawning tanks in a Poly-Ethylene tank

Hatching (Incubation)
After the collection of eggs and larvae the eggs will be transferred to an incubation system. These incubation systems are small RAS systems with 3 incubation jars. These incubation jars are called "McDonald" hatching jars and have a volume of 2,4 liter. An incubation system consists of 3 McDonald incubation jars, 1 sedimentation tank with filter blocks, 1 submergible pump of 40 Watt and UV 11 Watt, and has a total volume of 400 litres. When all three jars are full of eggs, 1 small system can maintain 120,000 eggs and larvae. Each jar can be stocked with +/-40,000 eggs (400 grams of eggs). Depending on age of the eggs (the moment of fertilization) the eggs will start hatching within a period of 3 to 5 days. The non-fertilized eggs will turn white, break down and float. Approximately 24-48h after egg collection, all non-fertilized eggs will be flushed out of the hatching jars, leaving only well developing larvae in the jars.

Figure 10 Two concrete spawning tanks together

Figure 9 Example of a spawning hapa

After hatching and developing, the yolk sac fry will flow out of the jar into a plastic tank of 12 liter. After complete yolk sac absorption the fry can be transferred to the swim-up fry systems.

Because the eggs and larvae are taken out of the mouth of the female, the larvae can possibly already be infected with parasites inside the mouth of the female (most common are infections with *Gyrodactylus* and/or *Trichodina*). The fry therefore need to be checked for parasites before transfer of the larvae to the swim-up systems, and any shooters (larger fry) need to be taken out. If the fry are infected, they need to be treated before being transferred to a clean and disinfected swim-up system. When the fry are transferred, the total amount needs to be weighed on a balance, in order to know exactly how many fry are transferred to each swim-up tank. All the water in these RAS systems is continuously circulated, all solids are trapped in the sedimentation area, and all dissolved waste (ammonia) is broken down in the trickling filter. Because of this continuous water recirculation, the water consumption of these systems is small. And as the density in these incubation systems is relatively high when the system is completely full with eggs (120K of eggs), there are 300 eggs per liter of water in the system. Therefore the refreshment rate is relatively high with around 150%/day. However, due to the small volume of the system, the absolute amount of water is still very low.

Figure 12 Two incubation systems side-to-side

Figure 11 Small incubation system with 3 hatching jars

Swim-up

The first 6 weeks of the lives of the fish are the most important period. During this time the body – in specific the immune system, enzymatic system, hormone system and the intestines - is developed. The fry needs to be observed very well and treated if necessary. The best feed available will definitely give the fry a head start. It is during this period that their performance is determined for the grow-out phase later on (for instance intestine development).

The small recirculation systems with bio-filtration units are straightforward and efficient systems. They are based on recirculation and are convenient for low budget facilities as well. The water coming from the fish tanks is first lead through a sedimentation tank. In this tank the non-soluble, solid particles are separated from the system water using gravity. The sedimentation tank is filled with a specially adapted polypropylene filter pack. The settled particles form a layer of silt on the bottom of the sedimentation tank. This silt is biologically very active: up to 60% of the nitrates produced by the biofilter are denitrified into nitrogen gas by the bacteria in the silt. Depending on the feed load on the system, the sedimentation tank must be cleaned regularly. The silt and water for cleaning is drained into a gutter that runs outdoor, flushing all water and waste to the helophyte filter pond.

After this mechanical treatment, the system water flows to the pump tank. This tank serves as a water buffer for the system. In this tank, filtered water is stored until it is pumped back to the fish tanks. An overflow is present in the pump tank. From the pump tank, water is first pumped through a UV unit before it flows back to the fish tanks through the bio-tower (UV light kills any parasites present, holds the bacterial pressure low and has a positive effect on the brightness of the system water).
As a final step before the water returns to the fish tanks, the water flows over a biological filter called a “trickling filter”, consisting of a “tower” filled with PP filter blocks and a water distribution plate on top.
The primary function of this filter is to provide space for nitrification. Nitrification is the biological process in which Ammonium produced by the fish is transferred in to less harmful Nitrate by bacteria. Because

this filter material has a very large surface area, there is a large contact surface between the water and the air. This large contact surface makes gas exchange easy. The CO_2 produced by the fish and bacteria is removed from the water into the air, and O_2 is added to the water.

The small size of these swim-up systems has the advantage of being managed easily.

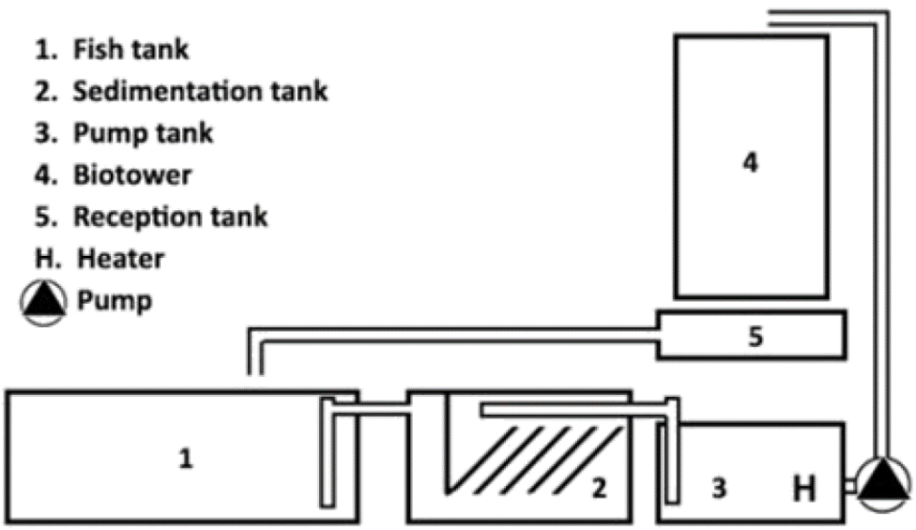


Figure 13 Schematic layout of a Recirculating Aquaculture System (RAS)

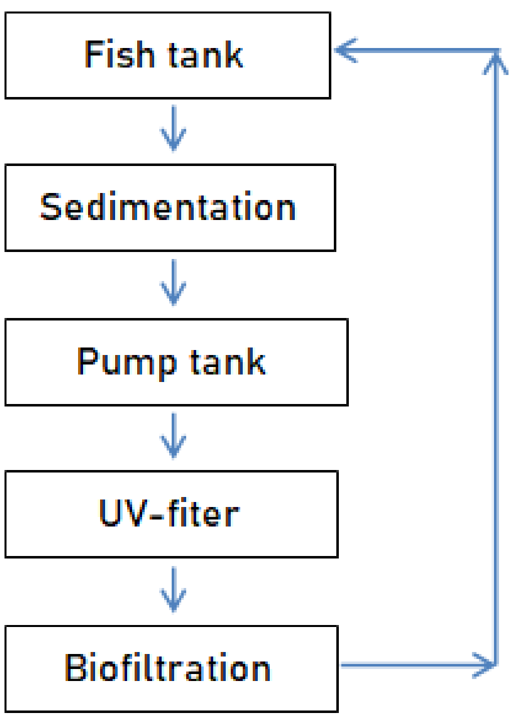


Figure 14 Schematic visualisation of all steps in a Swim-up system

Each tank should be equipped with an air stone for aeration. This aeration is only for security, as the main flow should be sufficient enough for oxygenation of the water and stripping out the carbon dioxide produced by the fish. If a pump breaks down, the air stone will give enough oxygen to have enough time for replacement of the pump, or for transfer of the fry to another system. Also during a treatment of the fish against parasites, the flow of the tank will be stopped, and the aeration of the tank is done with these air stones in each tank. Because the fry are swimming in clean water in these RAS systems, without algae, like they would in ponds outside, the only feed available for the fry is the feed provided to them. For optimal growth and a minimum of growth variation it is best to feed every 2 hours. The male ratio of the fry will also be best in this way, because the fry are always fed the hormone feed immediately from the first feeding, and all fry in one batch are from the same age class. From experience in a hatchery in Kenya, where they use hormonal sex reversal in these small RAS systems, the duration of the treatment does not need to exceed 14 days (rather than 21 days). This is due to the fact that the larvae do not eat any other feed like algae besides the hormone feed, and there is a little accumulation of hormone in the RAS systems. Because of the shorter duration of the hormone treatment, the fry can develop better, resulting in a stronger fish.

Figure 15 5 Small RAS systems for fry, so called "Swim-up" systems, installed in hatchery in Tanzania.

Although the fry are more or less from the same age, there will be growth differences between the larvae. After three weeks the larvae should be graded to get a more uniform batch of fish, and to give the smaller fry in the tanks a second chance to grow. These fry are mainly smaller due to social interactions. After grading, smaller fry will grow better. The fry should be graded a second time 2 weeks after the first grading. At that moment the fry weighs about 0.5 gram. After the second grading the fry can be sold as advanced fry. The smallest graded portion from the batch that was the smallest group in the first grading, should be discarded, as these fish do not have the required growth capacity, and it is economically best to cull these fish. This should be no more than around 10% of the total group of larvae harvested.

In each tank of a swim-up system +/- 40,000 fry can be stocked in the first two weeks. After these first two weeks, the hormone treatment can be stopped. This is earlier than most common practises, but this is due to the fact that the hormone treatment starts right at the first day of feeding. Practical experience in Kenya has proven that 14 days of hormone treatment is long enough. Sex reversal takes place in the first 10 days after hatching. The 28 days treatment is only necessary when the feeding of free swimming larvae that are harvested starts later. These larvae have already started eating algae in the mouth of the female. After these first two weeks of hormone treatment, the fry can be graded and re-stocked in densities of +/- 20,000 fry per tank.

The water consumption for refreshment, cleaning of the sedimentation and compensation for evaporation all together is approximately 6m^3/week. This is a refreshment rate of almost 100%/day, which is quite high for a RAS system. But with 6m^3/week for +/-40,000 swim-up fry in a system, this is only 150ml/fry/week (46 larvae/liter/day).

Day	system 1		system 2		system 3		system 4	
0-10	40	0						
10-21	20	0	20	0	40	0		
21- 31	10	10	10	10	20	0	20	0
	40	0			10	10	10	10

Figure 16 Production planning for numbers of fish in swim-up systems (numbers are #fry*1000).

Ponds

All leaking ponds should be fixed with a liner. To prevent accumulation of sediment when the ponds are drained, ponds need to have a slight slope towards the outlet. The outlet itself should be a concrete monk so the water level can be adjusted, and the pond can be drained completely, while the mud is flushed out.

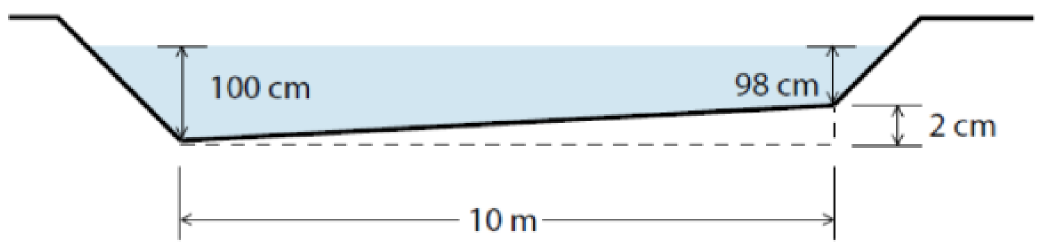


Figure 17 Indication for the slope of the bottom of a pond

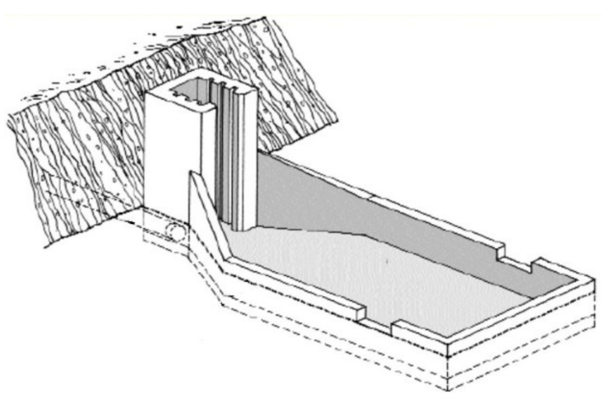


Figure 18 Drawing of a Monk for the outlet/drainage of a pond

Rachel hapas

When the advanced fry are 0.5 gram, but not yet sold to a client, the fry could be transferred to so called Rachel hapas with a mesh size of 3-5mm, that are placed inside an outdoor pond. By placing the fry in these Rachel hapas, the group can be fed properly, and can be easily collected again for later sales. If these advanced fry of 0.5 gram average weight are released into a pond without using a Rachel hapa, the fry will spread through the whole pond, complicating good feeding management as well as the collecting of the fry/fingerlings when they are sold.

It is advised to place an aerator in the pond(s) where the Rachel hapas are placed in order to optimise the oxygen level in the water and to have a good water refreshment of the water inside the hapa.

Figure 19 Detail of a "Rachel" hapa with mesh size of 3-5mm

3.2.3 Modifications on product and process flow

To improve the production of fry it is recommended that the procedure to collect fry is changed into a modern way of egg collection and artificial incubation of the eggs. With this new production method, the production per female and per m^2 of spawning area can be improved (with a factor 5 or even more compared to the current seining procedure of the spawning ponds). The new method of working with the small swim-up systems gives the opportunity to grade the fry, making the advanced fry a more uniform batch of fish. The small systems make it easier to monitor the health status of the fry, with the opportunity to treat them against parasites. This way a stronger and healthier advanced fry is produced. This higher quality advanced fry can be sold for a premium price compared to current prices, because of a higher uniformity in the batches and because the survival of the fry at the clients facility will be higher.

Due to the better health status of the advanced fry, the so called “hardening” method with a salt bath, to avoid an “ionic shock” will not be necessary anymore.

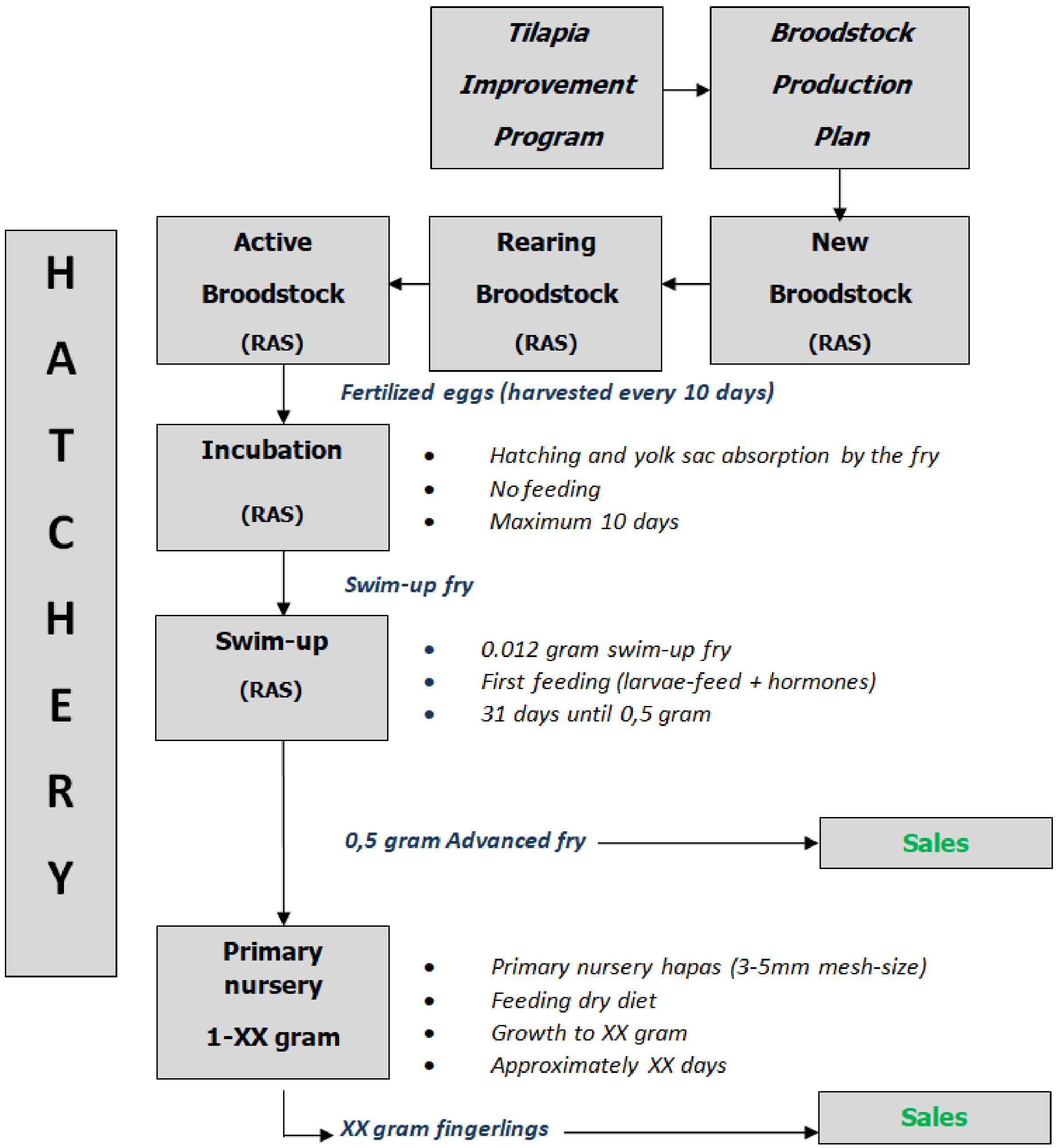


Figure 20 Schematic production flow

3.2.4 Technical layout and infrastructure

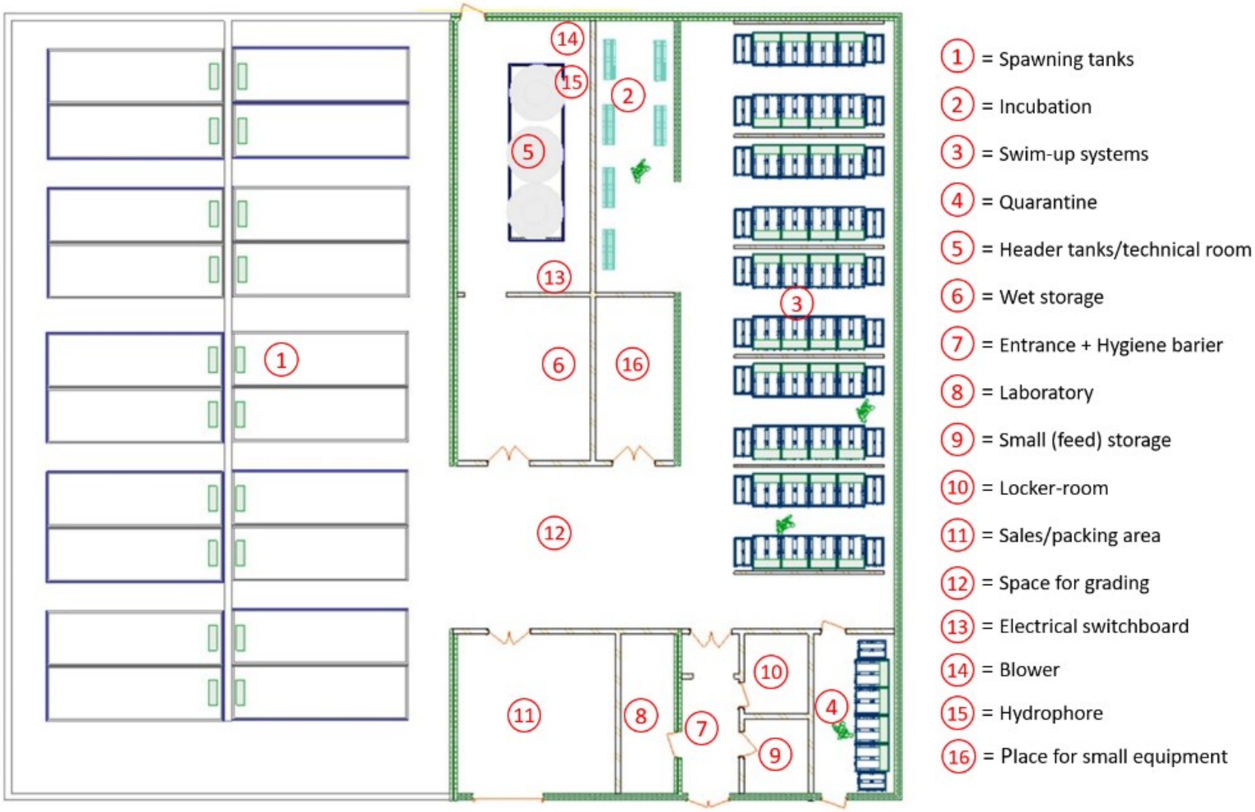


Figure 21 Overview of the indoor hatchery

Spawning tanks (1): For the production of 5 million advanced fry, 20 spawning tanks of 8x2.5 meter are required. These 20 tanks should be constructed from concrete, with 2 tanks against each other. This way each tank is accessible on one side to drive all fish to the front of the tank, where the eggs and larvae can be collected. These spawning tanks do not need to be covered under a roof; a shade net is sufficient.

Incubation (2): This is where the incubation systems are placed and the eggs are artificially hatched.

Swim-up systems (3): 20 Swim-up systems are placed (10 rows of 2 systems next to each other). Each system consists of 2 fish tanks and a sedimentation besides the system.

Quarantine systems (4): There are 2 quarantine systems for the reception of new broodstock when fish from other facilities is taken in (see chapter 6.2 about procurement of broodstock).

Header tanks / technical room (5): This is the place where the header tanks are placed that supply the whole hatchery with water. In this room also the filters (sand filter and UV filter) are placed that treat the water before it is pumped into the header tanks. The electrical switchboard should be placed in the technical room, just as the blower for the central aeration system. Also the hydrophore for pressure to clean the systems should be placed in this technical room. The room has an exit door, from the inside to be used as an emergency-exit and from the outside only accessible with a key.

Figure 22 Header tanks for water supply (example from tilapia hatchery in Costa Rica)

Wet storage (6): This is the place where all equipment that is used in the hatchery such as graders and nets should be stored. There should be a disinfection place where all equipment can be disinfected.

Entrance / hygiene barrier (7): A physical barrier at the entrance to prevent people from walking in without proper disinfection first.

Laboratory (8): The hatchery needs to have a laboratory where water quality can be measured and where a microscope is placed to perform health checks on larvae and larger fish. This laboratory should consist of a desk with a microscope, a sink with running water for cleaning equipment and a desk with a computer for administration.

Small feed storage (9): A small storage for open bags and a few bags for weekly usage of feed. For daily feeding small feeding buckets should be used that are filled for daily use, and can be easily taken to each fish tank for feeding. The larger storage of feed should be in a separate building.

Locker room (10): This is the place where employees can change clothes, store working clothes and have a personal locker for clean clothes and personal belongings during work in the hatchery.

Sales / Packing area (11): This is the place where the advanced fry are packed in transport containers or handed over to clients. The entrance door to the inside (place 12) should be a one-way door, only to be opened with a key from the “outside” side to prevent any client or other worker to enter the hatchery through this door without passing the disinfection at the entrance. The outdoor door should be a cargo door for easy access with for example a forklift or a car to transport the advanced fry to the hapas for further growth until fingerling size.

Space for grading (12): This area should be free to use as a space for grading the fry, for logistic processes of advanced fry going to the sales area, etcetera.

Electrical switchboard (13): All pumps and essential equipment in the hatchery need to be connected to an electrical switchboard. Each pump should be connected to its own switch. This switchboard should give an alarm when an electrical system is using more electricity than normal, indicating that a pump is broken or not running properly. This alarm should send a message by telephone to the facility manager when a switch is turned, or when all power breaks down. It could be connected to an acoustic alarm and/or light alarm inside the farm that can signal something is not going well. Not only the water pumps in the fish systems need to be secured, but also other essential equipment like the water pump that fills up the header tanks and a blower that is supplying the air to all systems. In figure 24 a floorplan is drawn with indications for all sockets that need to be secured to this switchboard.

Figure 23 Example of electrical switchboard

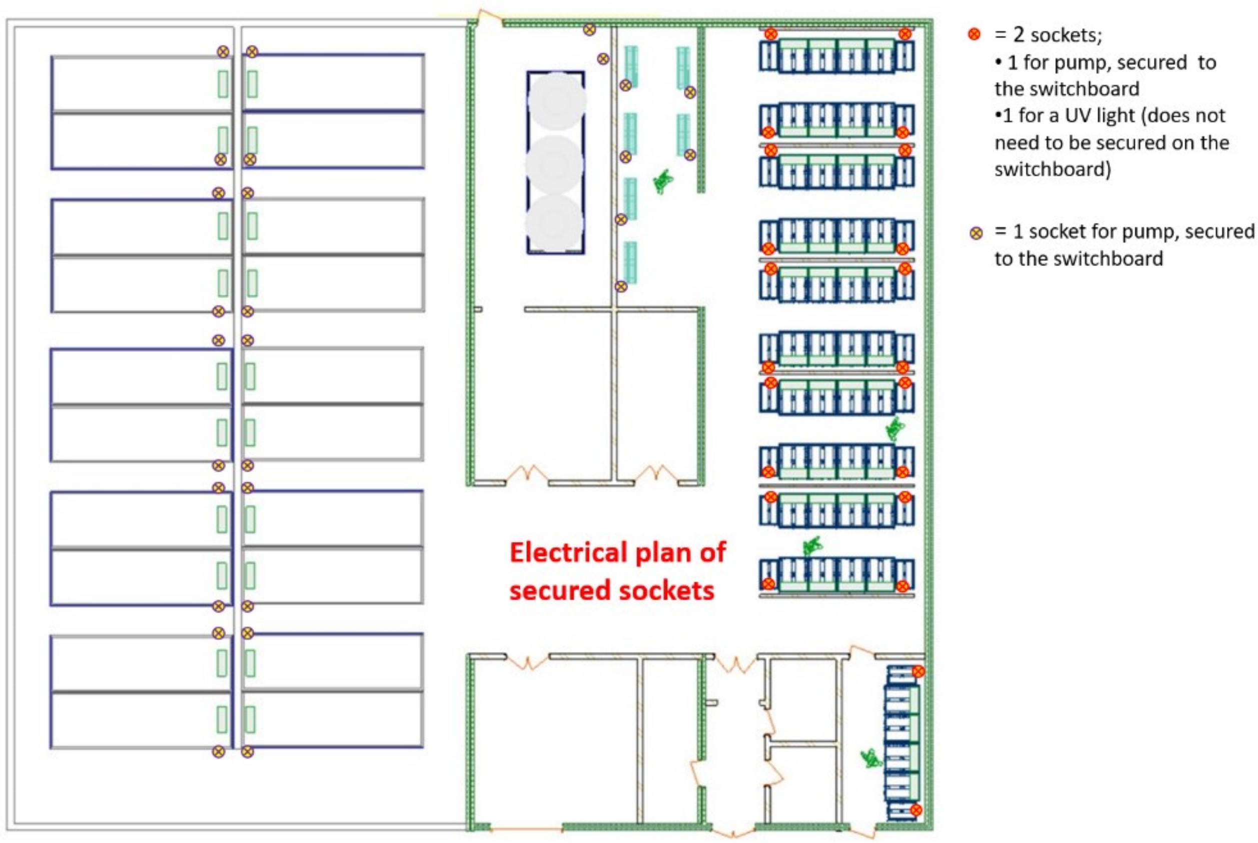


Figure 24 Overview of all locations with a secured socket

Blower (14): All swim-up systems need to be equipped with an air stone in each tank as a back-up in case the water flow into the tank is stopped. This can be because during grading the water flow is stopped to drain the tank, but it is also a back-up in case a pump breaks down. The best way is to install a central blower which is keeping a central aeration pipeline under pressure in the whole farm, to which each system is connected (see figure 25).

Figure 25 Layout for piping of the aeration of the farm

Figure 27 Root blower for air supply to all systems

Figure 26 Air stone for aeration in each tank

Hydrophore (15): For merely refreshment of the systems, the pressure of the header tanks should be sufficient. For cleaning, however, there should be a hydrophore to give some more pressure to clean the sedimentation tanks, nets, floor, etcetera.

Figure 28 Hydrophore for higher pressure for cleaning

Place for small equipment (16): This area is reserved for equipment that is needed in daily work and needs to be kept dry, such as a balance, feeding buckets, towels for drying hands, papers and forms.

Doors: Some of the doors should be one-way doors (see figure 42 for floorplan with indication of all one-way doors). This can be realized by using emergency-doors, preventing people to use the doors in two directions. To be opened with a key from the outside, but from the inside with a normal grip.

Figure 29 Example of a one-way door switch that can only be opened with a key from one side.

Light: The incubation as well as the swim-up area needs light 24 hours a day. LED is advised. High densities of fish are stocked in these systems. When it is dark the fish go to the bottom of the tank and oxygen depletion may occur. The spawning area does not need any artificial light. The broodstock need a normal day-night rhythm for good spawning.

Figure 30 Led TL light

3.3 Drawings

3.3.1 Broodstock (actual, re-design, upgrade)

Broodstock are animals that are used for reproduction. Female tilapia can spawn continuously, as long as the temperature is above 24°C. A female breeds the eggs in her mouth. As a result, the female is forced to starve during this breeding period, as she cannot eat and keep the eggs and larvae in her mouth at the same time. After spawning it is therefore important to feed the spawning fish well, in order for the females to recuperate fast. The younger a female, the faster it is recuperated and able to produce a new nest. The longer females are in production, the more time it takes before a female is able to produce a new nest. Older females are larger, on the other hand, and subsequently produce more eggs.

When a group of young new broodstock is placed into production, the production improves during the first few months. After about 5-6 months the spawning group has reached its optimal production. After this, the production per tank will slowly decline. One spawning group can be used for approximately 9 months to a year, after which the production has declined to a level that it is more economical to replace the broodstock. Because of this variation in productivity, it is advised to have more spawning groups of different age classes. This way not all broodstock needs to be replaced at the same time, making the overall production of all broodstock more stable. Figure 48 shows the production of more spawning groups together.

The spawning hapas need to be placed in concrete tanks with a water depth of 80cm. The hapas are 1.1 meter deep, keeping the sides of the hapas 30cm above the surface. This prevents the fish from jumping out of the hapa when all fish are caught together for the harvest of eggs. The hapas need to be mounted to a steel cable that runs from the front to the backside of the tank. Each tank should have its own small recirculation pump that pumps the water over a small trickling filter. Because of the relatively low density in the spawning tanks, and because of the usage of the hapa, a sedimentation tank is not necessary for these tanks. All waste will settle underneath the hapa. The water is only pumped over a small trickling filter for degassing and oxygenation. By using this small RAS technique of aeration of the spawning tank for the broodstock, the water quality for the broodstock can be better controlled and oxygen levels are always good. If the water of the spawning tanks becomes too turbid (which can be measured using a Secchi disk), some more refreshment water should be added. A spawning tank should be completely drained and refilled with clean water every 3 months. In order to prevent a peak in labour and undesired changes in production, it is best to flush two tanks each harvest. Male tilapia are used to dig a hole on the bottom of the pond and defend this as their territory. In a concrete tank with a hapa, it is impossible for the males to dig a hole. As an alternative, earthenware pots can be placed in the hapas on the bottom of the tank.

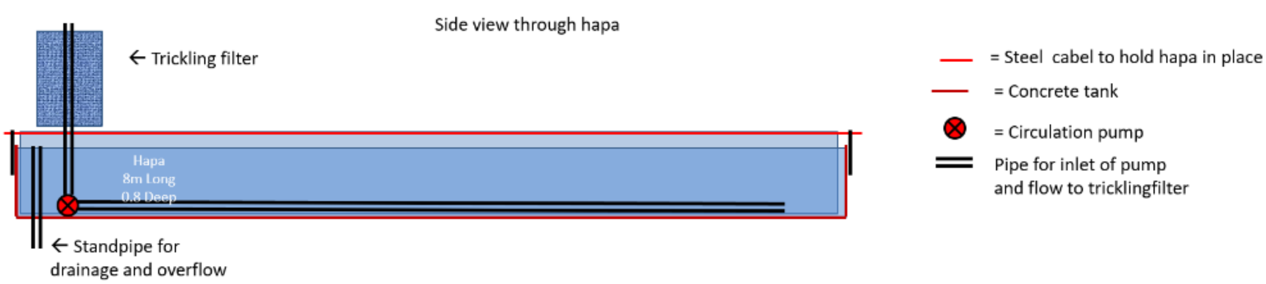


Figure 31 Schematic overview (sideview) of a spawning tank with pump and small trickling filter

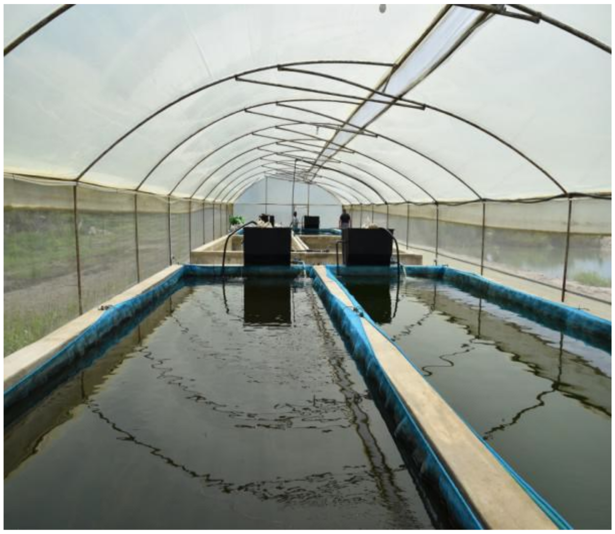


Figure 32 Spawning tanks with individual filter system, placed in a greenhouse

3.3.2 Nursery (actual, re-design, upgrade)

As described in earlier chapters of this report the new nursery will consist of incubation and swim-up systems. The last part of the growth of the advanced fry to fingerlings (the last part of nursery before the grow-out phase) happens in Rachel hapas outdoors.

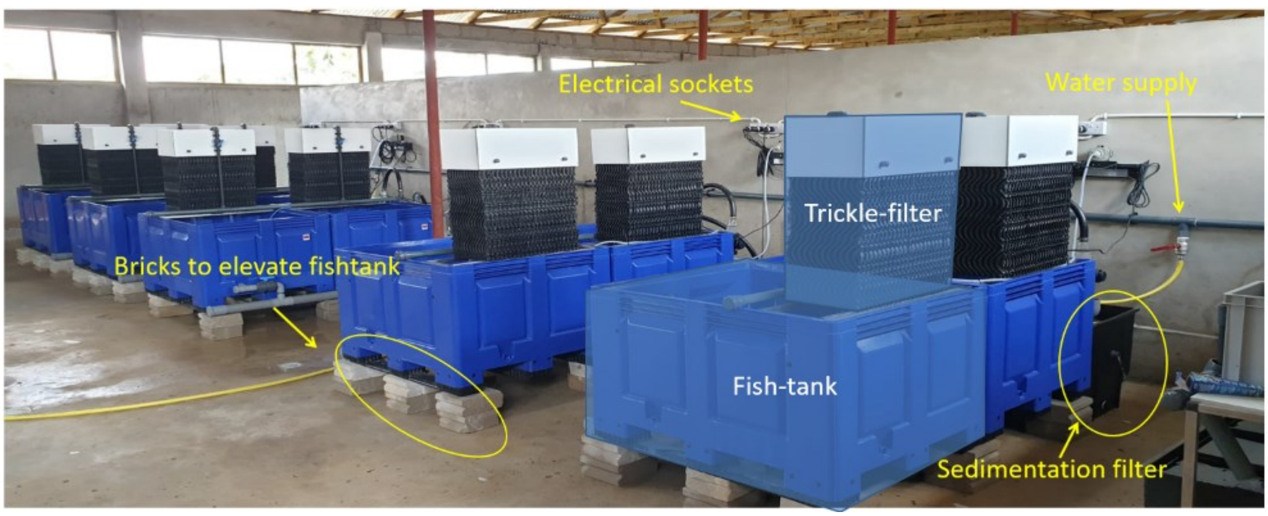


Figure 33 Overview picture of swim-up systems with indications of different elements (Tanzania)

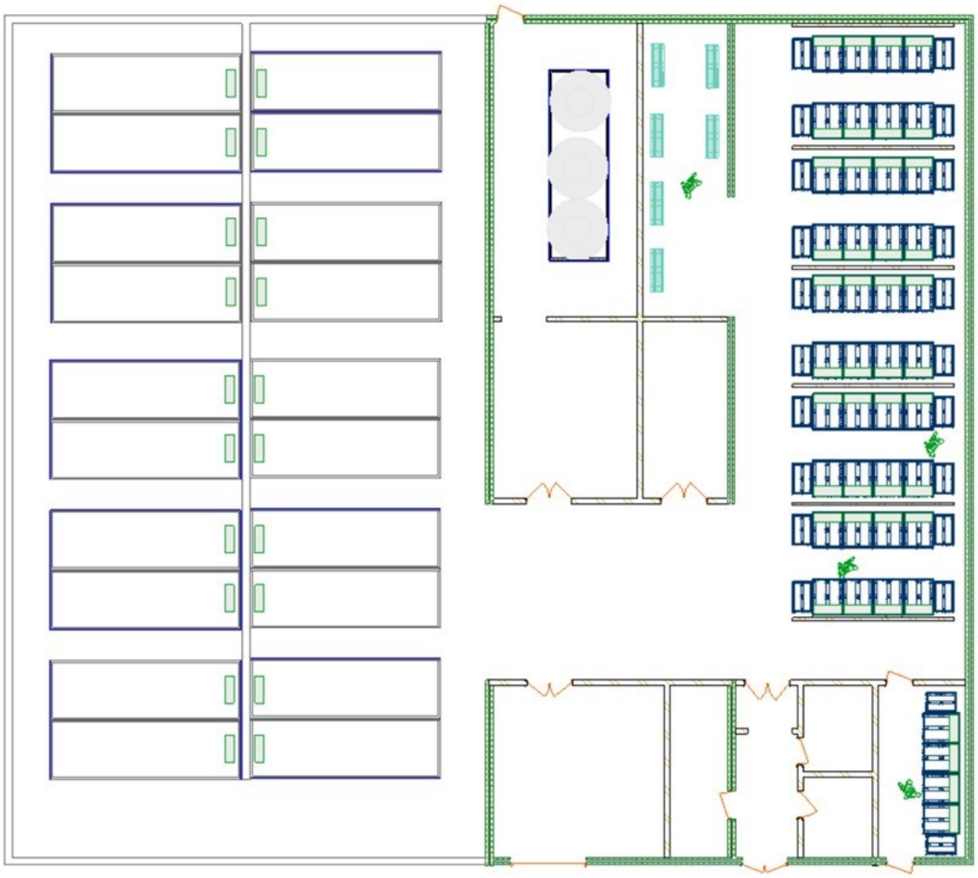


Figure 34 Floorplan of the indoor hatchery

3.3.3 Grow-out ponds (actual, re-design, upgrade)

All grow-out ponds need to be lined with a liner to fix the leaking. The outlet of the ponds needs to be equipped with a monk, with a sump for complete drainage. The bottom of the ponds should have a slight slope towards the outlet of the ponds. With a proper liner and a slight slope towards the outlet, the sludge can be flushed out when the ponds are drained. With good cleaning of the sludge from the ponds, the growth of filamentous algae can be prevented. To optimise the production of the ponds, it is advised to equip each pond with an aerator. The Rachel hapas (for the growth of fingerlings from 1 to 50 gram, as described in chapter 3.2), that need to be placed in the outdoor ponds, need to be mounted to steel cables. These cables should be hung from one side of the pond to the opposite side, so no poles need to be placed inside the ponds, as these poles might be a high risk of causing pond leakage.

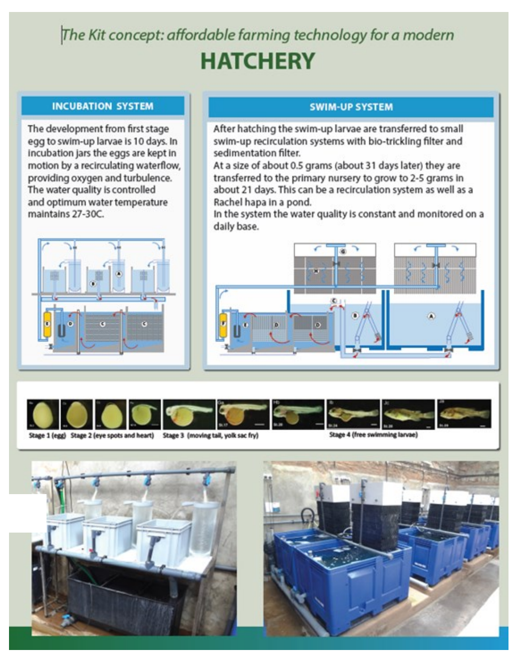


Figure 35 The Kit Concept

Figure 36 (Spawning) Hapas hanging on steel cables in a concrete pond

3.3.4 Supporting infrastructure water, electricity etcetera

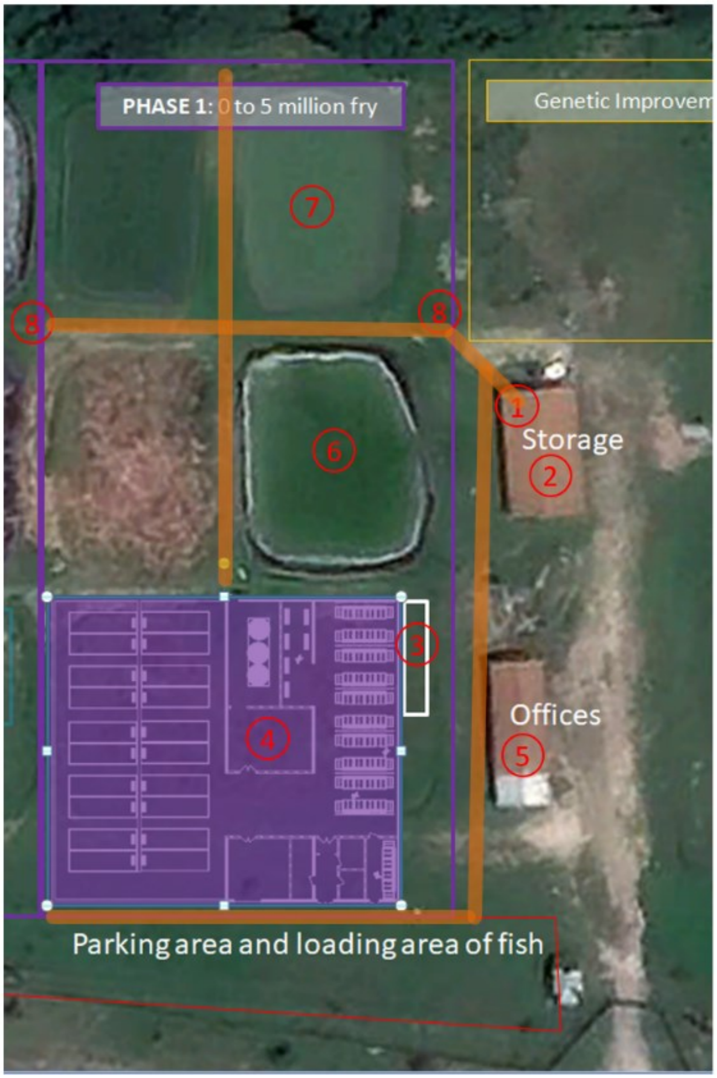


Figure 38 Overview supporting infrastructure

Figure 37 Generator for emergency power supply

(1) Emergency generator: In case of a general power cut, an emergency generator should take over the power supply automatically to supply the whole farm with power. This is a very important element in the facilities of any fish farm using RAS systems. The density of fish in the systems is relatively high. If there is no flow of water and no aeration in the tanks and the tank is full with advanced fry ready for sales, the fry can suffocate because of lack of oxygen within fifteen minutes. The eggs in the incubation system will start to die within a few minutes. This is because without a water flow, all the eggs will sink to the bottom of the incubation jars, and all eggs on the bottom do not get any fresh water, and the oxygen level will decrease very fast, depending on the amount of eggs in the jar. This is why each system needs to be connected to an electrical switchboard with an alarm. It is highly advisable to let this hatchery be delivered with full electrical connection equipment. In this case all wall plugs, cables and the electrical switchboard are delivered and installed with the systems. The electrical switchboard with thermal switches is advised for each system. In case a pump takes too much power due to e.g. a clogged water inlet, the thermal switch closes, shutting down the pump. A signal is sent to an indicator light in the switchboard and outside the hatchery to a light and a horn (e.g. in the staff building). This will save the pump. The whole switchboard has to be protected by surge protectors to prevent power spikes damaging the equipment.

It is recommended to install a solar system on the roof of the hatchery (about 500 m^2) large enough to deliver the maximum power usage per hour during daytime.

(2) Feed storage: The total hatchery uses approximately 6 tons of broodstock feed/year, and 2.5 tons of starter feed. As the quality of the feed decreases with a long shelf life, it is recommended to store not more than needed for 6 months of feeding. This means the feed storage should be large enough to store about 4-5 tons of feed. This feed storage needs to be dry and rodent-free, and needs to be locked.

(3) Water storage: To supply the header tanks with water, a water storage of at least $40m^3$ needs to be installed, which is large enough to cover two days of normal water usage of the hatchery. This water storage can be filled with borehole water coming from the canal. Because the borehole pump is not running 24h/day, this water storage can be filled during the day, so that enough water is available in case the borehole pump is not running or when a pond is filled closer to the borehole, and less water is running to Twickenham Park 2 of the site. As the borehole water is exposed to sunlight in the open canal, it is best to filter the water with a sand filter and UV, before it is pumped into the header tank. The water storage tank should be covered to prevent sunlight from entering the water, as this will cause algae growth. As this water storage will function as a large pre-sedimentation, where solids can accumulate, it is advised to clean this water storage tank once a year.

Figure 40 Covered water storage (Costa-Rica)

Figure 39 Sand-filter and UV-light

(8) Gates with key access: The whole hatchery has to be fenced. Inside the Twickenham Park 2 facility there should be a fence around the hatchery itself. For security and for the workers who need to feed the grow-out ponds, the outdoor area needs to be accessed through a gate with a locked door.

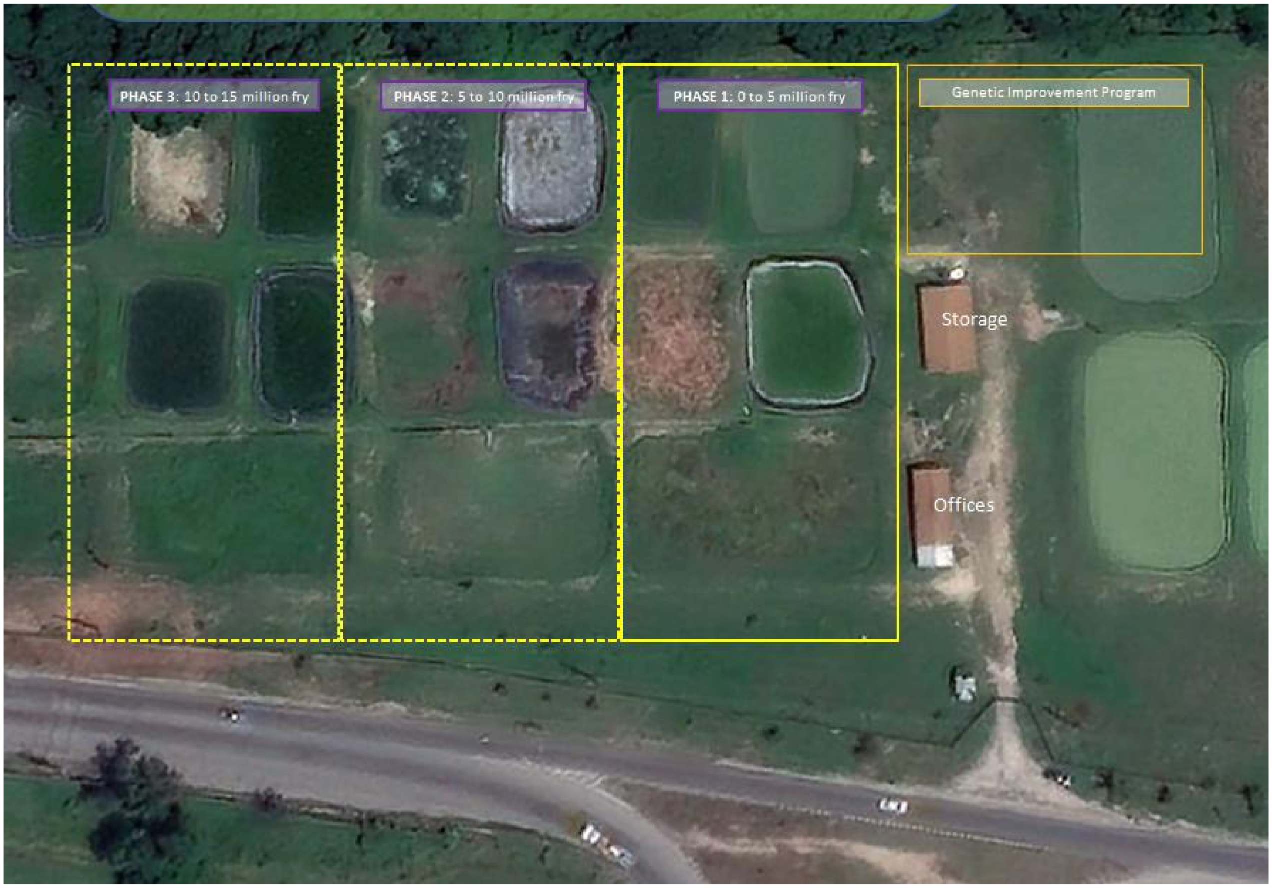


Figure 41 Yellow lines indicate the fencing around each phase

Feed availability: When fry have just been hatched, they start their first days of growth by absorbing their yolk sac. During these days the mouth of the fry is already open, and the fry starts to begin eating feed that it can find in its surroundings. When the fry are just starting to eat, they do not actively swim to the feed, but simply eat whatever they find during their swimming. Only after about 7-10 days the fry are able to swim actively towards the feed when the fry are fed. It is during these first days that the intestines of the fry are developing, and a bacterial population in the intestines is developed. The better the quality of the feed given in these first days, the better the larvae develop and the better their growth performance is during the grow-out phase. It is very important that a good quality starter feed is available. The best starter diet for swim-up fry has a size of 0.2-0.3mm for the first weeks, has a high protein content of >45%, and is rich in minerals and vitamins. It is this diet that should be used for mixing the hormones. After the first two weeks, a "larger" feed of 0.3-0.5mm can be used for the fry. After two weeks the fry already weigh 0.1 gram, which is 10 times larger than when they started feeding as swim-up fry.

Outdoor walkways: All walkways outdoors, from the hatchery to the offices, to feed storage and outdoor ponds, need to be paved in order to prevent any mud from shoes to spoil the floor of the hatchery, feed storage or offices.

Gutters: For the discharge of all wastewater from the systems, and any water that is spilt on the floor, a gutter should be made on the outer side of the rooms. This way all waste can easily be flushed into the gutter, keeping the working floor clean and dry. To optimally collect the (waste)water, the floor should have a slope downwards towards the gutter. A decrease in height of 1-1.5 cm per meter would be sufficient. The outlets that are in front of the systems are to be aimed towards this gutter.

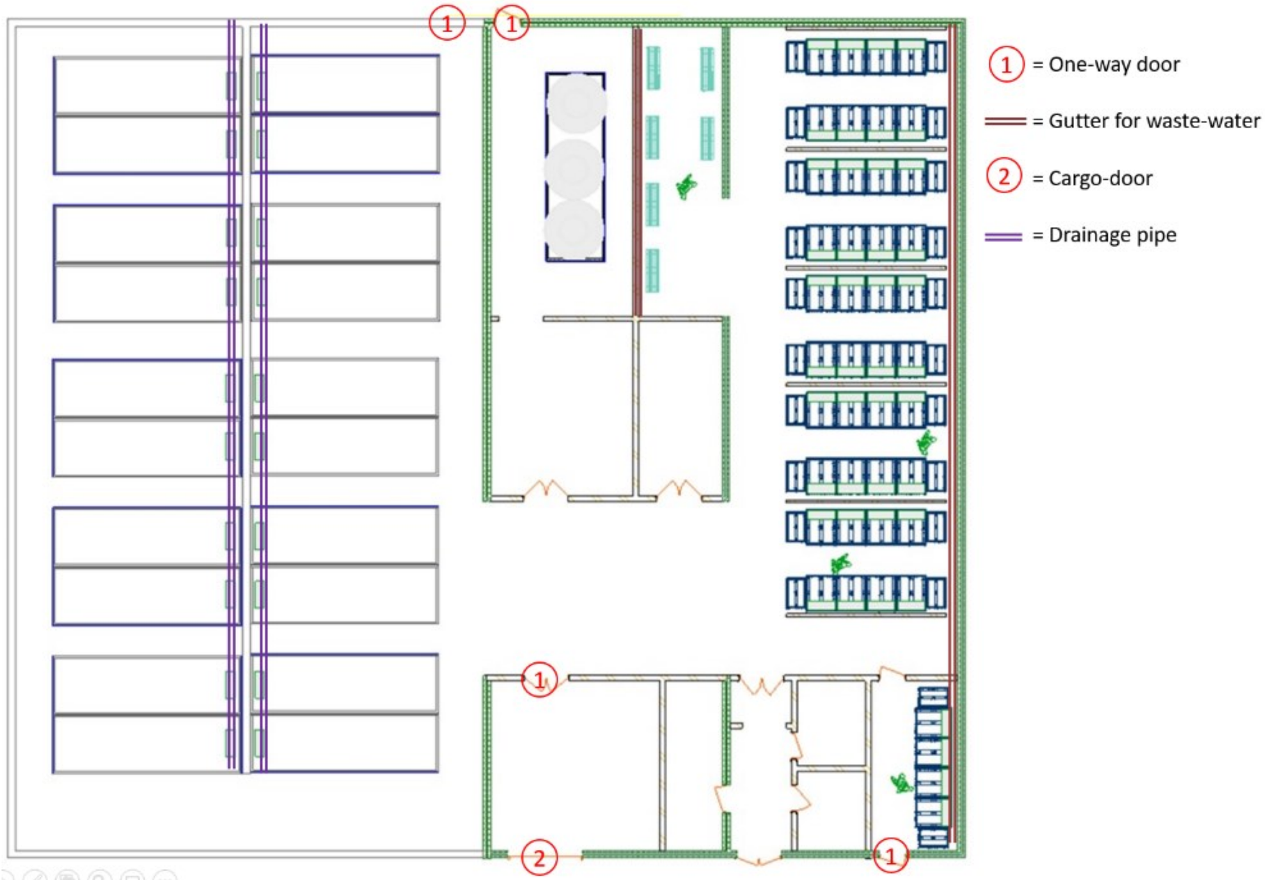


Figure 42 Overview of gutters and drainage pipes

Fences and cover nets: The whole hatchery needs to be fenced, and the outdoor part, with the spawning tanks, needs to be covered with a shade cover.

Figure 43 Shade netting and fences of a hatchery in Costa Rica and Mali

Helophyte /reed bed filter: The wastewater from the total farm should be pre-filtered before it is flushed into the canal flowing into the Rio Cobre. More details about this reed filter are described in chapter 4.2.

Figure 44 Example of a reed filter with several small reed ponds

PART IV D- 4.2 MANAGEMENT AND OPERATIONAL PLAN FOR THE HATCHERY

4 Management and operational plan for hatchery

4.1 Operational & technical measures on climate changes

In the current situation the whole farm is exposed to weather conditions outside. Workers that need to collect the fry from the spawning ponds are directly exposed to the heat of the sun. When there is heavy rainfall, all production facilities are exposed to the rain. With the changing climate, it can be expected that rainfall will become more severe and extreme, while there will also be periods of no rainfall and extreme heat. During periods of extreme heat and no rainfall the water temperature in the spawning ponds, and especially in the sex-reverse nursery ponds, can reach critical values. High water temperatures can have an influence on the sex ratio of the larvae. It is known that some strains of tilapia are more sensitive than other strains, but extreme temperatures can cause more variation in the sexual development of the fish, causing the effect of the hormone treatment to go down, resulting in a lower male ratio.

This might not only happen during periods of less rainfall, but the opposite can happen as well. During heavy rainfall the temperature of the water in the ponds might drop to quite a low level. Especially if the ponds run the risk of extra water coming in from the surroundings of the ponds. There is even the possibility of contamination of the ponds due to polluted water running in from the surrounding area. By working in concrete tanks that are placed above ground level, the risk of contaminated water running into the tanks is strongly reduced.

By using well water and RAS systems, the production is independent of the availability of surface water, which can be limiting during dry periods. The usage of RAS systems further reduces the amount of water needed for the production of fingerlings.

By working with closed systems in concrete ponds, workers do not need to stand inside the ponds to collect larvae and be exposed to the burning sun while they collect eggs, nor are they exposed to heavy rains during feeding and handling fish. The most vulnerable fish, the swim-up larvae, will be stocked in an indoor facility.

Taking climate change into account, it can also be expected to have more severe storms and hurricanes passing the Caribbean area, causing heavy damage to the local infrastructure. To be independent of the local infrastructure, an emergency generator can function as a back-up in case the local power grid is broken. This is also why the roof of the hatchery should be covered with solar panels. This way the production of fingerlings will not be influenced by a hurricane passing the facility. When fingerling production is not influenced by extreme weather, other farms that suffer damage from a hurricane, can restart their activities quickly with new fish, making the food supply to the local market of Jamaica less vulnerable.

4.2 Biological and ecological risks between hatchery and environment

One of the most important risks from a tilapia hatchery to the environment is the escapees of fry to the environment, as described in chapter 3.1.1. By using hapas in the spawning tanks, the fry cannot escape from the spawning facilities. The use of small RAS systems prevents the escape of larvae during the nursing phase. The use of RAS systems also reduces the amount of hormone feed needed for the fry, causing less hormonal effluent water to be flushed from the hatchery. In addition, the use of chemicals for disinfection of systems and equipment can also be a risk to the direct environment of the farm.

These risks are tackled by the construction of a helophyte filter pond (also called reed filter) where the wastewater is flushed into, before going to the NIC canal, ending in the Rio Cobre. The plants (reed) in the helophyte filter will break down dissolved organic waste (ammonia, nitrite, nitrate) and solids will settle in the helophyte filter. Any chemicals used in the hatchery for disinfection will bond to the organic material in the helophyte pond. Any remains of testosterone that are flushed away with the waste from the hatchery will be exposed to sunlight en will bind to the organic material in the helophyte filter. The water from the helophyte filter does not form any risk for the environment anymore. Any small larvae that manage to escape from the hatchery will be trapped in this reed filter. The longer the retention time of the water in this reed filter, the better. Therefore a large reed bed is advised of at least 1,000m^2.

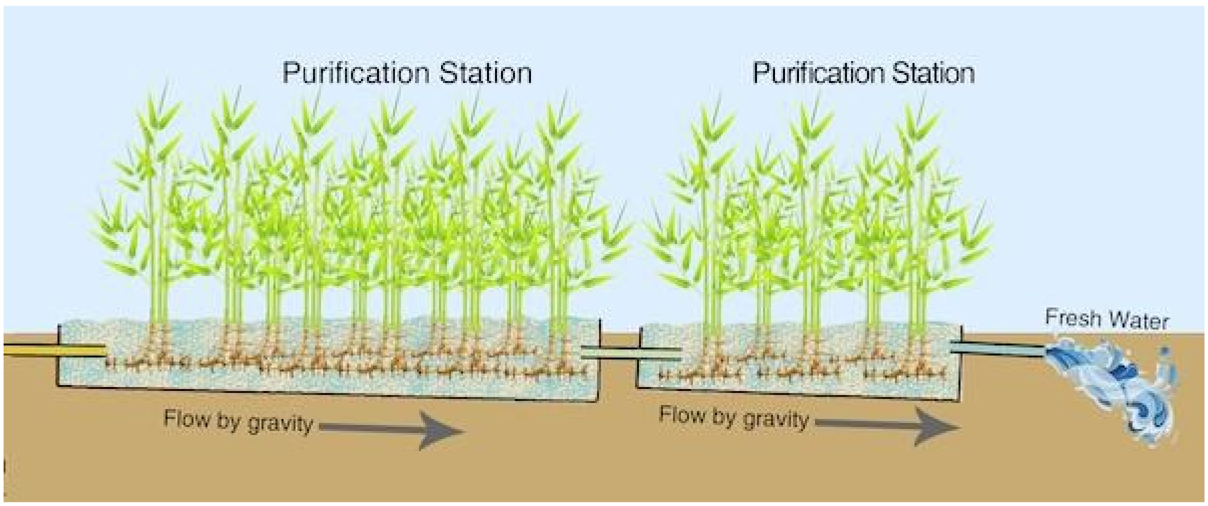


Figure 45 Flow diagram of wastewater through a reed filter

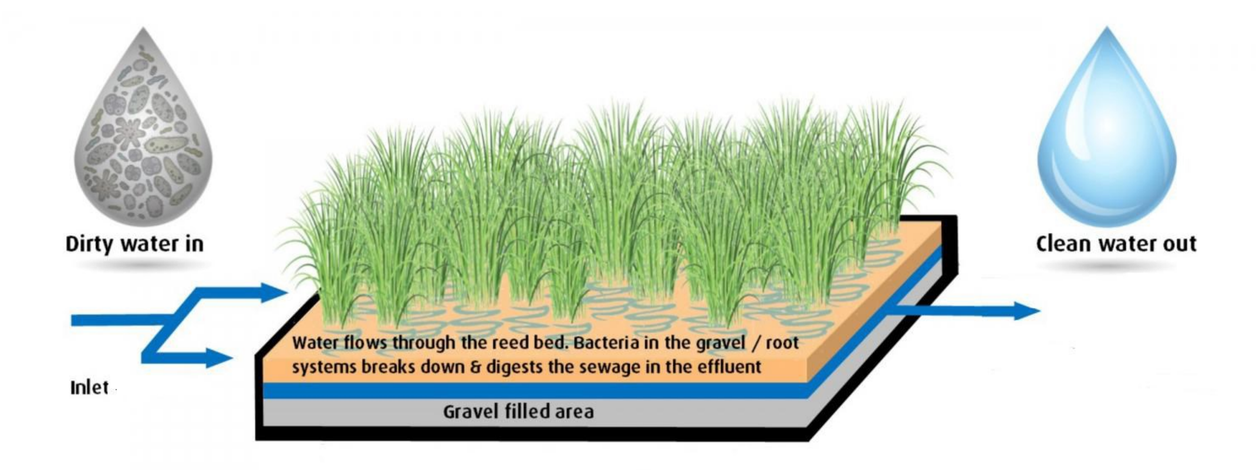


Figure 46 Principle of biological water treatment through a helophyte filter

4.3 Hatchery objective & tasks (function related)

The hatchery consists of several different units. There is the spawning area where eggs are collected, the incubation area where the eggs are hatched, the nursery where the swim-up fry are fed and graded, and there is the outdoor facility where new broodstock is grown for production. Each unit should have specialized workers that are dedicated to that unit. There should be a central hatchery manager that is responsible for the technical and operational process of the hatchery that reports to the site manager.

The staff requirements for the complete hatchery are:

- 1 Hatchery manager (also responsible for the purchase of materials and feed and transfer of fish to the nursery cages; reports to overall manager)
- 2 Hatchery workers (indoor, for the swim-up systems and incubation)
- 2 Hatchery workers (outdoor, for the spawning tanks)
- 1 Hygiene worker (also water quality and parasite control)
- 1 Maintenance worker

The hatchery manager is responsible for the planning and the production of the advanced fry, from broodstock until the fry are sold, and is the manager of all personnel working in the facility. He or she gets the numbers of order from the staff in the office, and consults with the sales staff when orders are ready for transport. The hatchery manager is also responsible for the proper collection of all production data. He or she should have a master's degree in aquaculture.

For the collection of eggs and larvae, two workers are needed. These workers are responsible for the maintenance of the spawning tanks, for feeding the fish and collecting the eggs and larvae, and for production data collection. These workers should have a basic education, but do not need to have a master's degree. All tanks need to be harvested for eggs every ten days. The best way is to clean 2 tanks each harvest. The broodstock needs to be fed twice a day, once in the morning, and once early afternoon (as spawning broodstock is most active during the late afternoon, it is best to disturb the spawning tanks as little as possible at this time). Broodstock needs to be fed 2-3% of their bodyweight /day. Just after the collection of eggs a little more feed should be given, as the spawning females have been starving for several days. Just before the egg collection (harvest), when many females (>30% of the females) have eggs in their mouth, feeding level can be reduced. The outdoor workers also help with the selection of the new broodstock, and with the harvest of the grow-out ponds.

In the indoor hatchery where the incubation and swim-up systems are placed, a minimum of 2 workers are needed to maintain the systems, feed the larvae, and grade the fry. These workers are also responsible for packing the fry and transport preparations. As these workers will be working with the RAS systems, they will need to be trained about the principals of RAS and about management of swim-up fry. A specific master's degree in aquaculture is not essential, but some experience in fish farming or education in aquaculture is necessary. After harvesting the eggs, the non-fertilised eggs will break down within the first 48 hours after placement in the incubation system. On average about 30% of the youngest eggs, from which no development can be seen at the moment of harvest, will not be fertilized. They will need to be flushed out of the incubation system.

After each cycle, the incubation systems need to be completely cleaned and disinfected before a new batch of eggs is placed inside. The same goes for the swim-up systems. These should be used in an all-in-all out manner, meaning fry coming from an incubation system needs to be placed in a clean and disinfected system. It is therefore important that fry are checked for parasites and treated if necessary, before they are placed in a clean environment.

The fry need to be graded regularly to make sure no shooters are present, and that the small fry of a batch of larvae get a better chance to grow after grading. The size variation is a result of normal variation and social interactions. By grading, the larger, dominant fish are separated from the smaller less dominant fish, and the social interaction will re-establish. As the larger fish are taken out with the grading, the smaller ones get a second chance to become the best fish of the group.

4.4 Improvements on current operation

(Also described in chapter 3.2.3.)

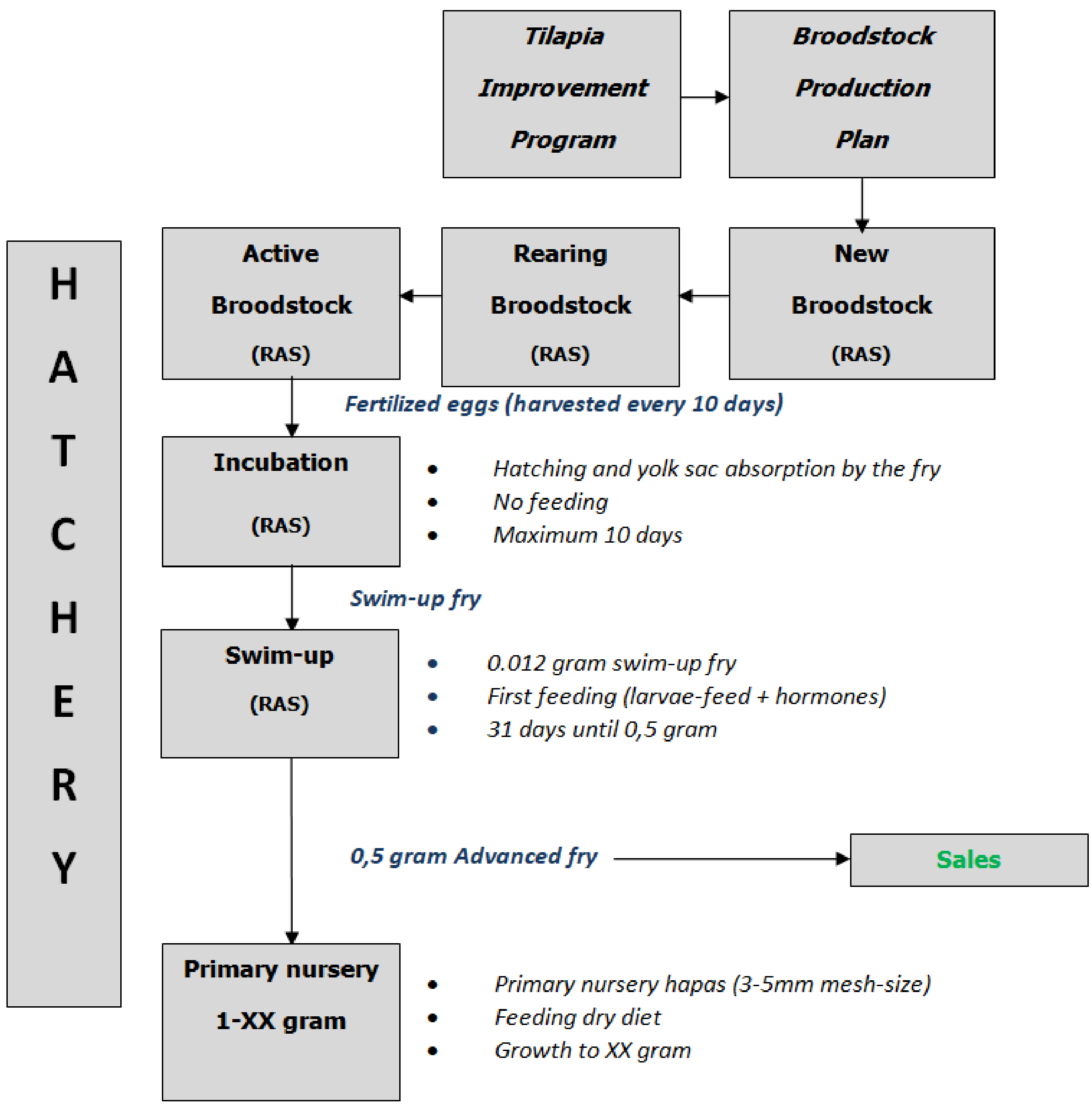


Figure 47 Production schedule of new operational flow

4.5 Broodstock management, strategies and procedures

For optimal production, egg collection should take place every 10 days. During the harvest the nests should be divided into 4 different groups of development. Stage 1 - eggs without visible development, stage 2 - eggs with clear development visible, but still eggs and not yet hatched, stage 3 - hatched larvae with a large yolk sac, which are not yet capable to swim up from the bottom by themselves, and stage 4 - free swimming larvae that can swim to the surface.

The reason for this distinction in development is to keep the groups of eggs and larvae as homogenous as possible in age class. With a very homogenous age class, the hormone treatment can always be started at exactly the right moment. Not all tanks should be harvested on the same day, splitting the spawning tanks into two groups of 10 spawning tanks a day, with about 5 days difference in egg collection between these two groups. This is not only better for the peak in amount of work when the eggs and larvae are collected, but this also gives a better distribution of eggs and larvae in the incubation and swim-up systems. When broodstock is placed in production for the first time, when the females are young, females do not produce many eggs. Because of the age of the females, however, they recover relatively quickly from a spawning and breeding cycle, and are able to spawn a new nest soon, sometimes even within 10 days. To keep the spawning interval short and to guarantee high survival, the broodstock should be harvested every 10 days and the collected eggs and larvae need to be artificially incubated in an incubation system.

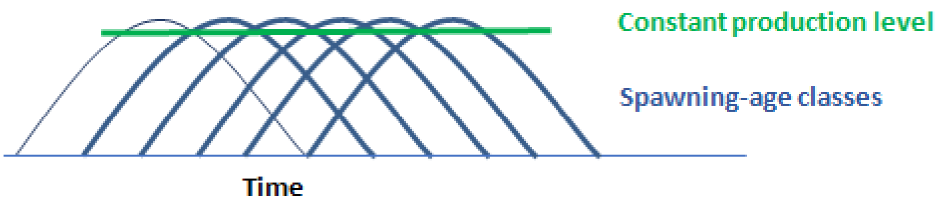


Figure 48 Spawning overview of several age classes of broodstock together

4.6 Fish health management

To secure animal health and separate a location from potential sources of infection, measures based on management and biosecurity have to be taken.

Biosecurity, as mentioned by the OIE (World Organization for Animal Health), means the set of management and physical measures designed to mitigate the risk of introduction of pathogenic agents into, or spread within, or release from, aquatic animal populations. The OIE Aquatic Animal Health Code establishes the standards for improvement of aquatic animal health worldwide as well as the standards for the welfare of farmed fish and the use of antimicrobial agents in aquatic animals. Biosecurity plays a key role in their recommendations.

The members of the WTO (World Trade Organization) formally recognise the recommendations of the OIE as the standard for animal health, zoonotic diseases and animal welfare. Jamaica has been a member of the WTO since 9 March 1995 and is thus held to adhering the recommendations of the OIE.

OIE WORLD ORGANISATION FOR ANIMAL HEALTH
Protecting animals, preserving our future

Biosecurity: essential for fish health

Since very few effective treatments are available for most aquatic animal diseases, effective biosecurity is the key to preventing these diseases. Especially hatcheries play a key role in biosecurity. By selling their seed, they can spread diseases all over the country or even all over the world. But also the introduction of new diseases onto a farm can have a devastating impact. Mass mortality may occur, and if certain pathogens are associated with the facility, it may consequently be unable to transport the fish to other farms or locations, resulting in a dramatic loss of market access.

To reduce the probability that a pathogen will infect the fish population on a farm, especially a hatchery, or negatively impact the surrounding farms or environment, biosecurity plans have to be developed. An effective biosecurity plan is tailored to a specific farm site, is adaptable, is based on local disease threats and avoids environmental insults.

There are a few routine key points in a biosecurity plan that are worth mentioning:

- It is important that effort is made to ensure that no pathogens are introduced into the farm from vehicles, visitors, staff, equipment or newly purchased fish.
- If possible, incoming water should be treated for pathogens using ultra-violet radiation or ozone. This is usually only practically possible in hatcheries or land-based recirculation systems where a relatively small volume of water is being treated. This is also the part of the production cycle where biosecurity is especially important, as juvenile fish are particularly susceptible to disease.
- Effective hygiene and disinfection procedures must be developed at each point ensuring that the appropriate disinfectant at the required concentration and contact time is being used.
- Appropriate hygienic protective clothing should be available for staff and visitors. Visitor control should include written assurance that they have not had any recent contact with other potentially infected animals.
- Appropriate predator and pest control must be in place as predators and rodents can also present a biosecurity risk.

Farm biosecurity audits and risk assessments should be made on a regular basis and appropriate control measures should be put in place at each risk point. All elements of the biosecurity program must be adequately monitored, documented (e.g. replenishment or replacement of disinfectant foot baths on a regular basis) and adapted if necessary.

Current biosecurity status government hatchery

At this moment the biosecurity level of the government hatchery is not sufficient. The biggest problem seems to be the lack of hygiene procedures (Project: Community-based climate resilience in fisheries sector – Jamaica, D3 – Seed production plan, Chapter 6.4).
For all identified shortcomings with regard to the biosecurity of the current hatchery, a solution is described in the new government hatchery design, offered in this report. Local circumstances are taken into account in the recommendations.

Biosecurity in the new design of a government hatchery and operational plan

The new government hatchery elaborated in this report has a modular structure. One modular unit has been set up to produce up to 5 million advanced fry. The active broodstock is kept under a shade net in hapas in concrete tanks. Incubation of the eggs and rearing of the fry up to 0.5 gram takes place indoors in small recirculation units. This most sensitive reproduction process from spawning up to advanced fry of 0.5 gram is completely enclosed and separated, and is considered as the indoor hatchery area. The rearing of new broodstock and further growth of unsold advanced fry for ongrowing takes place in ponds that are not freely accessible. These ponds and the indoor part of the hatchery together form a completely enclosed unit. See figure 6 and figure 21 for a detailed drawing of one module (phase 1) and the specifications of the indoor part of the hatchery. The hatchery area for genetic improvement is discussed in chapter 6.5.

The biosecurity measures for a whole modular unit (phase 1, for the production of 0-5 million fry) are described below and are focused on the current omissions found. Also costs and benefits are considered in the advice regarding biosecurity measures. In the case that fry production is increased, the module and described procedures can simply be copied to meet the higher production.

Water source

The incoming water is derived from a well, which normally is less risky than surface water. However, water sampling from the well shows a fecal coliform level of 920 MPN/100ml (Project: Community-based climate resilience in fisheries sector – Jamaica, D3 – Seed production plan, Chapter 9.7). The presence of fecal coliform bacteria indicates that the water has been contaminated with the fecal material of man or other animals. Improper sewage systems are most probably the cause.

The hatchery's water should be pathogen free to insure a high larval survival. The incoming water for the indoor part of the hatchery is therefore treated by the use of a sand filter and UV light (see figure 21, point 5). The pond area receives water directly from the well by the canal system. The fish in the ponds are considered to be more resistant than the swim-up fry in the indoor hatchery. Moreover, treating the volume of water to the ponds will be too costly. Therefore, this water does not require treatment.
The wastewater discharge from the indoor part of the hatchery and the ponds of the modular unit has to be treated to an acceptable level to reduce risks of spread of disease or contamination to the environment (Rio Cobre). Also the escape of (infected) cultured fish has to be prevented. See Chapter 4.2 for details on the treatment of wastewater.

Fish movement

The movement of fish into, within or off the farm is the greatest risk factor for disease introduction and spread:

- There is no purchase of new broodstock, so there is no risk to introduce important diseases from this side. A quarantine in the hatchery is foreseen (See figure 21, point 4) in case this changes in the future. If the quarantine system is not used, it can be stocked with swim-up fry.
- Movement of fish within the farm should be practiced as much as possible by the 'all in all out' principle, providing the opportunity to clean and disinfect regularly. For broodstock, year classes have to be separated. The fry is stocked in small swim-up systems (see figure 21, point 3 and figure 15) that can be emptied, cleaned and disinfected every month.
- To reduce the risk of spread of diseases off the farm, only healthy, well graded fish is delivered to clients in cleaned and disinfected transport containers and vehicles.

Fish health and husbandry
Infection and disease on the fish farm can result in direct loss, but also indirect loss like reduced growth rates, reduced feed conversion efficiency and reduced product quality. Keeping up an optimum fish health will lead to an improved ability to fight off infections of all kinds.

Optimum health is achieved by the following husbandry measures:

- The susceptibility of fish to disease is greatly influenced by *stress*. Stress is minimized by maintaining appropriate stocking densities (see factsheet 41), excellent water qualities (see factsheets 5, 7, 14, 15, 16, 18 and 19) and gentle fish handling (minimize mucus and scale loss).
- Provide a *proper nutrition*. This includes storage in a cool, dry and secured place (see page 33, feed storage; figure 6, storage and figure 21, point 9). Spilled feed is cleaned up to keep out vectors. The feed is used within 3-6 months.
- Fish has to be *monitored* frequently by personnel and the manager is called immediately when fish appear to be sick. Sick fish are examined in the laboratory (see figure 21, point 8). Antibiotics are only used based on veterinary advice and according to the dosage and for the full treatment period to avoid resistance (see factsheet 12 and 42). The fry in the indoor hatchery has to be checked regularly (weekly) on parasites, since the resistance against parasites is still low during the first month of their life and sometimes quick action is required (see factsheet 52).

Figure 49 Swim-up fry underneath the microscope for parasite control

- *Dead or dying fish are removed* at least twice a day, as disease can spread through water and can also spread when healthy fish consume dead or dying fish infected with pathogens. Dying fish should be euthanized humanely (head blow, cold water or clove oil). Dead fish should be *buried or burned* to prevent the spread of disease.
- Accurate *record keeping* helps to maximize production efficiency and detect disease problems, often already in an early or subclinical stage. Record keeping includes at least:
  - disease and mortality registration
  - parasite control registration
  - dates and treatments
  - growth and feed conversion ratios
  - fish movements on or off farm

Farm traffic: persons, animals, vehicles, equipment
Most diseases are transmitted by contaminated equipment like nets, buckets and shoes. But the number one way in which diseases move on and off the farm is through people. *This topic is the biggest hazard on Twickenham Park farm at this moment and it therefore needs much attention.*

The following protocols should be adopted to minimize the risk of contamination:

- Twickenham Park 2 is completely fenced with one controlled access point and visitor registration. Vehicles for supply of goods (e.g. feed) or for fry deliveries to customers are allowed to enter but their wheels and undercarriage are disinfected by passing through a bath at the gate entrance.
- There are restricted areas on the farm, indicated by signs. These are the indoor hatchery, the pond area in the modular unit and the genetic improvement area (see figure 6). They are treated like mini-farms and completely separated with restricted movement of employees. These areas have their own equipment to which chemical disinfection is applied before being used in another location.

Figure 50 Warning sign

- The indoor hatchery has one entrance from the outside. To enter the hatchery from the corridor a step-over bench has to be passed where clean boots are provided. Hands are washed and disinfected and then a foot dip with a disinfectant marks the actual entrance of the indoor hatchery. Only a limited number of well-trained employees work in the indoor hatchery and they have to wear clean clothing or coveralls. In the locker room a visitor's logbook is maintained. Visitors may serve as vectors for the introduction of disease. They should wear clean coveralls and disinfected or disposable boots. They are not allowed to visit the hatchery unattended and they are restricted from contacting water or handling the fish.

Figure 51 Hand sanitizer

Figure 52 Example of physical hygiene barrier

- The pond area of the modular unit can be entered by a gate with a foot bath (See figure 37, point 8). Scrub brushes are provided to remove physical debris from footwear. A clothing and footwear protocol should be established. Visitors, if allowed, follow the same protocol.
- Living animals can spread disease agents. Fish preying birds can carry pathogens on their body or feet or drop fish or fish parts at other locations. Domestic animals or rodents can travel between locations. As a result, bird nesting sites have to be minimized and dogs, cats and livestock should not be allowed on the farm. Grass and weeds should be trimmed around ponds fences and buildings. Feed spills are to be promptly cleaned up, just like waste and dirt. A rodent control plan has to be implemented.

Figure 53 Dead rats from an aquaculture system (Mali)

- Avoid

the use of porous construction materials or the use of wood for any working equipment. These materials cannot be properly cleaned and disinfected.

- If employees have to visit other aquaculture farms (fry deliveries), it is wise to visit only one farm a day. If that is not possible, the farms with the lowest risk are visited first.

Ideology behind the indoor hatchery construction in relation to biosecurity (see figure 21)

- The hatchery entrance is secured with a hygiene barrier (7).
- The concrete spawning tanks (1) are equipped with hapas that make it possible to harvest without going into the water.
- The area with the active broodstock (1) is connected with the incubation (2) and swim-up area (3). This guarantees a quick and clean transport of the harvested materials from the spawning tanks to the incubation and swim-up systems.
- Incubation and swim-up are completely protected indoors (building) as this is the most sensitive part of the reproduction. The spawning area is secured and covered by a fence and shade nets. In this way, broodstock still benefits from daylight, essential for good spawning results.
- The swim-up area (3) consists of 20 2-tanks small recirculation systems, easy 'all in all out' followed by cleaning and disinfection.
- The laboratory (8) is reachable from outside, so also fish from the pond area or genetic improvement area can be examined if needed without passing through the inside of the indoor hatchery.
- The packing area for the advanced fry to be sold (11) has a locked cargo door to deliver the packed live tanks with advanced fry to vehicles on the parking place in front of the door. The inner door to the inside of the hatchery is locked. So customers cannot enter the inside of the hatchery this way.
- The quarantine room (4) can only be opened from the inside to receive fish from outside if needed or to dispose fish to the outside.
- The technical room (5) has a one way emergency door to the outside.
- The spawning area has a receiving window or door (see figure 42, point 1) at the side of the pond area for scooping nets with new broodstock to restock the tanks if broodstock has to be changed.

Cleaning and disinfection

Many disease causing agents can survive in the environment for variable amounts of time. For this reason equipment such as nets, buckets, scales, boots, but also vehicles and tanks can serve as a potential source of disease transfer between facilities or units within a facility. To avoid disease transmission any equipment used at aquaculture facilities should be cleaned and disinfected before being reused in other locations, and even in another system on the same location (indoor hatchery). Fish tanks or ponds should be cleaned and disinfected between each lot of fish.

A proper cleaning and disinfection protocol for equipment, including fish tanks, should contain the following steps:

- Remove dirt and organic matter (e.g. high pressure hose): organic matter can inactivate the disinfectant
- Wash/scrub with soap and water
- Rinse
- Apply appropriate disinfectant at the proper concentration and duration

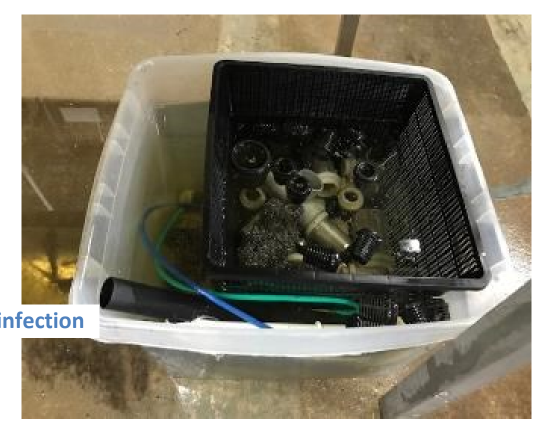


Figure 54 Overnight disinfection

- Rinse again to remove any toxic residues (hydrogen peroxide naturally breaks down quickly in water and oxygen)

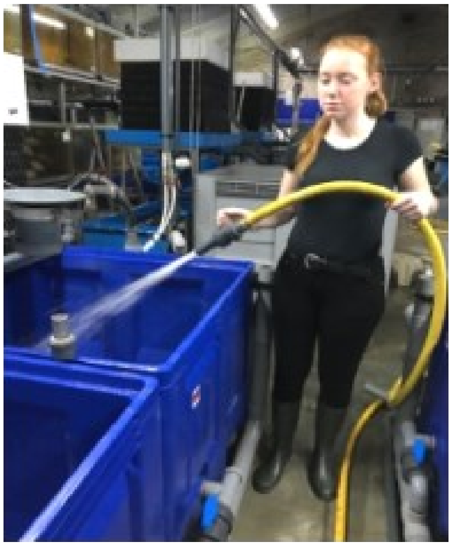



Figure 55 Rinsing of disinfected equipment

- Dry (if possible under the sun): drying can also destroy a number of fish pathogens
- Store nets and other equipment off the floor

Figure 56 Hanging equipment like nets and brushes to dry

- Sand filters can be washed and disinfected at regular intervals. After flushing the sand is removed to dry in the sun or replaced according to the instructions of the supplier.
- Vehicle cleaning should include the wheel wells, tires and undercarriage. The washing area should be on-site, away from the fish production area. The interval is between fish lots or farms.

Foot or wheel baths are placed near the entrance to all animal areas. Scrub brushes are provided in dirt areas to remove visible debris from footwear prior to use the footbath. As noted before, organic matter inactivates the disinfectant. Foot and wheel baths are checked regularly to ensure they are still clean. The disinfectant has to be replaced at least according to the instructions on the label.

Figure 57 Disinfection foot bath

Figure 58 Liming of a pond

Ponds should be drained, cleaned (flushed), disinfected by liming and dried in the sun for at least 3 days between each lot of fish. Liners in a pond need a good quality UV resistance to support the sun.

Overview of common disinfectants:

Disinfectant	Concentration	Duration	Comments
Benzalkonium Chloride	250-500 ppm	10-30 min	Plastics, floors, footbaths, walls, equipment and furnishings
Didecyl dimethyl Ammonium chloride	400 ppm	5 min	Plastics, floors
Phenols	2%-5% active ingredients	10-30 min	General disinfection
Chlorine	200-500 ppm	10-60 min	All surfaces except plastic; When cleaning tanks, disinfect for 24 hours, neutralize, rinse and dry; Highly toxic for aquatic animals
Ethyl alcohol	70%-80%	10-30 min	Hands, tools, work surfaces
Isopropyl alcohol	60%-80%	10-30 min	Hands, tools, work surfaces
Iodine	100-250 ppm	20-30 min	Antiseptic on tissues; follow product label instructions if using for egg surface disinfection; Highly toxic for aquatic animals
Hydrogen peroxide	3%-35% (weight percentage 3%-5%	5-30 min 5-15 min	General disinfection For fish tanks: 1-2 L/m3, overnight (use 35% H_2O_2) Follow label instructions to treat fish or disinfect eggs
Virkon® Aquatic	0.5%-1% or 50-100 g per 10 L of Water	10-15 min	General disinfection; Commonly used for footbaths
Chlorhexidine (most solutions contain 2% active chlorhexidine	Add 100 ml to 1 L of water for Disinfection	5-10 min	General disinfection; Commonly used for footbaths
Calcium carbonate (lime, $CaCO_3$)	Raise pH>10;		Used for fish tanks and ponds; Base: 1 kg/m³ water for fish tanks 200 g/m² burnt lime for ponds

Sources: -Bowker JD, Trushenski JT, Gailkowski MP and Straus DL, eds. 2014. Guide to using drugs, biologics, and other chemicals in aquaculture. American Fisheries Society Fish Culture Section.
-Yanong RPE and Erlacher –Reid C, 2012. Biosecurity in aquaculture, Part 1: An overview. SRAC Publications No. 4707
-Own experience

Formalizing the biosecurity
It should be defined who is responsible for which step in the above described biosecurity measures. Operational procedures have to be documented and actions have to be recorded. The effectiveness has to be evaluated periodically and measures can be adjusted accordingly. Training and awareness of the employees and staff form an indispensable part of the success of a biosecurity plan.

Disclaimer
All described biosecurity items above are based on the general biosecurity measures by OIE and adapted to the special situation at Twickenham Park Farm, as found during the conducted preliminary investigation.

And last but not least:

- Implementation of the biosecurity measures outlined in this document will not guarantee a farm to be safe from disease outbreaks. It provides the farm with the best defenses available for minimizing the risk of disease outbreak.
- A biosecurity plan should be a highly flexible document that allows for modifications as new knowledge is gained, conditions have changed or farm practices are improved.
- A biosecurity plan is only as effective as the effort made to implement it.

4.7 Maintenance management of hatchery and infrastructure

Regular daily work:	Feeding Registration of mortality (and removal of any dead fish) Registration of any abnormalities
Weekly work:	Clean and disinfect empty systems (both incubation and swim-up systems) Harvest spawning tanks Clean 2 spawning tanks Grading fish Check parasites (2x/week) Flush sedimentations of swim-up systems (3x/week) Replace disinfectant in foot baths and disinfection tanks for nets and other equipment Refill daily feed buckets Check water quality (2x/week)
Monthly work:	Check emergency generator (let it run for >10 minutes) Check feed storage and order new feed if necessary Check storage of chemicals and disinfectants Check if all UV lights are still OK, and replace light if necessary
Yearly work:	Clean water storage tank

5 Business plan on the economics of the climate smart facility

5.1 Market, sales and forecasts

The expected market for advanced fry for the next 5 years is 6.5 million today, growing to 20 million advanced fry in 2025. If the governmental hatchery takes 35% of this market share, the governmental hatchery should be able to produce 5.0 million advanced fry in 2025. In this assumption it is taken into account that the private hatcheries in Jamaica are able to grow in production as well in order to fulfil the total demand of 20 million advanced fry in 2025. If the other hatcheries do not grow in production, this would mean an even larger market share for the governmental hatchery, meaning the governmental hatchery should be able to produce the 5 million advanced fry even before 2025 (see Report D3 chapter 4.1, seed demand in Jamaica).

There is already a waiting list for advanced fry, as the current hatcheries do not meet the total demand for fry. If this situation continues, this will raise the price for advanced fry. This lack of production capacity for advanced fry, in combination with the expected growing market for tilapia, makes the forecast for prices and sales of advanced fry very positive. In the financial model it is calculated that a small portion of the production of advanced fry is sold as a slightly larger fish, and are grown to 5 gram fingerlings within the outdoor hapas.

5.2 Capital expenditures and operating expenses

Assumptions for the financial calculations:

Summary Fish Farming — v15 v2

HATCHERY		advanced fry (0,5g)	fingerling (5 g.)
Annual fish production	kg	**2500**	**1,500**
	pieces	5,000,000	300,000
		kg fraction 63%	kg fraction 38%
Annual fry sales		**18,800,000**	**12,000,000**
Annual operating expenses		9,840,632	5,904,379
Annual taxs and interest		3,560,370	2,136,222
Net profit after tax & interest		**5,398,998**	**3,959,399**
Annual production costs		costs per fry	per fingerling
broodstock or seed		0.3	3
feed		0.2	2
electricity and water		0.4	4
labour		0.6	6
other		0.1	1
depreciation and interest		0.6	6
corp tax		0.5	5
Cost price of production		**2.8**	**27**

PROPERTY		
Needs	JMD	%
Building and infrastructure	26,340,000	55%
Hatchery system	14,696,000	31%
Broodstock system	3,920,000	8%
Fixed assets	**44,956,000**	
Working capital	3,080,000	6%
Financing needs	**48,036,000**	100%

PROPERTY			
Contribution	JMD	%	
Shareholders' equity	-	0%	
Loan capital, bank long term	22,478,000	47%	50%
Other funds	-	0%	
Equity privat capital, operation	25,558,000	53%	
Financial contribution	**48,036,000**		

Technical and Financial assumptions Farming

ITEM	Units	Value phase 1	phase 2
Tank size (approx. liters)	liter	400	15000
Stocking weight (average)	g/fish	**0**	**0.5**
Harvesting weight (average)	g/fish	**0.5**	**5**
Survival rate	%	90%	80%
Number of fry stocked / tank	#	12222	8000
Number of fry harvested / tank	#	11000	6400
Number of tanks (or equavalent units)	#	40	10
Production cycle fry	days	30	60
Production cycles/Year	#	12	5
Additional time (buffer capacity), smaller batches	+	5%	6%
Total number of fry 0,5 produced per year	#	5,000,000	300,000
Broodstock sets in production	JMD/set	500	
Broodstock sets (3:1), replacement (yearly)	sets	500	
Tilapia start meal 55-15	412	75%	20%
Tilapia start #1 , #2 55-15	412	25%	80%
Tilapia start 1,5 mm, 2mm 50-15	266	0%	0%
Tilapia hi 45-16 2,5	235	0%	0%
Feed price average (price and volume ratio)	JMD/kg	412	412
Feed Conversion Ratio (FCR)	#	1.00	0.85
Annual feed consumption	kg	2,500	1,275
Water use	JMD/m3	24	
Oxygen price (bottles)	JMD/kg	50	
Oxygen rental	JMD/month	n/a	
Labour	JMD/h	400	
Labour	number	7	
Electricity price	JMD/kWh	47	
Electricity usage	kWh/h	7	0

ITEM	Units	Value	
Estimated Fees & License	JMD/yr	150,000	
Estimated Insurance (1% of 75% turnover)	JMD/yr	231,000	
Estimated property taxes (0,5%)	JMD/yr	26,880	
Miscellaneous expense (% Tot. Revenue)	%	1	
Interest on operating capital	%	7.5	
Interest on long-term capital	%	7.5	
Employee fringe benefits	%	20	
Beginning working capital	JMD	3,080,000	
Water use	m3/hour	1.7	0.4
Pieces produced per year	#	5000000	300000
Total kg of fish produced per year	kg	2,500	1500
Harvesting price (bases of sales)	JMD/ piece	-	4.0
Sales price per fish		4.0	40
Sales of fish numbers	#	**4,700,000**	**300,000**
Turnover fry / fingerlings	JMD	**18,800,000**	**12,000,000**
		advanced fry	fingerling
Average standing stock	kg	116	162
Grants on the hardware investment	%	0%	
Foreign long-term capital (investment)	%	50%	

Expenses and Cost price

ANNUAL EXPENSES:	Total cost	Fixed Cost	Variable cost	Per live kg	Percent total cost	Percent total Rev
Annual broodstock renewal	250,000		250,000	63	1%	1%
Feed broodstock	1,447,970		1,447,970	362	8%	5%
Feed fry and fingerlings	1,553,790		1,553,790	388	9%	5%
Electricity	2,891,445	2,891,445		723	17%	9%
Water	440,570	440,570		110	3%	1%
Oxygen	-		-	0	0%	0%
Gas / Heat	-		-	0	0%	0%
Employee wages	5,040,000	5,040,000		1260	29%	16%
Employee fringe	50,400	50,400		13	0%	0%
Fees & Licenses	150,000	150,000		38	1%	0%
Insurance	231,000	231,000		58	1%	1%
Property Taks	26,880	26,880		7	0%	0%
Miscellaneous expenses	-		-	0	0%	0%
Maintenance & Repairs	172,500	172,500		43	1%	1%
				0		0%
Depreciation	3,413,867	3,413,867		853	20%	11%
Interest on operational capital	76,591	76,591		19	0%	0%
Total Operating Expenses	**15,745,011**	**12,493,252**	**3,251,760**	**3936**	**90%**	**51%**
Interest expenses long term capital	1,685,850	1,685,850		421	10%	5%
Total Expenses	**17,430,861**	**14,179,102**	**3,251,760**	**4358**	**100%**	**57%**
Net profit before taks	13,369,139			3342		**43%**
Taxes (corp rates %)	4,010,742			1003		13%
Net profit after tax & interest	9,358,397			2340		30%

Investment and Depreciation & Maintenance assumptions

Item Description	Initial investment	Est.Life (years)	Annual Depr (SL)	Repair and Maintenance	Salvage value 5 years
Hatchery building	5,376,000	20	268,800	5,376	4,032,000
Broodstock shade structure	3,584,000	20	179,200	3,584	2,688,000
Facilities and storages building	5,376,000	20	268,800	5,376	4,032,000
Broodstock tanks (concrete)	6,144,000	20	307,200	6,144	1,536,000
Electric infrastructure and generator	2,400,000	15	160,000	2,400	1,200,000
Water infrastructure, ventilation and storage	2,000,000	15	133,333	10,000	1,000,000
Liner broodstock and fingerling ponds and fencing	1,460,000	15	97,333	1,460	730,000
Solar unit with battery pack	-	15	-	-	-
Subtotal building and infrastructure	**26,340,000**		**1,414,667**	**34,340**	**15,218,000**
Mounting / installation and prof services hatchery	2,400,000	10	240,000	-	120,000
Transport & Import Hatchery	1,200,000	10	120,000	-	60,000
Broodstock hapas nets (outside)	160,000	5	32,000	1,600	40,000
Incubation systems	1,400,000	10	140,000	14,000	700,000
Swim-up systems	6,400,000	10	640,000	64,000	3,200,000
Aeration system hatchery	640,000	7.5	85,333	6,400	160,000
Control panel and electrical items hatchery	800,000	10	80,000	8,000	400,000
Pre-growout hapas for pond	176,000	5	35,200	1,760	44,000
Farm equipment hatchery	400,000	7.5	53,333	4,000	100,000
Laboratorium equipment	560,000	7.5	74,667	5,600	280,000
Spare parts	560,000	5	112,000	5,600	140,000
HATCHERY	**14,696,000**		**1,612,533**	**110,960**	**5,244,000**
Mounting / installation and prof services grow out	800,000	10	80,000	-	40,000
Transport & import	400,000	10	40,000	-	20,000
Bassins Broodstock hapa nets	320,000	5	64,000	3,200	80,000
Water treatment of broodstock tanks	1,600,000	15	106,667	16,000	800,000
Piping system broodstock tanks	320,000	10	32,000	3,200	64,000
Control panel and electrical items	240,000	7.5	32,000	2,400	120,000
Farm equipment broodstock handling	240,000	7.5	32,000	2,400	120,000
BROODSTOCK	**3,920,000**		**386,667**	**27,200**	**1,244,000**
Subtotal hatchery and broodstock	**18,616,000**		**1,999,200**	**138,160**	**6,488,000**
Funding /support grants	**-**	**0%**			
Total investment	**44,956,000**		**3,413,867**	**172,500**	**21,706,000**

5.3 Cashflow operation

Cash Flow Analysis for five year planning horizon

Item	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Output in terms of % of capacity	0%	80%	90%	100%	100%	100%
Product volume number of fry	0	3,760,000	4,230,000	4,700,000	4,700,000	4,700,000
Price JMD/fry ~ annual increase of 2,5%	**4**	4.0	4.1	4.2	4.3	4.4
Revenu advanced fry		**15,040,000**	**17,343,000**	**19,751,750**	**20,245,544**	**20,751,682**
Output in terms of % of capacity	0%	50%	90%	100%	100%	100%
Product volume number of fingerlings	**0**	150,000	270,000	300,000	300,000	300,000
Price JMD/fingerlings ~ annual increase of 2,5%	**40**	40	41	42	43	44
Revenu fingerlings	+	**6,000,000**	**11,070,000**	**12,607,500**	**12,922,688**	**13,245,755**
Annual turnover		**21,040,000**	**28,413,000**	**32,359,250**	**33,168,231**	**33,997,437**
Fixed expenses		9,079,385	9,079,385	9,079,385	9,079,385	9,079,385
Variable expenses	+	2,601,408	2,926,584	3,251,760	3,251,760	3,251,760
Incremental cash expenses		**11,680,793**	**12,005,969**	**12,331,145**	**12,331,145**	**12,331,145**
Depreciation		3,413,867	3,413,867	3,413,867	3,413,867	3,413,867
Net before tax revenu		**5,945,341**	**12,993,165**	**16,614,239**	**17,423,220**	**18,252,426**
Est. income tax 30%	30%	1,783,602	3,897,949	4,984,272	5,226,966	5,475,728
After tax cash flow		**4,161,738**	**9,095,215**	**11,629,967**	**12,196,254**	**12,776,698**
Add back depreciation		3,413,867	3,413,867	3,413,867	3,413,867	3,413,867
Net operation cash flow		**7,575,605**	**12,509,082**	**15,043,834**	**15,610,121**	**16,190,565**
Initial investment	44,956,000					
Change in working capital	3,080,000					
Estimated Salvage Value						21,706,000
Book value						27,886,667
Gain (loss)						6,180,667
Tax increase (decrease)						5,475,728
Net cash flow						27,181,728
Changing working capital						3,080,000
Terminal year non operating cash flow						**30,261,728**
NET CASH FLOW	**48,036,000**	**7,575,605**	**12,509,082**	**15,043,834**	**15,610,121**	**46,452,292**

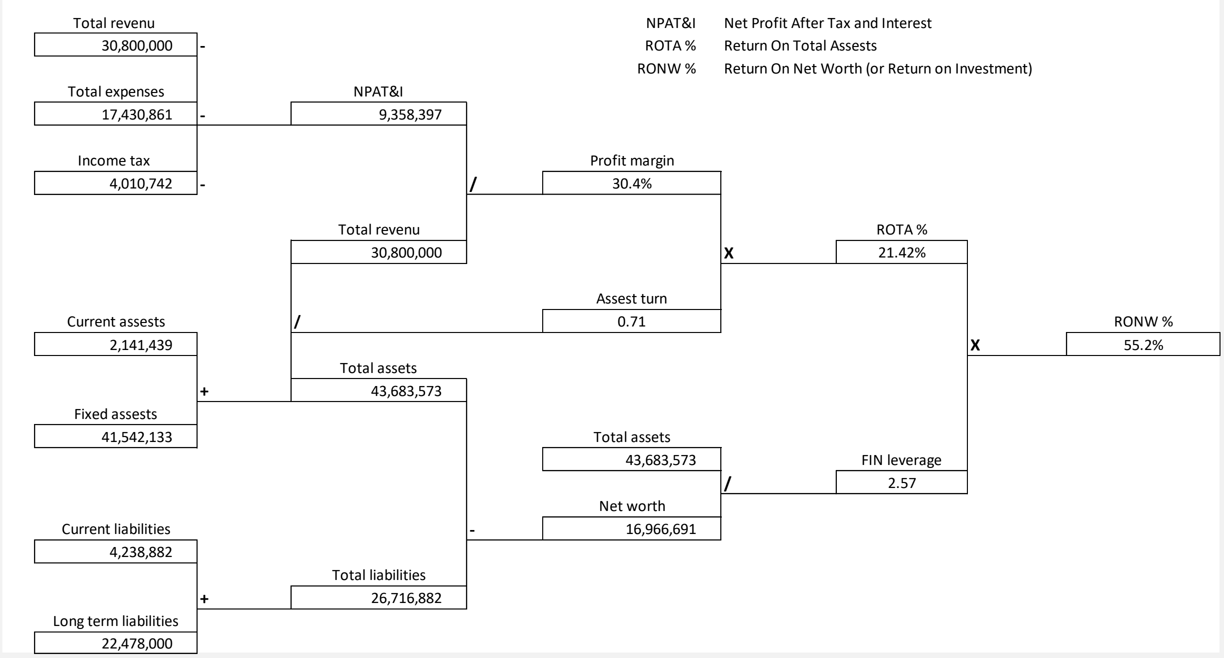
Year one ending pro-forma balance sheet

ASSETS			EQUITIES		
Cash		-	Accrued expenses		-
Accounts receivable (5% of yearly turnover)		2,566,667	Accounts payable 16%		2,553,032
Inventory (15% of annual production)		2,141,439	Notes payable		1,685,850
Total current assets		**2,141,439**	Total current liabilities		**4,238,882**
Equipment	18,616,000		Long-term liabilities (% of invest.)	50%	22,478,000
Less DEPR	1,999,200	16,616,800			
Facilities	26,340,000		Total liabilities		**26,716,882**
Less DEPR	1,414,667	24,925,333			
Land		-			
Fixed assets		**41,542,133**	Net worth		**16,966,691**
Total assets		**43,683,573**	Total liabilities & net worth		**43,683,573**

Selected Ratios

Net Profit %		43.4%	13,369,139	30,800,000	0.434
Return on total assets %		21.4%	9,358,397	43,683,573	0.214
Return on net worth % (ROI)	1.8	55.2%	9,358,397	16,966,691	0.552
Asset turnover		0.71	30,800,000	43,683,573	0.705
Leverage		2.57	43,683,573	16,966,691	2.575

Profitability Linkage model



6 Broodstock management plan

6.1 Status of current broodstock

The status of the current broodstock is far from good. The broodstock in use at the governmental hatchery is a red hybrid of various species: Oreochromis hornorum, O. mossambicus, O. niloticus and O. aureus. This strain is in use by the government hatchery since 1970s. The same broodstock is used for about two years. The average production of a female per month is estimated at 100 fry only, but varies throughout the year and depends on pond condition. When the production of fry significantly decreases, the broodstock is culled. In the past, standard procedure was a three month production cycle for each pond. Due to poor ponds, however, the brood fish stay in the spawning ponds for 6 - 8 weeks only. After this period, the broodstock is taken out and males and females are separated for a few days to rest. During the first 3 - 4 days the fish are not fed and are given a salt bath, after which the fish is stocked again in another spawning pond. The pond that was initially used, is dried.

Genetic selection takes place based on coloration, growth and shape at two stages - 80 gram and 100 gram. The selection is done by group spawning and selection of the best performing individuals from the group spawning. However, when looking at the growth performance of the fish, not much growth improvement has been realised. As there is no well defined breeding program in use, there is a high probability of inbreeding, although the inbreeding coefficient is unknown.

The shape of the broodstock is cylindrical. If the offspring for grow out-is also cylindrical, the fish is less suitable for filleting. Their growth is slow (for instance the broodstock is stocked at 250 grams and when they are taken out of production after 2 years, they are still only about 400 grams).

The low productivity and the high mortality in the fry can partly be the effect of inbreeding as a result of the breeding and selection procedures. The level of inbreeding significantly affects early fry survival and body weight at stocking. The female productivity (fecundity), expressed as the total number of eggs per spawning, is significantly affected by body weight and level of inbreeding. Research done by Yonas Fessehaye in 2006 showed that with 10% increase of the level of inbreeding, the numbers of eggs declined by 11% of the mean. Male reproductive success, calculated as the proportion of offspring sired per spawning, was affected by the level of inbreeding, condition factor, gonad weight of the males and sex ratio. Per 10% increase in the level of inbreeding, male reproductive success declined by 40% (Y. Fessehaye, 2006).

Tilapia is a natural breeder, and social interactions play a role in the reproductive success of an individual fish. The more dominant a fish, the more success it will have in being reproductive in a spawning group. Some of the less dominant fish will be less productive. About 70% of the spawning in a group spawning is done by only 30% of the males. When new broodstock is selected from a spawning group, and this is done by seining free swimming larvae from the pond, the chance is quite high that many of the fry collected are from only a few active males and females. If this selection method is repeated many times, the chance exists that the genetic basis has become quite small, as most of the fish might be full or half siblings.

The feeding of the broodstock might also be of influence to the quality of the current broodstock. It is unknown what the feeding level of the broodstock is, but as the growth of the current broodstock is quite poor, it is assumed that feeding might be a limiting factor.

The age of the broodstock is also far from optimal. Younger females reproduce better, with much shorter spawning interval then older females. Broodstock should be replaced after approximately 9 months of production.

6.2 Sourcing and procurement of broodstock

The opportunity for improvement depends on the genetic diversity of the starting population. The less variation within a population, the less progress can be expected. As the current broodstock at the government hatchery might be highly inbred, it is advised to start with a wider genetic population than the current broodstock only. The performance of an animal depends on its genetics and its environment. The best performing animals are the ones that are best adapted to the local circumstances. Jamaica has (not yet) had any major disease problems with tilapia. The import of new genetics from abroad might cause a high risk for the health status (see also chapter about hygiene and health). Therefore it is advised to expand the gene pool of the broodstock of the governmental hatchery with broodstock populations from other hatcheries located on Jamaica. This way the risk of bringing in a major disease in minimalized, while the gene pool is expanded with new genetics that have already been challenged with the local circumstances. With this gene pool a Tilapia Improvement Program could be completed, improving the performance with each generation.

New broodstock can best be obtained as fingerlings. This way no strong selection has been done on the group, and because the fish are small, it is easier to transport them and keep them in quarantine for several weeks. For the selection process, it is advised to get 3 different groups of broodstock from other locations. Together with the current broodstock that makes 4 groups of broodstock that need to be spread into a mating schedule in an intensive breeding program. As for a mating schedule, the stocking density stays 1 male to 3 females, so 3 times more females than males are required for the breeding schedule. Not all these females will actively participate in the breeding plan, only 30% of the females need to spawn to have enough different families. For the breeding schedule, 25 males and 75 females of each group are needed. Therefore it is best to bring in the fingerlings when they are still small (<5gram). After the quarantine period the new broodstock first need to be grown to market size (>350 gram) under normal farming conditions, as though it is normal ongrowing. At 50 grams the fish should be sexed, and the males and females should be kept separately to prevent any reproduction in the ongrowing ponds. When the sexed fish reach market size, the best 25 males and the best 75 females are selected. These fish will be stocked in the mating schedule with the males and females from the other broodstock groups.

6.3 Broodstock nutrition

The feed currently used is not a special broodstock feed for spawning. A good quality broodstock feed should contain at least 40% protein. Extra vitamine E and Astaxantine are also positively related to fish spawning in general. It is unknown what the current feeding level of the broodstock is, but as the growth of the current broodstock is quite poor, it may be assumed that feeding is limited. Broodstock need to be fed 2.5% of their bodyweight on a daily basis. The best way would be to spread this amount over two feedings. One feeding moment in the morning, and one feeding in the beginning of the afternoon.

6.4 Genetic improvements

The improvement of the genetics of broodstock is a continuous process, of with the benefits will only become clear after several years. Selecting for both growth as well as robustness is essential to stay ahead of the competition: By not implementing a good breeding plan for improvement, no progress will be made. Without making progress, competitors (from abroad) will catch up and soon have an advantage with their improved stock. Therefore an improvement program is essential to keep up with competitors.

The ultimate goal of a breeding program is to improve future generations. The underlying mechanism is to make optimal use of the variation between individuals. This variation is expressed in the so-called **phenotype** of the different individuals. The phenotype is defined as "all the observable characteristics of an organism that result from the interaction of its genotype (total genetic inheritance) with the environment" (see figure 59). A breeding program means selecting the best individuals for a chosen trait to transfer their genes to the next generation.

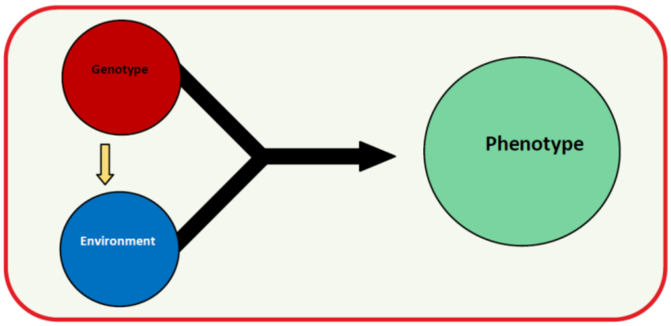


Figure 57 The interaction of genotype (genetic make-up) and environment (water, feed, handling) resulting in the observable phenotype (appearance and performance).

The effect of a well-designed breeding program is often underestimated, while performance can be improved with >10% for each generation. A lot of literature has been published about such results of breeding programs in tilapia. For instance, Hamzah A, Thoa NP, Nguyen NH (2017) describes a body weight gain of over 12,5% per generation through genetic selection. Another well-documented project is the Genetically Improved Farmed Tilapia (GIFT), which showed a realized response to selection on body weight of 13.6% per generation (ranging from 9.0 to 20.1%). After five generations this resulted in an accumulated response of 88% compared to the base population (Hans B.Bentsen, Bjarne Gjerde et all, 2017).

An improvement of 10% better growth each generation should be feasible if the base population has enough variation and is not yet inbred. Given the aforementioned results, it is surprising that still a lot of tilapia producers have not yet implemented any kind of breeding program. Especially when calculating the potential economic benefits (table 1). A tilapia farm with an annual production of 2,500 tons can produce 250 tons extra with the same resources, saving fixed costs for those extra tons of production. Generating this profit will start from the second year of the program since the first year is required to obtain the improved broodstock. These fish will then start to provide better performing offspring – while at the same time the ultimate top grade will produce the next improved generation. This means the first year is the only year of pre-investment.

To be prepared for the future and to realize a better performing fish with every generation, it is best to set up a Tilapia Improvement Program in order to improve the productivity of the broodstock and to improve the performance of their offspring.

The opportunity for improvement depends on the genetic diversity of the starting population. The less variation within a population, the less progress can be expected. As the current broodstock at the government hatchery might be highly inbred, it is advised to start with a wider genetic population than the current broodstock only. To make optimal use of a breeding program, a minimum number of 100 separate **families** is required to provide enough variation for obtaining genetic progress while keeping inbreeding limited.

As stated, the best performing animals are the ones that are best adapted to the local circumstances. The import of new genetics from abroad might cause a high risk for the health status (see also chapter about hygiene and health). To start with enough genetic variation, it is therefore advised to collect several families from other farmers on Jamaica. This way the starting population will have more genetic variation. A breeding schedule with 100 families that have to be grown individually would be a very elaborate set-up. The most practical way would thus be to split these 100 families into two selection groups of 50 families each. To compensate for the small amount of inbreeding in these groups with 50 families, the males of one group could be combined with the females of the other group as a kind of "compensation". After several generations, both groups will get their own genetic "signature", and a cross of both groups will give a heterosis effect, making it a stronger fish then the individuals from the two selection groups. To distinguish both selection lines of 50 families each, one group of 50 families can be given the name of "male" line, and the other the "female" line.

To obtain 50 families, spawning (natural reproduction) will be performed in multiple small spawning compartments. To accommodate as many spawning groups as possible, a spawning pond should be divided into small spawning compartments. This can be done by hanging small hapas (net structure) of 1 x 2 m (2 m^2) next to each other in a spawning pond (see figure 36, page 31).

To maximize the chance of reproduction, each compartment should be stocked with 2 males and 6 females. The 2 males can compete and increase reproductive activity and chances for an active male is doubled by definition.

It is important to produce 50 nests with a minimal age difference. Assuming one nest per hapa, this would require one spawning cycle of 10 days.

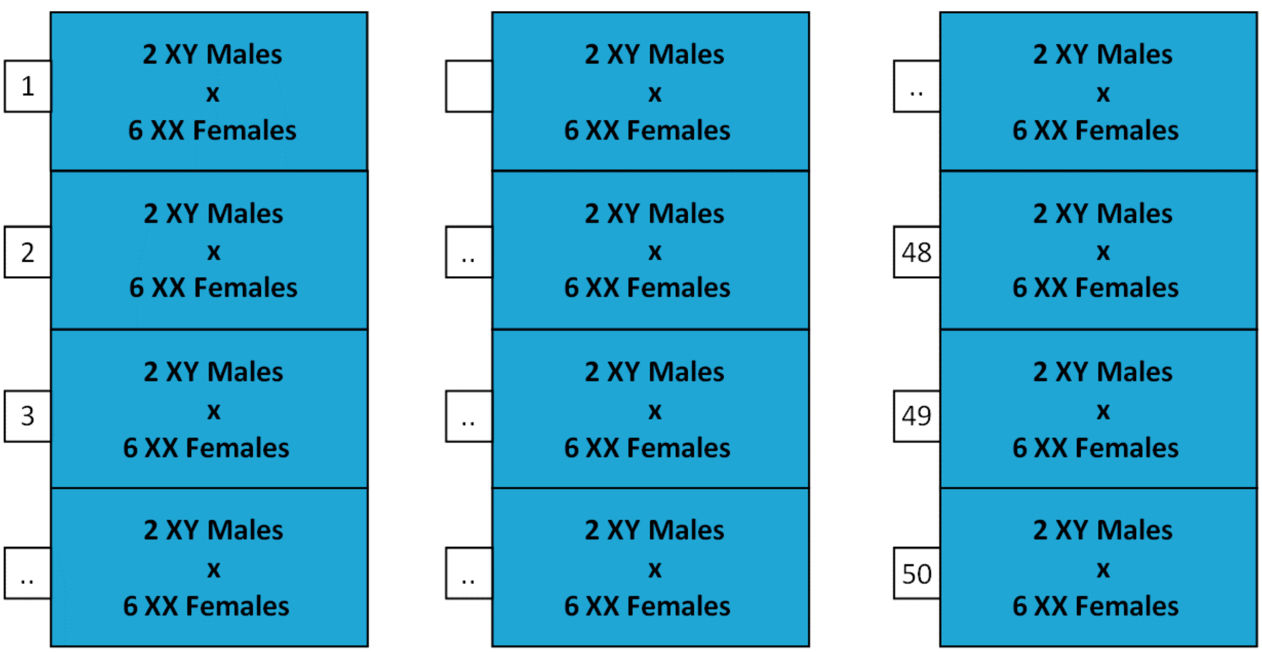


Figure 58 Schematic visualization of 50 spawning compartments to produce 50 families

After being harvested, each nest should be incubated/stocked separately in respectively its own incubator (figure 61a), plastic container (figure 61b) and plastic basket (figure 61c). These small holding instruments can be mounted within a swim-up system (figure 15 and 62) to accommodate multiple families per tank.

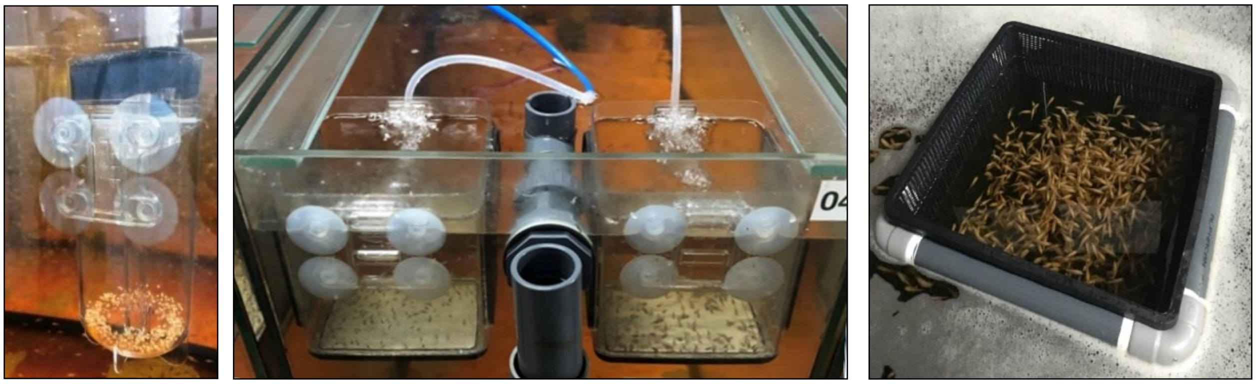


Figure 59 Individual holding instruments for various fish sizes: Mini incubation (a), fish container (b) and basket (c).

Figure 60 Complete swim-up system with 2 tanks to mount with multiple smaller holding instruments

From the harvest, the 50 nests that are large enough (>200 eggs or fry) and have the smallest age difference should be selected and kept for further growth. After harvest these 50 nests are then stocked in the plastic containers for approximately 4 weeks.

Selection

After these 4 weeks, the fish have reached a weight of >0.3 grams each. The top 100 fish of each nest should be selected and transferred into black baskets (figure 61C) which are larger and have better water exchange. Again, multiple baskets can be placed inside a swim-up tank so the 50 groups of 100 fish each can still be stocked separately.

When the fish reach an average weight of approximately 1 gram each, they need to be taken out of the baskets and transferred into small hapas within a swim-up tank to continue optimal growth.

Two small hapas of 1x0.5 m would fit in 1 swim-up tank. This means 25 swim-up tanks are required. To have 25 swim-up tanks, a minimum of 13 swim-up systems with 2 tanks each are required (figure 64).

The fish are grown to an average individual weight of 15 grams (at which they are about 75 days old). At this size the best 25 fish of each group can be selected and chipped. Individual weights will be recorded and the 50 groups of 25 fish each will be mixed; leaving 1,250 chipped fish. These will be stocked together. The non-tagged fish can be used as new spawning broodstock, but will not be used in the future for the selection program.

After approximately 40 days, the fish reach an individual weight of 70 grams at which they can be manually checked for their sex (stripped). Due to the previous gradings the female to male ratio might have dropped from 1:1 to possibly less than 1:4. At the same time more females need to be selected than males (3 females for each male). Selection for the males is therefore more severe.

After the sexing, the chipped fish need to be transferred into separate ongrowing facilities (ponds/hapas in ponds), one for the males, and one for the females. In these ponds the selection fish can be farmed under normal farming conditions in the targeted water quality. When the fish reach market size, they are all weighed individually. After data recording and processing, the best females and the best males are selected to produce the next generation - that will undergo the same complete selection procedure.

Registration

For a proper selection it is essential to have good data available about growth performance of the fish that have to be selected. To keep track of individual fish of different families within the same group, all fish that are part of the selection group need to be marked using a microchip. This way all individual fish can be traced, and their performance and pedigree can be registered. To do this performance and pedigree registration, it is essential to have a good registration system.
For the evaluation of the performance of each generation of fingerlings, it is important to get reliable feedback from on-growers that use these fingerlings. Calculating the improvement of each generation and predicting the improvement of future generations can only be done based on proper feedback.

As the performance data of the fish are sensitive information (as it reveals the (economic) status of a farm), it is therefore advised to sign a Non Disclosure Agreement between all parties involved in the set-up and implementation of the selection process and the farmers who give feedback on the performance of the fish.

Materials needed

To execute the whole selection and breeding program as described in this document, a lot of equipment and facilities are required. For the quarantine facility where the new broodstock is stocked for the first 6 weeks, one or two small ponds with aeration will suffice, although a small RAS system would be better to observe the fish and see if any problems occur. The whole quarantine area should be fenced and covered with a net to prevent any contamination entering or leaving the quarantine (e.g. birds can be a severe risk of spreading a disease).

For the selection and breeding program itself a large (spawning) pond is required to place 50 small spawning hapas in. One or two small ponds with a total surface area of at least 300m^2 are required.

Besides this spawning pond, a facility is needed with small RAS systems (called “swim-up systems” in this manual). These swim-up systems should be placed inside a building, just like the hatchery itself.

For the last growth period of the selection fish, after the fish are sexed, they should be stocked in two ongrowing ponds. It is advised to have two small ponds available.

Figure 61 Indicated in yellow: where the genetic improvement plan could be installed

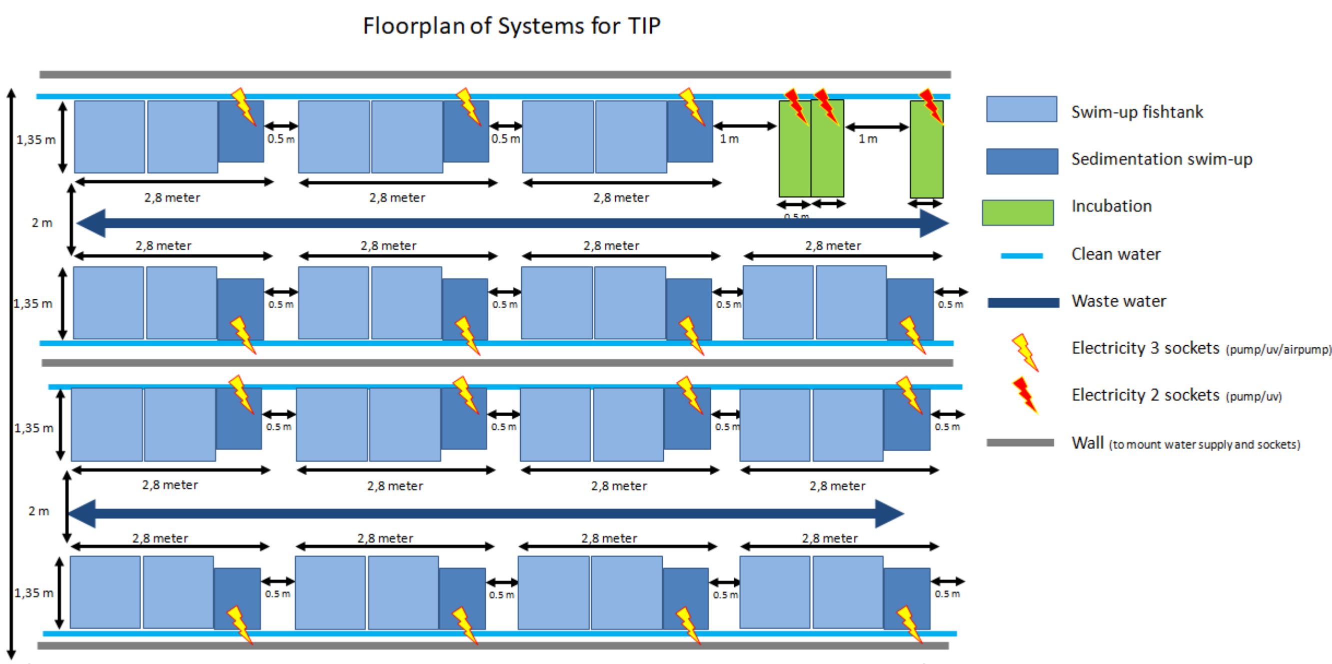


Figure 62 Floorplan with all "swim-up" RAS systems needed for the breeding plan

Besides the systems and ponds, there is a small list of additional equipment like the tags and a tag reader. Some of the equipment will already be part of a normal hatchery, like the graders, and a microscope for health checks and parasite checks. It is not necessary to have a special microscope for the breeding and selection part only. It is advised, however, to have small graders just for grading the small numbers of the selection fish. These graders should not be used anywhere else in the farm, just like small scooping nets, harvest equipment and other materials used for a normal hatchery, described in the hatchery manual.

TYPE	# REQUIRED
Spawning hapas → 2x1 (=2m^2)	50
Mini incubators	50
Plastic fish containers	50
Black baskets	50
Stocking Hapas → 1x0.5 (=0.5m^2)	50
Swim-up systems (incl 2 spare)	15
Graders	2
Ongrowing ponds	2
Scale	1
Tags/Chips (2x 1,250#)	2,500
Chip reader	1
Administration sheets	

Table 1: List of equipment necessary for a breeding plan

The selection program is only to improve the genetic basis of the population. The selection program itself does not produce broodstock fish for normal fry production. It only forms the genetic basis for broodstock production. After the selected fish are used to produce a new generation for the selection schedule, the tagged fish can be used for the production of new broodstock. This is done by combining the males of one selection line with the females of the other selection line, and vice versa (see figure 65 for a graphic overview of the selection schedule and production of broodstock).

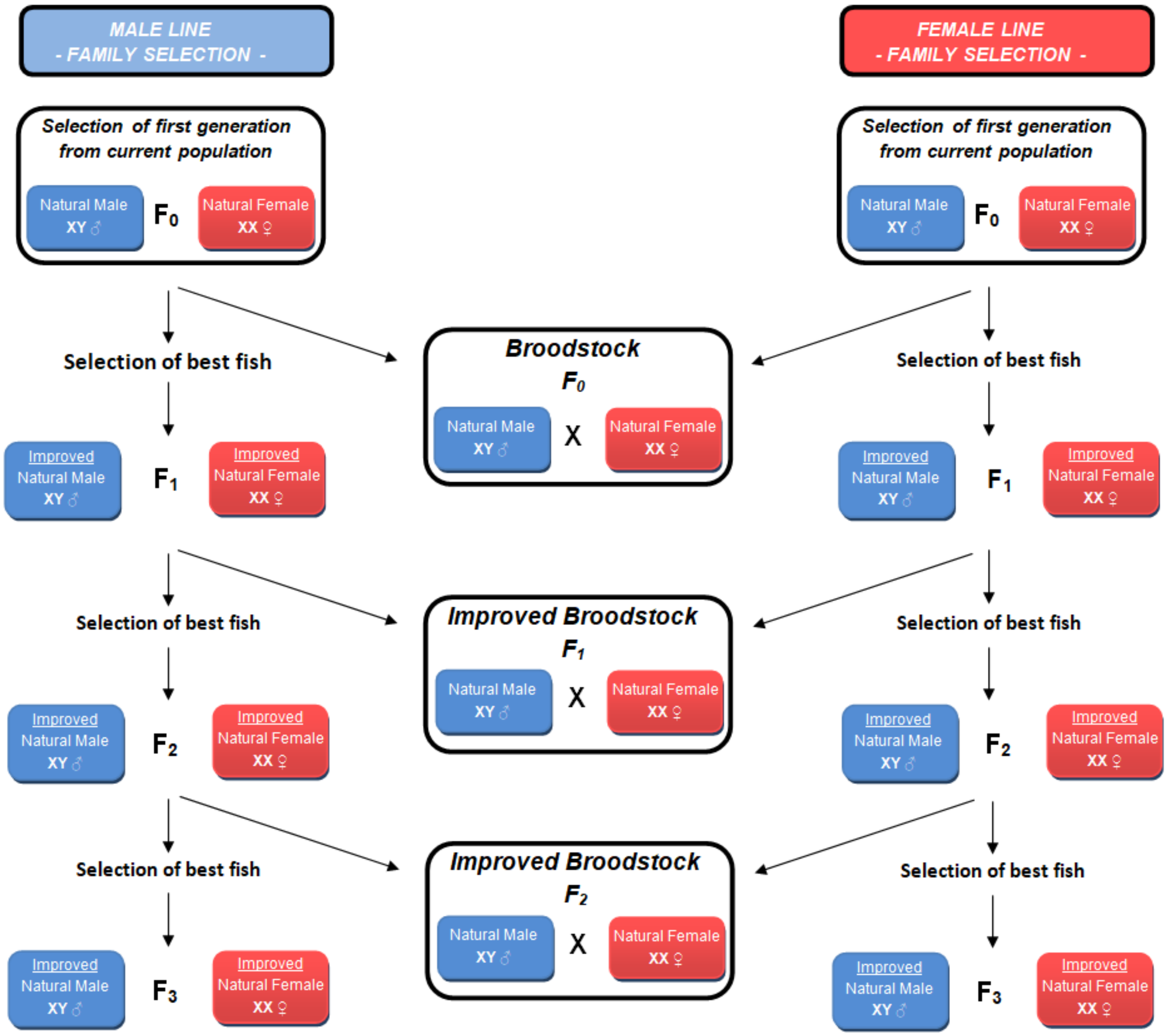


Figure 63 Schematic overview of generation of selection and broodstock production

6.5 Health management

Most of the fish health management is discussed in chapter 4.6. However, in this chapter some extra attention is given to the health situation in the area of the genetic improvement program. As stated before, effective biosecurity is the key to preventing diseases and maintaining a good fish health.

For the genetic improvement program the choice is made to work with hapas in ponds in a separated area of Twickenham Park Farm 2 (see figure 61 for location). This choice is made in particular because lots of small family groups are needed to perform a selection program. All conditions regarding biosecurity as discussed in chapter 4.6 apply here too. A selection of the most important biosecurity measures is summarized below.

Biosecurity in the genetic improvement area

Water source

The ponds receive water directly from the well by the canal system. This is a calculated risk since the fecal coliform bacteria level of the well water is high. Treating the incoming water by UV and the use of a sand filter, however, is less cost-effective for ponds than for the hatchery unit with the recirculation systems.

It may be considered to drill a new borehole at a greater depth than the current one to find a pathogen-free source for the whole farm.

Fish movement

The genetic improvement program can be executed with the existing broodstock. The consideration is to expand the gene pool by bringing in parent stock from other fish farms in Jamaica to reduce inbreeding. New arrivals should be isolated before they are added to the current stock in order to reduce the risk of disease transfer. The quarantine room of the hatchery can be used for this (see figure 21, point 4). The length of the quarantine period should be at least 4 weeks. The quarantine area has its own small recirculation units with separated water flow circuits. Dedicated equipment is used here to avoid cross contamination to resident fish. The care of the fish in the quarantine room should occur after the resident fish in the indoor hatchery, or by a specially appointed employee.
After a successfully completed quarantine period the fish can be transferred to the genetic improvement area (leaving the quarantine via the one way door, (see figure 42 point 1). Quarantine, recirculation units and materials are thoroughly cleaned and disinfected.

Fish health and husbandry

All earlier mentioned husbandry measures (Chapter 4.6) are applicable. Since in this area the genetic base of the farm is gathered, it is advised to act immediately when signs of illness are noticed. Dead or dying fish are removed. Necropsy and examination of ill fish in the laboratory (see figure 21, point 8) can help to identify a potentially infectious disease and act accordingly. An aquatic veterinarian or fish health specialist may be required.

Figure 64 Necropsy of a tilapia

Farm traffic

Since diseases are mainly transmitted by living beings and materials, the following measures should receive extra attention:

- The genetic improvement area is restricted and thus fenced. It can only be entered by a gate with a foot and wheelbarrow bath (a wheelbarrow is used for the fish feed) and a scrub brush. Signs are posted indicating that access is restricted.
- A well-trained specialized team of employees is working in this area.
- The area has its own equipment. Clean cloths and boots are required.

- Domestic animals are forbidden, feed spills and waste are cleaned immediately, weeds and grass around the ponds are trimmed regularly and wild birds are not fed. Nets have been placed over the ponds to keep away the wild birds as much as possible.

Figure 65 Netting over a pond

Cleaning and disinfection

All equipment is dedicated to the area and cleaned and disinfected on a regular basis, also the hapas in the ponds. The equipment can be chemically disinfected or thoroughly dried in direct sunlight (nets, hapas) or both. When the production cycle of the genetic program allows it, the ponds itself have to be flushed, disinfected (limed) and left dry for at least 3 days. Since liners are advised for the ponds, a good quality UV resistant liner is required.

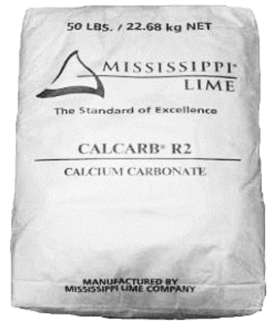


Figure 66 Bag with lime

Training

To ensure the effectiveness of biosecurity and to give staff and employees a clear understanding of responsibilities, a training on the protocols is required. From time to time the biosecurity program has to be reviewed and updated, followed by a new training.

Figure 67 Training of staff on the biosecurity protocols (Tanzania)

7 Recommendations for Implementation

To implement all recommendations and systems in this report, construction work has to be done, like decommissioning old ponds and construct a new building for the hatchery. It is recommended to only work with certified local contractors. The selected contractor(s) should work with local employees as much as possible to minimize transport, reducing the carbon-footprint of the work. The contractor needs to take environmental impact into account, and should work with the newest insight in sustainability. It is best if the helophyte filter, as described in chapter 4.2 is constructed as one of the first things, as this will ensure a minimal impact of wastewater running to the NIC canal and the Rio Cobre.

The design and layout of the hatchery is done is such a way that minimal adjustments need to be done to the existing facilities. The decommissioning of any facilities present that needs to be decommissioned for the construction of the hatchery as described in this report, is not taken into account in this report however.

During the construction, and after the implementation, when the hatchery is in full production, all solid waste needs to be collected at a central point, in accordance with to local legislation, and separated as much as possible for recycling (glass/paper/plastic/metals/chemicals/ biological waste).

All personnel working in the hatchery, as described in chapter 4.3, need to be trained. Extended training courses have already been developed by the authors of this report. The factsheets that are in the annex "factsheets" of this report, are part of these training courses. The hatchery manager of the facility needs to have a master degree in aquaculture, but it is recommended that this hatchery-manger also attends a training dedicated to tilapia hatchery management.

Example for the training module

Aquaculture course FisHub RAS systems / Hatchery		BASIC HATCHERY to become:		BASIC GROWOUT to become:		ADVANCED to become:
List of skills / topics		hatchery operator / animal caretaker		system operator / animal caretaker		farm manager (hatchery and / or growout)
Farm rules and regulations		x		x		x
A) Practical farm management						
A1. Biology and production stages	A11	Broodstock, incubation, swim-up, prim. nursery	A12	Pre-growout and growout	A13	Genetics YY, hormonal treatment versus YY
A2. Handling, counting and grading	A21	Handling brookstock, fry, and juveniles	A22	Grading and harvesting	A23	Sex determination and sampling
A3. Control of biomass and feeding	A31	Growth and feeding fry and broodstock	A32	Growth and feeding growout	A33	Feeding lines and Adjustments
A4. Water quality monitoring	A41	See A42	A42	Measurements and dilution	A43	Registration, abnormalities and actions
A5. Fish-health	A51	Parasite control	A52	Stress, signs, disease and routines	A53	Diagnosis, registration and medication
A6. Hygiene	A61	Cleaning and dlsinfection hatchery	A62	Cleaning and dlsinfection growout	A63	Health and safety
A7. Biosecurity	A71	Biosecurity	A72	Biosecurity	A73	Developing a biosecurity plan
B) Intensive farming techniques						
B1. Essential farm equipment (RAS)	B11	Flowchart and equipment hatchery	B12	Flowchart and equipment growout	B13	Starting a biofilter
B2. Control of filter and equipment	B21	Service and maintenance hatchery	B22	Service and maintenance growout	B23	Control and emergency plan
B3. Stocking density and production	B31	Stocking density and capacity	B32	Interaction between fish and oxygen	B33	Biofilter capacity
B4. Fish - farm - feed relationships	B41	See B42	B42	Daily feed management and appetite	B43	Interaction between feed load and the system
C) Operational management						
C1. Transport	C11	Transport and receiving fry	C12		C13	Mortalities and actions
C2. Stocking and production planning	C21		C22		C23	Production plan
C3. Monitoring software	C31		C32		C33	Calculation and use monitor software
C4. Registration, costs and efficiencies	C41	Registration hatchery	C42	Registration (pre-)growout	C43	Analyse technical results
D) Marketing and sales						
D1. Product Quality	D11		D12		D13	Storage, packaging and food safety
D2. Tracking & tracing	D21		D22		D23	Batch coding
D3. Differentiation in customers	D31		D32		D33	Client portfolio - product market combinations
D4. Market	D41		D42		D43	Fish market Tanzania

8 Literature and References

8.1 Literature

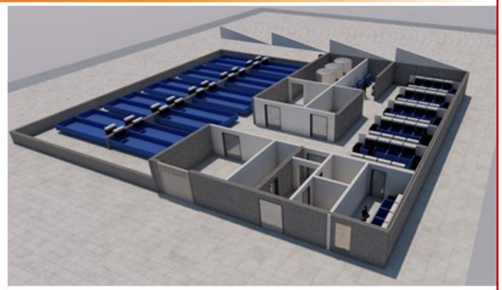
Natural mating in Nile tilapia (Oreochromis niloticus L.), Implications for reproductive success, inbreeding and cannibalism, Yonas Fessehaye, 2006.

Optimisation of selective breeding program for Nile tilapia (Oreochromis niloticus), Trịnh Quốc Trọng, 2013.

8.2 PowerPoint slides Hatchery plan

Content of presentation

1. Introduction
2. Systems
3. Lay-out of Hatchery
4. Biosecurity
5. Product-flow
6. Broodstock
7. Production cost price
8. Summary



9 HOLLAND AQUA COMMUNITY BASED CLIMATE RESILIENCE IN FISHERIES SECTOR – JAMAICA | 2020

1. Introduction

The aim is to design a modern climate resilient tilapia hatchery with the capacity to produce 5 million advanced fry/year.

Current:

- Not enough production
- High mortality
- Labour intensive
- Not biosecure
- Leaking ponds
- Poor quality of broodstock

Goal:

- Increase production to 5 million fry/year
- Lower mortality
- Climate resilient
- Biosecure
- Modern
- Modular

10 HOLLAND AQUA COMMUNITY BASED CLIMATE RESILIENCE IN FISHERIES SECTOR – JAMAICA | 2020

2. Systems

Climate resiliant solution: **RAS** (**R**ecirculating **A**quaculture **S**ystems) are **controlled production systems** on which the environment has little effect

Advantages of RAS:

- Low land use
- Low labour
- Low water usage
- **Total Control:**

• Water Quality	→ Optimal growth
• Biosecurity	→ Low risk of diseases
• Parasite control	→ Low mortality
• Treatment	→ Option to take actions
• Grading	→ Uniform batches

2. Systems

RAS for hatcheries

- Small fish are expensive per kg!
- Small fish → Small system
- Easy to manage:
  - Uniform batches through regular grading
  - Full control → High survival
- Easy to maintain
- Good start is essential for good performance later!
- No influence of weather conditions

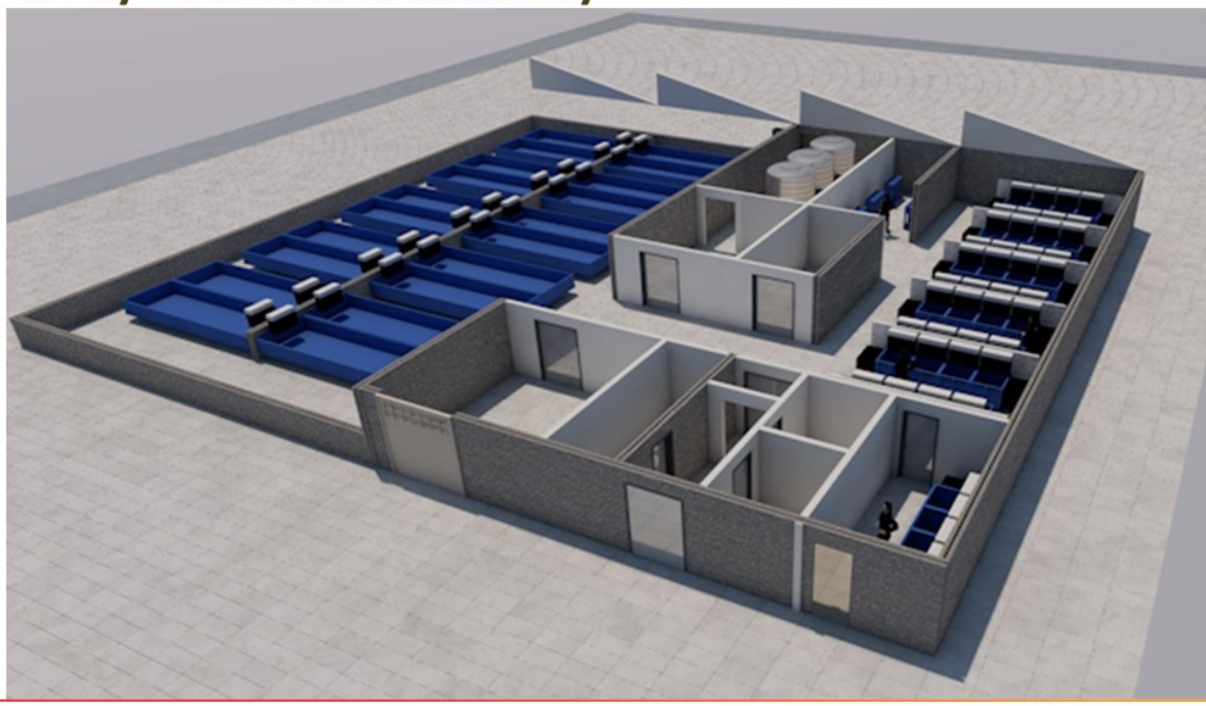
3. Lay-out: Site

13 HOLLAND AQUA COMMUNITY BASED CLIMATE RESILIENCE IN FISHERIES SECTOR – JAMAICA | 2020

3. Lay-out: Site

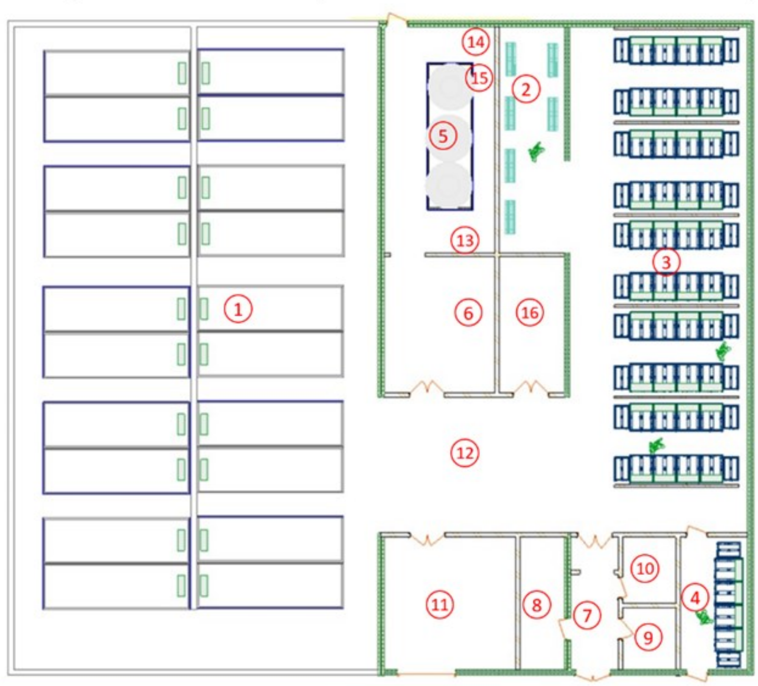
14 HOLLAND AQUA COMMUNITY BASED CLIMATE RESILIENCE IN FISHERIES SECTOR – JAMAICA | 2020

3. Lay-out: Indoor hatchery



15 HOLLAND AQUA COMMUNITY BASED CLIMATE RESILIENCE IN FISHERIES SECTOR – JAMAICA | 2020

3. Lay-out: Floorplan indoor hatchery



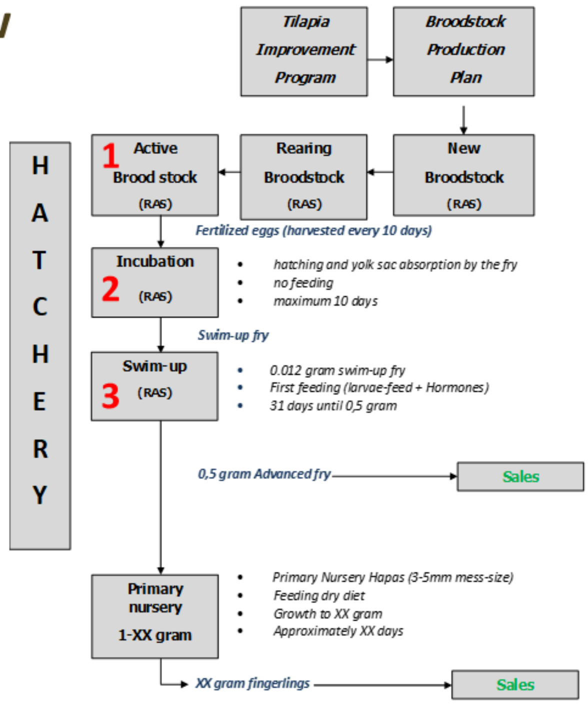
1 = Spawning tanks
2 = Incubation
3 = Swim-up systems
4 = Quarantine
5 = Header tanks/technical room
6 = Wet storage
7 = Entrance + Hygiene barier
8 = Laboratory
9 = Small (feed) storage
10 = Locker-room
11 = Sales/packing area
12 = Space for grading
13 = Electrical switchboard
14 = Blower
15 = Hydrophore
16 = Place for small equipment

16 HOLLAND AQUA COMMUNITY BASED CLIMATE RESILIENCE IN FISHERIES SECTOR – JAMAICA | 2020

4. Product flow

Focus on:

- Spawning (1)
- Incubation (2)
- Swim-up (3)



4. Product flow

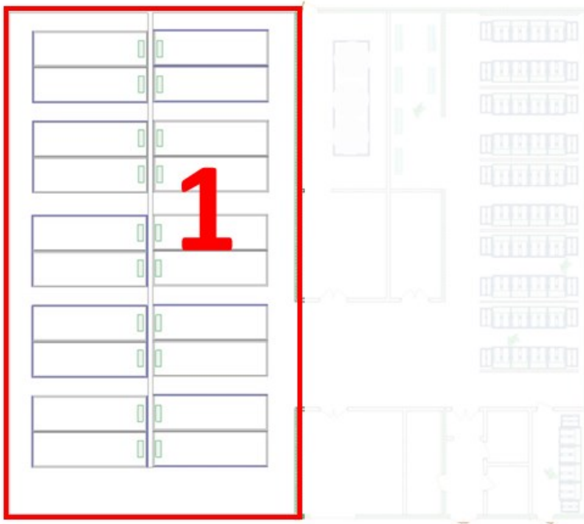
1 = Spawning

2 = Incubation

3 = Swim-up

4. Product flow: Spawning

- 20 Spawning tanks of 20 m^2 each
- Harvest eggs every 10 days
- Production of 12,500/m^2/year



4. Product flow : Spawning

Specifications:

Artificial tanks (concrete or PE)
Hapa of 2.5 x 8 x 1.1 meters
Spawning surface: 20m^2
Water volume: 15m^3

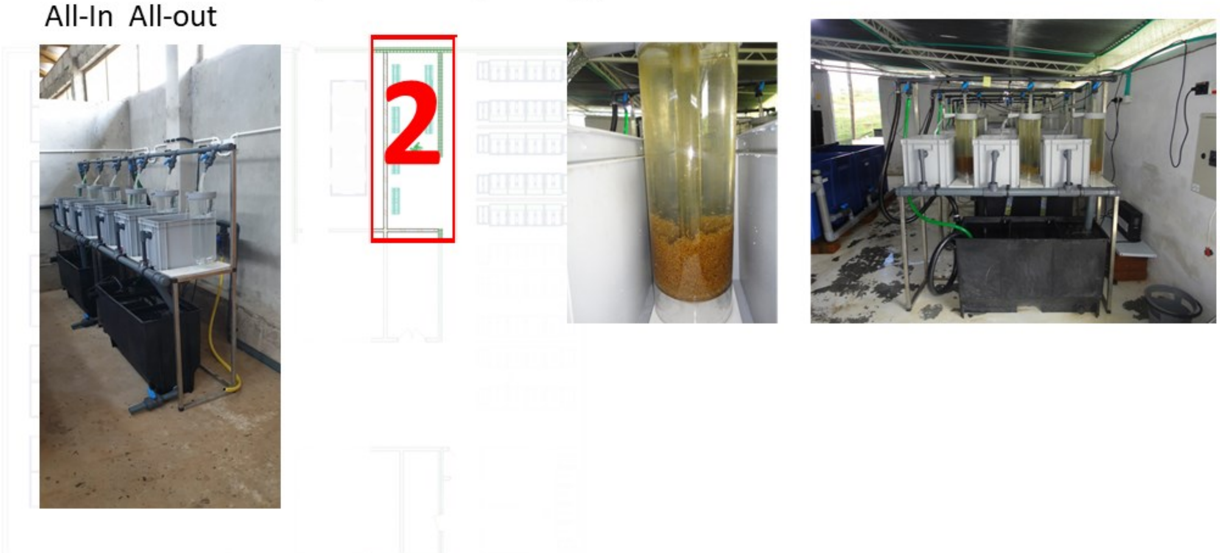
Stocking:
Depending on size of broodstock
1 set/m^2 (equals 1 kg/m^2)

Harvesting:
Every 10 days egg/larvea collection

Production:
7,500 fry/tank/harvest

4. Product flow : Incubation

6 incubation units with 3 hatching jars each
Distinction in developmental stages of eggs
All-In All-out



4. Product flow : Incubation

Recirculating Aquaculture System

Specifications:

- 3 “McDonald” incubation jars
- 1 Sedimentation tank with filter blocks
- 1 Submergible pump
- 1 UV light

Water volume: 400L

40,000 eggs/jar
All-in → All-out
Easy to manage

4. Product flow : Swim-up

20 Swim-up systems with 2 tanks each

4. Product flow : Swim-up

Recirculating Aquaculture System

Specifications:

- 2 HDPE fish tanks (1.2m x 1.0m x 0.76m)
- 1 Sedimentation tank with filter blocks
- 1 Submersible pump
- 1 UV light
- 2 Bio-towers with distribution plates

Water volume: 1.200L
Electricity: 115 Watt

40,000 swim-up fry/tank
All-in → All-out
Easy to manage

5. Broodstock

Current production of broodstock is very low and needs to be improved

Better feeding: special broodstock feed

Faster replacement of broodstock

Better water-quality in small concrete spawning tanks with biofilter

Tilapia Improvement program:

- New local genetics to improve genetic variation
- Selection of new generation of broodstock each year
- Better performance each generation: >10% improvement on growth per generation

6. Biosecurity

Biosecurity: essential for fish health

OIE WORLD ORGANISATION FOR ANIMAL HEALTH
Protecting animals, preserving our future

OIE establishes the standards for biosecurity

WTO members recognize the OIE standards -> Jamaica WTO member since 9/3/1995

Current status government hatchery: especially lack of hygiene procedures

New design hatchery:

- Modular
- Indoor hatchery from spawning to advanced fry
- Completely controlled and focussed on hygiene procedures
- Training staff and employees; regular review and update of protocols

6. Biosecurity

Biosecurity measures focussed on:

- **Watersource:** indoor hatchery sand filter and UV
  -> insure high larval survival
- **Fish movement:** risk to (introduce) and spread diseases within or off the farm
  -> all-in all out; only healthy well graded fish to customers
- **Health and husbandry:** optimum health -> optimum resistance
  -> minimize stress; proper nutrition; monitor frequently;
  remove (and bury) dead or dying fish; record keeping
- **Farm traffic:** disease transmitters are **persons**, animals, vehicles and equipment
  -> fences; restricted areas; entrance, clothing and hygiene protocol for persons;
  footbaths; wheel bath for vehicles; prohibition for domestic animals; rodent
  control plan
- **Cleaning and disinfection:** protocols to avoid disease transfer between or within units

7. Production cost price

Production cost price (JMD)	fry / piece (0.5 gram)	%	fingerling /piece (5 gram)	%
Broodstock	0.3	11%	3	11%
Feed	0.2	7%	2	7%
Electricity and water	0.4	14%	4	15%
Labour	0.7	25%	6	22%
Other	0.1	4%	1	4%
Depreciation and interest	0.6	21%	6	22%
Crop tax	0.5	18%	5	19%
Cost price of production	2.8	100%	27	100%
Sales price	4.0	142%	40	148%

Sales of 5 million fry and 300,000 fingerlings result in:

Total revenu of hatchery: **30.8 million JMD**
Net profit after tax and interest: **9.35 million JMD**

8. Summary

The farming principle which has been selected is **intensive recirculation** in order to minimise the interaction with the environment (maximise controls)

The complete hatchery is modular in design and exists of:

- 2 Lined ponds for the growing up of new parent stock; outdoors
- 2 Quarantine units (RAS) with sedimentation tank and bio-towers; indoors
- 20 Spawning units (RAS) with small bio-towers covered by shade nets
- 6 Incubation units (RAS) with sedimentation tank; indoors
- 20 Swim-up units (RAS) with sedimentation tank and bio-towers; indoors
- 2 Lined ponds for fingerling and juvenile production; outdoors

Labour→ only 7 people to run total hatchery for 5 million fry year

Survival→ with RAS survival is >90%

Production cost is 2.8 JDM/Fry

Total investment: 48million JMD → Net profit after tax and interest: 9.35 million JMD

Contact and further information

Frans Aartsen
+31 6 2189 4942
Frans@hollandaqua.nl
www.hollandaqua.nl

Erik Bink
+31 6 3335 8551
Info@til-qua.com
www.til-aqua.com