SOUTHERN REGIONAL AQUACULTURE CENTER

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Good Aquacultural Practices

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Good aquacultural practices (GAqPs) are activities, procedures, or considerations that maximize environmental and economic sustainability, product quality and safety, animal health, and worker safety, while also minimizing the likelihood of a disease outbreak on the farm. Similar terms such as best management practices (BMPs) and good agricultural practices (GAPs) are often used to express the same concepts, which has caused confusion within the aquaculture industry. In this publication we will use the GAqP designation. Good aquacultural practices can be generic or specific, depending upon the application or use. Generic GAqPs often are used to convey concepts or practices for wide application, with individual facilities then using these to develop site-specific GAqPs.

In some localities, BMPs have become regulatory in nature. The good aquacultural practices described here are not intended to promote any regulatory rule, but rather to describe *general* principles, concepts, applications, and considerations to enhance the sustainability of both individual aquaculture producers and the industry as a whole. These GAqPs are voluntary and may be adapted and adjusted as appropriate for individual situations and conditions. Adjustments might be made because of factors such as production species, systems used, location, and even potential markets. We will begin with GAqPs generic to finfish and crustacean production, then describe more specific GAqPs for various production systems. Finally, we will present comprehensive GAqPs associated with harvest and post-harvest handling.

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Generic good aquacultural practices

Regulatory and non-regulatory compliance

Any aquaculture production facility must comply with all laws and maintain current permits to remain in regulatory compliance. These should be reviewed regularly and renewed as necessary. Managers should keep abreast of changes and additions to regulations pertaining to operational permits, worker safety, environmental compliance, and final product safety. Non-regulatory compliance pertains to “voluntary” rules and regulations to which the producer subscribes in the best interest of his operation, the industry, or the environment. An example of this can be a producer certification program whereby the producer commits to certain practices and/or codes of conduct, often to access specific market sectors or buyers.

Facility siting and design

The first step when considering facility siting and design is to have the site evaluated for wetland determination under Section 404 of the Clean Water Act. Section 404 regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in U.S. waters regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development, and mining projects. Section 404 requires that a permit be obtained before dredged or fill material may be discharged into waters of the U.S. unless the activity is exempt from Section 404 regulation (e.g., certain farming and forestry activities). The program states that no discharge of dredged or fill material may be permitted if: 1) a practicable alternative exists that is less damaging to the aquatic environment; or

2) the nation's waters would be significantly degraded. In other words, when you apply for a permit, you must first show that steps have been taken to avoid harming wetlands, streams, and other aquatic resources; that potential impacts have been minimized; and that compensation will be made for all remaining unavoidable impacts.

The site selected for an aquaculture operation should be one where there is no danger that the facility will be flooded and one that is a reasonable distance from other industrial or agricultural activities that could adversely affect the type of aquaculture production system being built. For example, an aquaculture pond facility should not be located adjacent to agricultural land that is regularly treated with pesticide unless there is a buffer zone or at least an agreement with adjacent landowners. For extensive outdoor production, soil should be analyzed to ensure that it is appropriate (such as having adequate clay content for ponds) and that it isn't contaminated with chemicals from previous land use.

The facility should be designed to minimize access from one production phase to another. That is, if hatchery or fingerling production will occur, these areas should be sited and designed to minimize exposure to other production units. This includes physical separation, worker access and flow, and even security considerations as appropriate. Facility designs should be scaled appropriately to conservatively meet production goals *without* pushing system or species-specific production densities. Further, waste management systems/facilities should be sized to meet *and* exceed anticipated waste volumes. Both production and wastewater treatment systems should be inspected routinely and maintained to ensure proper operation, and promptly repaired as needed. Depending upon the type and intensity of the production system, some form of emergency back-up power is required. The more intensive the production system or the greater the dependence upon electricity, the larger and more reliable a back-up system needs to be. Auto-start and auto-transfer for intensive operations are a must. When construction is completed, all exposed soils should be stabilized to minimize erosion.

Source water

Source water is a critical GAqP consideration during site selection. Source water, regardless of the production system to be used, directly affects the health, quality, and safety of all products and can be a make-or-break factor in the long-term viability of any operation. Source water can be categorized as closed (wells and springs) or open (ponds, lakes, rivers, and oceans). Closed water sources usually have consistent water quality but may have a seasonal fluctuation in flow. If they are free of fish and organic material, they are more biosecure. Open water sources are prone to variability in quality and introduce a biosecurity risk because they may contain aquatic pathogens. Surface water intake systems should include prefiltration to prevent larger animals, fish larvae, crustaceans, and debris from entering culture facilities. Excluding outside fish and crustaceans through prefiltration helps minimize predation and disease transfer to cultured fish. Topography can affect runoff and drainage into surface water that can cause intermittent quality irregularities, especially if downstream from agricultural or industrial sites.

Regardless of the water source, historical records for source water volume and reliability should be traced back at least 10 years, or to a specific historical drought record, to verify that the water source will be reliable. Water quality records also should be reviewed to document seasonal or environmental relationships. Once the aquaculture facility is operational, the producer should continue to monitor for water quality, chemistry, and potential contamination as often as dictated by potential seasonal/environmental fluctuation and proximity to potential contamination sources. Monitoring also will help maintain compliance with any non-regulatory commitments. Lastly, if the aquaculture facility drains water back into the same water body, facility intake should be up current of the discharge structure.

Facility security

Security is a broad category generic to all production systems. Not only should property and product be secure from theft or vandalism, but also all holding, transport, and culture systems should be operated and maintained to prevent the escape of animals. Any containment method that keeps fish from escaping may be used. Security also pertains to protecting crops from predators that can deplete production and transfer pathogens or invasive species into the facility. The best way of minimizing predator damage is to use exclusion devices such as perimeter fences, individual pond fences to prevent predators or disease vectors from spreading from one pond to another, or structures or netting over the production areas. Other effective means are to harass the nuisance wildlife with non-lethal devices such as balloons, aerial noise devices, or noise cannons until the problem abates. USDA APHIS Wildlife Services can provide assistance in preventing wildlife depredation. In extreme circumstances, wildlife depredation permits may be obtained. For additional information on predators in aquaculture, see SRAC Publication Nos. 400, 4001, and 4002.

Facility security also addresses biosecurity concerns. General biosecurity GAqPs include "cleaning" source water; buying Specific Pathogen Free (SPF) eggs, larvae, or juveniles; and ensuring that vehicle/public entry points have appropriate disinfection protocols to address identified biosecurity risks. Personnel access to the farm also should be strictly controlled. Workers should change clothes upon arrival and visitors who have been to another aquaculture facility the same day should be prohibited or required to change into clean clothes before entering production areas. For farm workers, biosecurity zones should be identified (from high to low) and strictly enforced. That is, workers in a low-level biosecurity area are not allowed access to higher levels without significant cleaning and sanitation. However, access from high to low is permitted, such as from the hatchery to growout facilities.

Animal health

The goal of the producer is to manage the system to reduce the risk of fish health problems. The best approach is to use good animal husbandry and animal health GAqPs. A producer must develop a biosecurity plan that meets the needs of his production system.

While significantly affected by facility biosecurity, animal health has additional GAqP components relating to husbandry. The critical factor to fish health is water; water quality always should be maintained at an optimal level for the target species. When a facility has poor water quality parameters, such as high ammonia levels, this will increase animal stress and can result in disease outbreaks. For example, *Streptococcus* outbreaks in tilapia facilities are often linked to poor water quality. It is imperative that water quality be monitored frequently in accordance with the type of production system used. Should a water quality deviation occur, it must be corrected as soon as possible.

The reason for such concern with water quality is that the environment is one of the three components of the Fish Health Model (FHM). The FHM has three basic components: the host (fish); the environment (water); and the pathogen. It is the interaction of these three components that results in a disease outbreak. Fish pathogens may be present but not cause a disease outbreak. It generally is not until the aquatic environment deteriorates (poor water quality) that the pathogen can infect the host and cause disease. Thus, biosecurity and water quality management are critical GAqPs for maintaining animal health.

Animal health is also maintained by minimizing overall stress in the production process. To this end, GAqPs include routine monitoring of animal health to develop baseline health indices (such as relative weight, skin and gill health, internal organ appearance, etc.) and then routine testing to compare fish with that baseline. Deviations can indicate the progression of a disease, poor water quality, nutrition or feeding issues, and more. Another animal health GAqP is to develop a relationship with a qualified aquatic veterinarian. The veterinarian should make periodic site visits and assist in developing a site-specific health plan. If there is a disease outbreak, there are just a few antibiotics and one paracide (formalin) approved by the FDA for aquaculture. Therefore, it is absolutely essential that the correct treatment is chosen, that the proper dosage is used, and that proper withholding periods are observed before products are sold for human consumption. A veterinarian can help with these tasks, too. All chemicals and antibiotics must be kept in their original containers and stored in a cool, dry place. Always follow the instructions on the label.

A significant GAqP relating to animal health is the use of a fish health management plan. The plan should describe the predetermined steps a producer will take if fish begin to die unexpectedly. When fish are dying, it is critical to identify the cause correctly before the disease spreads to other systems and/or facilities in the area. Once identified, predetermined corrective actions must be implemented quickly. Fish may need to be examined by a veterinarian.

Feed management

Feed management GAqPs range from nutritional composition to storage and application. Aquaculture feeds come in many formulations, sizes, and types. It is important to feed the correct nutritional composition, feed size, and feed type (floating, sinking, or slow-sink) to match the species, life stage, and production system being used. Feed rations are affected by water quality parameters such as dissolved oxygen and temperature. For outdoor extensive systems, these two parameters can vary widely and need to be closely monitored and adjusted. In indoor intensive systems, these variables are controlled by the system and come into play only when there is a system malfunction.

Fish can be fed manually or with demand and auto feeders. Feed equipment should always be kept clean and in proper operating condition. Animals should never be overfed; an appropriate feeding level is about 80 percent of satiation daily. Splitting a daily feed ration into several smaller feed amounts and feeding several times a day can enhance fish growth and feed conversion ratios and minimize the water quality fluctuations associated with increased oxygen demand during and after feeding, as well as spikes in nitrogenous wastes.

Feeds should be stored with their labels, which include dates of manufacture, feed mill ID, and lot number. Inventory should be rotated back to front and feed should be stored in controlled environments whenever possible. Feeds should be used before their expiration dates, generally about 3 months from the manufacture date. To maximize shelf life, feed should always be stored off the ground, away from contact with walls, with air space between pallets, and in an area with appropriate animal and pest control. Feed on pallets should never be stored more than one pallet high to avoid crushing the pellets into unusable fines and to prevent worker injury from falling or shifting bags. Wet feed should *never* be used or stored because it will rapidly become moldy and spoiled. Moldy feed can cause rapid mortality in fish or compromised immunocompetence because of the toxins associated with molds. Because feed costs may be more than 50 percent of the total production cost, proper feed management is critical to all production facilities.

Record keeping

Records are a significant aquaculture facility GAqP component. Keeping thorough records allows you to properly oversee the operation and comply with internal or external audits (some buyers may periodically review documentation of your quality assurance program). You should, of course, have records of inventories—fish in and fish out, but you also need to document licenses and permits, cleaning and sanitation, inspections, repair and maintenance, feed, treatments, waste management, employee training, and employee health. Keep records on the use of chemicals and antibiotics. Record when it was used, for how long, the dosage, and the reason for use. Keep this type of information in bound record books in a safe location.

Records should always include date, time, individual entering the data, the required information, and any pertinent notes. Records should routinely be monitored by management and filed for future reference as needed.

Employee training

Employees should be trained in all GAqPs, with an emphasis on production and operations, feeding, fish handling and husbandry, biosecurity, perimeter security, production system management, cleaning and sanitation, chemical handling and storage, spill prevention and response, and employee health. The depth and detail of this training will be specific to the facility and the employee's areas of responsibility. There are also standard OSHA training and record keeping requirements for larger facilities.

Production system good aquacultural practices

Recirculating aquaculture systems (RAS)

RAS are systems that recycle or reuse 90 percent or more of the system volume on a daily basis. Intensive in nature, they generally carry 0.25 to 1 pound of fish per gallon of water (30 to 120 kg/m^3). These systems typically have components for solids removal, biofiltration, oxygenation, degassing, disinfection/oxidation, and temperature and pH control. RAS tanks come in several different shapes. An important design consideration is where water flows into the tank and where the water is withdrawn from the tank to the recycling system. The culture tank should act as the primary solids collection device from which the water is removed directly to solids filtration. This treatment flow should equate to about 10 percent of the recirculation rate (ideally one to two times per hour). The remaining 90 percent should go from the upper portion of a side wall (or Cornell drain) where the fewest solids would be found direct to biofiltration, gas control, and back to the tank (Fig. 1). This minimizes the capital costs and operating expenses associated with solids removal.

Because of the high animal densities often associated with RAS, makeup water for the system should be properly treated to ensure no pathogens are introduced to the system. This often involves significant solids filtration and

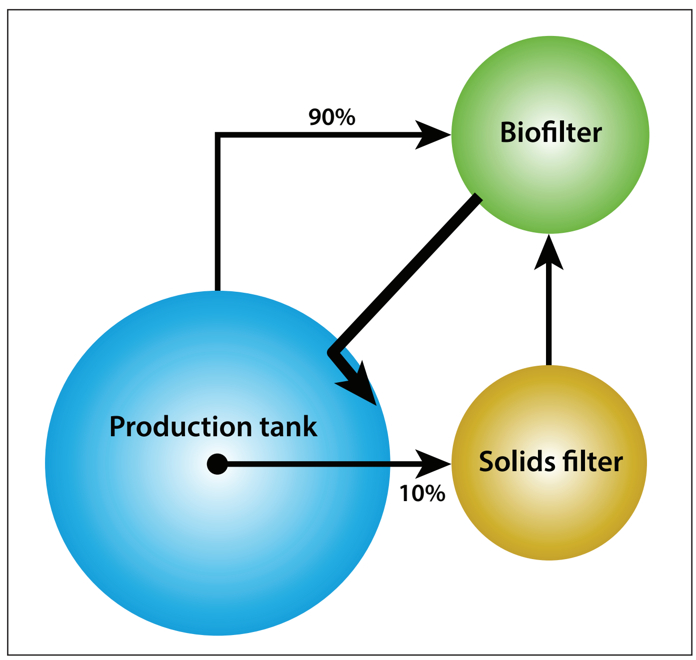

Figure 1. Water flow diagram for RAS: 10 percent of treatment flow from tank through solids collection to biofilter; 90 percent of flow from tank to biofilter. All water returns to tank from biofilter.

subsequent disinfection. Makeup water added to the system should be introduced into part of the support infrastructure, such as the reservoir or biofilter, rather than directly to the tank, and should be as close as possible to system water quality parameters such as temperature and pH. It is critical that RAS systems not be stocked or operated at densities beyond design specifications. While this is often done with the expectation of higher financial returns, in the long run overstocking erodes safety margins and increases animal stress to the point that diseases and animal losses are more likely to occur.

Biosecurity is even more important in RAS. Hatchery or juvenile production facilities have the highest biosecurity requirements and MUST be separated (usually in another building) from growout operations. Personnel access must be restricted between the two.

Being highly mechanical and complex in nature, RAS have significant maintenance, repair, monitoring, and employee training criteria. Given the high fish density and heavy reliance on water quality maintenance equipment, even a short period of the system not working properly can have devastating effects. Further, because the working environment has heavy mechanical equipment, water, and electricity, following all safety protocols and conducting periodic retraining are important. Systems should be operated to maintain the designated water quality criteria with a minimum of fluctuation and tested frequently, if not automatically, to ensure this. For additional information on RAS, see SRAC Publication Nos. 450, 451, 452, 453, 454, 455, 456, 4500, 4501, 4502, and 4503.

Raceways

Traditional raceways are gravity flow-through systems where water flows linearly through a channel and cascades from one raceway unit to another through a system of serial reuse and is then discharged into surface waters. Raceways are much simpler in design than RAS, since water is not filtered or recycled, and they may be operated as intensively as RAS with oxygen supplementation. Raceways are designed to confine the fish and control the water flow (Fig. 2). Ground water sources on land with a modest natural slope and free from the risk of flooding are suited for traditional raceways. Sites for this form of aquaculture are limited because large volumes of water are required for commercial production. Traditional raceways are the basis for the trout industry in the U.S. and have proven to be reliable, energy efficient, labor efficient, and profitable when properly designed and managed.

Raceway GAqPs include a properly designed water intake to capture the flow and reliably screen debris from entering the raceway system. Keyways secure dam boards to control water distribution and screens to confine the fish. Raceways may share a common wall and have keyways that allow fish to be crowded into adjacent raceways or flow to raceways below with minimal handling. Fish are excluded with screens, creating a quiescent zone where solid waste may settle to the bottom. A clean-out drain fitted with a standpipe provides a way to divert solid waste accumulated in the quiescent zone after each water use. Aeration occurs as water cascades into each raceway,

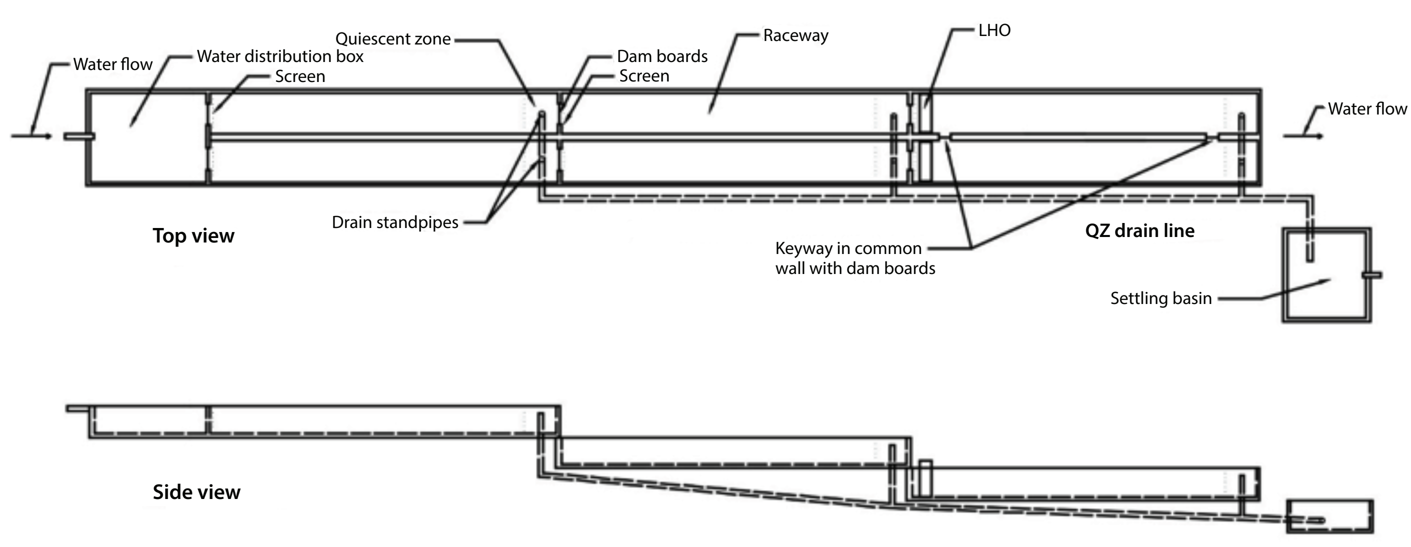

Figure 2. Elements of a typical trout raceway.

where low head oxygenators (LHO) may be fitted to supplement dissolved oxygen. Predators should be excluded with fencing at ground level and netting overhead.

The result is an aquatic feedlot where fish are easily monitored and accessible for feeding and harvest, and where water quality is predictable and risks can be easily managed. There is no temperature control in typical flow-through raceways. The fish species grown must tolerate high density. Serial water reuse exposes fish lower in the system to increasing concentrations of nutrients and the potential for disease transmission from units above. Interruptions in flow can result in rapid and disastrous fish mortality if no supplemental oxygen system is available.

Stocking rates and carrying capacity for trout are primarily a function of available oxygen rather than raceway volume or water flow. Under GAqPs, dissolved oxygen concentrations leaving each raceway unit should be kept above 60 percent of saturation for trout. Concentrations below this level will affect growth and feed efficiency. High-energy diets (e.g., 45% protein, 20% fat) are efficiently digested and yield less waste than less nutrient-dense feeds. Feeding below satiation also contributes to excellent feed efficiencies. Feeding several times a day will distribute the associated oxygen demand.

The water velocity needed to transport particulate waste out of the raceway is estimated at 0.1 feet per second (3 cm/s), but fish activity will re-suspend particulate material and solid waste will be removed at lower velocities. It is recommended that raceway units have a flow rate allowing at least four exchanges per hour. Soluble waste dissolves in the water and is not recovered. Particulate material is solid waste in either settleable or suspended forms. The basic strategy for waste management in traditional raceway systems is to separate settleable solids from the effluent discharged into surface waters and dispose of recovered solid waste in a sustainable manner.

Waste management is an important aspect of raceway system maintenance. Live fish must be excluded from raceway quiescent zones and settling basins for them to operate as designed. Solid waste collected in the quiescent zone should be removed on a routine, perhaps daily, basis. The effluent "sludge" may be handled in a variety of ways. It can be left to dry in the settling basin or be carried away and used to fertilize land or placed in a constructed wetland. It can be dewatered with a microscreen drum filter or a geotextile bag. Small operations may irrigate directly from an off-line settling basin. Sludge may also be composted, yielding a marketable product.

Waste management and water quality should be considered when inventorying, grading, and harvesting aquatic animals to minimize the discharge of accumulated solids. Screens should be cleaned regularly to prevent clogging and potential overflow. The effluent from cleaning screens should be diverted to the waste treatment system. Dead fish should be removed regularly and properly disposed of.

The GAqPs associated with traditional raceway systems also apply to other flowing water systems such as floating raceways or in-pond raceways.

Ponds

There are two general types of ponds used for aquaculture—levee and watershed. Levee ponds are filled by pumped water and watershed ponds are filled by runoff from the surrounding land. Ponds should be located on contaminate-free land (levee ponds should be on land with a slope of less than 2 percent to minimize earth moving costs). The clay composition of the soil should be at least 20 percent so that the pond will hold water adequately and so that soil excavated from the center of the pond can be used to build up elevated berms, allowing the pond to be drained by gravity. The ideal soil pH is 6 to 8.5

Average pond depth should be about 6 feet (1.8 m), with a minimum shallow depth of 3 feet (0.9 m). This facilitates harvesting and minimizes daily temperature and water quality fluctuations. The maximum depth at the drain should be 8 feet (2.4 meters). For overflow, a sleeved standpipe should be installed (Fig. 3) to help reduce pond stratification and pull water from the bottom of the pond. The pond bottom at the discharge pipe location should be above the drainage canal to allow complete draining.

Water loss from ponds must be controlled. Water seepage can be minimized by positioning collars on pipes so that water does not leak along the length of the pipe. All levees should include a core trench to inhibit lateral seepage. Interior and exterior levee slopes should be 3:1,

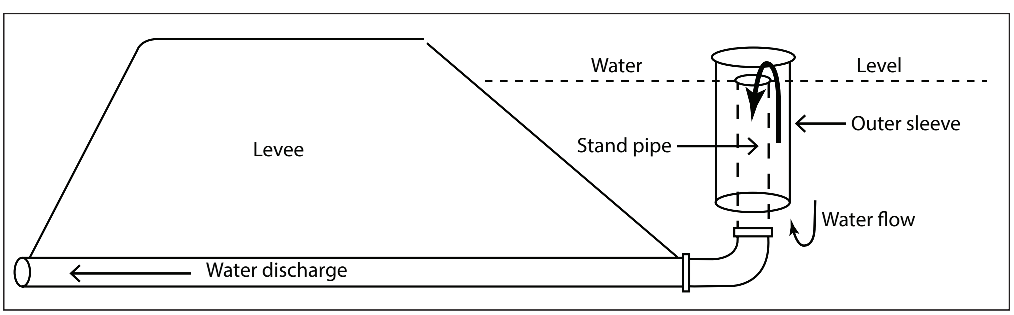

Figure 3. Pond levee with sleeved standpipe/drain.

with longer levees perpendicular to the natural wind direction to prevent excess erosion. Layouts can be specific for portioned pond culture or for freshwater shrimp with external harvest basins. An impervious layer of 12 inches (30 cm) of compacted clay at the pond bottom will prevent vertical seepage. If soil clay content is insufficient, pond liners will need to be used, although they will increase capital and operating costs.

Levee ponds can be constructed with a common berm to reduce construction costs. If multiple ponds are desired, a central area with electrical power and a common harvesting area can be designed. All berms should have convex surfaces to allow rain runoff and prevent pooling and be wide enough to allow vehicle traffic associated with stocking, feeding, harvesting, and other production activities. The tops of levees should have a layer of gravel to permit all-weather access. Once constructed, vegetation should be quickly established to minimize erosion. For additional information on pond construction, see SRAC Publication Nos. 100, 101, 102, 103, 104, 105.

As a general GAqP for pond production, the water source, pump, and pipe system should be capable of delivering about 25 gallons per minute per acre (250 L/minute/hectare) to replace water lost to evaporation and refill ponds if they are drained at harvest. Water exiting ponds should be detained in sedimentation lagoons or privately owned drainage canals before it is discharged from the facility. This practice is a way to minimize any potentially detrimental impacts on water quality downstream. Some facilities have gone to zero-discharge operations, whereby water drained from ponds is held in lagoons for an extended period of time to allow natural bioremediation. After a sufficient time has passed, this water can then be pumped back into ponds.

GAqPs require fish to be properly acclimated at the pond bank before stocking. Any summer stocking should be done during cooler times of the day. When stocking fry, be sure sufficient zooplankton is present to feed the fish until they grow large enough to eat commercial feeds.

In pond production, a floating feed is most often used so that feeding behavior can be observed. At cooler water temperatures, sinking feeds should be used because fish will not feed at the surface. It is critical that feed amounts be based on estimated biomass and that compensation be made for temperature. Floating feed should always be fed from upwind so the feed can drift across the entire pond before encountering a levee.

Always maintain optimal water quality parameters, test dissolved oxygen frequently, and keep emergency aeration equipment on site and in working condition. During the hot summer months, nighttime DO monitoring is essential. Aeration is also important to help break up any stratification whereby cooler water may stagnate below the warmer water above, causing oxygen stratification. Aeration can inhibit this tendency.

Aquaponics

Aquaponics is the term used for a production system that combines RAS and a hydroponic plant production system in which plants are grown without soil (i.e., in a nutrient solution or in some type of artificial media). In temperate zones, year-round aquaponic production requires a greenhouse or lighted and enclosed area that must be heated and cooled, making energy cost a large expense. A generic GAqP for aquaponics is that growers should investigate alternative energy sources such as geothermal water, solar, bioenergy, and wood heat to improve system sustainability. Lighting for a structure that doesn't have natural light could make use of compact fluorescence, high-pressure sodium, metal halide, high-intensity discharge lamps, LED (light-emitting diode), or induction.

The plant growth units most often used are media beds, nutrient film technique (NFT), and deep water culture (DWC, sometimes referred to as raft culture). In media beds, the media acts as a filter, which adds to the simplicity of system design. However, the media must be cleaned periodically or it will become clogged and create anaerobic zones. In some designs, worms (the same types used in vermicomposting systems) are added to the media to help digest solids trapped by the media.

NFT is a system that uses horizontal pipes or gutters for growing the plants. A GAqP for this type of aquaponics is to slope channels about ½ inch per 10 feet (1.5 cm per 3 m) to allow for easy drainage through the channel. Systems should always be designed with slopes in the direction of water flow to facilitate water transfer through production systems.

In an aquaponics system the fish production unit is typically operated as an RAS. While it is important in aquaponics to keep fish tanks covered to prevent fish from jumping out, exclude predators, and inhibit algal growth, it is becoming ever more important to protect the plant production units from being splashed by the production water. This is due to upcoming FISMA regulations that deal with concerns of food safety when fish culture water comes in direct contact with ready-to-eat vegetables. Evolving GAqPs in aquaponics are now considering physically separating fish and plant production systems and, in some cases, even disinfecting fish water before it is transferred to the plant production units. Once used by the plants, the water is free to return to the fish units without similar disease vectoring concerns.

Cages in ponds

When fish are raised in cages in agricultural ponds, a water resource can be used that is not suitable for other aquaculture production techniques. For cage production in ponds, GAqPs suggest a pond be no less than 0.75 to 1 acre (0.3 to 0.4 ha) in size. Usually two to four cages can be placed in such a pond, with approximately 300 fish in each cage, without the need for supplemental aeration. If the pond carries a higher fish density, supplemental aeration will be required. Regardless of the stocking density, it is recommended that electricity be available at the site to run aeration equipment in an emergency. It is recommended that stocking level never exceed 13 fish per cubic foot of water (446 fish/m^3) even if supplemental aeration is used.

A pier constructed into the pond is an appropriate structure from which to attach cages. A pier will simplify stocking, feeding, and harvest and also provide a safer working platform for the culturist. There should be good vehicle access to get supplies and fish to and from the pier. The bottoms of the cages should be at least 2 feet (61 cm) from the bottom of the pond, with a minimum of 2 to 3 feet (61 to 91 cm) separation between cages. The cages should be approximately 4 to 6 feet (1.2 to 1.8 m) in depth.

Catfish, hybrid striped bass, and rainbow trout are the species mostly grown in cage culture. In catfish cage production in temperate areas of the U.S., stocking 8- to 10-inch (20- to 25-cm) fingerlings in the spring is recommended so that market-size fish can be harvested in the fall to eliminate overwintering. In such a model, trout can be cultured in the same cages during the winter months when catfish would typically grow very little. For stocking trout, a farmer should start with fingerlings no less than 6 to 8 inches (15 to 20 cm) in size. In Virginia, trout fingerlings are stocked into cages in late October and early November and harvested by mid-April. For additional information on cage culture, see SRAC publication Nos. 160, 161, 162, 163, 164, 165, and 166.

Good aquacultural practices for harvesting and handling

Good aquaculture practices for pre-harvest and harvest focus on maximizing the quality of the product and minimizing stress on the animal. Prior to harvest, feed should be withheld for a predetermined number of days to allow for gut evacuation. This enhances the shelf life of the product and reduces the chance for off-flavor in the product due to leaching from the gut. It is also critical to make sure all harvest equipment is in proper working order, that containers for receiving the product are properly cleaned and sanitized, and that sufficient high-quality ice is ready to properly chill-kill the product. Chill-killing in water/ice slurry is critical to rapidly lowering the core temperature of the harvested product, which reduces spoilage. Once harvested, the product must be kept below 38 °F (3.3 °C) before, during, and after processing. Proper records must be kept from production through sales. For additional information on harvesting see SRAC Publication No. 394, *Harvesting Warmwater Fish.*

To minimize bacterial contamination, all surfaces and utensils that might come in contact with the product must be cleaned and sanitized before processing begins and after each batch of product is processed. This includes items such as utensils, knives, totes, tables, cutting boards, ice makers, ice storage containers, hands, gloves, aprons, trucks, and nets. Sweep or rinse surfaces to remove soil and other matter and then wash and rinse the surface with the appropriate cleaning agents. It is just as important that no non-food grade chemicals and no material hazards (e.g., a fractured piece of metal from a knife) come into contact with your product. You must, according to federal regulation, develop a hazard analysis and critical control points (HACCP) plan for all of your processing operation. HACCP is a systematic preventative approach for ensuring that each of your processing, packaging, and storage steps do not compromise the food safety of your product. Contact your county Extension agent for help in setting up an HACCP plan for your processing needs. At *http://www.fda.gov/Food/GuidanceRegulation/HACCP/ucm2006764.htm* you'll learn more about seafood HACCP. Or, see SRAC Publication No. 4900, *The HACCP Seafood Program and Aquaculture.*

Processing GAqPs include rapid cooling, rapid freezing, and temperature control during storage. Reduce the temperature of the product as fast as you can using an ice bath or blast freezer, or by spreading the product out in single layers in a refrigerator or freezer. Do not cool the product in big batches. For example, do not fill a bag with 10 pounds (4.5 kg) of fish fillet and place this bulky pile of fish in a freezer. The product in the middle of the mass may not freeze for 24 hours and will compromise the rest of the product.

Products should be stored at a temperature of 32 °F (0 °C) or colder unless they will be sold immediately. Seafood stored at 32 to 40 °F (0 to 4 °C) will degrade within a few days. Never store product for extended times at a temperature higher than 40 °F (4 °C). Shelf life is dependent on the product type, how it is packaged, and how it has been handled during storage. Colder temperatures will slow down degradation. To extend shelf life, store product at less than -10 °F (-23 °C) in freezers without defrost cycles.

Minimize risk during transportation by ensuring that the transportation vehicle is clean. The truck should be cleaned and sanitized between uses, especially if the truck has been used previously to transport other food products such as eggs, raw meat, or poultry. Never transport your product in a truck that has been used previously to carry live animals, manure, or garbage. During transportation, the product should be properly packaged and must be kept frozen or cool to maintain product quality and safety. Digital temperature loggers can be used to track the temperature of your product throughout the processing, packaging, storage, and transportation steps. Tracking temperatures is a critical part of maintaining good records and will help ensure that your food products are safe and of the highest quality.

Summary

Good aquaculture practices are a common sense approach to enhancing animal welfare, product quality and safety, worker safety, and environmental and economic sustainability. The larger and more intense the facility, the more detailed will be the associated GAqPs, as well as the record keeping. If situations change over time, so should the GAqPs. Good aquacultural practices should be adjusted whenever there are intended or unintended changes. Good aquacultural practices and the documentation that accompanies them will enhance buyer confidence and producer accountability.

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USDA United States Department of Agriculture National Institute of Food and Agriculture

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