Operation & Management Plan

Mariculture Demonstration Facility

MINISTRY OF INDUSTRY, COMMERCE AGRICULTURE & FISHERIES

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AquaBioTech Group

Central Complex, Naggar Street, Targa Gap, Mosta MST 1761 - MALTA G.C.

Tel: +356 2258 4100 **E-mail:** aqua@aquabt.com

Content

Acronyms

COVID	Corona Virus Disease
MICAF	Ministry of Industry, Commerce, Agriculture and Fisheries
NEPA	National Environment and Planning Agency
NFA	National Fisheries Authority
NGO	Non-Governmental Organisation
OPESCA	Central American Fisheries and Aquaculture Organisation
RAS	Recirculating Aquaculture System
RFMO	Regional Fisheries management Organisation
SMS	Short Message Service
UV	UltraViolet
UWI	University of the West Indies

1 Introduction

1.1 Context

The development objective of the Promoting Community-based Climate Resilience in the Fisheries Sector Project for Jamaica is to increase the adoption of climate resilient practices among targeted fishing and fish farming communities in Jamaica. The project aims to achieve the following components: (i) strengthening the fisheries policy and regulatory framework; (ii) diversification and fisheries-based alternative livelihoods; (iii) capacity building and awareness raising; and (iv) project management and monitoring and evaluation.

This assignment intends to assist National Fisheries Authority of the Ministry of Agriculture and Fisheries (MAF) in realising the aquaculture potentials of Jamaica. The AquaBioTech Group has been contracted to assist in the development of a climate smart/climate resilient mariculture demonstration facility at the Fisheries Division's Bowden Mariculture Facility. A design was presented to the MAF.

This operation and management plan is developed for the mariculture demonstration facility at the Fisheries Division's Bowden Mariculture Facility. This manual includes human resource requirements, organisational structures, and management protocols. The manual includes a technical description of the design with system specifications (design and biological specifications, water quality limits, technical equipment information and energy requirements), production plan, and operational procedures for the hatchery and grow-out activities. Operational procedures include broodstock management, egg collection and incubation, larval rearing, husbandry, feed management, water quality management, disease control, harvesting and transportation, staff training and record keeping.

1.2 Objectives

The objective of this operation and management plan is to outline how the mariculture demonstration facility management will function. It includes management structures, organization charts and decision-making structures, an overview of targeted activities, an overview of Human Resource needs and operation protocols and guidelines. The purpose of the mariculture demonstration centre is to provide training and demonstration activities to build capacity and promote mariculture in Jamaica.

2 Management and organisation

2.1 Key personnel

Facility manager

The facility manager is responsible for the day-to-day operations of the facility. Ensuring objectives of the facility are reached in terms of demonstration and training activities.

Finances and procurement

In charge of the financial aspects of the day-to-day management and responsible for achieving the financial goals and targets set by the general manager and the project steering committee. The financial manager reports to the facility manager.

Aquaculture manager

The aquaculture manager is in charge of the hatchery and grow out activities at the facility as well as the laboratory.

Technicians

The aquaculture manager is assisted by aquaculture technicians. They will also take care of maintenance and cleaning of aquaculture equipment.

Trainers

Besides the general management of the project, the second key staff component is a pool of dedicated and experienced teachers. The number of trainers hired depends on the volume of trainings and trainees.

Drivers, cleaners and guards

Guards will ensure safety of the infrastructure and staff. Cleaners should be assigned to the general cleaning of the facility and maintenance of the garden. Drivers should be made available by the NFA when needed.

Experts for training of staff and trainers

Other than the operations team, expert will be needed, especially in the first stages of the project to get the production up and running. The following experts were identified as available experts for the selected species. These experts may be hired by the project to provide training of trainers' courses and practical advice and assistance.

Grouper:

- Jonah van Beijnen, VB Consultancy, jonah.vanbeijnen@gmail.com
- Kyra Hoevenaars, AquaBioTech Group, kyh@aquabt.com
- Zack Daugherty, University of Miami, zackdaugherty@gmail.com

Parrot fish:

- Till Deus, Bocas mariculture, till.deuss@bocasmariculture.com

Oyster:

- Rob Garrison, New Seas, rob.garrison@new-seas.com

Sea cucumber:

- Alvaro Hernandez, Inapesca, a.hernandez.inapesca@gmail.com
- Enrique Gonzales, University of Campeche, eagonzal@uacam.mx

2.2 Human resource requirements

The Human Resource requirements have been calculated for the first three years of operation and it is project that the project will grow from 8.5 fulltime (FT) positions in year 1 to a total of 10.5 FT by year 3, as shown in Table 1.

Table 1: Required personnel and load for the project from operational year 1 until year 3.

Function	**Year 1**	**Year 2**	**Year 3**
Facility manager	1 FT	1 FT	1 FT
Aquaculture manager	1 FT	1 FT	1 FT
Technicians	2 FT	2 FT	3 FT
Trainers	1 FT	2 FT	2 FT
Finances and procurement	0.25 FT	0.25 FT	0.25 FT
Driver	0.25 FT	0.25 FT	0.25 FT
Cleaner	1 FT	1 FT	1 FT
Guards	2 FT	2 FT	2 FT
Total	**8.5 FT**	**9.5 FT**	**10.5 FT**

FT = Fulltime, a workload of approximately 40 hours per week

2.3 Organisational structure

The general organizational chart of the Mariculture Demonstration Facility is presented in Figure 1.

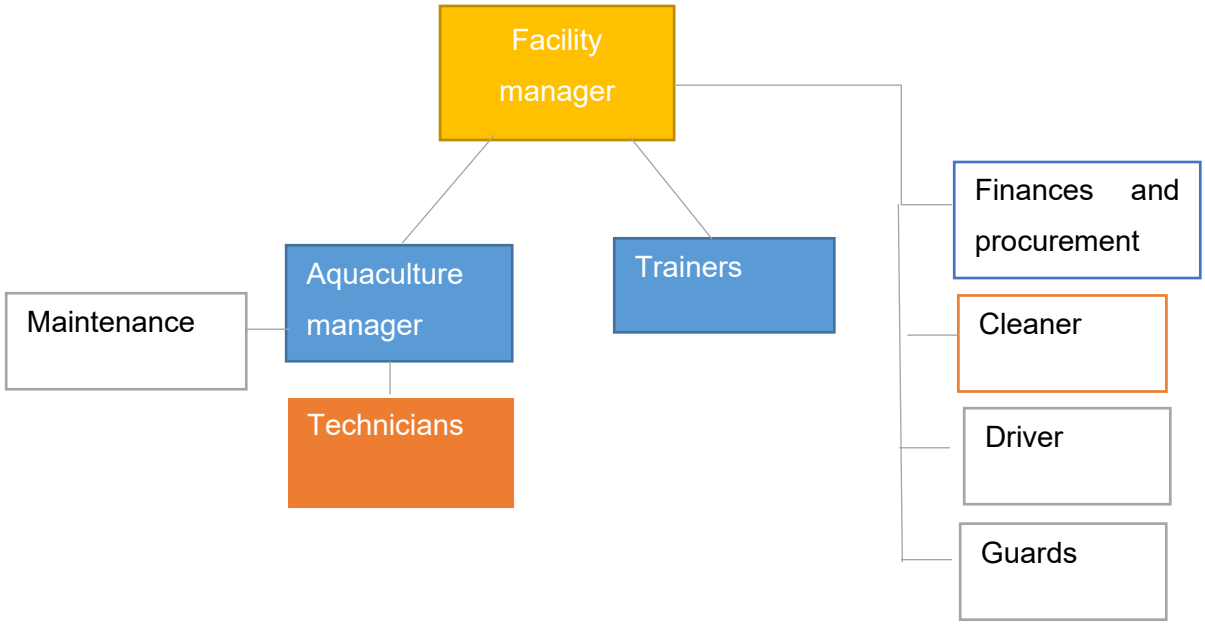


Figure 1*:* The general organizational chart for the Mariculture Demonstration Facility

The key management team consist of the facility and aquaculture managers. The key management personnel are responsible for a number of important management and organisational processes and these are sorted and outlined in Table 2. The main management responsibilities carried out by the key management personnel are planning and budgeting, system design and improvement, operation management and monitoring and evaluation. In order to carry out these activities, core processes are developed. The key management personnel are supported by the following finances and procurement, a cleaner, guards and a driver.

Table 2*:* An overview of the core organizational processes and activities.

Category	**Sub-category**	**Management activities**
Management	Planning and Budgeting	Strategic plan
		Operational plan
		Financial plan
	System design and improvement	Team composition
		Processes

		Support mechanisms
	Operational management	Task management
		Coordination of staff
		External communication
	Monitoring and evaluation	Financial results
		Beneficiary satisfaction
		Employee satisfaction
		Training results
Core processes	Training course development	Curriculum development
		Course design
		Training materials
	Training delivery	Training delivery plan
		Training of trainers
		Training evaluation and reporting
	Research activities	Development of aquaculture protocols
	Extension services	Provision of seed to community projects
		Demonstration of activities
Support	Administration	Registration and schedules
		Resource management
		IT
		Marketing
		Procurement
	HR	Recruitment
		Staff training

2.4 Management protocols

To streamline the management processes and activities outlined in the previous section, a number of protocols and SOPs will need to be developed by the operator of the facility. These include management protocols and guidelines on the following topics:

- Decision making
- Employee hiring and evaluation
- Fair and honest recruiting and contracting
- Anti-discrimination

- Staff training
- Monitoring Procedures
- Records and data management
- Information dissemination
- Cooperation with local stakeholders
- Reporting
- Material and equipment usage, storage and maintenance
- Health and safety
- Event management

An overview of the required operational protocols, SOPs and guidelines is given in Chapter 6.

3 Site description

3.1 Land site

The NFA site at Bowden Bay is approximately 1,220 m2. The site is located deep into Bowden Bay in proximity to the mangrove area. Currently it houses an office building (6x6m) and 2 work sheds (15.5x5.8m and 3.6x6.7m respectively).

The site is connected to the main electricity grid (single phase, 220V, 50 Hertz) and no generator is available. It would take a month the install a 3-phase connection. Electricity is charged at a commercial rate of $18.55 per kWh. Fresh water is delivered through the main line and no intake system for sea water is present. Medical oxygen is available from IGL Blue.

The site has a drainage to avoid floods during heavy rains. However, some areas are still prone to flooding.

Figure 2: Land-based NFA site at Bowden Bay.

3.2 Marine site

The area dedicated to oyster farming is approximately 60,000 m2, 190m from the shore. The average water depth is 8ft (2.4m). Closer to the shore the depth is 3 ft (0.9m). This site will also be used for the grow-out of sea cucumber and the culture of Irish moss.

Figure 3: Oyster racks at Bowden Bay

3.3 Climate

Rainfall

Table 3: 30-year (1971-2000) monthly mean parish rainfall for St. Thomas

Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Rainfall (mm)	94	81	68	92	162	170	120	180	255	287	217	116

The average salinity in the marine site is 36 ppt and varies between 33-39 ppt.

Water quality

Table 4: Water quality data measured at Bowden, Morant River water shed, St. Thomas.

DATE	Nitrate (mg/l)	BOD (mg/l)	Phosphate (mg/l)	TSS (mg/l)	Faecal Coliform (MPN/100ml)
23-Jul-08	0.664	1.16	0.006	n/a	n/a
12-Mar-09	2.293	0.85	0.003	n/a	n/a
11-May-09	0.155	0.21	0.003	n/a	n/a
16-Jul-09	0.950	0.34	0.006	n/a	n/a
29-Mar-10	0.004	0.33	0.011	n/a	n/a
3-Mar-14	<0.004	1.05	0.01	220	<2
27-Oct-14	<0.004	0.32	0.04	164	<1.8
9-Feb-15	0.01	1.03	<0.003	184	<1.8

4 Description of the facility

4.1 Description of the facility

The mariculture demonstration facility in Bowden bay aims to facilitate training, research, and demonstrate grow-out activities through pilot farms.

4.1.1 Species

The facility has been designed for culture of the following species;

1. Grouper (*Epinephelus striatus*)
2. Parrot fish (*Scaridae sp.*)
3. Irish moss (*Gracilaria sp.)*
4. Four-sided sea cucumber (*Isostichopus badionatus)*
5. Mangrove oyster (*Crassostrea rhizophorae)*

It can also be used for other fin fish species.

4.1.2 Lay-out

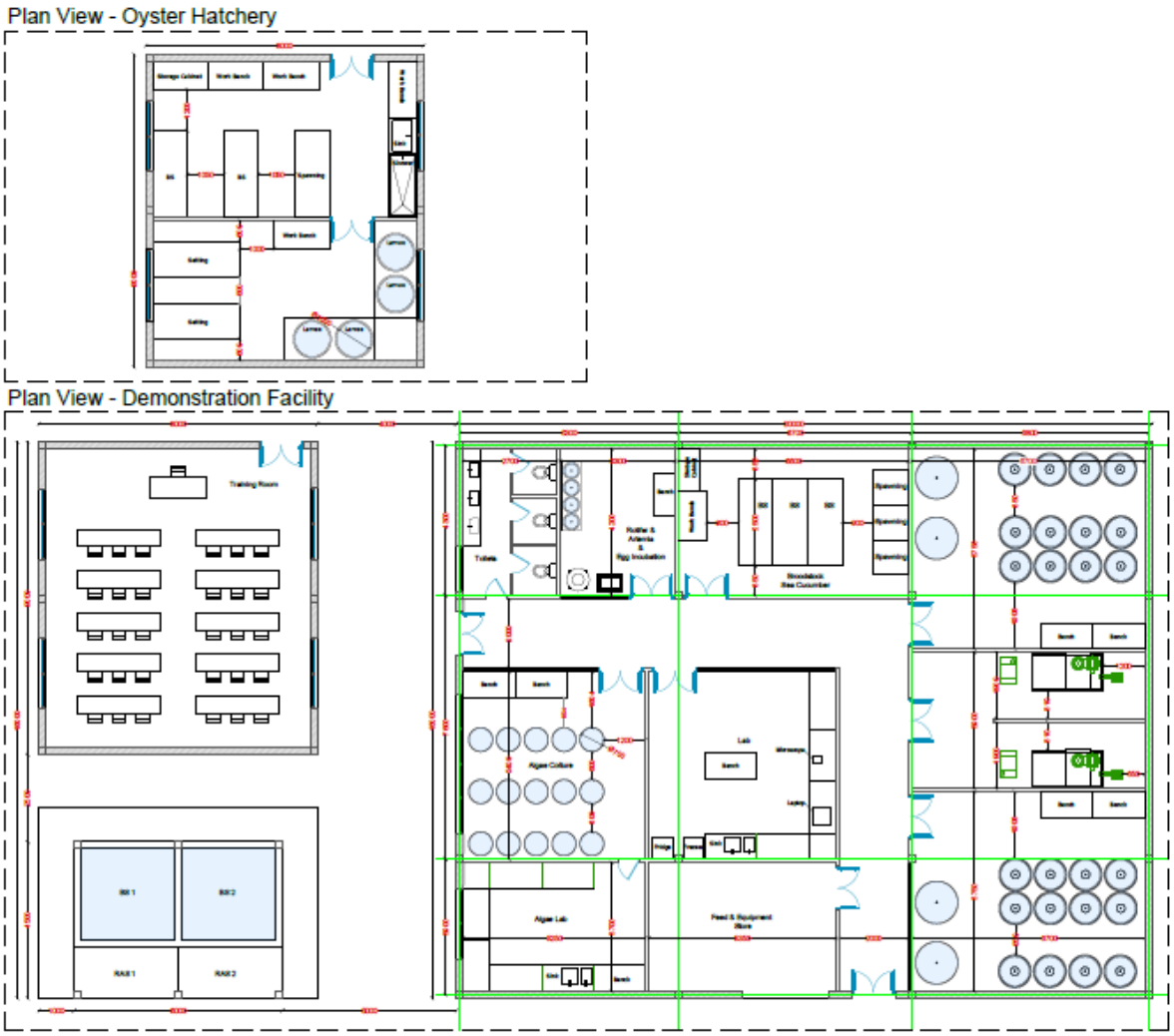


Figure 4: Lay-out of the mariculture demonstration facility

4.1.3 Facility components

Table 5: Different components of the mariculture demonstration facility.

Item	Name and required parameters	Specifications
1	Building construction	Concrete housing of the facility.
2	Training room	A training room with a capacity for 30 people. The room will be equipped with desks and chairs and should have a projector and screen.
3	Broodstock tanks (fish)	The broodstock unit consists of two 25m^3 broodstock tanks. The broodstock unit will run on a Recirculating Aquaculture System (RAS) in which 90% of the water is reused, The broodstock tanks

		are partly underground and on work level a concrete platforms is constructed around them. The tanks and the RAS are covered with a galvanised roof.
4	Broodstock & spawning tanks (sea cucumber)	The sea cucumber broodstock room contains 3 brooodstock tanks and 3 spawning tanks. The broodstock tanks will run on RAS.
5	Hatchery	The larval rearing unit consists of 12 300 litre tanks and 2 700 litre tanks with lids and is connected to a RAS unit that recirculates 90% of the water.
6	Nursery	The nursery unit consists of 12 300 litre tanks and 2 700 litre tanks and is connected to a RAS unit that recirculates 90% of the water.
7	Live feed laboratory & egg incubation	Before the water enters in the egg incubation jars it is channelled through a UV sterilizer. The egg incubation will consist of 4 conical tanks that can also be used for artemia incubation and rotifer enrichment. The rotifer system is a high-density system consisting of 1 self-regulating tank.
8	Algae laboratory and culture room	The algae laboratory will house a work bench and sink and shelves for small-algae cultures (in flasks and carboys). The culture room.
9	Store	Store for feed and materials.
10	Laboratory	The laboratory will be equipped to conduct water quality testing and to conduct disease monitoring. The laboratory will have a sink and working tables. It will be equipped with microscopes and a computer. There will also be a fridge and freezer to store algae products and starter cultures as well as other substances that need cold storage.
11	Sanitary facilities	A toilet and hand washing facilities. Equipped with a septic tank.
12	Oyster hatchery	The oyster hatchery houses 2 broodstock tanks, 1 spawning tank and 2 setting tanks, as well as 4 circular larvae tanks. It has a cleaning area with a shower, sink and workbench to clean the broodstock. A small store is included as well to store equipment.
13	Grow out pond	A 20 m3 concrete pond will be constructed for grow out of fish species. The pond will have a flow through system with a

		settlement tank at the outlet to ensure solid waste is not going back into the sea.
14	Tidal Floating Upweller System for oyster nursery	A Floating Upweller System will be constructed as a nursery for oysters with 8 compartments. A solar pump will facilitate the upwelling water flow.
15	Oyster Grow out racks	Current facilities will be upgraded. Car tires need to be replaced with other substrate and a bag culture test site should be established.
16	Seacucumber grow out pens	Enclosure (1 pen of 25x25 meters) made with poles and hapa nets in the shallow area of the bay.
17	Seaweed growing area	Different seaweed grow out methods will be tested; rope farming and bottom stocking.
18	Working sheds	Existing working sheds used for preparation of materials for seaweed, sea cucumber, and oyster grow out in the sea.
19	Office	The existing office will be used as office.
20	Intake water system	To ensure sufficient water supply for the facility a borehole should be constructed. The office, laboratory and sanitary facilities will be provided with water from the main water supply.
21	Generator	To provide a backup power supply in case the main grid fails.
22	Waste disposal facilities	Septic tank for liquid waste and storage bins for other waste outside the building.

4.2 Intake system

Oysters require natural sea water and water will be pumped directly from the sea and require no treatment or filtration with the exception of mesh filters (size depending on stage). A dual pipe system is used to control biofouling as one pipe is always dry and closed at both ends.

For the other species, a borehole is installed providing naturally filtered water to the hatchery.

4.3 Tanks

Table 6: Tank types, details and quantities

Tank type	Details	Quantity
Oyster broodstock tanks	Throughs 2.5x1x0.4m	3
Oyster setting tanks	Throughs 2.5x1x0.4m	2
Oyster larvae tanks	450L circular tanks 1m diameter	4
Sea cucumber broodstock tanks	Throughs 2.5x1x0.4m	3
Sea cucumber spawning tanks	100L plastic transparent tanks	

Egg incubation and artemia tanks	80 L conical tanks	4
Hatchery/nursery tanks large	700L 1.29m diameter circular tanks	4
Hatchery/nursery tanks small	300L 0.9m diameter circular tanks	24

4.4 Filtration systems

Intake water for oyster and sea cucumber modules is pumped from the sea and filtered before going to the reservoir by cartridge filters down to 5 or 1 microns depending on the needs.

The water for the other modules is pumped from the ground using a borehole and stored in header tanks.

The Recirculating Aquaculture Systems were designed in such a way to minimize energy use while facilitating ease of use. Water from the culture tanks flows by gravity from the main drain of the tank and the overflows into the drum filter collection box and then into the drum filter. The drum filter has a mesh of 40 micron and is backwashed periodically by a pump. From the drum filter water flows into the biofilter where bio-media is kept moving in the water by air flowing through an air-grid. Small solids are removed by a protein skimmer. Water is disinfected using a UV. Water is pumped from a clean partition in the biofiltration sump to the culture tanks. Aeration is provided to the tanks using air diffusers connected to an air pump.

The recirculation systems for the broodstock system of oysters and broodstock will used a simplified recirculation system containing of a reservoir with filtration mats (sponge and biomedia) and is pumped around using a small pump.

Main pump

The main pumps ensure recirculation of the water through the system. Electric centrifugal pumps are used with a built-in high capacity prefilter. These pumps operate from the thrust generated by the high-speed spinning of water in the pump head. The body of the pump is made from fibreglass reinforced technopolymer.

Solids removal

Settable and suspended solids are removed using a drum filter with a fine mesh screen (40 µm). The drum rotates so the screen can be back-washed using high pressure water sprays to prevent clogging of the screen. This is done using a backwash pump connected to the drum filter. Water and solids are collected in a gutter in the drum filter and removed from the system to the main drain.

Fine and dissolved solids are removed using a protein skimmer. By removing these solids, water turbidity is reduced, and oxygen demand of the system reduced. The protein skimmer has capacity of 3,000 L/hr. In the protein skimmer, air bubbles flow from the bottom of a closed water column. As the bubbles rise through the column solid particles attached to the bubbles creating foam at the water surface at the top of the column. The foam is channelled into a waste collector. Flowmeters are located before the protein skimmer to measure the flow rate of the water entering the protein skimmer.

Biological filter

In the biofilter, dissolved waste is removed by using bacteria. Ammonia, which in its un-ionised form (NH3) is very toxic to the fish, is utilised by nitrifying bacteria for growth and nitrite is produced as a by-product. The concentration of un-ionised ammonia can be controlled by maintaining an optimal pH of 7.0 (max. 8.75). Nitrite is less toxic than ammonia, but it is still harmful for fish. Nitrites are used by Nitrobacter bacteria to produce nitrate, which is only toxic to fish at very high concentrations. The bacteria grow on the surface of biofilter substrate (biomedia).

The biofilter consists of a sump tank divided in two partitions separated by a screen mesh, one part with biomedia chips and a clean sump. The surface of the biomedia chips used in the system is 700 m2/m3. The biofilter contains 0.75m3 of bio media chips. An air grid provides air for water movement in order to keep the biomedia moving and provide oxygen to the bacteria. A level sensor is installed in the sump that sends a signal to the controller when water level is low to alarm the technician to fill-up the tank.

Aeration

Aeration is provided to the biofilter sump and culture tanks using an air pump connected to an air grid and submerged air stones respectively. The flow of air bubbles increases contact with air and thus oxygen exchange between the air and water. This type of aeration also strips carbon dioxide from the water.

UV disinfection

Treatment using Ultra Violet light eliminates harmful micro-organism from the water. A UV unit with a capacity of 12,000 l/hr is used for the hatchery/nurseries. The UV units include a separate microprocessor that features a LCD display with lamp working hours, operating status and faults, countdown hour meter, alarm indicator and relay for remote monitoring, remote on/off relay and timer. Lamps must be changed after 9000 hrs of operation (every year).

4.5 Algae system

The algae laboratory consists of 2 rooms. One for the stock and small cultures (algae laboratory) and one for the large cultures (culture room).

Algae laboratory

The algae laboratory will house shelves for the small cultures in flasks and carboys. Small air blowers (Resun) provide air to 8 carboys each. The stock culture is kept in a fridge in sealed flasks or bottles. The algae laboratory room also has a work bench and a large sink for cleaning and disinfecting.

Algae culture room

The algae culture room has a rack with space for 15 algae bags with a tap on the bottom for harvesting. Air is provided to the cylinders by 2 air pumps.

4.6 Rotifer system

The 500L Varicon HDRS intensive Rotifer Production System is made of food grade MDPE with a diameter of 820mm and a height of 1560mm. The system comprises of a main electrical control panel, ph control (including peristaltic pump), do control, ammonia control, influent liquid process control, harvest overflow, internal air and oxygen diffusers, flock traps, chemical and feed dosing containers, feed chiller. (mini fridge), feed dosing pumps, associate solenoids, flow meters and a salinity adjustment system incorporating 2 off variable area flow meters, 2 off flow control valves, and 2 off inline non return valves.

4.7 Monitoring system

4th Gen galvanic membrane dissolved oxygen probes are installed in each of the culture tanks. A pH and redox probe are also included in the monitoring system. The monitoring system includes a touch screen display and associated alarms, and SMS notification should any of the measurements not remain within set limits.

The system permits easy access to the Commander Pacific systems used in the project by means of wireless connection, and it will also function with a wired connection. It can be used on a smartphone and tablet as well as on a PC. The wireless connection uses a standard wireless IP connection, i.e. Wi-Fi, and a wireless access point must be connected to the main Pacific or Commander Pacific system in order to obtain wireless connection. It provides an excellent and easy-to-use system for normal, everyday operation of the systems. It is set up with the algorithms necessary for such normal, everyday operation and does not present the user with functions and possibilities that are not needed.

5 System specifications

5.1 Technical information

Table 7: Technical information per system

System	Equipment type	Quantity	Specifications
Live feed	Air pump	1	160 L/min
	Heater	1	300W heater up to 34°C
	UV	1	12m3/hr @ 40mJ/cm2 T=80%
Sea cucumber broodstock	Pump	1	3.5m3/hr @ 0.5 bar
	Air pump	3	160 l/min
	Drum filter	1	15m3/hr 780x490x720mm mesh 40 microns
Hatchery/nursery 1&2	Backwash pump	1	3 m3/hr @ 10 bar
	Recirculating pump	1	15 m3/hr @6-8m
	Protein skimmer	1	3m3/hr
	UV	1	12m3/hr @ 40mJ/cm2 T=80%
	Air pump	2	160 l/min
	Drum filter	1	15m3/hr 780x490x720mm mesh 40 microns
Oyster hatchery	Air pump	2	160l/min
	Heat pump	1	Reversible air to water heat pump 7-35 °C
	Air pump	2	160l/min
	Recirculating pump	2	15 m3/hr @6-8m
	Protein skimmer	2	Flooded protein skimmer 9m3/hr
Broodstock fish	Air pump	2	160l/min
	Recirculating pump	2	15 m3/hr @6-8m
	Protein skimmer	2	Flooded protein skimmer 9m3/hr

5.2 Biological specifications

Table 8:Biological design specifications for RAS systems

System Design	Unit	A. Sea cucumber BS	B. Finfish BS (1&2)	C. Hatchery/nursery (1&2)
Number of tanks	#	3	1	12+2
Volume / tank	m^3	0.75	25	0.3+0.7
Volume total	m^3	2.25	25	5
Total RAS volume (fish + water treatment)	m^3	4.5	26	7
Max density	kg/m^3	5	5	8
Stocking size	g	200-900	450-1000	0

Max fish weight	g	900	1000	5
Max biomass per tank	kg	3.75	125	2.4+5.6
Average feeding rate	%	n/a	1%	10%

5.3 Water quality limits

Table 9: Water quality limits

Description	Criteria	Finfish	Sea Cucumber
Optimal Average temperature	°C	28-30	25
Optimal Average Salinity	‰	31	36
Optimal DO	mg/l	5-7.5	5-7.5
Optimal DO	%	70-100	70-100
Optimal Average pH		6.8-8	6.8-8
Maximum Ammonia NH_3	mg/l	0.1	0.1
Maximum TAN -NH3/NH4+ (pH dependent)	mg/l	2	2
Maximum NO_3- -N	mg/l	300	300
Maximum NO2-	mg/l	0.1	0.1
Maximum CO2	mg/l	40	40
Calcium hardness	mg/l	50-100	50-100
Chloride	mg/l	100-300	100-300
Alkalinity	mg/l	100-250	100-250

6 Production plan

The facility is designed as a multiple species facility so the production plan can be adjusted to the needs of the sector.

In the production plan presented in Table 9, the full capacity of the centre is used and 4 different species are produced; oyster, grouper, sea cucumber and Irish moss. The grouper facilities can also be used for another finfish species. The hatchery/nursery can be used for both finfish and sea cucumber, might research or production needs change.

Assumptions used to develop the production plan are provided in Table 9.

Table 9: Assumptions harvest sizes in hatchery and grow-out stages and average growth time.

Type	Species	Size	Growth period
Seed	Oyster	1 mm	1 month
	Grouper	2 gr	2 months
	Grouper	5 gr	3 months
	Sea cucumber	3-4 cm (5 gr)	3 months
	Parrot fish	10 cm	3 months
Market size	Oyster	7.5 cm	1-2 year
	Grouper	500 gr	8-10 months
	Sea cucumber	250 gr	2 years
	Irish moss	1 kg	3 months

Table 10: Example of production plan

		Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Oyster	Production level hatchery	0.2	0.4	0.6	0.8	1	1	1	1	1	1
	Seed production (1 mm)	3,360,000	6,720,000	10,080,000	13,440,000	16,800,000	16,800,000	16,800,000	16,800,000	16,800,000	16,800,000
	Sales (1 mm)	3,195,429	6,555,429	9,915,429	13,275,429	16,635,429	16,635,429	16,635,429	16,635,429	16,635,429	16,635,429
	Demo Nursery (12 mm)	115,200	115,200	115,200	115,200	115,200	115,200	115,200	115,200	115,200	115,200
	Demo Grow out (7.5 cm)	0	0	72,000	72,000	72,000	72,000	72,000	72,000	72,000	72,000
Grouper	Production level hatchery	0	0.05	0.1	0.20	0.50	0.75	0.75	1	1	1
	Seed production (2 gr)	0	6,000	12,000	24,000	60,000	90,000	90,000	120,000	120,000	120,000
	Sales (2 gr)	0	6,000	11,500	23,500	59,500	89,500	89,500	119,500	119,500	119,500
	Demo Grow out (500 gr)	0	0	400	400	400	400	400	400	400	400
Sea cucumber	Production level hatchery	0.00	0.00	0.2	0.4	0.6	0.8	1	1	1	1
	Seed production (3-4cm)	0	0	4,000	8,000	12,000	16,000	20,000	20,000	20,000	20,000
	Sales (3-4cm)	0	0	0	3,000	7,000	11,000	15,000	15,000	15,000	15,000
	Demo Grow out (250gr)	0	0	0	0	4,000	5,000	5,000	5,000	5,000	5,000
Irish moss	Demo Grow out (1 kg)	1,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000

7 Operation procedures

7.1 Finfish

The facilities are designed to host a range of finfish species. Nassau grouper (*Epinephelus striatus*) and Parrot fish were selected as species with a high market potential. However other marine finfish species can also be reared in the facilities such as rabbit fish and snapper.

Since the protocol for breeding of parrot fish is not yet established, only the method for grouper is outlined here and the protocol for parrot fish will be developed in the facility. However, the following is foreseen for the culture of Parrot fish:

Parrot fish eggs will initially be collected from spawning events in the sea while broodstock protocols are be researched. Species will be selected on size, market, and availability. Different species need to be studied and the species best suited for captivity should be further used. The same infrastructure will be used for parrot fish with exception of grow-out tanks. Broodstock of grouper and parrot fish can be kept together if spawning does not occur simultaneously. Grow-out of parrot fish will be trialled in the nursery tanks. Larvae settle on the tank walls after 7 weeks. They are fed with rotifer, artemia and copepods. From the nursery stage rocks need to be added to the tanks to mimic their natural environment. Juveniles are weaned on pellet feeds and adult artemia (for 1 month) up to 4 Inch.

7.1.1 Broodstock management

Broodstock assessment

A group of 15-20 individuals of Nassau Grouper should be used for breeding purposes. If wild caught fish are used, they need to be conditioned to captivity before they can be used as broodstock. Sexually mature fish are around 450-650 grams and a minimum of 5 years old.

To determine the sex and sexual maturity of the breeders, an assessment needs to be carried out. The breeders are measured for weight and length as well as checked for sex and maturity. The sex can be determined by the presence of milt or eggs. Male fish can be identified when milt is excreted when pressing gently on the abdominal part of the fish from head to tail. Cannulation is used to determine the presence of eggs in a female.

Feeding

Broodstock is fed three times per week with good quality fresh fish such as sardines, mackerel, and round scad in the late afternoon. Before expected spawning events, the broodstock should be fed with squid and tuna. Do not overfeed the fish.

Broodstock tanks

Broodstock is kept in a 25m^3 deep tanks using a simple water recirculation system. Water in broodstock tanks should be kept at 24-27°C for spawning promotion. Broodstock can spawn naturally or can be induced with HCG hormone to induce spawning. Nassau Grouper usually spawn at full moon or between new and full moon. When females have a dark colour this is an indication that they are ready to spawn.

Egg collection and incubation

If spawning occurs, the eggs are carefully collected with a fine mesh net after 10 minutes to ensure fertilization. Eggs are transported from the tank to the incubation area using buckets with aeration.

Eggs are rinsed with fresh water to remove algae and other foreign materials. After this, the eggs are cleaned in water with iodine for 1 minute. Only floating eggs should be used for incubation.

The eggs are transferred to the incubation tank (conical tank with discharge valve in the bottom) with aeration of 5-10 L/hour and a temperature between 27-29°C. The eggs hatch between 24-28 hours after incubation. The density of eggs should be 0.5ml per litre. Remove dead eggs by opening the valve in the bottom of the conical tank. Record the amount of bad eggs in order to calculate the hatching rate.

7.1.2 Larval rearing

Grouper larvae are extremely sensitive and go through several metamorphoses before they reach the juvenile stage. Careful and precise management is necessary to successfully rear this species.

Stocking

Larval rearing tanks should be stocked with larvae with a stocking density of 3 larvae per litre. Drops of fish oil should be added during the first 4 days of larval rearing to avoid trapped larvae in the water surface tension.

Tank management

Aeration is installed equally throughout the tank using air stones. Aeration should be monitored and adjusted regularly to avoid larvae aggregation. Larvae aggregation can cause mass mortalities due to entanglement of their spines. Day 1-8 the aeration needs to be gentle, after this the aeration can be increased. After Day After Hatching (DAH) 25 the aeration should be strong to provide sufficient dissolved oxygen.

Larval rearing tanks should be filled 4 days before larvae stocking and treated with 5 ppm formalin (37%). Salinity of the water should be between 26 and 31 ppt. The first 4 days of larval rearing no water is removed or added to the tanks. On DAH 5, 10 percent water exchange is done and increased to 50 percent on DAH 12. The bottom of the tanks should be cleaned carefully using a siphon starting DAH 8. Algae are added to the rearing water from drums using a small hose to maintain an optimal colour to prevent aggregation and surfacing of larvae. It also serves as food for rotifer. Water temperature should range between 27 and 30 °C. Water can be heated using electric heaters and kept cool by covering the tanks with plastic during the day. Artificial light should be above the tank (evenly spread) during the day between DAH1 and 10. Manually remove dirt on the water surface of the tank when necessary.

Feeding

The first feeding occurs on DAH 3 when the mouth of the larvae are large enough to consume rotifer. Rotifer are fed up to DAH 25. The rotifer density in the Larval Rearing tanks should be counted twice a day and when the count is lower than 5 ind/ml additional rotifer should be added. Artificial pellets should be introduced as early as possible but latest on DAH 12. Artificial feeds are fed every hour between 6 am ad 5 pm. Artemia are fed 2 times daily between DAH 12 and DAH 30, starting with newly hatched artemia and as the larvae increase in size the size of artemia used should also increase. Rotifers and artemia should be enriched with fish liver oil, vitamins, spirulina and garlic or a commercial product like Aquaran can be used. The rotifer or Artemia are kept in aerated water with enrichment for 2 hours before feeding. Use 1 ml of enrichment for every 2 million Rotifer. After enriching the artemia or rotifer, rinse with fresh water.

	DAH 3	DAH 4	DAH 5	DAH 10	DAH 12	DAH 15	DAH 20	DAH 25	DAH 30	DAH 35	DAH 40
Rotifer	**1 ind/ml**	**3 ind/ml**		**5 ind/ml**				**10 ind/ml**			
Artificial feeds					**100 - 200**	**200 - 400 micron**		**400 - 600 micron**			
Artemia					**0.1-0.3/ml**	**0.3-0.5/ml**		**0.5-1 ind/ml**			

Harvesting of fry

Between DAH 38 and 45 all larvae finished their final metamorphosis into juvenile stage. The fry is then harvested from the Larval Rearing Tanks and stocked in nursery tanks. Lower the water level to approximately 25 cm and use plastic trays to catch the fry. Then transfer them to a sorting tray to count and grade them into 3 different sizes (small, medium and large) in order to minimize cannibalism in the nursery stage.

7.1.3 Nursery

In the nursery the fish are grown up to 3 Inch, when they are strong enough for stocking in cages or ponds. It takes 1.5-2 months to complete the nursery stage.

Density in the nursery should be kept high to prevent cannibalism. During this stage, the fish should be fed regularly. Water exchange is high during the nursery stage (500%) and aeration is strong. Tanks should be cleaning several times per day (at least early morning and late afternoon), depending on the stocking density.

Feeding

Juveniles are fed ad libitum with commercial artificial feeds for grouper between sunrise and sunset. In the early nursery stage the occurrence of cannibalism is very high for most grouper species and feeding should be done at least every hour. When the juveniles grow and cannibalism reduces, the feeding frequency can decrease to 4 times per day for 3 Inch fingerlings.

Sorting and grading

Grading of fry is very important after the initial development stages to minimise mortality caused by cannibalism and dominance. By grading the fish uniformity in the tanks is maintained. The first grading is done after the larval stage and the second grading when the fry is harvested from the nursery. During the grading activity, accurate sample weighing can be done. Grading is done by hand using grading trays or by using special grading devices. Deformed juveniles should be removed and disposed of properly.

Harvesting of fingerlings

The tank water is reduced, and the fingerlings are put in the grading tray with cool (24°C) water. Depending on where the fingerlings will go (nearby ponds or off-shore cages) protocols vary. If transported, ice is used to cool down the water. Fingerlings are put into plastic bags with cool water and oxygen for transportation. On bag can accommodate 40-50 3 Inch juveniles depending in the travel time. The maximum travel time without reoxygenation is 12 hours.

If fingerlings are stocked in nearby tanks, they can be transferred from the nursery using buckets.

7.1.4 Grow-out

Nassau Grouper will be grown up to 500 grams. This should take less than 1 year but depends on water quality and feed quality.

Acclimatisation and stocking

Grouper grow-out in the demonstration facility will take place in ponds. Before stocking the fish in the pond, slowly increase the temperature in the bucket with fish. To increase temperature, you can slowly scoop pond water into the buckets. When the temperature of the pond water and the bucket has 0-2 degrees Celsius difference the fish can be released in the pond. Observe the behaviour of the fingerlings and record any extraordinary behaviour. First release one bucket, and observe the fish for a few minutes. If the fish do not show signs of shock, all fish can be stocked.

Conditioning

- Feed the fish the day following stocking at 6 am.
- Make sure the fish do not experience additional stress in the first 24 hours after stocking, no feeding, diving, quick movements etc.
- Start with feeding the fingerlings ad libium and slowly decrease number of feeding sessions until you feed 4 times a day
- Always feed the fish in the same corner of the pond
- First sort the fish 6-7 days after stocking

Stocking density

Stocking density pertains to the number of fish recommended to be put into the pond. In general, increase in size of the grouper results in a decrease in number of the fish stocked in the pond. For the demonstration facility, a low stocking density of 3-5 fish per m3 can be maintained. High stocking densities can result in cannibalism, stress, diseases and mechanical injury.

Fish sampling

Fish are sampled to monitor growth and checked for health. If needed fish will also be graded in size in hapas in ponds. Sampling, sorting, and grading allows fish to be grouped according to their size to prevent cannibalism. Furthermore, grouping the fish on the same size allows the operator to also determine the amount and size of the feeds to be prepared.

Sampling is conducted every month wherein 10-15 fish are collected per pond to determine the average growth rate and health of the fish.

7.1.5 Feed management

Guaranteeing feed quality

To guarantee optimal growth rate, survival and health of the fish, it is important to ensure and maintain feed quality and therefore:

- Packages should be properly labelled with description of composition, storage conditions, expiry date, feeding rate and other necessary guidance in adequate language
- The content of the feed must fit the declaration on the label and the products should be hygienically acceptable
- Content of additives and veterinary drugs should comply with National regulations

Feeding practices

Feeding practices also play an important role in optimizing the growth rate and health of the fish and therefore:

- Feeding practices should minimize the risk for biological, chemical, and physical contamination of feed and farmed fish
- Feeding practices should ensure the maintenance of water quality
- Operators should follow the instructions of the manufacturer when using the feeds
- Feed and fresh stocks should be purchased and used prior to the expiry of their shelf-life (First In – First Out)
- Traceability of all feeds and feeding activities should be assured by proper record-keeping

Pellet feeds are used to feed grouper and parrot fish after live feeds. Fish are fed manually in order to observe feeding behaviour. The first pellet feed is fine powder that floats on the water surface. Small fry eat between 15-20% of their body weight. As the fry grows larger feeds should be offered. The feed size should be based on the smallest fish in the tank, feed the largest size of pellets they can eat so they spend less energy on feeding. Broodstock fish are fed 2% of their biomass per day with 3-5 mm pellets.

Average fish weight (grams)	**Feed size (mm)**	**Range of feeding rate (% biomass/day)**
Post-hatch- 0.05	0.2-0.3	15-20
0.05-0.5	0.25-0.75	15-20
0.5-3	0.75-2	10-15
>100	3-5	2-3

When feeding, ensure that all fish can eat. Provide feed in different places of the tank to ensure that fish that were crowded out also eat. When feeding slows, feeding application should be stopped or decreased to reduce the amount of uneaten feed. If feeding behaviour is not normal, stop feeding, check the water quality and fish health.

Feeding should be spread over the day in five different feeding sessions for fish up to 2 grams, and then reduced to four sessions for fish above 2 grams. Fish in ponds are fed twice a day and broodstock if fed once per day or less.

Feed storage

Proper storage of feeds is important to maintain the quality of the feeds and it is recommended that:

- Dry fish feeds should be stored in a cool and dry area to prevent spoilage, mould growth and contamination
- Transportation conditions should be conforming to the specifications on the label
- Medicated feeds should be clearly marked on the package and stored separately, in order to avoid errors

7.1.6 Disease control

Aquaculture has been the fastest growing animal production sector for the last 20 years, but diseases are increasingly limiting production. This is especially a problem in tropical countries as microbes and other disease-causing organisms prefer warmer water, resulting in a higher variety of diseases, and the increased outbreak of diseases in tropical countries.

The aquaculture sector needs to continue to expand, as a means of food production, and therefore it is crucial to ensure that aquaculture operators are protected from the impact of diseases through proper disease management. It is very important to understand that a successful approach to disease management requires the implementation of general hygiene procedures, feed management, veterinary drug management, post-harvest management and good record keeping. These are all of vital importance to keep your fish healthy and to prevent diseases from spreading.

Disease prevention

The best way to prevent diseases is to follow appropriate culture procedures to minimize the potential for microbiological and chemical contamination during aquaculture production. An operator does this by implementing all procedures that are discussed in this manual. Additionally, it is recommended to:

- Carry out a visual inspection of fish behaviour 3 times per day and record abnormalities.
- Monitor fish stocks and water quality regularly to identify potential disease outbreaks
- Design and construct equipment such as tanks and nets in a way that ensures minimum physical damage of the fish during the growing stage

Fresh water bath

Bathing is a part of disease prevention and treatment wherein fishes are soaked in fresh water for 5 to 10 minutes. The purpose of bathing is to kill parasites with the sudden change of salinity.

Diseases

Disease is defined as a disturbance in function or structure of any organ or part of the fish. It is common to find more than one cause of disease. In case of diseases, put the sick fish in quarantine and contact the project manager. Diseases can be caused by infectious microorganisms like viruses, bacteria, fungi and parasites. It can also be due to stress brought about by over-stocking, poor water quality, deficiency in nutrients and abrupt environmental changes. Fish with diseases grows slowly or may be stunted in growth, requires more food to grow, takes longer grow-out periods and has unsightly body changes. Furthermore, if disease outbreaks continue, mass fish loss will occur.

There are two ways of transmitting diseases. These are the following:

1) Vertical transmission

-Vertical transmission means passing of diseases from the parents to the offspring. In this project, it is assured not to occur as eggs and brood stock are managed in a hatchery and nursery facility.

2) Horizontal transmission

-Horizontal transmission or direct transmission can occur through the environment, feeds and fouling organisms.

There are specific signs for different grouper diseases. In general, the groupers exhibit the following signs of diseases:

1) Abnormal changes in colour.
2) Loss of appetite.
3) Retarded growth.
4) Abnormal swimming behaviour.
5) Unusual marks.
6) Abnormalities in the anatomy of the fish.

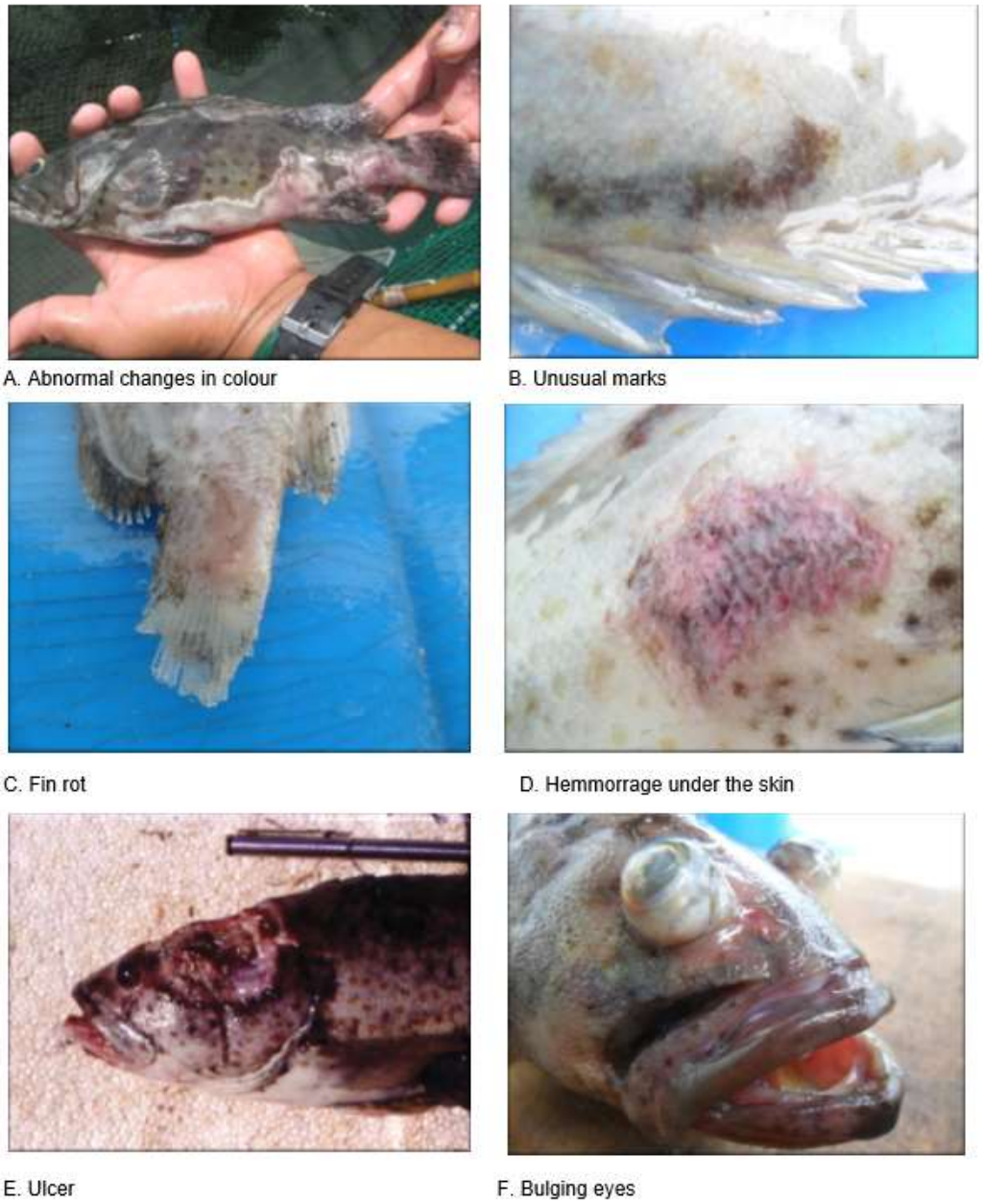


***Figure 5**-A-F: Disease symptoms in grouper*

Fish should be monitored for these signs and if they occur, a fish health specialist should be contacted.

7.2 Sea Cucumbers

Sea cucumbers are reared globally, however, the specific species selected for Jamaica, the four-sided or chocolate chip sea cucumber (*Isostichopus badionatus),* the culture of the species is still in the early stages of development and commercial protocols need to be established.

Here, general procedures for the culture of sea cucumbers is provided using experience with other species and expert information from researchers that worked with *Isostichopus badionatus* and Zacarias-Soto et al. (2013)[1].

7.2.1 Broodstock management

Broodstock collected should be between 200-900 grams. It is acclimatised and washed to remove parasites be for placed in the broodstock tanks.

For broodstock, recirculation systems are used with continuous flow. Aeration is provided through diffuser stones. Temperature should be around 25°C, pH around 8 and natural salinity. Light is provided to the broodstock for 12-14 hours per day. Broodstock are kept in troughs (30cm depth) with natural sand. Broodstock is fed with ground algae and/or blended fish feeds and spirulina mixed with sand. Alternatively, sand can be harvested from the sea. The sand is changed every third day. Faeces should be siphoned out daily.

7.2.2 Spawning

Spawning can either occur naturally (July-November) or can be induced and is connected to the moon cycle. Local spawning patterns should be studied since this can vary between locations. Two days before spawning, no more food is provided. Zacarias-Soto et al. kept males and females in the same tank, so spawning was induced by the presence of sperm or sperm was collected from males and released in tank with females. Once spawning starts, females are moved to small tanks for egg release and sperm (extracted from gonads) is added for fertilisation after females are put back in the broodstock tank. Eggs are collected, rinsed, and then counted and measured using a microscope.

7.2.3 Larvae rearing

Eggs are stocked at 1-2 eggs/ml (mixed from multiple females). The first 12 hours there should be no water exchange or aeration. After that gentle aeration is added and water is partially exchanged. Larvae are fed with microalgae, in the first stages with *Isochrysis* and T*etraselmis* and later with *Chaetoceros*. Use 20,000-50,000 cells/ml depending on the larvae size. Both live algae and instant algae paste can be used. The larvae stage (including juvenile stage) takes approximately 3 months (reaching 3-4 cm). Many sea cucumbers need settlement sheets with a biofilm to settle, however *I. badionotus* settles on the tank bottom and preferably shaded. Juveniles are reared up to a size of 15 grams. Juveniles are fed with powdered macroalgae enriched with Algamac.

[1] Zacarias-Soto, M.Z., Olivera-Novoa, M.A., Pensamiento-Villarauz, S. and Sanchez-Tapa, I. 2013. Spawning and Larval Development of the Four-Sided Sea Cucumber, Isotichopus badionotus (Selenka 1897), under Conotrolled Conditions. Journal of the World Aquaculture Society. Vol 44:5.

7.2.4 Grow-out

Grow-out is done in sea pens. The sea cucumbers can be stocked in the sea when 15 grams. The stocking density should be 20 individuals per square meter until they reach a length of 6-8 cm. After this, the density should be 3 individuals per square meters. The sea cucumbers must be covered by water all times. During grow-out there is no need to feed the sea cucumbers. The most important thing is to provide security to ensure the sea cucumbers are not stolen. *I. badionotus* are harvested after 2 years when they reach around 250 grams.

7.3 Irish Moss

Irish moss (*Gracilaria sp*.), a red algae, are used for the preparation of drinks and desserts.

7.3.1 Vegetative Propagation

The initial vegetative materials are collected from the wild while subsequent cuttings can be obtained from previous cultivation.

7.3.2 Grow-out

Gracilaria spp. grow for around 6 months. Two methods for grow-out should be trialled in Bowden Bay and the most productive method should be adopted. In method 1, vegetative cuttings are inserted in three strand twisted rope lines staked to the substrate while in Method 2 vegetative cuttings are planted in the sea bottom.

Method 1: Rope farming

The vegetative materials are inserted (tightly twined) in or tied to a nylon of monofilament line. Ropes are suspended between fixed stakes inserted in the sea bottom or on a floating raft. *Gracilaria* should be submerged between 0-1m.

Method 2: Bottom stocking

A shallow area should be selected for this method to make planting and harvesting easy for divers. Polyethylene tubes are filled with sand and used as an anchor for thalli. Thalli (20cm) are attached to the tub with rubber bands. Tubes are placed 1 meter apart in parallel, perpendicular to the coastline. Alternatively, the thalli bundles can be directly inserted in the sandy bottom. An advantage of this method is that *Gracilaria* can develop underground thallus system maintaining the vegetative growth of the plant.

Culture starts with cuttings of 20 cm with a distance of 10cm per cutting. When harvested, the thalli are pulled manually while holding the plant to the substrate or rope. For bottom stocking,

when done in a shallow enough area, this can be done during low tide, else divers have to harvest. Replanting should take place when the cover drops due to storms or repetitive harvesting. Harvest frequency should be between 2-3 months initially and be adjusted if results are not satisfactory.

7.3.3 Disease control

*Gracilaria c*an be affected by herbivores, parasites, bacteria, or environmental parameters. Invertebrates may raze on the *Gracilaria* resulting in a loss of biomass. Filamentous algae and microorganism can cause reduced growth. Some bacteria and fungi can cause whitening of the thallus increasing its fragility. Imbalance in environmental factors, such as light, temperature and availability of nutrients, can cause loss of pigments.

To avoid grazers, the floating culture method can be adopted or control measures for grazers need to be implemented. Grazers can, however, also be useful to remove epiphytic algae. If problems with microorganisms occur, the moss should be transferred to areas with a higher current.

7.4 Oysters

7.4.1 Broodstock management

Clean and quarantine all incoming oysters to prevent disease transfer. This can be done using a paint clipper and a hard bristle brush and placing the oysters in water with bleach (1ml/gallon) for 15 min. Adult oysters should be placed in a conditioning tank filled with ambient sea water and phytoplankton. Broodstock should be fed twice daily with algae (100,000 cells/ml). Temperature should be around 20-22 °C. If temperature from ambient sea water (unfiltered) is higher or lower, temperature should be slowly adjusted. The tanks should be cleaned on a daily basis. When cleaning the tank broodstock should be rinsed and the tank should be filled with clean water. Conditioning should take 3-5 weeks.

7.4.2 Spawning

Oysters that are ready to spawn (ripe), should be thoroughly cleaned by scrubbing and no feed should be provided for 24 hours before spawning. Spawning can be induced by chilling (12-15 °C) or drying the oysters the night before spawning.

Oysters are placed in the spawning tank (in individual containers) with water of 25-28 °C. Oysters should be observed for spawning activity. Oysters can be induced by adding sperm to the water stripped from a male using a pipette. Males are removed from their shell and the gonads are incised so that sperm can be removed. The sperm is then mixed with seawater.

Another way of inducing spawning is to decrease the salinity of the water by adding freshwater (with the same temperature).

Once oysters spawned, the eggs are rinsed through a sieve (85-105µm) into buckets with filtered water. Oysters are put back into the conditioning tanks. Eggs are then counted and mixed with sperm (few drops) for fertilisation. The fertilisation process is monitored under a microscope. Once most of the eggs are fertilised, the eggs are stocked in the larvae tanks.

7.4.3 Larval rearing

Embryo and larvae culture take place in the larval tanks at 28°C and 25ppt. For the first 2 days no feed is added. The larval stage takes 12-20 days and water exchange is continuous using a banjo to prevent loss of larvae. Tanks are stocked with 5,000-15,000 eggs per litre (can be higher or lower, lower densities lead to higher survival). Larvae are fed with algae, algae are continuously dripped into the tank from drums.

Larvae are regularly counted and measured while the tanks are cleaned. Larvae are removed from the tank using the tank drain (remove standpipe) with sieves into buckets. Tanks walls need to be rinsed to ensure all larvae are removed. The larvae are then rinsed, counted and measured before they are returned to the clean tank.

Counting larvae

Stir the water in the bucket up (rapidly) and down (gently) to evenly suspend the larvae in the water column. Immediately take 1ml sample with a pipette. A Sedgewick rafter is used to count the larvae. Depending on the size of the bucket, the number of estimated larvae in the bucket can be calculated.

Measuring larvae

The larvae are measured using a microscope with a measuring eyepiece. The longest length of the shell should be measured by aligning the eyepiece with the larvae. Depending on the ocular of the microscope the length can be determined.

Stocking densities

Stocking densities are approximate and depend upon water quality and health of the larvae. Water temperature also determines the length of larval stage(s). A sample stocking/feeding protocol is shown below:

Stage	Age (day)	Length (µm)	Sieve size (µm)	Density (#/ml)	Algae Dens (Cells/ml)	Algae type
Egg	0	60	35	10-15	-	-
D-stage	2	70-80	35	10	20-25,000	Nanno-Iso
Veliger	4	120	55	5-8	20-25,000	Nanno-Iso
Veliger	6	180	55-85	5-8	30-35,000	Iso
Veliger	8	250	85-105	3-5	50,000	Iso
Veliger	10	280	85-105	3-5	50,000	Iso
Veliger	12	300	105-125	2-4	70-80,000	Iso
Eyed larvae	14	320	125-150	1-4	100-150,000	Iso-Chaet

7.4.4 Setting

After 12-20 days larvae are ready to set or metamorphose. Larvae are usually ready to set when 300µm in length, extends its foot to search for substrate or develops a photosensitive organ called an eye. Once these larvae are identified, they are sieved through a 220-250µm sieve. Smaller larvae are returned to the larvae tanks. Oyster larvae attach themselves to particles of oyster shell of a size so that only one larvae can attach to each particle, thus producing individual oysters. The retained larvae are transferred to the setting system. Larvae are placed in the downwelling setting bins. Water flow should be medium to avoid blasting larvae out of the bin. The oysters are fed twice per day (150,000 cells/ml) with 50% diatoms. The setting bins and oysters should be rinsed daily and every other day the water should be replaced with clean water.

It takes several days for the oysters to set and metamorphose into juvenile oysters. Feeding quantities should be adjusted to ensure adequate supply of food. Feeding is done in the morning and in the afternoon. If the tank is not clear upon the second feeding, feeding should be reduced. If the water is clean long before the second feeding, feeding quantity should be increased.

Once per week juveniles should be sieved and sorted by size. Mesh sieves can be designed to function as setting bins as well. Stocking density should be reduced accordingly to scarcely cover the bottom of the bin with oysters

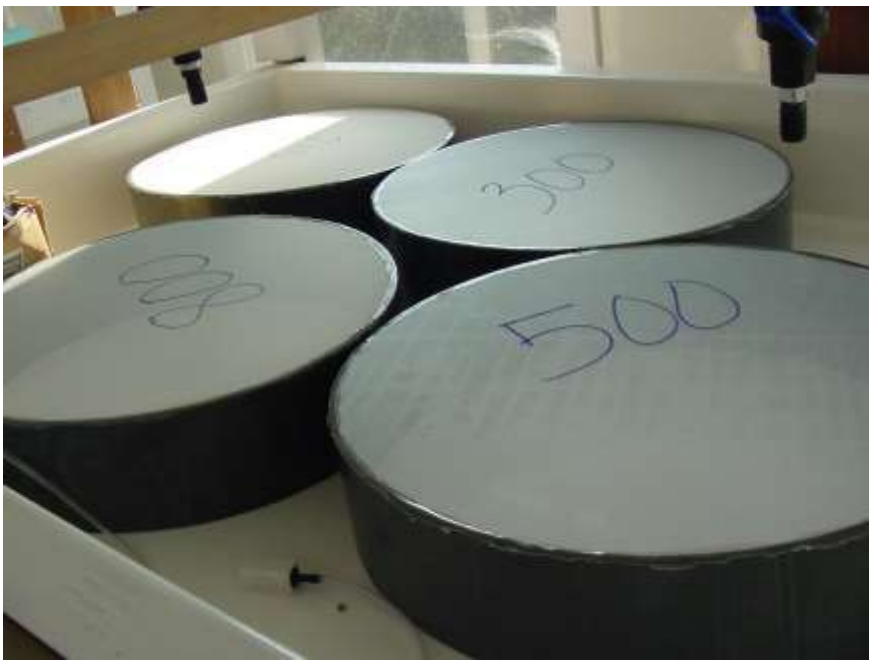


Figure 6: Mesh sieves that act as downweller setting bins.

Oyster that reach 500µm should be gradually acclimatised to ambient conditions. This is done by gradually reducing temperature and filtration after which it is gradually switched to a flow through system. Once on completely acclimated, the oysters are transferred to the nursery system.

7.4.5 Nursery

The nursery consists of upwelling bins. The oysters are counted and sorted by size in the bins at appropriate densities. The bins are placed on a floating platform in the sea.

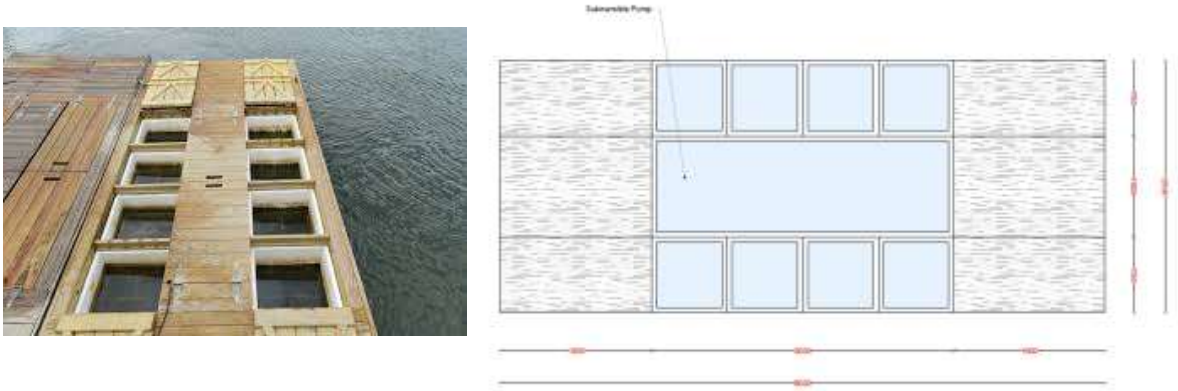


Figure 7: Example (left) and drawing (right) of a floating upwelling system for nursing oysters.

Water flow should be as high as possible but avoiding washing oyster away. Mesh screens can be used to avoid small seeds to go down the drain. The nursery tanks are drained daily, cleaned, and rinsed. Only resume water flow once all oysters are set. Once per week, bins are sieved, and oysters are sorted in appropriate mesh bins. Stocking densities are approximately

60,000 per bin (4mm) to 3,600 per bin (12 mm). Average growth rate is 1 mm per week but depends on the conditions.

7.4.6 Grow-out

An alternative grow out method is proposed. The method of culturing oyster in bags with floaters on lines (see figure 8) should be tested and results should be compared with the current method. Since individual oysters are produced in the hatchery, they do not reattach themselves. To prevent them to grow into the mesh of the grow out, the floating bags must be shaken and flipped over every two weeks. Plastic bottles can be used as floaters to reduce costs but floaters such as displayed on the picture are ideally used. The mesh can be found in rolls at construction supply places. The difference mesh sizes needed are 1/8", ¼" and ½". The bags are attached to a rope that are connected to a buoy anchored to the sea floor. Approximately 150 oysters are stocked in 1 bag.

Figure 8: Oyster grow-out culture in bags.

7.5 Live feed production

7.5.1 Micro Algae

Species

The following algae species are of importance for culture of finfish, oyster and sea cucumber. In fish hatcheries, they are used for green water culture, feed and enrichment of rotifer, and enrichment of artemia. Algae are also used as feeds for oyster and sea cucumber.

Chaetoceros calcitrans (diatom)

Chaetoceros is a rich source of both valuable ω-3 fatty acids EPA and DHA, but also cholesterol. Used as feed for oysters, green water culture, and to enrich rotifers and artemia for finfish.

Isochrysis galbana

Isochrysis is rich in carotenoids such as β-carotene and fucoxanthin and is the preferred source of the valuable ω-3 fatty acid DHA. Used to enrich rotifers with DHA and green water culture.

Nannochloropsis sp.

Nannochloropsis has EPA as important ω-3 fatty acid and is also a rich source of pigments, such as β-carotene, violaxanthin and zeaxanthin. Used for green water culture and rotifer culture.

Tetraselmis sp.

Tetraselmis is an excellent source of EPA and linoleic acid. Essential fatty acids for larvae development and growth performance. It is rich in amino acids which stimulate the feed intake in marine animals. Use to feed rotifer and artemia and filter feeders.

Species	**Nannochloropsis spp.**	**Isochrysis galbana (T-iso)**	**Chaetoceros calitrans**	**Tetraselmis**
Color	Green	Golden brown	Brown	Green
Salinity	22-25ppt	28ppt	24-28ppt	24-28ppt
Nutrients	n/a	High in DHA	High in EPA/AA	n/a
Silica	Without silica	Without silica	With silica	No silica
Days of culture	3-5, peak at 4	6-12 days, peak at 8-9 days	3-5, peak at 4	3-5, peak at 4
Use	Green water culture and rotifer feeding	Enrich rotifers and artemia	Feed for oysters and sea cucumbers, enrich artemia	Green water culture, feed for sea cucumbers

Media preparation

F/2 media is prepared with filtered seawater to maintain stock and for culture of algae. Media is usually made in a larger flask and then transferred to the stock and culture flasks. It is important to start with sterile, clean containers, airlines and stoppers. These can be cleaned using bleach water and a sponge and brush. After this they should be rinsed and for the flasks and stoppers (especially for stock cultures), they should be autoclaved as well.

Flasks are filled with 1µm filtered and UV treated seawater and the required F/2 is added using a pipette. For diatoms, silica is added too. This is then stirred for mixing.

Medium	Ingredients	Quantity/Litre distilled water
F/2-medium	NaNO3	75 g
	Na2HPO4	5.65 g
	NaSiO3 9H2O	3 g
	Na2EDTA	4.16 g
	Vitamin stock	
	B1	
	B12	
	Biotin	
	Trace metals	
	FeCl3.6H2O	3.15 g
	CuSO4.5H2O	0.01 g
	ZnSO4.7H2O	0.022 g
	CoCl2.6H2O	0.01 g
	MnCl2.4H2O	0.18 g
	Na2MoO4.2H2O	0.006 g

Other types of mediums can be used as well for larges cultures such as TMRL or Conwy.

Medium	Ingredients	Quantity/Litre distilled water
Conwy	Na2EDTA	45 g
	NaNO3	100 g
	H3PO3	33.6 g
	FeCl3 6H2O	1.3 g
	MuCl2 4H2O	3.6 g
TMRL	KNO3 or NaNO3	100 g
	Na2HPO4 12 H2O	10 g
	FeCl3 6H2O	3 g
	NaSiO3 9H2O	1 g

For mass culture, chemical fertilisers are used. Different combinations are possible:

Table 11: Different combinations of fertilisers used for mass culture of algae (FAO, 1996)

FERTILIZERS	A	B	C	D	E
AMMONIUM SULFATE	150	300	100	-	-
UREA	7.5	-	10-15	-	12-15
CALCIUM SUPERPHOSPHATE	25	50	-	-	-
N:P 16/20 FERTILIZER	-	-	10-15	-	-
N:P:K 16-20-20	-	-	-	12-15	-
N:P:K 14-14-14	-	-	-	-	30

Culture preparation

For all types of containers, flasks, carboys, and large cylindrical containers (with covers), it is important to start with sterile, clean containers, air lines, and stoppers. These can be cleaned using bleach water and a sponge and brush. After this they should be rinsed, and the flasks and stoppers (especially for stock cultures) should be autoclaved as well. Carboys, if not clean, can be cleaned with muriatic acid and water solution.

Once media is added to flasks, they are placed in the autoclave and put on a 20-minute slow exhaust cycle with foam stoppers in place. After this, the flasks are cooled down to room temperature. For carboys and cylindrical containers, instead of the autoclave, bleach is added (1.5 ml/L) to the water for 24 hrs with aeration. Before carboys and cylinder tanks can be inoculated, sodium thiosulphate should be added to neutralise the bleach (for 2 hours). A chlorine test kit can be used to ensure there is no bleach left. Alternatively, boiled water can be used.

Maintaining stock cultures

Stock cultures are transferred once a month to new media. The media is prepared as described above. A 250 ml flask is used with 75 ml of media. 25 ml of stock culture is transferred using sterile techniques (flaming the top of each flask before and after each inoculation, and not touching or contaminating any of the surfaces of the flasks and stoppers). The stock cultures are sealed with the sterile foam stopper of the appropriate size for the flask. The stock cultures are placed in a clean, temperature-controlled room (temperature is kept at 22º C). It is best to keep the stock cultures away from the grow lights used for the other flask cultures to prevent them from multiplying too quickly and crashing. (The flasks should be

swirled manually once every day or every other day to help mix the culture and prevent the phytoplankton from clumping at the bottom of the stock flasks.)

Inoculation of cultures

Production flasks are inoculated with stock cultures using the remainder of the stock culture used to inoculate the new stock flask. It is important to use the first pour to inoculate the stock flask, as it is usually a cleaner healthier section of the phytoplankton. A sterile rigid air tube is placed inside the production flask, and then they are sealed with a sterile foam stopper of the appropriate size. A piece of tin foil is also wrapped around the top of the flask, airline and stopper to help prevent any air contamination from entering through the small opening caused by the airline. Each flask is then attached to an airline with filtered air.


Figure 9: Production flask culture (left) and carboy culture (right)

The carboys are inoculated using the production flask cultures. If there are unhealthy or clumped algae on the bottom of the flask, do not use the lower portion of the flask. Maintain the temperature in the algae laboratory between 20-24°C.

Culture schedule

The programme for algae culture depends on the need of the hatchery. It is recommended that algae paste from a commercial supplier is partly used for feeding rotifer and enriching rotifer and artemia. In the algae laboratory mainly algae for green water larvae culture and feed for oyster and sea cucumber is cultured.

Master stock cultures are kept in test tubes or small flasks. Upscaling from a small flask to a cylinder takes 14-32 days, depending on the species. Cylinders can also be inoculated with a starter from another cylinder.

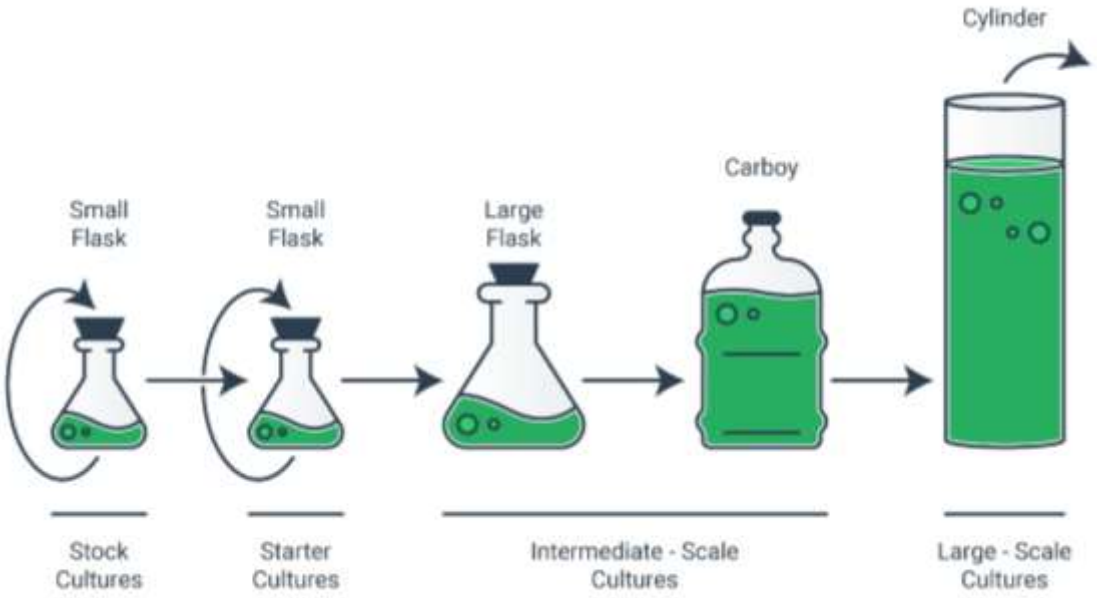


Figure 10: Production scaling from stock culture to large-scale culture.

Determining algae density

In order to ensure that the algae cultures are performing well and to determine how much to add to the culture tanks the following procedure should be followed:

- Take an algae sample with a Pasteur pipette.
- Count as soon as the sample is collected.
- Pipette sample inn the counting chambers.
- If flooding occurs, rinse haemocytometer and start again.
- Check if density is low enough for counting, else dilute the sample with distilled water (e.g. 10 or 100ml depending on the density).
- Count the algae separately in the 4 corners squares. If the sample is very low in cells count the whole chamber (9 squares)
- Start counting at the top left square and count only the cells touching the top and left-hand side rulings of each square.
- Record the results.
- Rinse haemocytometer with distilled water.
- To obtain cell density, calculate the average number of cells per square and multiply by the conversion factor (for most meters 10^4) and dilution factor (if any)

7.5.2 Rotifer

Rotifer is the first feed for marine fish larvae. They are fed with rotifer for about 14-20 days. A high-density continuous rotifer culture system is proposed. Water parameter such as salinity, temperature, pH and feed dosing are controlled, and reduce fluctuation sin culture conditions. Consistent feeding and harvesting increase rotifer health and quality.

Rotifer are harvested and fed with the same quantities on a daily basis, providing for a simple management system and thus minimise chances of mistakes. Labour and space requirements are also minimised. Rotifers are fed with frozen concentrated algae paste (*Nannochloropsis* or Chlorella), for the optimal density 0.95 litres of *Nannochloropsis* paste or 1.3 litres of Chlorella paste is needed per day.

An operating density of 3000 rotifers per ml is recommended. The number of rotifers is optimal at 3 billion rotifers per single tank. This can be increased subject to competence of the technicians. Systems operate on a flow through basis of 30% per day (circa 150L exchange per day). The average harvest per day from 1 tank is ± 0.5 billion Rotifers operating on a 50% turnover.

Inoculation of the system is done with a starter that has to be obtained from a commercial supplier. Once inoculated the culture can be maintained.

7.5.3 Artemia

After rotifer, Artemia, or brine shrimp, are commonly used to feed larvae of finfish. Artemia are fed for a period of 20-40 days). Artemia cysts, can exist in a zero-metabolism state for decades and are therefore available in cans. They can then be incubated for 24 hours. There are different types of artemia products available, most of them either capsuled or decapsulated cysts. Capsulated cysts need to be decapsulated as a first step. Once a can is opened, it should be stored in a refrigerator.

Decapsulation of artemia cysts

- Hydrate cysts for 1 hour in freshwater at 26-28° use gentle aeration
- Prepare a bucket of 1 litre of salt water and chill to 10°C using ice in a bag
- After hydration, rinse cysts thoroughly using fresh water
- Prepare decapping solution by adding 500 ml of normal household bleach to the bucket
- An exothermic oxidation reaction starts to occur, and a colour change will be noticed from a greyish colour to an orange colour. The eggs will turn white and then orange, and start

to settle to the bottom. Maintain this solution between 15 — 20 °C, adding ice as needed, until all of the eggs are orange.

- Once colour has completely changed to orange, pour this mixture through a 100-120µm net and thoroughly rinse with freshwater until no bleach odour is detected.

Hatching of artemia cysts

Place cysts (5g per litre water) in hatching tank for hatching at a maximum density of 1gram per litre. The water in the hatching tank should consist of 60 % salt water and 40 % fresh water. The artemia hatching tanks are usually conical with a drain in the bottom. A PVC pipe with screen should be inserted in the drain to prevent cysts to rot in valve pipe at the bottom of the tank.

The salinity should be maintained between 18 – 22 ppt and pH>8. The aeration needs to be strong in the tank to create an upwelling flow. Air stones are placed at the bottom of the tank. For the first 2 hours of incubation stir the water by hand every 10 minutes to remove cysts from surface and tank wall. Tanks should have 24 hours lighting (1000 lux). Temperature should be maintained between 25 – 30°C. Hatched artemia are called nauplii.

Harvesting of artemia

After the majority of the artemia hatched (20 – 26 hours), remove the aeration and PVC pipe and drain unhatched cysts. These cysts can be incubated again. Put PVC pipe back in place and place a dark cover on the tank and place 2 lights at the bottom of the tank. Cysts shells will float to the surface (if not add natural sea salt), artemia will be attracted by the light and go to the lower part. Remove a few litres of water until all shells are removed (a magnetic technology to separate shells from nauplii is also available[2]). Now only the artemia are left in the tank. Remove the PVC pipe and enrich if necessary or harvest immediately. Open valve to harvest the majority of the artemia using a harvest net (100 micron). Close valve for the last few litres so shells and remaining cysts stay in the tank.

Rinse the artemia using freshwater. Hold all the artemia in a harvest net. Wash the artemia in a bucket so they are submersed at all times. Rinse for 2 – 3 minutes. Dip the artemia for 1 minute in a bucket containing 5 litre of salt water and 2 ml of Iodine. The artemia can then be transferred to a bucket with saltwater and fed to the larvae.

[2] https://www.inveaquaculture.com/product/artemia-il/

Enriching artemia

Artemia contain essential fatty acid (EFA) 20:5(n-3) which is essential for marine fish. However other EFAs are lacking (22:6(n-3))[3]. Artemia can be enriched by feeding them with a high EFA diet (algae, yeast, fish oils etc.).

Artemia biomass

Artemia biomass refers to juvenile and adult artemia. Nauplii can be grown further to provide live feed to larger fish larvae. In this case artemia should be fed with algae when they are 3 days old.

7.5.4 Copepod

For the rearing of Parrot Fish and grouper, copepods are very beneficiary but not required. Copepods can be harvested from the wild using light traps or can be bought commercially (planktonic.no/, cfeed.no/products/, reedmariculture.com). Culturing of copepods is also possible but complicated since they have a long reproduction cycle (2-3 weeks) and have a much lower culture density compared to rotifer. Copepod also require live algae.

7.6 Water quality management

Factors affecting water quality

- Excess feeds

Excess pellet feeds can pollute the water. Feeds should be given in the right amount depending on the recommended values for the different fish sizes; furthermore, tanks should be cleaned of the excess feeds during monitoring.

- Poor water circulation

Water circulation is important to give the fish newly exchanged water with dissolved oxygen that they breathe through their gills. Poor water quality which affects fishes with clogged gills or death. Therefore, sufficient water circulation or exchange should take place.

- Presence of pollutants and run-offs

Harmful substances affect water quality through contamination. These harmful substances include sewage, chemicals, and detergents. During the culture, the presence of these substances may the fish health negatively by causing diseases and death.

[3]https://www.researchgate.net/publication/36454771_Use_of_Artemia_as_a_food_source_for_aquaculture

- Presence of fresh water

Groupers and parrot fish generally live in sea water habitats During rainy seasons freshwater influx can affect the salinity or amount of salt contents in the water making it stressful for the fish.

Water parameters

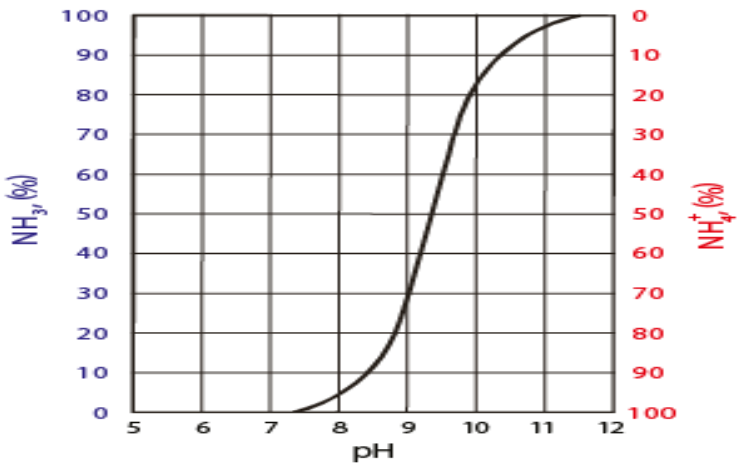
The following water quality parameters should be monitored:

Temperature — Temperature should be optimal for the species and live stage. Temperature is measured by the monitoring system. In case of failure of the monitoring system this can be recorded with a manual thermometer (Handheld probe).

Dissolved oxygen — Operating levels of between 5.0 and 7.5 milligrams per litre (mg/L) are recommended. Growth and feed conversion will be affected by chronically low DO concentrations below 3.5 mg/L. Dissolved oxygen is measured by the monitoring system or by the handheld DO meter.

pH —pH should be between 6.8 and 8. In tank systems, dissolved carbon dioxide causes pH to decline because of the formation of carbonic acid (H_2CO_3) in solution. A minimum pH of 6.8 is suggested as the lower limit of tolerance for the nitrifying bacteria of the biofilter. Due to the presence of dissolved carbon dioxide, high pH is generally not a problem in tank systems. pH is measured by the monitoring system or using test kits.

Ammonia (NH3) — Ammonia exists in two forms in the tank environment, un-ionized NH_3 (highly toxic) and ionized NH_4+ (less toxic). Avoid concentrations of un-ionized ammonia greater than 0.1 mg/L. Consult other sources to understand the relationship between pH and



the toxicity of Total Ammonia Nitrogen (TAN), un-ionized ammonia and ionized ammonia. Test equipment is available in the laboratory.

Nitrite (NO2-) — Avoid concentrations greater than 0.1 mg/L nitrite-nitrogen if chloride (Cl^-) is low (less than 10 mg/L). Maintain chloride concentration of 150 to 200 mg/L under normal operating conditions, and increase chloride concentration when nitrite is elevated. The chloride ion alleviates nitrite toxicity and can be added as sodium chloride (NaCl) or calcium chloride ($CaCl_2$). This can be measured with test-kits.

Nitrate (NO3-) — Nitrate toxicity can occur if levels in water reuse systems exceed 300 mg/L nitrate-nitrogen. Normal water exchanges during filter backwashing or solids removal generally control nitrate concentrations. Water exchange or a denitrification process may be required. Test equipment is available in the laboratory.

Carbon dioxide (CO_2) — Maintain at less than 40 mg/L. Elevated carbon dioxide levels cause lethargic behaviour or slow feeding response in fish. While some fish can tolerate a wide range of pH, dissolved carbon dioxide gas stripping is required in water reuse systems to keep pH above 6.8 and promote conditions favourable to nitrifying bacteria in the biofilter. This can be measured with test-kits or probe.

Calcium hardness — Maintain between 50 and 100 mg/L. Dissolved calcium in the water aids in osmoregulation and relieves stress in fish. It is usually added as calcium chloride ($CaCl_2$), which dissolves readily and also increases chloride (Cl^-).

Chloride (Cl^-) — Maintain between 100 and 300 mg/L. See description under Nitrite. Also see the Harvesting and Marketing section. This can be measured with test-kits.

Alkalinity — This is the measure of the pH buffering capacity of water, and should be maintained at 100 to 250 mg/L by adding a soluble carbonate or bicarbonate source. Sodium bicarbonate is commonly used because it is readily available, highly soluble, and safe to handle. Dissolved carbon dioxide reduces pH, so higher alkalinities must be maintained if CO_2 stripping is poor. Choosing a water source with higher alkalinity reduces operating expenses because less supplemental alkalinity will be needed. This can be measured with test-kits.

Table 12: Equipment used to measure different water quality parameters and their units.

Parameter	Unit	Equipment
Temperature	[°C]	Monitoring system, temperature probes
Oxygen (O_2)	[mg/L]	Monitoring system, hand meter, dissolved oxygen probe
pH		Monitoring system, hand meter, pH probe
Ammonia, as total ammonia (NH_3+NH_4^+)	[mg/L]	Test kit
Nitrite (NO_2^-)	[mg/L]	Test kit
Nitrate	[mg/L]	Test kit
Carbon dioxide (CO_2)	[mg/L]	Portable CO_2 analyser
Carbonate hardness/alkalinity	[mg/L]	KH/ALK test kit
Salinity	[ppt]	Salinity meter

Figure 11: Examples of water quality test equipment: salinity meter (right) and DO meter (left).

When a parameter is out of its optimal range the following measurements can be taken:

Observation	Possible measures
Low dissolved oxygen	• Increase aeration • Stop feeding until corrected • Watch for symptoms of parasites/disease
High carbon dioxide	• Increase aeration • Watch for symptoms of parasites/disease
Low pH	• Add alkaline buffer (sodium bicarbonate) • Reduce feeding rate • Check ammonia and nitrite concentration
High ammonia (un-ionized)	• Exchange system water • Reduce feeding rate • Check biofilter: pH, alkalinity and DO • Watch for symptoms of parasites/disease
High nitrite	• Exchange system water • Reduce feeding rate • Add 5 ppm chloride per 1 ppm nitrite • Check biofilter: pH, alkalinity and DO • Watch for symptoms of parasites/disease
Low alkalinity	• Add alkaline buffer (sodium bicarbonate)
Low hardness	• Add calcium carbonate or calcium chloride

7.7 Emergency procedures

Disease diagnosis and monitoring

Movement of fish/oysters/sea cucumbers to the facility should be controlled. Sanitary measures should be taken, such as disinfection of the system and followed before stocking. When irregularities or symptoms of disease are observed by staff, the facility manager should be notified. If the cause cannot be identified by the manager, a fish health specialist should be contacted, and a sample of the animal should be sent to the laboratory for checking. In case a disease is diagnosed, treatment should be carried out by an authorised person.

- It is advisable to keep diseased fish in a separated quarantine area
- In case fish/oysters/sea cucumbers cannot be moved to a separate quarantine area, seal off the area with diseased fish
- Inform all staff of the disease outbreak and place the tank under quarantine
- Dead fish should be disposed of immediately in a sanitary manner that will discourage the spread of disease

Guidelines for disease treatments

- Only use chemicals and veterinary drugs from suppliers that are registered with the authorised authority.
- Veterinary drugs, medicated feeds and other chemicals should be labelled in an adequate language, with clear information on: name, active substances, target animal species, storage conditions, prescribed dosage, route of administration, expire date and withdrawal period.
- Veterinary drugs, medicated feeds, chemical and biological substances should be used according to the instructions of the manufacturer and as specified on label.
- Substances requiring prescription should be used under adequate supervision by a qualified expert.
- Veterinary drugs need to be stored in a separate room from standard feeds.
- Veterinary drugs, medicated feeds and other chemicals should be stored according to manufacturer's instructions.

In case of a serious disease problem all animals should be removed from the system and killed and disposed of properly. The system should be disinfected according to the procedure described in chapter 6.8.

Power failure procedure

In the event of a long power cut (15 minutes and longer), staff must follow the instructions below:

1. During the duration of the power cut, feeding of fish must stop.
2. If the power cut is longer than 2 hours or the monitoring system loses power, the oxygen should be monitored using a handheld DO meter.

7.8 Biosecurity

Biosecurity involves practices, procedures and policies used to prevent the introduction and consequent spreading of bacteria, viruses, fungi and parasites as well as aquatic invasive species that may cause diseases. A biosecurity plan will be included in the management and operations manual to prevent the introduction of disease agents on the facility. A disease outbreak can cause severe financial losses and be a serious setback for a hatchery operator. Diseases can come from many sources, such as new broodstock, water, contaminated equipment, staff, and pests. Biosecurity procedures prevent the introduction of pathogens into a hatchery from outside the facility or from one area to another within a hatchery. Biosecurity will be incorporated in the hatchery design and construction (i.e. separate entries for different areas; each pond/tank has its own water in-and outlet; foot baths and hand washing facilities at entrance of hatchery). Other biosecurity measures that will be included in the plan are ensuring clean water supply, quarantine of incoming fish/oysters/sea cucumbers, cleaning and disinfection procedures, personal hygiene, treatment and disposal of wastewater and solid waste and disease and disease risk management. All staff should be trained in biosecurity.

To prevent diseases, it is important that the facilities are bio-secure. Using RAS, it is expected that risk of pathogen introduction/spreading is reduced.

- The water going into the system should be disease free and sterilized (using UV f.e.)
- People entering the facility should follow strict bio security measures (use disinfection footbaths, wash hand thoroughly use alcohol, do not touch anything for visitors etc)
- Contact with the systems, system water or material in the systems must be kept to only the necessary minimum.
- Between batches the systems should be thoroughly disinfected. Different systems should be strictly separated in terms of use of equipment and staff/visitor bio-security measures

Personal hygiene

- Clean T-shirts should be worn at the facility with the staff exchanging clothes and footwear before entering.
- Hands should be disinfected when entering the facilities and moving between systems. Ethanol should be sprayed on the hands and distributed evenly so that hands and wrists are completely wetted. Watches and rings can hamper effective disinfection, and must be taken off before entering the facilities.
- Disinfect the boots (foot bath) when moving between systems.
- No material should be brought into a system without being thoroughly sterilized.
- No material should be moved between systems. If this cannot be avoided, each item must be disinfected before it can be moved.

- It is not allowed to store material on the floors. Any material, which was in contact with the floor must be considered contaminated, and needs to be disinfected immediately. The floors must be kept dry whenever possible.

Quarantine of incoming animals

Wild animals will be used for broodstock and can carry pathogens which could spread through the facilities causing severe impact on the activities carried out. This has to be prevented with the appropriate measures. Incoming animals can be quarantined in a separate tank without connection to tanks with other animals. This tank should be disinfected before animals are stocked. Physical contact with the animals should be minimised and personal hygiene measures should be strictly followed. Depending on the species, animals should be quarantined between a 7-14 days.

Pest control

Most aquaculture operations have issues with pest animals like mice, rats, cockroaches and flies. One of the most important reasons why it is important to control these animals is because of health and food safety issues associated with these animals. Pest animals can bring microbes and diseases, have an impact on production and resources and cause damage to facilities and equipment. By implementing a pest control system, operators ensure that the risks of contamination of feed, equipment and farming systems are minimized. A pest control system typically includes the following steps:

- Correct pest identification as different pest animals require different control strategies
- Planning of preventive strategies like proper cleaning and sanitation, a good waste disposal system and very importantly by storing all feeds indoors in a sealed room
- Selection of optimal pest control tactics, like mouse and rat traps and electric fly killers
- Proper monitoring and recording of the pest control activities
- Regular evaluation to see if your pest control system is still working well

Handling of mortalities

Dead fish should be removed from tanks and ponds as quickly as possible. Dead fish left in the water too long can affect water quality and spread diseases. Dead fish should be checked for parasites and diseases. In case of mass mortalities, a fish health specialist should be contacted.

Mortalities are soaked in water with chlorine for anti-bacterial purposes and should be disposed of properly. Any mortalities collected shall be recorded and sampled according to protocol (date, system, tank, etc), and should be disposed of immediately in a sanitary manner.

- Observe bottom of tanks for dead animals.

- Tare bucket on scale if mortality needs to be weighted.
- Place net into the tank and remove the mortalities taking special attention not to disturb other fish.
- Count mortalities from net into bucket.
- Once all mortalities removed, record on sheet.
- If the mortality appeared to be the result of disease or infection report immediately to manager or a veterinarian and take appropriate actions.

Equipment cleaning

Cleaning and sanitation of facilities and equipment for harvesting and sorting is a very important part in preventing the occurrence and spread of diseases in a hatchery. Proper cleaning and sanitation can be achieved by strictly implementing the following procedure:

- Put on appropriate protective clothing before starting any cleaning and sanitation activity (apron, gloves, and boots)
- Prepare cleaning tools (brooms, scrubbing brushes, shovels, water hoses, cleaning cloth, buckets, detergents, sanitizers, etc.)
- Dismantle any equipment (like fish sorters) to clean it well
- Remove all visible rubbish and place in appropriate disposal bins
- Wipe surfaces to remove loose surface dirt
- Rinse all surfaces materials and equipment with clean water
- Apply detergent to break down grease and remove any stains and scrub all surfaces from the top down to remove all dirt
- Rinse off the detergent from the top down with plenty of clean water
- Apply sanitizer to kill and reduce bacteria to a safe level
- Rinse off sanitizer with plenty of clean water
- Dry the materials and equipment by removing excess water that may remain behind and allow bacteria to grow
- Properly store all clean materials and equipment

System cleaning

While carrying out cleaning of a system or part of a system, record activities in the System Cleaning Checklist.

- Clean tank walls inside: Brush slowly and carefully in order to stress the fish as little as possible.
- Clean tank walls outside: Clean the external surface of the tanks using a brush with tap water, if needed use alcohol to remove stubborn dirt.

- Brush Standpipes: Isolate the tank by closing both drain and inlet valve and then remove the dirty standpipe from the tank with one hand and immediately replace it with a clean spare standpipe held next to it on the other hand. Special care should be taken while replacing standpipes to minimize the risk of small fish being trapped in the outlet. Open the drain valve and the inlet valve and then repeat all the operation in all the tanks. Brush all the standpipe`s surface especially the perforated and internal part and rinse them with tap water.
- Brush overflow pipes: Remove the dirty overflow pipe from the tank with one hand and immediately replace it with the clean spare standpipe held next to it on the other hand. Special care should be taken while replacing overflow pipes to minimize the risk of small fish being trapped in the outlet. Brush all the pipe`s surface especially the perforated and internal part and rinse them with tap water.
- Brush inlet pipes: Remove all the inlet pipes from the tanks. Using a brush clean all the surface of the pipe with particular care to the perforated part. Clean the inside of the inlet pipe with a pressured water jet of tap water, shake it well and rinse it twice. Put back all the inlet pipes in place and make sure that the correct water flow direction is followed.
- Clean Sump: Clean the wall of the sump using the tank broom.
- Brush outlet pipe Drum Filter: Clean the drum filter outlet mesh by using the brush or the tank broom if the pipe is not easy to reach.
- Clean lids: Clean the mesh of the lids by using a brush and rinse the brush in a bucket with tap water, flip the lids and do the same operation on the other side.
- Clean air stones: Take the air stone out from the tank, brush it and spray it with alcohol. Dry the air stone and place it back in the tank.
- Clean skimmer foam outlet: Use the alcohol sprayer for breaking the foam inside the outlet pipe, clean inside with blue paper or with a brush, if it is possible to disassemble the pipes for a deeper cleaning, rinse all the pipes with tap water and put the outlet back in place.
- Clean skimmer foam trap: Remove the lids from the foam trap, spray with alcohol to brake the foam and remove all the dirt from the surface.
- Clean O_2 probes: Clean all the O_2 probes with a soft brush and then use paper to gently clean the membrane, never use a brush or other aggressive methods for clean this part so as not to break the membrane.
- Clean the floor: Use the floor broom and tap water for cleaning the floor and underneath the tanks and other equipment.

- Remove dust\dirt from equipment: Remove all the dust\dirt from all the equipment in the system like protein skimmer, drum filter, air blower, electrical box, flowmeter and UV unit. Use paper and an alcohol sprayer.
- Tidy Up: Tidy up all the System and check that all the equipment is clean and in the right place.
- Clean and fill footbath: Empty the footbath, rinse it with tap water and use the brush if needed. Then fill the footbath with approximately 10 litres of tap water and add 50 mL of Bleach.
- Clean all the cleaning equipment: Clean with tap water all the cleaning equipment used and disinfect. Put back all the cleaning equipment in the designated place.

System disinfection

System disinfection is only carried out when the whole system is emptied and cleaned, not during continuous operations. For system disinfection follow the following procedure:

- Switch off the UVs
- Remove pH and O2 sensors from the water. Spray and clean probes with a 15% bleach solution. Leave the solution on the probe for 10 minutes and then rinse with clean water. Leave the pH probe inside a clean feed container filled with enough tap water to cover the electrode (it is important that the electrode does not dry).
- Throw out rubbish and replace the bin bag for a new one.
- Wear appropriate Personal Protection Equipment to handle bleach including impermeable protective clothing and arm length gloves and apply the appropriate volume of concentrated sodium hypochlorite (bleach) solution.
- Leave all husbandry equipment (empty spray bottles included) within the tanks so that all equipment is in contact with the bleach solution.
- Leave the system running overnight with sodium hypochlorite (bleach) solution.
- Drain the system
- Scrub down the tanks, pipes, buckets, lids etc.
- Disassemble and clean inside the protein skimmer
- Siphon and brush the back of the drum filter
- Snake the system and drain all water
- Wipe down all the pipes, equipment, lights, lids and table.
- Rinse all tank surfaces and anything which was in contact with the Bleach solution (including standpipes, buckets, nets etc.) with fresh water and drain and place equipment in the designated area. (For systems which cannot drain remove all rinse water by alternative means)

- Remove biomedia and place it in the bleaching vessel. For large systems remove only half of the total biomedia.
- Clean the flowmeters
- Fill the system with fresh water and run through the whole system for 2 hours, check for chlorine
- Disconnect tanks, UV, drum filter pump, and system pump. and completely drain all the components
- Leave system to air dry
- Carry out a system check.
- If any leaks were detected or notice damaged equipment, inform maintenance staff if required. Inform maintenance team to carry out their checks, including UV sleeve cleaning.
- Throw out any other remaining rubbish
- Fill a footbath with 33% bleach solution and dip the challenge boots inside.
- Take all documentation and hand it over to the person in charge

Preparation of system for new batch

- Fill up all the system, tidy up equipment.
- Switch UV system on
- Before the system is operated: Switch on the air blowers.
- Before transferring fish into the system, check that the system is equipped with: nets, buckets (clean, water and bleach), spray containers (alcohol and bleach) and each tank is equipped with: standpipe, overflow pipe and inlet pipe.
- On the day fish are actually going to be placed into the system, the technician in charge of the operation has to check again for free chlorine
- After transferring fish into the system add the biomedia

7.9 Harvest and post-harvest management

Harvesting and packing is the last phase of in the grow-out activity, therefore, it should be done cautiously to prevent loss during the process.

Harvesting involves a lot of handling and stress can be minimized when it is done in a cautious and organized manner. When handling fishes, especially during harvesting and packing, make sure that loss of scales will be prevented as well as infliction of wounds. The aforementioned can affect marketability of fishes.

Handling

To minimize the damage of animals during harvesting and post-harvest handling operators should:

• Use equipment that has been designed for rapid and efficient handling of aquaculture products without causing mechanical damage. Any scratches on the animals should be avoided

• Use harvesting areas and equipment for harvesting, catching, sorting, grading, conveying and transporting of products that are smooth and easy to clean.

Harvesting procedures

Harvesting activities should be planned in advance and should be organized timely in order to avoid that fish are exposed to high temperatures for longer periods. Additionally, technicians should ensure that:

- Fish, oysters, and sea cucumber should be purged by not feeding them for at least 24 hours. This allows them to excrete all body wastes. Only healthy fish that show no clinical sign of disease should be harvested
- Detailed records need to be maintained during harvesting to tallow for proper traceability
- Do not subject the fish to extremes of heat or cold or sudden variations in DO
- Slowly cool down the fish using ice when sorting and packing to avoid stress during transport
- Minimize physical damage and stress during packing and transport by fast and efficient handling

Fry will be harvested, graded, and weighed before packing. The grading and weighing procedures described in 6.6 should be followed. Basins will be used for harvesting, grading and weighing. Fish will be transported life in containers (plastic bags are not available in Kenya due to the plastic ban) and supplied with oxygen (medical grade).

7.10 Monitoring and control

The monitoring system of OxyGuard has two main parts, Overview and Log. There are also several panels, partly for an event log and also for system configuration information, as well as a set-up menu.

7.10.1 Overview

The overview shows here-and-now measurements and the actual state of I/O's and relays. Please note that there is an update interval of a few seconds. For detailed information click on the item of interest. At the right-hand-side of the top bar of each column the latest event log is shown, together with the number of such messages for the last 12 hours.

Warnings and alarms

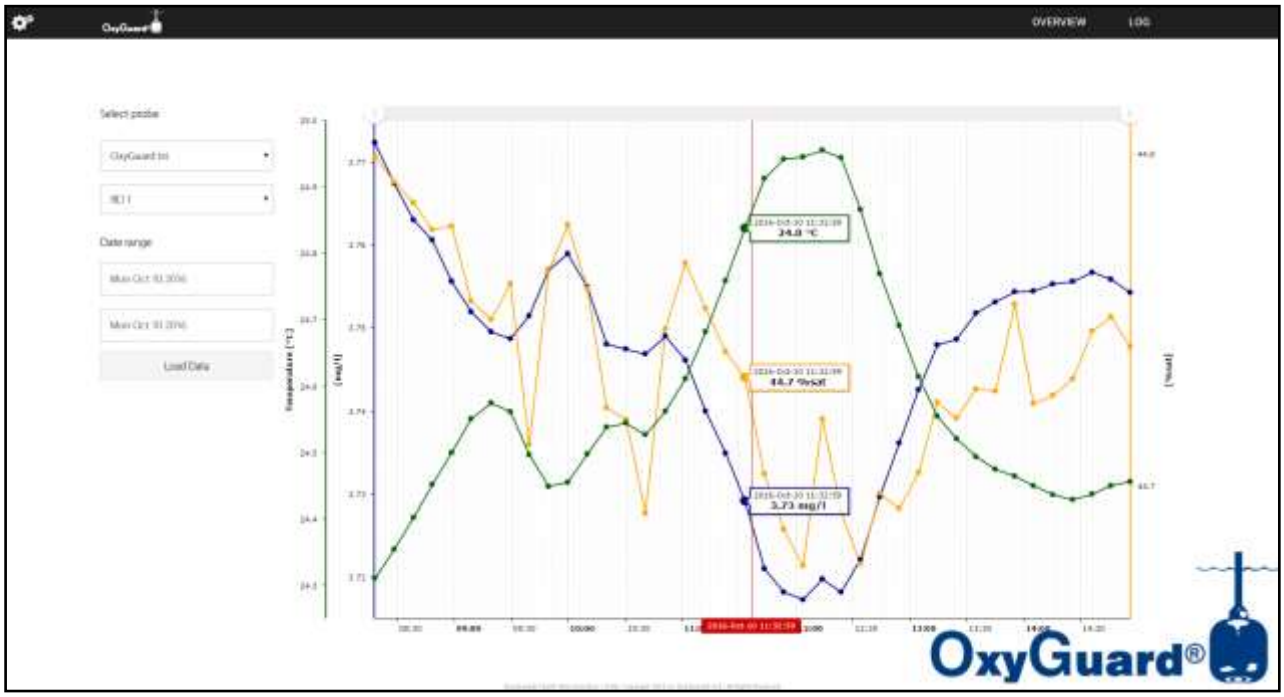
If there is a warning or alarm the associated measurement value will blink yellow or red accordingly, and a message is shown allowing the warning or alarm to be acknowledged, if the operator has appropriate access permission.

7.10.2 Log

The Data log gives access to measurement values stored on the Pacific. To store the log on a PC it must be downloaded, either by using the web interface or by taking a backup of the Pacific. A standard Pacific has capacity to store between 1 and 6 months of values.

View graph

To view a graph, you must choose the system, choose the probe, choose the start and stop dates and then choose "Load Data". When the data has loaded you can inspect it.



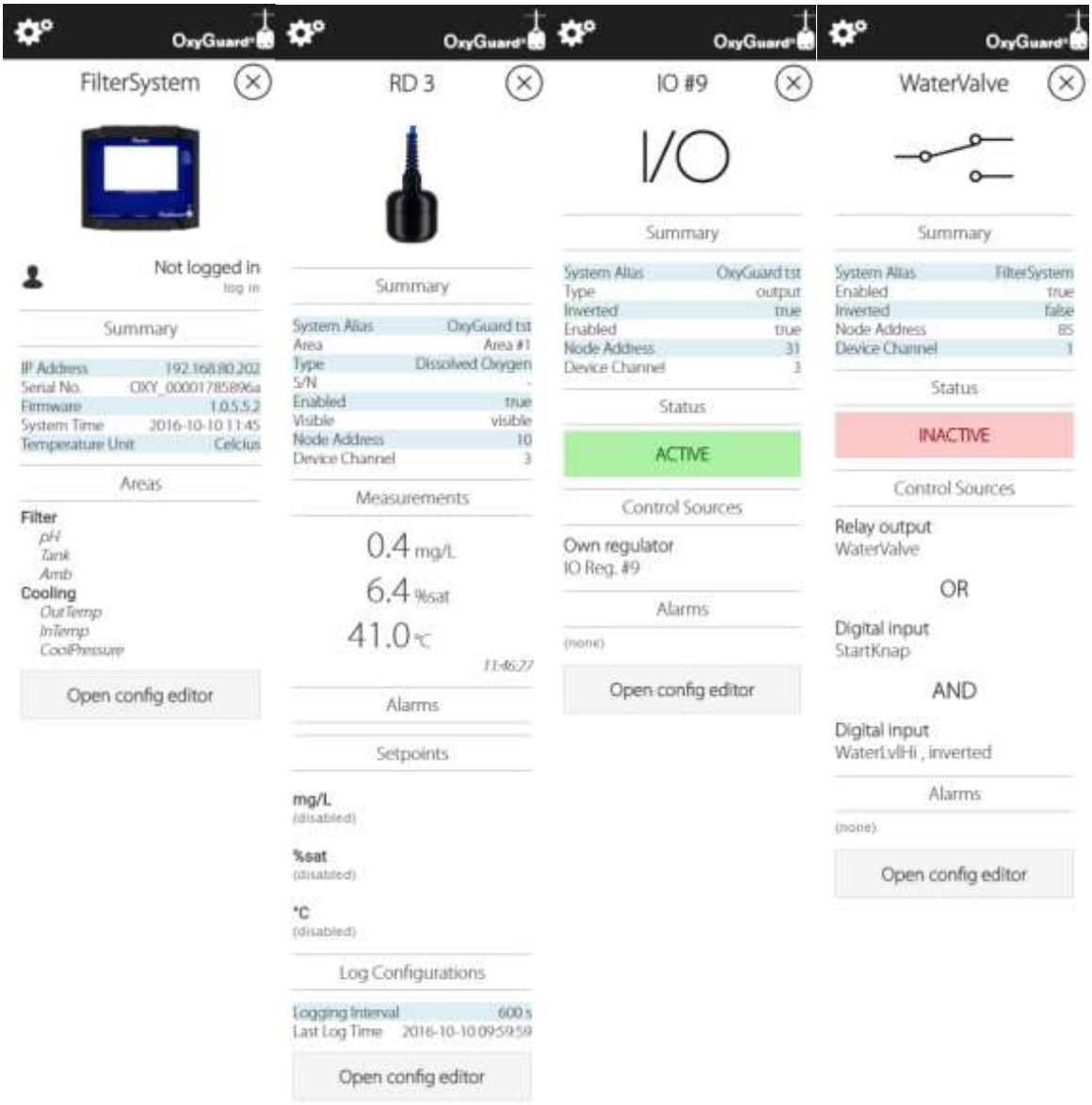
Export data

To export data, click on "LOG" at the top right of the graph, and then choose "Export" from the resulting menu. To obtain a .CSV file choose the system, then the probe or probes concerned,

then “comment labels”, then start and stop times, and then click on “Compile Data”. When the data has been collected click on “Download” to save each result.

7.10.3 Configuration panels

The detailed configuration information obtained by clicking on a part in the Overview display depends on what type of part is concerned:



If changes are needed, click on ”Open config editor” at the bottom of the panel.

7.10.4 Login

You must be logged in to acknowledge warnings and alarms, or to make changes to the configuration. To log in click on the system that you will connect to or the Overview, and then click ”log in”. A padlock icon shows whether or not you are logged in.

7.10.5 DO probe- Directions for use

The DO probe does not need regular service or renovation – just keep the membrane reasonably clean. Renovation intervals are typically between 3 and 5 years. Please see the maintenance instructions.

The probe does NOT need frequent calibration. The actual calibration frequency depends on the actual conditions and on the accuracy wanted. It is recommended that a calibration check, that also will ensure that connected equipment is working, is performed at suitable intervals.

Calibration check

You can check calibration by wiping the membrane clean and placing the probe in the air, protected from sunlight and direct heat. Check the measurement after a few minutes. If it is close (e.g. +/- 3%) to the calibration value of 100.5% saturation, then calibration is probably not needed. Any deviation is probably because the probe has not attained the same temperature as the air. The temperature should be stable. If, after 30 minutes, there is still a deviation then calibration is indicated. The probe must have the same temperature as the water or air it is calibrated in and must be allowed to attain this temperature before being calibrated.

Calibration

If a calibration check indicates that calibration is needed the automatic calibration process can be started. Please see the instructions for the system concerned.

7.10.6 DO probe- Maintenance

The frequency with which care is needed varies according to the actual conditions. You can start with frequent cleaning and control and increase intervals as needed to maintain the measurement accuracy that you want.

Once a month, the following maintenance should be carried out;

Wipe the membrane. There is biological activity that deposits a film on all surfaces in all healthy waters, and thick deposits can give errors. You can check measurements before and after wiping the probes. If the measurements, when steady, are the same before and after you can probably choose longer intervals for wiping the probes.

Check the measurement. Take the probe up, wipe the membrane and hang it in the air. After a couple of minutes, it should give a measurement of between 98 and 103% saturation. This

is a good, quick check that both probe and electronics are working. A deviation from 100 or 100.5% is because the probe does not have the same temperature as the air.

If the measurement is not between 98 and 103 you should wait. If conditions are unstable, i.e. if the temperature is changing, it might not be possible for the probe to stabilize because temperature equalisation happens slowly in the air. If calibration is indicated, follow the calibration instructions.

Fault-finding

The most probable cause of unstable measurements in a new installation is that the probe is placed over a diffuser. If the probe has worked well for a long time renovate it. Instability can also be caused by the probe being not completely filed with electrolyte, in which case renovation is indicated.

To check cables and connections start by checking visually. Check the cables, open any junction boxes and check that they are completely dry. You can switch the probe under investigation, with one that you know is in order, at the junction box nearest the probe. If the measurement is now OK renovate the probe under investigation. If there is still a fault, connect the good probe directly to the equipment terminals. The fault will probably now disappear, indicating a fault in the wiring.

If the dissolved oxygen value in a tank with oxygen dosing oscillates, i.e. swings between two values at regular intervals, the dosing settings probably need adjusting. This can also be caused by poor mixing of water in the tank or by unfortunate placing of the probe.

Membrane replacement

The probe's membrane should be wiped clean from time to time.

Membrane replacement should only be performed if:

- The membrane is damaged
- After long use (years), you cannot calibrate up to the correct value
- The probe is not completely full.

7.11 Record keeping

Water quality monitoring

All quality parameters discussed in section 6.6 should be measured and recorded.

Feed management

- Origin of feeds and feed ingredients (e.g. raw material details, supplier details)

- Feeding records (e.g. quantities of feed used, bag numbers)
- Storage and control records (e.g. checking expiry dates, verifying the First In, First Out system)

Quality control

- Clean and sanitation records (e.g. cleaning and sanitation checklists and forms)
- Workers hygiene records (e.g. worker hygiene checklist)

Management of chemicals and veterinary drugs

- Origin of the chemicals and veterinary drugs used in the facility (records should proof the legality of the product and verify proper labelling of the product)
- Required records for every application of drugs and other chemicals should include the treatment start date, treatment stop date, compound used, diagnosis and symptoms, dosage, withdrawal period, MRL, identity of ponds or cages where the drug was applied, and harvest date for the treated ponds or cages

Post-harvest management

Records of harvesting and packing of fish should be properly maintained to ensure product traceability including:

- Species (scientific name)
- Harvest date and slaughter date
- Origin (tank number)
- Treatment history

Records for the transport of fish should be properly maintained to ensure product traceability including:

- Departure time
- Arrival time
- Net and Gross weight
- Source (tank number)
- Transportation method (including vessel registration number and/or license plate number)
- Origin
- Destination

7.12 Climate change adaptation and mitigation

It has been recognized that climate change will affect aquaculture indirectly through the changes that will be brought to the ecosystem, its productivity and behaviour (e.g., hydrology). It has also been recognized that the effects of climate change on the ecosystem will be highly unpredictable, random and extremely localized and therefore, any mitigation or pro-active action needs to be locally adapted. Caribbean islands are specifically vulnerable to changes like sea level rise, ocean warming, and acidification, but also from sudden impacts such as an increase in the frequency and intensity of storms and heat waves. Other effects of climate change on aquaculture activities are increased invasions from alien species, increased spread of diseases and changes in the physiology of the cultivated species by changing temperature, oxygen availability and other important physical water parameters. Eventually impacts caused by climate change will lead to loss of production and infrastructure. Climate change is also predicted to impact food safety, where temperature changes modify food safety risks associated with food production, storage and distribution. In this project, a strong focus is placed on building general adaptive capacity.

7.12.1 Mitigation

Minimise water and energy consumption

A number of measures can be taken to reduce the fossil fuel consumption of the facility, thus reducing greenhouse gas emissions. These include the use of efficient machinery and lighting, the use of gravity for the movement of water, and the use of renewable energy (e.g. solar, biofuel, hydro and wind energy). Water consumption can be reduced through the improvement of water use efficiency, for example by reusing water for agriculture or by using recirculating aquaculture systems.

Minimise transportation

By marketing fish locally, less transportation is needed. Aquaculture operators can work together through clusters to reduce the transportation footprint of supplies to the facility and of products to the market.

Optimisation of feed management

The highest impact of the aquaculture sector on climate change is attributed to feed production and the transportation of feeds and feed ingredients. Sourcing more sustainable alternative feed ingredients reduces the carbon footprint. By improving the Feed Conversion Ratio (FCR), the amount of feed needed to produce 1 kilogram of fish, less feeds will be

needed. Operators can achieve this by using high quality feeds and by implementing efficient feeding methods that minimise waste and that maximize efficiency.

7.12.2 Adaptation

Implementation of Best Management Practices

Implementing BMPs in all aspects of production will improve the overall resilience of the facility. Ensuring fish health through the implementation of BMPs will reduce disease risks. Environmental measures that ensure the protecting of local ecosystems will decrease the vulnerability to climate change. For example, if mangroves in the area are protected, they will provide a barrier against storms and high waves.

Flood prevention

When planning a aquaculture operation and selecting a site, climate change effects should be taken into consideration to avoid future risks and costs for future adaptation. For example, marine cage operations should not select a site that is unprotected from high waves or strong currents, and pond farming operations should select sites that have a low risk of flooding.

Use available monitoring and early warning systems

Operators should be familiar with reliable sources of information on climate change and climate variability. It is important to understand and interpret the meteorological predictions such as weather forecasts well. Most AMS have national agencies in place that provide daily online weather forecasts, and which provide information on upcoming extreme weather events, like typhoons and extreme high tides. When changes in salinity, water availability and other important parameters are predicted in advance, operators can prepare their farm to minimise losses and damage.

8 System operation and maintenance procedures

8.1 Daily checklists

Every day each system is checked on the following for about 6 times per day:

- Water quality measurements: see section 6.6
- Check drum filter-nozzles: Technicians should check drum filter spray nozzle function once per day. If blocked, the drum filter spray nozzles can be cleaned with a brush to remove debris. If after cleaning persistent pollution of the same nozzle occurs the nozzle can be placed in diluted acetic acid for 1-2 hrs to remove blockages; wash in clean water before fitting back into nozzle holder.
- Tank sump and levels: Check the water level of all tanks and sumps. Water levels are marked on the inside of the tanks.
- Check for leaks: Check the whole system for leaks in tanks, fittings, pipes and equipment.
- Check flow meters: Check the flow on the flow meters and if it is corresponding with the required flow going to the protein skimmers.
- Purge and syphon: In case a lot of debris can be found on the tank bottom, some water needs to be purged from the tank removing the waste or the tank should be siphoned. For purging open the outlet valve for a few seconds until the waste has drained. For siphoning a small hose if used attached to a stick and debris can be removed accurately.
- Add buffer for pH if necessary: As fish grow, they produce metabolic wastes and carbon dioxide. The accumulation of CO2 and the consumption of alkalinity in the biofilter will reduce pH and the water will become increasingly acidic. To maintain pH within optimal levels of between 7 and 8, this drop in pH needs to be controlled by the dosing of Sodium Bicarbonate to control the buffering capacity of the water. Sodium Bicarbonate will be added daily into the systems during system checks. Sodium Bicarbonate will be added into the system by dissolving a set amount into a 10 L bucket and mixing it thoroughly until it is completely dissolved into the water. The solution will then be added into the clean sump (and not into the biofilter).

a. Sodium Bicarbonate amounts should be weighed out for each system at a level of 40% (0.4) of the feed amount the night before. After checking the pH and Alkalinity of the water, this value could be reduced to a minimum of 20% (0.2) if the pH and Alkalinity are above the set points (Alkalinity 150 – 250 mg/L as CaCO3 or 3 – 5 mEq/L and pH between 7.3 and 7.5). A minimum value of 20% of the feed should be added per day.

b. At every daily check from 7 am to 7 pm 1/5 - 1/6 of the amount must be mixed with 10 L of freshwater from the tower supply to each system and added to the clean sump at the point where the system pump draws water. This must never exceed 500g of bicarbonate mixed with 10 L of water.

c. During the daily checks, if the pH is below 7.2:

Sodium bicarbonate at 10% (of the feed amount) must be added in case the pH is below 7.2.

d. If pH is above 8.6 a water exchange must be performed in the system in order to bring the pH back to the optimal range

• Clean buckets and probes: Clean the cleaning materials, buckets and brushes with clean water as well as the probes.

• Change rubbish, alcohol bottles: Change the rubbish bags in the bin and dispose of garbage properly. Check if alcohol bottles still have sufficient content and replace if necessary.

Tank	O_2 (ppm)	
	AM	11 PM
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
Initials		

Tank	Mortalities		
	AM	Noon	5 PM
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
Initials			

Tank	Feed (g)		
	In	Out	Total
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
Initials			

Date	/ /	
	AM	5 PM
T (°C)		
pH		
P1 (rpm)		

DAILY FEEDING & SYMCHECKS (Tick)

Time	07:30	08:30	10:00	12.30	14:30	17:30	19:00
Feeding	X	X	X	X	X	X	X
Fish health							
Hormone treatment							
DF - Check net & nozzles are working	X		X	X	X	X	X
O_2 and pH within parameters							
Check flowmeters (m^3/h) (airlocks?)	X		X	X	X		X
Tanks and sump levels		X					
Check for leaks	X		X	X	X		X
Purge and syphon if needed	X		X	X	X		X
WQ scheduled	X		X	X	X	X	X
Check there is still NaOH in the bottle *		X	X	X	X	X	X
Add 1/5 of the total initial amount of NaHCO3 in 10l of water			X		X		
Dry biosecurity area if needed	X	X	X	X	X	X	X
INITIALS							

OXYGEN	AM	5 PM	11 PM
			Emergency
O_2 emergency working			

COMMENTS / OBSERVATIONS / ABNORMALITIES / MORTALITIES	Checked by supervisor/s			
	AM		PM	

* Switch on if pH < 7.1 [time:____]; Switch off if pH > 7.1 [time:____]

Figure 12: Example of daily checklist

8.2 Biofilter start-up and maintenance

Starting up the biofilter is to manage and control the seeding of nitrifying bacteria cells in the biological filter. When starting up the biofilter in a natural way with fish in the tank, high water exchanges are necessary to keep the ammonia within limits. Feed rates must be reduced until biofilter activation occurs.

When starting up the biofilter without fish in tanks following steps have to be taken:

- Prepare water of the system. System should be free of chlorine. Temperature, pH, alkalinity and hardness should match the requirements of the incoming stock.
- Provide alkalinity (carbon source). Sodium bicarbonate or baking soda can be added to the water to increase alkalinity to 150 mg/l for *Nitrosomonas* to grow. In order to establish the *Nitrobacter* an alkalinity of 200-250 mg/l is optimal. Add 53 g of sodium bicarbonate to increase by 10 mg/l for every 3.8 litres (1 gallon). Also adjust the pH if necessary.
- Provide ammonia and nitrate. Add ammonium hydroxide, ammonium chloride, ammonium nitrite or unscented household ammonia until the level is between 3-5 mg/l. 60ml per gallon of clear household ammonia (10% aqueous ammonia) will raise ammonia levels with 1.6 mg/l. Use ammonia test to check the concentration when the water is mixed.
- Once one biofilter is running, this can be used as a starter for the biofilters in the other systems.
- Monitor water quality parameters. Check culture tanks (at the same time and place) every day for ammonia, nitrite, pH, temperature and alkalinity. When both *Nitrosomonas* and *Nitrobacter* are established, ammonia and nitrite concentrations stabilise to acceptable levels.
- Stocking of fish can now occur. If stock was present in the tanks, feeding can start with a low rate.
- Start the biofilter with a low aeration and increase as more bacteria cells become established on media surfaces.

8.3 Water exchange

The procedure involves draining a portion of the system water and replacing it with new water. To do this, follow these steps:

- Fit the drain line so that system water can be removed and sent directly to the floor drain or open the drain line valve
- At the same time open the water line located at the system sump
- Try to balance the outflow with the inflow to prevent draining or overflowing the system sump.
- Always add new water to the system sump to allow for sterilization before reaching the rearing tanks.
- When doing large water exchanges make sure the sludge pump is the waste sump can cope with the flow and does not overflow
- When finished, close the inflow valve and the drain line valve
- Check the system after 30 minutes to see if there is any problem with the water level in tanks or sump.

8.4 Equipment maintenance

Proper cleaning and maintenance for all tanks, equipment, pipes and fittings is very important for functioning of the system and to avoid break down of equipment and thus reparation costs. Equipment should be serviced regularly according to the applicable Standard Operation Procedures, Technical Information, and user manuals.

System attention checks

System attention checks are carried out once a week. The following functions are checked, and the record form filled up:

DATE		
SYSTEM	**Hatchery/nursery 1**	**Hatchery/Nursery 2**
UV		
Lamps working		
DRUM FILTER		
Clean water level sensor		
Check nozzles flow		
Check completely drum filter net for holes		
Check Water pump (Working/Leaks)		
Check net cleaning-manually		
WATER CIRCULATION		
Check for leaks		
Check flowmeters		
Check/Regulate water inlet in tanks		
MONITORING SYSTEM CLEANING		
Cleaning pH, Redox and CO_2 probes		
INITIALS		

COMMENTS