# Design and Operation of a Hatchery for Seawater Production of *Tilapia* in the Caribbean

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## ABSTRACT

En Bahamas Central, se llevaron a cabo experimentos en el cultivo en aguas saladas del híbrido rojo de la tilapia de Florida (hembra *Oreochromis urolepis* hornorum x macho Orechromis mossambicus). Estas fueron cultivadas desde tamaño de jaramugo hasta tamaño comercial. Los jaramugos se obtuvieron de charcas de agua dulce dos partes por mil (2ppm), luego se le cambió el sexo a las hembras para obtener sólo machos, después, fueron aclimatados para vivir en agua salada (37ppm) y por último se dejaron crecer hasta tamaño de alevines en charcas con agua de mar fertilizadas seguido por cultivo en jaulas colocadas en mar abierto, para pasar la etapa de alevines hasta la de tamaño comercial.

La producción promedio de jaramurgos por hembra por puesta fue de 170. Durante el período de cambio de sexo (28 días) los peces recibieron un alimento que contenía la hormona masculina (17 alfa-etinil-testosterona) creciendo de 0.1g a o.5g a una tasa de crecimiento específico (log natural) de 14.0% día. Los peces fueron aclimatados al agua salada durante un período de 5 días, incrementando gradualmente los niveles de salinidad a 15, 20, 25, 30, 37 ppm respectivamente.

Dos grupos experimentales fueron cultivados de 0.7g a 15.1g (en un período de 47 días) y de 1.3 a 7.2g (en un período de 20 días) en charcas donde se le suministraba alimento en perdigones flotantes, estos crecieron a una tasa de crecimiento específico de 6.5 y 8.6% por día respectivamente. Al mismo tiempo, dos grupos experimentales de jaramurgos fueron cultivados de 0.7g a 12.7g (en un período de 20 días), en charcas que fueron fertilizadas con estiércol de gallina, obtuviéndose una tasa de crecimiento específico de 6.2 y 8.0% /días, respectivamente. Las cantidades de fertilización, densidades de siembra de los peces, las tasas de producción de la biomasa de los peces y los porcentajes totales de mortalidad de los dos experimentos donde se utilizaron fertilizantes fueron los siguientes: 50 y 105kg. de estiércol (peso seco) ha/día; 400,000 y 250,000 peces/ha; 39.1 y 64.6kg. de peces (peso mojado) ha/día; y 59 y 9% respectivamente.

En los dos ensayos preliminares, los alevines cultivados en jaulas en el mar alcanzaron un peso de 100g a 227g (0.5lbs.) tamaño comercial en dos meses y de 50g a 454g (1 lb) tamaño comercial en cuatro meses. En estas jaulas flotantes colocadas en el mar abierto se utilizó alimento en perdigones flotantes y fueron manejadas por residentes bahameños.

## INTRODUCTION

The Caribbean Marine Research Center (CMRC) is developing techniques to culture tilapia in seawater for tropical and semitropical regions with limited freshwater resources. Florida red-hybrid tilapia (*Oreochromis urolepis hornorum* females X *O. mossambicus* males) have been selected as a promising strain for seawater culture (Watanabe *et al.*, 1989). Techniques being developed for the seawater culture of this hybrid will focus on the following:

1. Egg and fry production in brackish water (10 to 25 ppt).
2. Artificial egg incubation in brackish water.
3. Sex-reversal and rearing of fry in brackish water for one month.
4. Acclimatization of fry to full-strength seawater over a period of one week.
5. Fry grow-out in fertilized and/or fed seawater ponds to market or cage stock size.
6. Grow-out to market size (150 to 600 g) in open seawater cages, using floating or dough feed.

The purpose of this paper is to describe the design and operation of a hatchery research facility built by CMRC on Lee Stocking Island, Exuma Cays, Bahamas, for the seawater production of tilapia.

## OPERATIONAL GOALS

The hatchery is designed to produce in excess of 20,000 male fry per week for seawater grow-out experiments and developmental extension projects. The hatchery is also designed to support research aimed at developing fry production techniques that conserve freshwater, minimize broodfish number and pond area, and produce fry optimally suited for seawater grow-out. The hatchery system allows spawning, incubation of eggs, and sex-reversal of fry at any salinity between fresh and seawater, and seawater acclimatization of fry at any age. Thus, optimum and maximum spawning salinities for fry production and salinity acclimatization methods that maximize growth and survival during seawater grow-out can be determined (Watanabe *et al.*, 1989). Open tank, net enclosure, and behavioral fry production techniques will be studied to determine broodfish biomass, broodfish holding area, and labor and equipment requirements for fry production. These criteria will be used to choose techniques and to design future hatcheries according to specific resources and goals in other regions of the Caribbean.Freshwater conservation will be accomplished by the use of water recirculation systems and brackish water. Water quality criteria and metabolic rates of tilapia on which the hatchery's aeration and water treatment systems are based will be tested and refined to allow more precise, cost-effective designs in the future. Operation of the water recirculation systems will be evaluated, regarding water-treatment efficiencies and management costs.

## HATCHERY DESIGN AND OPERATION

The hatchery facility (Figure 1) consists of fry production sex-reversal and seawater acclimatization systems. The fry production system consists of six 34,200 l broodfish holding tanks and two independent water recirculation systems. The fry rearing and sex-reversal system consists of six 6.5 l egg incubators, sixteen 560 l fry rearing tanks, and two independent water recirculation systems. The sea water acclimatization system consists of eight 4,900 l fry holding tanks which can be operated on flow-through or recirculated water.

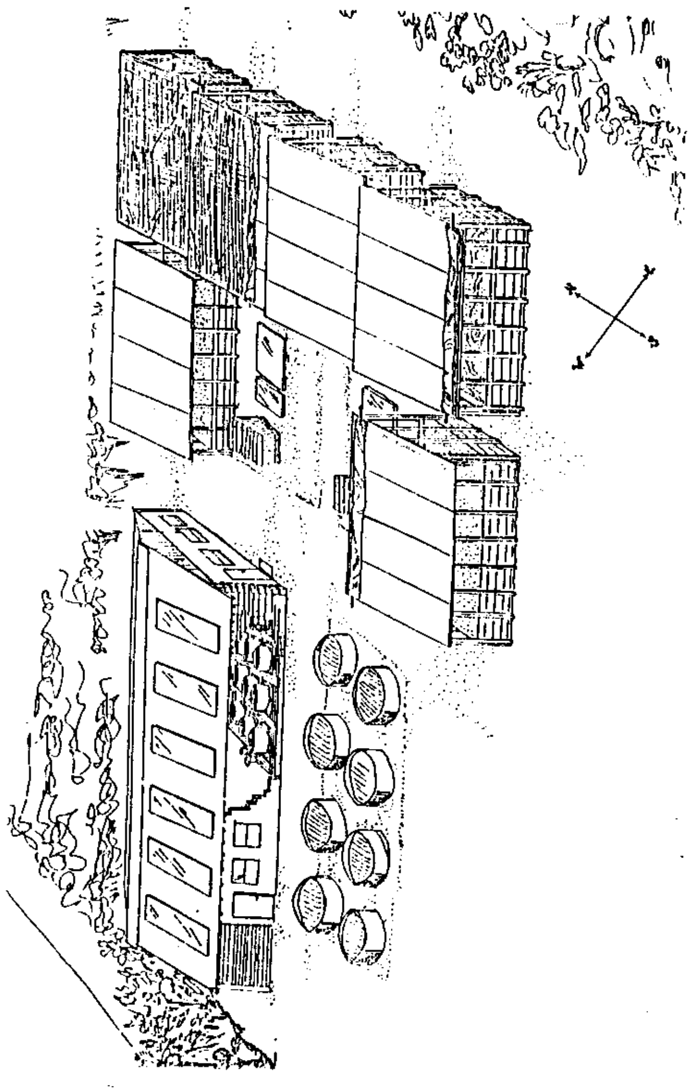

Figure 1. Aerial view of hatchery facility.

**Broodfish Holding Tanks and Management**

Broodfish holding tanks are constructed of treated framing lumber and have inside dimensions of 7.6 m long by 4.5 m wide by 1.3 m deep (Figure 2A). The tank wall posts are tied together with roof rafters and buried floor joists. The sand bottom and wood walls of the tank are lined with a puncture-resistant fabric (Agri-Fabric) which protects the water-holding plastic liner (Permalon). An additional piece of plastic is placed over the rim inside the tank to protect the liner from ultra-violet light degradation above the waterline (Figure 2C). The tank bottom is sloped to a drain and standpipe in one corner (Figure 2B). Roof rafters are high enough for people to work inside the tank and the upper framework provides attachment sites for various cover materials used to maintain desired water temperatures and to control algal growth. In hotter months, the roof is covered with shadecloth and the upper walls are left open for ventilation. In colder months, the upper structure is enclosed in clear fiberglass to capture solar heat. Open tank, net enclosure, and behavioral fry production methods are incorporated into this tank design.

Table 1 compares fry production rates and methods used commercially and reported in the lature. Preferred ranges of operator-controlled criteria include younger, smaller broodfish of 75 to 250 g, densities of 5 to 11 fish/m$^2$, female-to-male sex ratios of 3 to 5, seed collection frequencies of 7 to 14 days, ad lib feeding of a high-protein diet, water temperatures of 26° to 32°C, dissolved oxygen concentrations greater than 3.0 mg/l, and ammonia concentrations not exceeding 0.4 mg N/l.

**Open Tank Method**

The open tank method is appropriate for large-scale, intensive fry production where fry production-per-broodfish biomass and holding area are maximized and a large brood fish population is maintained (Balarin and Haller, 1982; Berrios-Hernandez and Snow, 1983; Snow *et al.*, 1983; Thompson,1986, pers. comm.). Broodfish are stocked at the desired sex ratio, average weight for each sex and density, and are allowed to spawn freely. Broodfish are sorted regularly at 7—10 day intervals using a crowding grate, and eggs and larvae are taken from brooding females. All eggs are artificially incubated and the number of free swimming fry should be negligible at this sorting interval. One hundred to 200 g broodfish will be stocked at 240 females and 60 males per tank for a density of 8.8 fish/m$^2$. This method has the potential of producing 20,000 fry/tank/week.

**Net Enclosure Method**

The net enclosure method is appropriate for smaller scale, intensive fry production and allows small groups of broodfish to be managed separately within one tank (Balarin and Haller, 1982; Hughes and Behrends, 1983; Beveridge, 1984; Harris and Dewandel, 1984; Rakocy, 1985). These rectangular, open-top net enclosures, commonly referred to as hapas, are suspended in the water column and stocked with broodfish. Eggs and larvae are taken from brooding females at 7—10 day intervals and eggs are artificially incubated. An efficient procedure for sorting broodfish in hapas is described by Rakocy (1985). The net enclosure method is also amenable to longer sorting intervals where free swimming fry are easily concentrated and netted. Five hapas, each measuring 3.0 m long by 1.2 m,wide by 1.2 m deep with a mesh size

**Table 1.** Broodfish stocking variables and fry production rates for open tank, hapa, and behavioral tilapia fry production methods.

| Stock n/m² | F:M ratio | Wt M(g) | Wt F(g) | Seed Produced per month per m² | F | kg F | kg M + F | Method, Species, and Reference |
|---|---|---|---|---|---|---|---|---|
| 10.0 | 3.0 | 75 | 75 | 200 | 27 | 360 | 267 | 18 m² tank, fry netted daily; *O. aureus*; Shelton (1978)* |
| 3.0 | 4.5 | 400 | 300 | 410 | 170 | 570 | 432 | 7.3 m² pool, fry netted daily; Florida red hybrid; CMRC preliminary study |
| 2.2 | 3.0 | 126 | 103 | 489 | 298 | 2890 | 2038 | 7.3 m² pool, fry netted, oral clutch taken monthly; *O. aureus*; Snow *et al.* (1983) |
| 10.2 | 3.0 | 450 | 226 | 685 | 90 | 400 | 238 | 79 m² trough; *O. mossambicus*; Hida *et al.* (1962)* |
| 1.6 | 3.0 | 213 | 206 | 882 | 700 | 3400 | 2673 | 7.0 m² pool, oral clutch taken every 10-12 days; *O. aureus*; B.-H. & Snow (1983) |
| 11.2 | 3.0 | 142 | 113 | 1688 | 200 | 1770 | 1250 | 4.5 m² tanks; *O. mossambicus*; Uchida & King (1962)* |
| 8.4 | 3.8 | 300 | 300 | 2350 | 375 | 1250 | 933 | 2.3 m² tanks, fry removed every 2 weeks; *O. niloticus*; McAndrew (1982)* |
| 9.0 | 5.0 | 90 | 65 | 3881 | 517 | 7954 | 6160 | 33.5 m² tanks, fry & oral clutch taken every 7 days; *O. niloticus* x *O. mossambicus*; Thompson (1986, p.c.) |
| 6.0 | 5.0 | — | — | 175 | 35 | — | — | 4 m² hapa; tilapia; Beveridge (1984) |
| 13.0 | 3.3 | 72 | 54 | 275 | 28 | 519 | 362 | 2 m² hapa; *O. mossambicus*; IFP (1975)* |

Table 1 (continued).

| Stock n/m² | F:M ratio | Wt M(g) | Wt F(g) | Seed Produced per month per m² | F | kg F | kg M + F | Method, Species, and Reference |
|---|---|---|---|---|---|---|---|---|
| 8.1 | 4.0 | — | — | 724 | 116 | — | — | 3.7 m² hapa, post larval fry removed every 14 days; *O. aureus*, Rakocy (1985) |
| 5.0 | 2.0 | 58 | 116 | 2233 | 620 | 5345 | 4652 | 3.3 m² hapa, all seed removed every 10-18 days; *O. nilotica*; Hughes and Behrends (1983) |
| 10.1 | 4.0 | 85 | 85 | 2928 | 488 | 5741 | 3405 | 1.5 m² cages, fry escape from cages to tank; *Oreochromis* spp.; Bizzell (1986, p.c.) |
| 1.9 | 6.0 | 375 | 140 | 190 | 117 | 836 | 576 | 3 ringed behavioral system; *O. aureus* x *O. niloticus*; Haller and Parker (1981), Balarin and Haller (1982) |

*Studies cited in Balarin and Haller (1982)
Abbreviations: n = Number, Wt = Mean Weight, F = Female and M = Male broodfish.

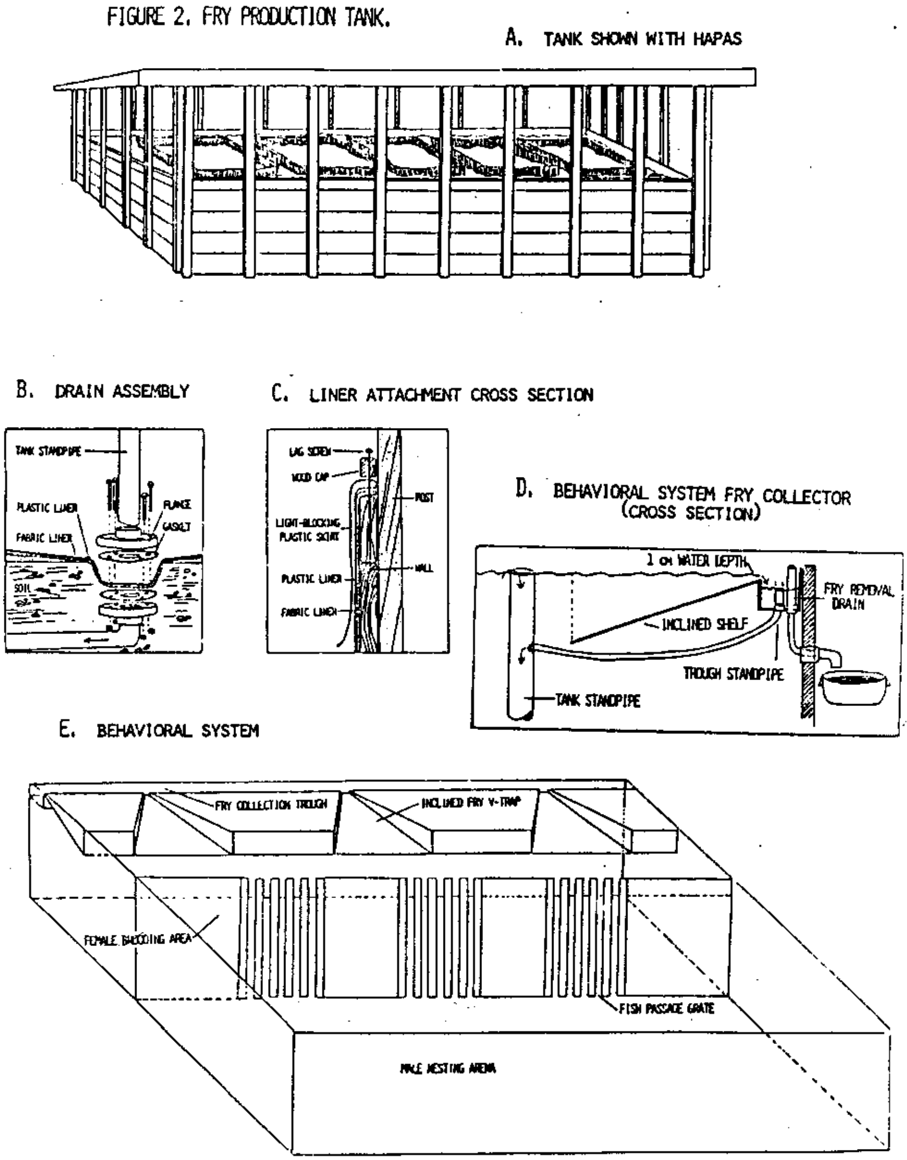


**Figure 2.** Fry production tank; (A) Tank shown with hapas; (B) Drain assembly; (C) Liner attachment, cross section; (D) Behavioral systenm fry collector, cross section; (E) Behavioral system

of 1.6 mm, are arranged laterally in the tank, with a water depth of 80 cm and a freeboard of 40 cm (Figure 2A). One hundred to 200 g broodfish are stocked at 28 females and 7 males per hapa for a density of 9.7 fish/$m^2$. This method has the potential of producing 10,000 fry/tank/week.

In the open tank and net enclosure methods, eggs and larvae are taken from brooding females by manually opening their mouths and rinsing out their clutch with a gentle stream of water. The rationale for artificial incubation is that, by removing the fish's clutch, the time interval between successive spawns is reduced and the fry production rate per female is increased (Siraj *et al.*, 1983; Snow *et al.*, 1983).

**Behavioral Method**

The behavioral method eliminates some of the disadvantages of the open tank and net enclosure methods, including handling stress on broodfish, disruption of spawning, and the labor requirement of sorting and collecting eggs and fry. This method, developed by Haller and Parker (1981) and based on natural tilapia behavior as described by Bruton (1983), provides shallow water for collecting fry, a secluded area for brooding females, and a nesting arena for males.

The internal design of the behavioral tank (Figure 2E) is adapted from the concentric-circle design of Haller and Parker (1981). The male arena and female brooding area are each 17 $m^2$ with the dividing wall centered longitudinally. The male arena is provided with an 8 cm sand substrate for nest building and males are confined to the arena by grates through which the smaller females may freely pass. Stocking of females no larger than 125 g and males no smaller than 200 g requires a grate gap width of approximately 3.2 cm. Thirty males are stocked into the arena at a density of 1.8 fish/$m^2$ and 180 females are stocked into the brooding area at a density of 10.5 fish/$m^2$. The fry collection structure extends 1.4 m into the female brooding area. Fry are attracted into the shallow, inclined V-traps and collected in the trough. A standpipe in the trough, slightly below the water level in the tank, causes a current into and through the trough (Figure 2D). This current maintains water quality in the trough and aids in containing captured fry. The trough is periodically emptied to the outside of the tank and the fry caught in a container (Figure 2D). This method has the potential of producing 7,000 fry/tank/week.

**Aeration of Broodfish Tanks**

Oxygen is supplied to broodfish by Hinde hose air diffusers placed in the tanks. The calculated oxygen consumption rate per tank is based on the highest potential biomass density of 300 fish per tank, or 35 fish per hapa, at a 200 g mean fish weight and an equation in Romaire *et al.* (1978) giving oxygen consumption per fish (mg $O_2$/fish/hr) as fish weight (g) to a power of 0.82. Although other published equations (Melard and Philippart, 1980; Balarin and Haller, 1982; Ross and Ross, 1983) give lower consumption rates, this design is based on the highest oxygen requirement. The design is also based on a minimum dissolved oxygen (DO) concentration criteria of 5.0 mg/l, an equilibrium DO concentration of 6.8 mg/l (20 ppt, 30° C), a minimum diffuser oxygen transfer efficiency of 2.8% at 76 cm water depth (Hinde hose lature; Colt and Tchobanoglous, 1979) and a safety factor of 100% to account for diffuser fouling and oxygen demands other than fish.

These conditions result in required air flow rates of 100 lpm per tank and 11.6 lpm per hapa. Based on an air flow rate criterion of 7.5 lpm per meter of diffuser, the required lengths are 13.3 m per tank and 1.5 m per hapa. Diffusers are placed on tank or hapa bottoms. The required air pressure inside the diffuser is the sum of its required air-release pressure of 35 cm water and the maximum ambient water pressure of 100 cm water. Air is supplied by a regenerative blower selected to satisfy these flow rate and pressure criteria. The blower, the most critical life-support component, is equipped with an alarm activated below a minimum operating pressure.

**Water System for Broodfish Tanks**

Required water flow rate through a tank is based on the broodfish maximum unionized-ammonia criterion of 0.4 mg NH3-N/l. Derived by a simplified total ammonia nitrogen (TAN) mass-balance analysis, the required water flow rate per tank (lpm) is the broodfish TAN-excretion rate per tank (mg N/min) divided by the difference between the tank influent and effluent TAN concentrations (mg N/l). Based on salmonid data (Westers and Pratt, 1977), the broodfish TAN excretion rate is considered to be 0.15 mg nitrogen per mg oxygen consumed, where oxygen consumption is calculated as above at the highest potential biomass density. A tank effluent TAN concentration of 2.0 mg N/l is used, as results from the unionized-ammonia criterion and an expected maximum unionized-ammonia component of TAN of 20% (freshwater, 30° C, pH = 8.5). A tank influent TAN concentration of 0.8 mg N/l is used, assuming 60% TAN removal in the water recirculation system. These conditions result in a required water flow rate per tank of 48.2 lpm or two water exchanges per day.

Tank effluent water is recirculated through a treatment system that removes nitrogenous compounds. Suspended solids resulting from uneaten feed, fish feces, and algal and bacterial growth are also removed but most solids settle in the tanks due to the 12 hour water retention time and are removed by vacuuming. Recirculated water is returned at the furthest point from tank drains or directly into hapas.

There are two separate water recirculation systems, with three tanks per system (Figures 3 and 4), to allow comparative water quality studies. Each recirculation system consists of two foam fractionation columns, a solids sedimentation basin, a solids filter, a biofilter, and a water collection sump. The systems, recessed to ground level, are gravity fed by effluent tank water. Other than a few components, the recirculation treatment unit is constructed of ABS plastic. Each recirculation system can also supply water to four fry-acclimitization tanks, resulting in a total combined water flow rate of 190 lpm persystem.

Foam fractionation removes surface-active dissolved organic compounds that are precursors to TAN generation and biochemical oxygen demand (Wheaton, 1977). These solutes are attracted to air bubble surfaces and are carried into a foam layer which accumulates and spills over the top rim of the foam fractionation column into a collector. These columns extend 120 cm below normal water level in the headbox and have an inside diameter of 30 cm. The columns rest against the floor of the sedimentation basin and have a bottom opening for water escapement. The length of column above the water level is adjustable according to foam height and collection. A silica-glass air diffuser

Figure 3. Schematic of hatchery air, water, and waste systems.

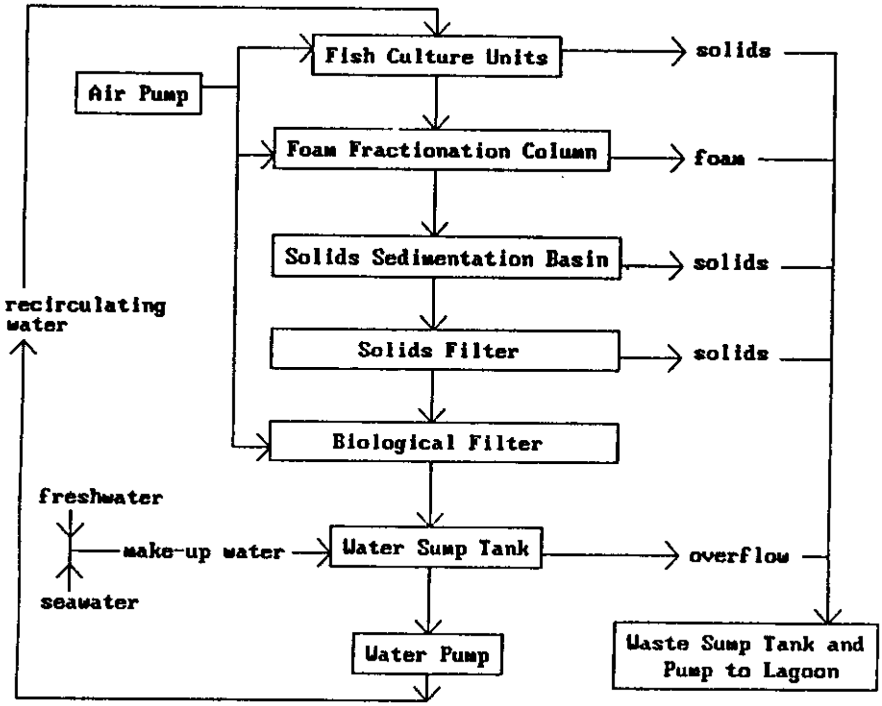


Figure 3. Schematic of hatchery air, water, and waste systems.

supplied with air at 14.2 lpm is placed at the bottom of the column, and air and water flow in opposite directions in the column for maximum air and water contact. In this way the columns also function as aerators and add approximately 1.25 mg oxygen per l of water. The headbox and columns function as a water pressure compensator for flow resistance exerted by the gravel filter bed. The water will rise in the headbox, as the filter clogs with solids, indicating the condition of the filter and providing the additional driving pressure required.

The sedimentation basin has a sloped bottom and sides to concentrate solids at one end for periodic removal. At a water flow rate of 190 lpm, the 5,660 l basin has a water retention time of 30 minutes allowing most of the settleable solids to be removed (Jensen,1972). Solids are removed by pumping water from a basin's deepest point via an access tube through the media above it. By stopping the flow of water into the treatment system this process also back-flushes the gravel filter.

The solids filter is 4.3 m x 1.8 m x 15 cm and, with the total water flow rate at 190 lpm, the areal flow rate is 25 lpm/m$^2$. The media is 2—4 cm gravel (local marl rock) resting on a steel grate. Particulate solids not settling in the basin are

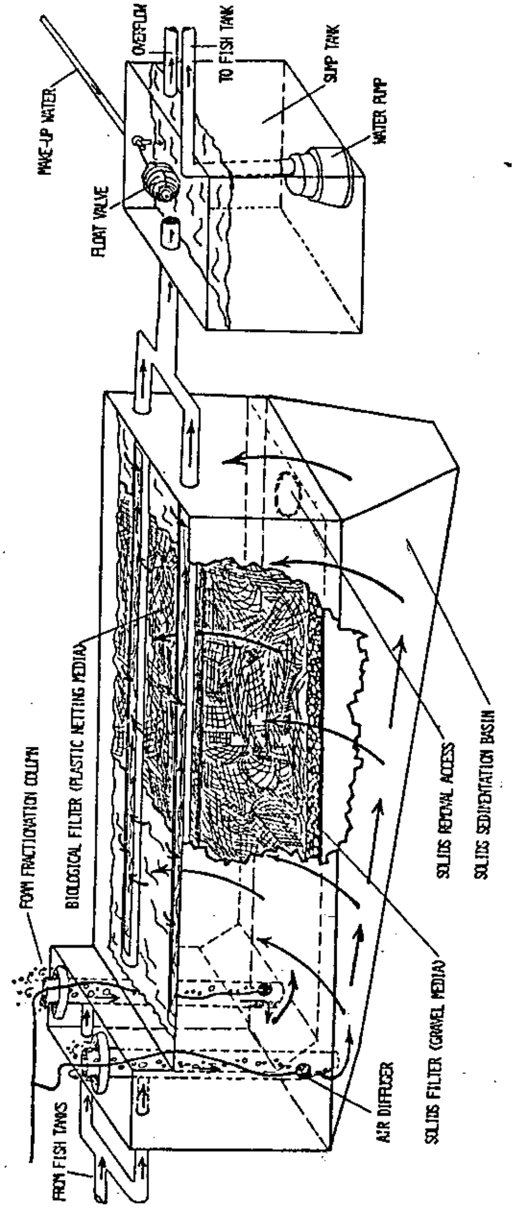


**Figure 4.** Water recirculation system (water flow follows arrows).

removed here and the calcium carbonate rock also provides some pH buffering capacity.

The biofilter provides substrate for nitrifying bacteria which oxidize ammonia to nitrite and nitrite to nitrate. The biofilter is 4.3 m x 1.8 m x 0.9 m for a media volume of 7.0 $m^3$.The media is polyethylene bird-netting (1.9 cm mesh, 0.25 mm diameter strands) which has a surface area-to-volume ratio of 87.5 $m^2/m^3$ when 0.9$m^2$ of netting is put into a volume of one l. The hydraulic load on the filter is 25 lpm/$m^2$ cross-sectional flow area and the TAN load on the filter is 0.527 g N/$m^2$ media surface area/day (Liao and Mayo, 1974). The biofilter bed is aerated by three 4.8 m diffusers (Hinde hose) placed under the media. These diffusers are supplied with air at 109 lpm to satisfy the 4.8 mg DO/l required to oxidize 1.2 mgTAN/l (Wheaton, 1977). The entire biofilter is covered with an opaque roof so that no light is available for algal growth.

Water taken from the surface of the biofilter enters a 1,200 l collection sump and is returned to the broodfish tanks by a submersible pump supplying 190 lpm at 3 m of water head. The sump also contains an overflow shunt to the wastewater system and float valve which regulatesthe flow of make-up water. Exchange, make-up, and flow-through water supplies are adjusted to required salinities by mixing fresh and seawater with manually adjusted valving systems. Daily monitoring of water system salinity is necessary due to salt accumulation from evaporation and salt production by the fish and water-treatment processes.

Freshwater (1 to 2 ppt) is pumped from the Island's lens-aquifer and seawater (37 ppt) is pumped from the ocean. Due to the Island's small size (5 $km^2$ ), the capacity of the aquifer is limited and its water extraction rate and salinity must be regularly monitored (Cant, 1980) to prevent seawater intrusion.

A wastewater system is required to prevent nutrient and salt pollution of the Island's aquifer. The wastewater system, which discharges water to an aerobic seawater lagoon, consists of a collection sump and a submersible pump activated by a float switch. The collection sump receives water from recirculation system overflow shunts, fish tank vacuuming and draining, sedimentation basin solids removal, and foam fractionation discharge. Fish tanks on flow-through operation drain directly to the wastewater sump.

**Fry Rearing System**

To allow comparative water quality studies, the fry rearing system consists of two separate water recirculation systems with three egg incubators and eight fry tanks per system. Both systems are housed in a 170 $m^2$ building where air and water temperature are passively controlled by varying levels of solar shading and convective ventilation. Egg incubators are clear plastic cylinders with hemispherical bottoms, 15 cm in diameter and 40 cm in length, each holding up to 20,000 eggs. An upwelling current is maintained through the incubator to gently roll the eggs. As they hatch, sac-fry swim up into the water column above the eggs where they can be decanted or held for capture. The 107 cm diameter fry tanks are constructed of black ABS plastic with a water volume of 560 l and freeboard of 8 cm. The tank bottom is cone-shaped with a 30° slope to aid in removing solids. A standpipe is fitted into a drain at the bottom of the cone.

The tanks are stocked at a maximum of 5,000 fry per tank for a density of 5,618 fish/$m^2$ or 8,828 fish/$m^3$ (Rothbard *et al.*, 1983). Fry are treated in these tanks with a male hormone for at least 25 days to sex reverse genotypic females to phenotypic males. The sex-reversal treatment increases the growth rate of females (Guerrero, 1975; Behrends *et al.*, 1982) and prevents unwanted reproduction during grow-out. Sex-reversal is achieved by incorporating the androgen 17-alpha ethynyltestosterone (ET, Sigma Chemical Co.) into the fry feed at 60 mg ET per kg feed (Guerrero, 1975). During the 25 day treatment, fry grow from an initial weight of about 0.01 g to a final weight of about 0.5 g. Fry are fed by automatic feeders, beginning atapproximately 30% body weight per day.

Each fry tank is aerated with two silica-glass air diffusers (3.8 cm x 3.8 cm x 7.6 cm) supplied with air at 8.5 lpm per diffuser. This design is based on a maximum biomass per tank of 5,000 fish at a mean weight of 0.5 g and the procedure outlined above with an oxygen transfer efficiency of 2%. Ozone is mixed into diffuser air for tankwater disinfection of fish pathogens (Blogoslawski and Rice, 1975). The water flow rate in the fry tanks is based on TAN, using the same criteria as the broodfish design with a maximum tank concentration of 0.30 mg NH3-N/l and a minimum TAN removal rate of 50% in the water recirculation system. These conditions result in a required water flow rate per tank of 9.4 lpm or one exchange per hour.

The water recirculation systems are functionally similar to the broodfish systems but are smaller in size. The foam fractionation columns are not housed in a headbox, however, and the columns alone serve for pressure compensation. The columns are also longer in relation to the main unit. The foam fractionation columns have a water height of 152 cm and an inside diameter of 20.3 cm. The column diffusers are the same as those in the fry tanks and are supplied with air at 8.5 lpm per diffuser. The columns also strip residual ozone from the water to prevent contact with the biofilter bacteria. These dimentation basins have a volume of 1,000 l and a retention time of 15 minutes. The solids filters measure 2.4 m x 1.1 m x 10 cm. The biofilters have a volume of 1,400 l, a hydraulic loading of 30 lpm/m$^2$ cross-sectional flow area, and a TAN loading of 0.664 g N/m$^2$ media surface area/day (Liao and Mayo, 1974). Each biofilter is supplied with diffused air at a rate of 32.7 lpm. The 225 l collection sumps contain submersible pumps which supply 110 lpm at 3 m water head. The sumps receive make-up water at the desired salinity through float valves and have overflow shunts to the wastewater system.

**Fry Acclimatization System**

Eight 2.5 m diameter acclimatization tanks are stocked at a maximum of 10,000 fry per tank or 2,037 fish/m$^2$. Based on a mean fish weight of 1.0 g and the above design procedure, each tank is aerated with a Hinde hose diffuser, 6.3 m in length and supplied with air at 47.3 lpm. When salinities are compatible, tank water is exchanged by the broodfish recirculation systems at four tanks per system and four exchanges per day. During seawater acclimatization, the tanks receive flow-through water at the desired salinity. Acclimatization is accomplished by increasing salinity 5 ppt per day until full strength seawater is achieved. Fry are fed during this period and continue to grow.

Alternatively, seawater acclimatization can be accomplished during sex-reversal by operating the fry tanks on flow-through water. Continuation of water recirculation during acclimatization may be possible but the ranges and rates of salinity fluctuations tolerated by biofilter bacteria must first be studied.

The hatchery described here will provide data for designing tilapia hatcheries at other Caribbean sites, particularly in estuarine and marine areas.

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