



Overview of Good Aquaculture Practices

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Aquaculture continues to be the fastest growing sector of food production world-wide. The Virginia aquaculture industry produces a variety of different foodfish, baitfish, shellfish, and ornamental species. Likewise, a variety of different production methods are implemented across the state, including pond production and indoor, intensive recirculating aquaculture systems (RAS). Continued expansion of aquaculture in the state, as well as across the region and country, demands attention to both environmental and economic sustainability.

Good aquaculture practices (GAQPs) are a series of considerations, procedures, and protocols designed to foster efficient and responsible aquaculture production and expansion and to help ensure final product quality, safety, and environmental sustainability. GAQPs include considerations for: site location; production system design; incoming seed stock; facility biosecurity; feeding management, procurement, and storage; production techniques to maximize fish health; harvest; and cleaning and sanitation basics to ensure final product quality and safety. This document provides an overview and general framework for GAQPs, oriented to Virginia's growing pond and RAS aquaculture production sectors.

Business Planning

While business planning is not traditionally mentioned in the discussion of good aquaculture practices, experience has demonstrated that it is a crucial step in the development and management of a successful aquaculture business. A large portion of aquaculture ventures that fail, do so as result of financial challenges; cash flow in particular. It is essential to develop a business and management plan for the business. This is equally true for both new ventures and existing businesses. The process of developing a thorough business plan requires careful consideration of all aspects of the

business, including production, marketing, and capital. Preparation of financial statements is crucial, and it is best to be conservative when projecting yields and revenues. There are various tools available to guide and assist with the development of business plans. The business plan should be regarded as a living document and should be revisited at least once per year to assess business performance and make any adjustments to the plan. Making small changes and adjustments in the business over time can help to improve the long-term position of the business and can potentially help to avoid having to make large investments or costly changes all at once.

Site Selection

Proper site selection takes into account environmental resources as well as access to industrial infrastructure such as roads, airports, and reliable electrical power. Environmental parameters focus on water resources (typically surface water or groundwater) to supply aquaculture operations as well as water discharge. Surface water and groundwater sources for incoming water should be analyzed for water quality and for chemistry parameters appropriate for the culture species. Sampling should be conducted periodically over a year's time to evaluate seasonal fluctuations that can affect both quality and quantity. Historical data should be obtained going further back in time to determine impacts from droughts.

Topography has a significant effect on surface water, directly impacting runoff and drainage patterns. If a facility is downhill or downstream from agricultural or industrial activities, they may become an intermittent source of water contamination from fertilizers, manure, pesticides, or other chemicals. Thorough testing of water quality is essential to determine whether contamination risks exist. Aerial spraying is also a potential source

of direct contamination from adjacent agricultural activities and is independent of topographical layout.

Specific to pond site selection is slope, soil composition, and depth. Ponds are designed to hold water, so unless expensive liners will be utilized, soil clay composition should be a minimum of 20 percent to ensure water retention. In addition, soil quality such as pH and organic matter concentrations are important. Ideally, soils with a pH of 6-8.5 are best, requiring minimal treatment. Soils with high organic matter should be avoided because they can create high oxygen demand and release toxic nitrogen compounds.

Production System Design

Ponds

Good aquaculture practices in pond design provide for adequate levee height and width to accommodate required production and harvest equipment. Ponds should have adequate depth to maintain seasonal water-quality parameters and thermal stability while minimizing seasonal stratification from a minimum of 3 feet on the shallow end to a maximum of 8 feet at the deep end. Pond levee slopes of at least three to one (3 feet wide for every 1 foot in elevation) are recommended to reduce wind-induced erosion and facilitate harvesting. Ponds should also have graded bottoms that are higher than discharge waters to allow for complete drainage as part of pond bottom mud and organics management. Ponds should have adequate levee height to absorb documented heavy rain episodes. For surface water locations, intake structures should be upstream of



Proper design of ponds and levees will allow easy access for harvesting and will drain completely to provide for sun drying and disinfection.
(photo by Andy Lazur)

facility outflow. In addition, discharge waters should go through a detention pond to precipitate settleable solids, reduce nutrient concentrations, and improve other water-quality parameters prior to leaving the farm site.

Recirculating Aquaculture Systems

Good aquaculture procedures for RAS design allow for sufficient sizing of support-system components to maintain adequate water-quality parameters for the species under production. These components typically include solids separation, biofiltration, re-aeration/degassing, some form of water sterilization (ultraviolet light, ozone), and protein skimming. Tank circulation and discharge points should be oriented so that the tank circulation concentrates the settleable solids at the discharge location, effectively making the production tank a first-stage, solids-collection device. Typical tank turnovers for RAS are one to two turnovers per hour (10 percent flow through the solids filter, and 90 percent of the flow from the tank to the biofilter and directly back to the tank (see Figure 1). Tanks should be shaped to facilitate grading and harvesting of the species under consideration. Typically, round to octagonal tanks provide adequate internal circulation to facilitate fish swimming behavior, concentrate/remove solids, and accommodate harvesting.

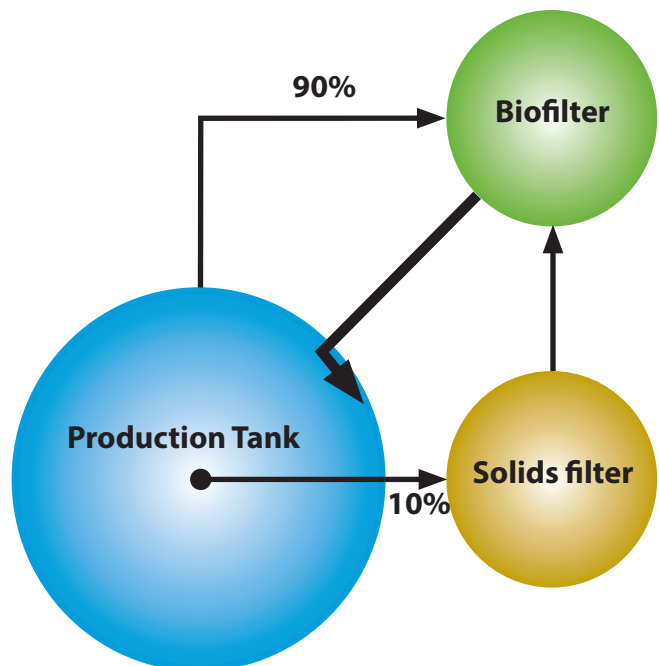


Figure 1. Water flow diagram for RAS: 10 percent of treatment flow from tank through solids collection to biofilter; 90 percent of flow from tank to biofilter. All water returns to the tank from the biofilter.
(based on original diagram by Michael Schwarz)

Table 1. Optimum values for major water-quality parameters.

Parameter	Optimum Concentration	Frequency of Monitoring
Dissolved oxygen	> 4.0 mg/l	Twice daily in ponds, more frequently in RAS
pH	6.5-8.5	Twice weekly in ponds, several times daily in RAS
Alkalinity	Minimum of 50 mg/l, 100-400 mg/l preferred	Several times a year in ponds, 2-3 times per week in RAS
Hardness	Same as alkalinity	Same as alkalinity
Ammonia (NH ₃)	< 0.15 mg/l	Twice weekly in ponds, once daily in RAS
Nitrate (NO ₃)	< 50 mg/l	Once daily in RAS
Nitrite (NO ₂)	< 0.5 mg/l in low-chloride water	Weekly in ponds, once daily in RAS
Hydrogen sulfide	< 0.15 mg/l	Upon initial use and periodically throughout season

Incoming Seed Stock

While generally incorporated in a processing facility, Hazard Analysis Critical Control Point-based (HACCP) standard operating procedures (SOPs) and GApPs can also be applied in the hatchery phase. If seed stock is to be outsourced, you should acquire some prior background information or knowledge about the shipper. For example, how long have they been in business? Ask for references and talk to customers they have shipped to previously. Ask if they have disease certifications for their hatchery and if you will be supplied with a disease certification with your shipment. Bringing animals from outside into your facilities is a very important disease-control point, and they should conform to some agreed-upon disease certification standard. For interstate shipments, some of these certifications may be mandatory for regulatory compliance.

Outsourced seed stock should remain in a quarantine facility for a predetermined time period. During this time, additional disease testing can also be done or redone. It is not uncommon to remove some of the animals just received and place them in a separate stressful environment to determine if a disease episode can be induced.

Production/Growout

Good aquaculture procedures are designed to maintain optimal production parameters throughout the culture period to maximize production performance as well as animal health, safety, and welfare. In production ponds, minimum oxygen levels and other water-quality parameters (ammonia, pH, and nitrite) – all of which are species-specific – should be maintained. Ponds should be kept destratified with aerators as needed. Research

has demonstrated importance of adequate aeration to maintain a minimum level of dissolved oxygen. Maintaining adequate dissolved oxygen allows fish to continue feeding and results in better growth; which has implications for crop harvest cycles and cash flow (Tucker 2005, Torrans, 2018). Feeding should occur in the morning after dissolved-oxygen levels from photosynthesis begin to rise, and if two feedings per day are applied, the second feeding should occur at least three hours before sunset to allow for oxygen levels to rebound after feeding activity. If dissolved-oxygen levels are running low overall, the second feeding should be eliminated until levels improve. If levels continue to be problematic, the first feeding can be reduced or temporarily eliminated as well, while pond management techniques such as continuous aeration and pond flushing are applied. Stressed animals should



Use of aerators and regular water-quality monitoring are essential practices to provide a good-quality environment for culture species.

(photo by Andy Lazur)

never be graded, harvested, or otherwise handled, as this additional stress is generally sufficient to cause a secondary disease outbreak or mortality.

Every three to five years or so (depending on species, production levels, and organic matter buildup), it is important to rotate ponds temporarily out of production, drain, dry, and disk hydrated lime into the bottom soils to help maintain pH, and oxidize organics that accumulate during production phases. Rates of 1,500-2,000 pounds of hydrated lime (calcium oxide) per surface acre are recommended for sterilizing pond bottoms.

Developing a biosecurity plan is essential for all types of production systems. Care should be taken to minimize cross-contamination between ponds or tanks by sanitizing harvest gear such as seines, waders, nets, and hauling tanks; personnel access should be limited.



Simple net sanitation and footbaths are important biosecurity measures.
(photo by Andy Lazur)

In recirculating aquaculture systems, water-quality parameters such as ammonia, nitrite, nitrate, pH, and alkalinity should generally be checked at least daily. Frequency of water-hardness testing is dependant upon source water and the percent of daily water exchange rates for the RAS. The frequency of dissolved-oxygen testing frequency is very much dependent on system design and animal density. For intensive systems with densities in excess of 0.5 pounds per gallon (60 kilograms per cubed meter), oxygen monitoring should be continuous through automation. Emergency aeration equipment, backup power supplies, or pure oxygen injection are mandatory for all RAS applications.

Harvest

The cultured animals should be withheld from feed for a predetermined time to allow for evacuation of the feed (for finfish in warm water, this is typically at least 24 hours). Some species may exhibit an off-flavor (caused by certain algae-released compounds). Always sample product for quality and flavor prior to harvest and sale. In ponds, this may be addressed by holding off harvesting for a few weeks while the algae population and corresponding off-flavor compounds change. In RAS, purge the fish or system by adding new water or ozone to remove off-flavor compounds in the water.

Feeding Management and Feed Handling

Using good quality feed of the proper size and nutritional value (protein, vitamins, and minerals) for the size of fish being cultured is essential to maximize growth, maintain a healthy immune system, and reduce feed waste and associated negative impacts on water quality. Feeding multiple times per day enhances fish growth and allows for the nutrient wastes to be released more evenly throughout the day and be “processed” by the beneficial bacteria, rather than having pulses or spikes of nutrients from single or infrequent feedings. Carefully observing fish-feeding behavior and good record keeping of feeding amounts will provide valuable information to reduce feed waste and provide insights on fish health.

Feeds should always come from reputable feed suppliers and be utilized within about three months of receipt to help maintain feed quality and safety. Onsite, feed should be stored in a cool and dry environment, preferably in a building or enclosure that can also be kept clean and free of rodents and other pests. If moisture, mold, or rancidity can be detected, the feed should be immediately removed from the site and disposed of properly. If moist or evidence of moldy feed arrives from the feed manufacturer, it should be immediately rejected.

It should be noted that legislative changes at the Federal level require a prescription for the purchase and feeding of medicated feeds. The use of medicated feeds is not permitted without a Veterinary Feed Directive (VFD) issued by a licensed veterinarian. It is advisable to consult a licensed aquatic veterinarian ahead of time in order to be familiar with this process and thereby in a better position to respond quickly to any emergencies or needs.

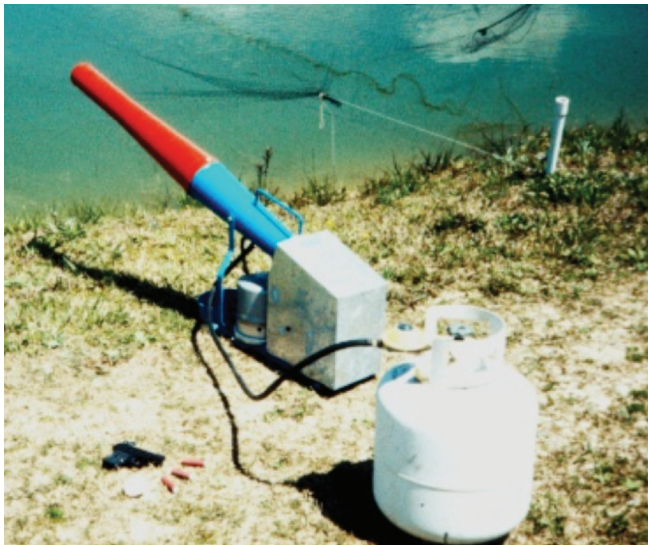
Cleaning and Sanitation

Equipment used in the facilities to handle or move fish should always be dipped in disinfection vats prior to reuse. Equipment should never be used in multiple areas of the facility. Fishnets, buckets, and other pieces of equipment that are used in a hatchery should never be used anywhere else. Likewise, equipment that has been used in the growout section of the facility should never be allowed within the hatchery or juvenile production areas.

Animal and Pest Control

Good aquaculture procedures for animal and pest control involve exclusion, control, and eradication measures where appropriate. In pond production, the more significant animal vectors are birds and four-legged animals. For bird control, a combination of scare tactics and lethal depredation techniques are often the most effective (depredation requires permits, usually from a state game and fish agency). Terrestrial animal control usually incorporates facility fencing, and sometimes pond fencing. For rodents, perimeter traps close to habitat may be effective.

Recirculating aquaculture systems are typically housed in buildings, so the structure itself is usually effective to exclude most birds and terrestrial animals. However, rodents, roaches, and other pests tend to be more concentrated around RAS structures due to the attraction of feed and fish. Therefore, effective plans



A variety of bird predation control measures are available, including netting, propane cannons, and hand-held noisemakers.

(photo by Andy Lazur)

to operate and maintain rodent traps are important, as is proper chemical pest control for roaches and such. Great care must be taken with chemical control to assure that chemicals or sprays do not come in contact with feed, water, or production equipment. Emphasis on pest control is required in the feed-storage area.

Facility Biosecurity

While most biosecurity issues at the facility level can be managed using procedures based on HACCP principles and SOPs, there are generic biosecurity aspects that can be initiated under GAQPs. Incoming water should receive some type of pretreatment. A typical surface-water intake system incorporates a screened intake and a holding reservoir depopulated of fish or crustaceans to allow for sedimentation and disease control. This reservoir should typically be able to hold several days' to a week's worth of typical water requirements. For RAS applications, this would be followed with additional solids filtration or disinfection (depending on the degree of biosecurity desired) prior to introduction into the tanks.

Personnel access to the farm, as well as worker access within the farm, should be strictly monitored. People who visit the facility must not have been to another aquaculture facility within the last 24 hours or worn any of the same articles of clothing between washings, because people can be a disease vector between facilities. Vehicles that have visited one farm should not be allowed to enter another facility without first washing down with a detergent to remove dirt, rinsed, and then sanitized with a disinfectant. Also, fish-hauling tanks and equipment should be cleaned, sanitized, and dried between facility visits to reduce the possibility that the equipment will transmit pathogens.

Within a facility, personnel access should flow from areas of highest biosecurity concerns to areas of lower biosecurity concerns. For example, larger facilities with multiple personnel should restrict access to the hatchery to essential personnel only. If the same personnel work in the hatchery and on the farm, then shift work should be scheduled in the hatchery first, followed by other work on the farm.

Summary

Good aquaculture procedures are relatively simple, common-sense practices that can significantly benefit fish production, disease incidence, product quality, and safety. The larger and more intensive the facility or

production, the more important and detailed the GAQPs will become. After development of the appropriate GAQPs, a next step is to develop more specific procedures and record keeping to be handled under SOPs and HACCP-based principles. If the facility conducts processing prior to sale (e.g., heading, gutting, or filleting), the Federal Drug Administration requires a food safety HACCP plan. For further assistance with HACCP or SOP development, please contact your area aquaculture Extension specialist.

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