PennState Extension

AGRICULTURAL ALTERNATIVES

Introduction to Aquaculture

Aquaculture is the production of aquatic organisms, including fish, mollusks, crustaceans, and aquatic plants, and the cultivation of freshwater and marine plants and animals under controlled conditions for all or parts of their life cycles. Because of restrictions on the wild harvest of many fish species, demand for "farm-raised" options is very strong. Aquaculture sales exceed $1.4 billion annually in the United States, with Pennsylvania operations generating around $8.8 million in sales (2017 data). In Pennsylvania, trout farms make up approximately two-thirds of the total value of aquaculture production, with "all other farms" making up the remaining third. There is much diversification in Pennsylvania's aquaculture industry, with more than thirty species and varieties of aquatic animals raised (Table 1).

Table 1. Species raised in aquaculture operations in Pennsylvania.

COLDWATER	COOLWATER	WARMWATER
Rainbow trout, normal	Crayfish (closed system only)	Baitfish (black and rosy red fathead minnows, golden shiners)
Rainbow trout, albino	Hybrid striped bass	Bass (largemouth, smallmouth)
Rainbow trout, golden[1]	Muskellunge	Catfish
Brown trout	Norther pike	Crappie
Brook trout	Walleye	Grass carp
Tiger trout[2]	Yellow perch	Ornamentals (goldfish, koi, guppies, tropical fish)
		Sunfish (bluegill, pumpkinseed, redbreast)
		Tilapia
		Other (snails, tadpoles)

[1]A variant of rainbow trout.

[2]A cross between brown and brook trout.

Source: Engle, C. R. *The Economic Impact of Aquaculture in Pennsylvania.* Report prepared for the Pennsylvania Department of Agriculture, Harrisburg, Pennsylvania, 2018.

Marketing

Before beginning an aquaculture enterprise, it is wise to research possible markets in your region. Potential customers for your product should be identified and contacted to determine their needs and expectations. You should also understand the nature of your competitors, both domestically and internationally. U.S. producers are at somewhat of a disadvantage in the production of warmwater species, but they do have a comparative advantage in the production of cool- and coldwater species grown in fresh water on a largely grain-based diet. In the past, coldwater species such as trout haven't done well on these feeds, but research and trials that are working at converting these species to all-grain diets are being conducted. Increasing competition for tilapia from China and Central America, shrimp from China and Southeast Asia, and catfish from Vietnam have had significant impacts on the prices for domestic aquaculture products despite increasing demand.

Aquaculture products can be marketed through farm-based retail sales, farmers markets, supermarkets, mail-order firms, restaurants, and food brokers. Some producers also develop value-added products, like smoked trout, which are marketed through gourmet shops and the Internet.

Fish grown on small farms may be sold whole (for processing by the buyer) or as dressed whole fish or fillets. If you are planning to start an aquaculture operation, check with your state health department and department of agriculture about regulations concerning processing requirements.

This publication was developed by the Small-scale and Part-time Farming Project at Penn State with support from the U.S. Department of Agriculture-Extension Service.

Fee fishing operations are also proving to be an excellent investment opportunity. A recent survey conducted for the Pennsylvania Department of Agriculture determined that 79 percent of all sales from aquaculture farms in Pennsylvania were used to supply recreational fishing markets. Fee fishing operators often rapidly outstrip their ability to stock their own ponds and must rely on other aquaculture operations for product. Before committing to this type of operation, investigate the demand for fee fishing/pay lakes in your area as part of your business plan.

Aquatic plants, koi, and goldfish can be readily produced for the ornamental or homeowner market. This rapidly developing industry has capitalized on homeowners' growing interest in water gardening. Ornamental production is a very competitive and specialized industry, however, and you should research this niche market carefully before entering it.

Planning and Permits

The type of aquaculture operation that you begin will be influenced by your financial and labor resources as well as available markets. For example, a small pond in a suburban area might be best for producing ornamental aquaculture plants, while a large spring in a rural area might be more suitable for rainbow trout production. In food fish production, 5 acres of ponds is generally considered the minimum size for small-scale commercial aquaculture, while a large spring on 5 acres of land can be developed into a full-time enterprise.

If you do not have any existing water resources on your property, you can still consider developing an aquaculture enterprise. A production method called recirculation aquaculture has been used in tanks, troughs, and even swimming pools to raise fish or plants successfully. However, closed-system or recirculation aquaculture is often very expensive and management intensive.

A propagation license is needed for commercial aquaculture operations. More information on necessary licenses and health certificates can be found on the Pennsylvania Department of Agriculture website at **https://www.agriculture.pa.gov/Animals/AHDServices/licenses-certificates/Aquaculture%20Licensing/Pages/default.aspx**. Discharges from aquaculture facilities are regulated by the Pennsylvania Department of Environmental Protection and the U.S. Department of Environmental Protection under the National Pollutant Discharge Elimination System (NPDES) (see **https://www.epa.gov/npdes/npdes-aquaculture-permitting**). New pond construction may require working with several governmental agencies, including your county's conservation district, USDA's Natural Resources Conservation Service, the Pennsylvania Fish and Boat Commission, the Pennsylvania Department of Environmental Protection, the U.S. Army Corps of Engineers, and your local government. More information on the agencies and permits required for pond construction can be found at **https://extension.psu.edu/pond-agencies-and-permits-in-pennsylvania**.

Facilities and Equipment

Water Resources

Water source, quality, and supply are critical considerations in planning an aquaculture enterprise. Sources include groundwater, surface water (ponds and streams), and recirculation systems that continually purify and reuse water. Groundwater can be drawn from natural springs or well systems. While springs and wells usually are good water sources, the cost of pumping water makes springs a much more cost-effective choice.

Water from ponds and streams tends to have variable chemical and physical characteristics; however, most aquaculture species are tolerant of some environmental fluctuation. For example, the U.S. catfish and baitfish industries are based on pond culture. Stream-based aquaculture operations are likely to be impacted by discharge and water appropriation permits. In addition, producers have no control over stream water quality, and operations using streams can suffer from serious contamination problems.

Production Methods

The three primary production systems used by aquaculture operations are pond culture, flow through, and recirculating. Depending on the life stage of the fish when you acquire them, it can take up to two years before your fish attain marketable size regardless of the system you use.

Pond Culture

Because ponds are well suited for production of a variety of species, pond-based culture is the most widely practiced form of aquaculture in the United States. Production levels of 2,000 pounds per surface acre are typical, but increased production can be realized with intensive management and aeration. Existing ponds can often be used for aquaculture without modification. Cage culture, a technique in which fish are grown in cages, permits aquaculture production in many ponds that are not well suited to fish culture. Cage culture also allows producers to simultaneously use one pond for recreation, irrigation, or other agricultural purposes. New pond construction for aquaculture can be very expensive. The returns from a small-scale aquaculture business may not justify the costs of constructing a new pond.

Flow Through

Flow-through systems involve the continual flow of a high-quality water source through a tank or raceway. Fish wastes are flushed through the system by water flow. Treatment of these fish wastes is often required before the water can be discharged into the environment. Many high-yielding springs have been adapted for this type of fish culture. New technology makes the production rates from smaller springs attractive for a small-scale or part-time aquaculture enterprise. Yields of up to 100 pounds per gallon of water flow per minute can be obtained with the proper conditions and management.

Recirculation and Reuse Systems

Recirculation and reuse systems are expensive and require that the producer have advanced technical skills. Closed or recirculation systems are often used in areas with limited water resources and stringent discharge regulations, or when warmwater fish like tilapia are being raised for local markets. These systems consist of tanks, particulate filters (to remove fish wastes and feed particles), and biological filters (to convert toxic ammonia from fish excretion to nitrate, which is considered harmless). An adequate supply of oxygen is critical because of the typically high fish density of recirculation systems; adequate oxygen can be supplied by mechanical aerators or liquid oxygen. In recirculation systems, water is purified and used continually. Fresh water is added only

to compensate for evaporation and losses that occur when wastes are removed.

Water reuse systems use a percentage of their water several times before discharge. An example of a reuse system is one in which water flows through a series of tanks or raceways, with each unit receiving discharge from the preceding one. Reuse systems may also use particle and biological filters with aeration to improve water quality.

Equipment

In addition to the production system, various types of equipment are required for the overall operation of an aquaculture facility. Water testing equipment for pH, nitrites, ammonia, and dissolved oxygen is essential for proper water quality management. Treatment chemicals for maintaining water quality include lime, bicarbonate, gypsum, calcium chloride, and permanganate. Small-scale producers can often use inexpensive test kits developed for aquariums. Larger operations, particularly reuse or recirculation systems, require more sophisticated testing equipment. Other necessary items include aeration devices, nets for harvest, a scale, feeding equipment, protective netting, and processing equipment.

Hatcheries

Most part-time aquaculture producers purchase fingerlings from hatcheries for stocking and grow-out. Hatcheries specialize in spawning (breeding) and raising fish to sizes used by other segments of the aquaculture industry. Some hatcheries are part-time enterprises as well, but spawning and rearing fish from the fry to the fingerling stage requires more advanced technical skills than are required for a grow-out operation. Fingerlings of striped bass, rainbow trout, and tilapia are available in the Mid-Atlantic region. A list of commercial fish hatcheries is available from the Pennsylvania Fish and Boat Commission, Bureau of Administrative Services, 1601 Elmerton Avenue, Box 67000, Harrisburg, PA 17106-7000. A list of Pennsylvania Fish and Boat Commission hatcheries and a map of cooperative nurseries is available at **https://www.fishandboat.com/Fish/Stocking/StateFishHatcheries/Pages/default.aspx**.

Fingerling prices vary from $0.35 to $1.50 per inch depending on species and availability. Fry are much less expensive, but the grow-out time is longer and the mortality rate is higher. Deliveries of larger fingerlings are generally made by trucks with tanks equipped with aeration devices. Small fingerlings and fry can be shipped in plastic bags filled with oxygen to support the fish for several days of travel.

Temperature shock is a major cause of fish losses. Mortality rates can be minimized by gradually adjusting the shipping water temperature by floating bags of fry in receiving water and checking temperature periodically or by pumping receiving water into the shipping tanks.

Nutrition

An important consideration in selecting a species to grow is whether a commercially formulated diet is readily available. Many species that appear attractive because of their high value may prove difficult and uneconomical to produce if nutritional requirements are poorly understood. Commercial feeds for established species often are substituted for diets formulated for new aquaculture species. Suboptimal dietary conditions, however, result in poor growth and inefficient feed utilization.

Aquaculture feeds are prepared from grain (corn and soybeans) and animal by-products (including fish meal), along with vitamin and mineral additives. The most obvious difference among feeds for different aquaculture species is the protein level, which may range from 25 percent for adult catfish to 38 percent for salmonids or hybrid striped bass. Feeds for well-established commercial species are available in different sizes and compositions to suit various stages of fish development. Feeds are available dry or moist and in floating or sinking forms. To be successful, you must select feeds and feeding methods that produce efficient and rapid growth.

Health

Fish are subject to a variety of parasites and pathogens. Stressful conditions such as poor water quality and poor nutrition can make fish more susceptible to infections, leading to decreased production and death.

You can help prevent disease by maintaining a healthy environment (especially water quality). If you suspect a disease, it is important to get an accurate diagnosis before treatment is begun. Contact a fish veterinarian (see "Find a Fish Vet" at **https://www.fishvets.org**) or your local Cooperative Extension office for the location of a diagnostic laboratory and the procedures for sending a sample. Once a diagnosis is made, a treatment can be prescribed, such as using sodium chloride for external parasites. However, with the implementation of the Veterinary Feed Directive in 2015, use of medicated feeds for disease treatment is permitted only under the professional supervision of a licensed veterinarian.

Predation

Fish confined in tanks, cages, raceways, and even open ponds can attract various predators, including herons, ospreys, raccoons, and mink. Fish in isolated facilities are also subject to poaching. You can reduce or eliminate losses by covering cages and tanks with mesh or using various repellents. Predators such as the great blue heron are a protected species and cannot be removed without a permit from the U.S. Fish and Wildlife Service. Losses to predation can be serious enough to result in business failure and should be anticipated when planning an aquaculture enterprise. For answers to questions concerning predators and their control, contact the Pennsylvania Game Commission.

Budgeting

An important step when planning any new enterprise is to realistically estimate the cost of production and the value of sales. If you are seeking financing, this type of information will be necessary as part of your business plan. Enterprise budgets should be prepared to ensure that all costs and receipts are included in your calculations. For aquaculture operations, payroll, fish purchases, and feed are some of the most expensive variable cost components. Annualized fixed costs for facilities are also major ongoing costs that must be included in your profit calculations. Costs and returns are often difficult to estimate when developing an enterprise budget because they are numerous and variable. In these

situations, it is useful to make your estimates with a range of costs, prices, and yields to see how sensitive your potential profitability is to changes in various production assumptions. Additional information on the use of enterprise budgets can be found in "Agricultural Alternatives: Budgeting for Agricultural Decision Making."

For More Information

Publications

American Fisheries Society. *Fish Hatchery Management.* 2nd ed. **https://fisheries.org/bookstore/all-titles/professional-and-trade/x55040pxm/**.

Bardach, J. E., Ryther, J. H., and W. O. McLarney. *Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms.* Somerset, NJ: John Wiley, 1981.

Landau, M. *Introduction to Aquaculture.* Somerset, NJ: John Wiley, 1992.

Malison, J. A., and C. F. Hartleb, eds. *Best Management Practices for Aquaculture in Wisconsin and the Great Lakes Region.* University of Wisconsin Sea Grant and Water Resource Institute. **https://publications.aqua.wisc.edu/product-category/aquaculture/**.

McLarney, W. *The Freshwater Aquaculture Book: A Handbook for Small Scale Fish Culture in North America.* Point Roberts, WA: Hartley and Marks, 1988.

Stickney, R. R. *Principles of Aquaculture.* Somerset, NJ: John Wiley, 1994.

Stickney, R. R. *Principles of Warmwater Aquaculture.* Alabama Agricultural Experiment Station, Auburn University: 1990.

Swenson, W., S. Nichols, S. Craven. *Managing Wisconsin Fish Ponds.* Wisconsin-Madison Division of Extension. **https://learningstore.uwex.edu/Managing-Wisconsin-Fish-Ponds-P592.aspx**.

Periodicals

Aquaculture Magazine
Box 2329, Asheville, NC 28802
www.aquaculturemag.com

Aquaculture North America
PO Box 530, 105 Donly Drive South, Simcoe, ON, Canada N3Y 4N5
https://www.aquaculturenorthamerica.com/
Phone: 1-888-599-2228

North American Journal of Aquaculture
Published by the American Fisheries Society
https://afspubs.onlinelibrary.wiley.com/journal/15488454

Associations

American Association of Fish Veterinarians
https://www.fishvets.org • info@fishvets.org

American Fisheries Society
https://fisheries.org/

National Aquaculture Association
PO Box 12759, Tallahassee, FL 32317
http://thenaa.net/ • 850-216-2400 • naa@thenaa.net

PennAg Industries Association
Northwood Office Center, 2215 Forest Hills Dr., Suite 39, Harrisburg, PA 17112
717-651-5920 • pennag@pennag.com
http://www.pennag.com/

United States Trout Farmers Association
1165 Riggles Gap Road, Altoona, PA 16601
814-515-2570 • ustroutfarmersassociation@gmail.com
https://ustfa.org/

Aquaculture Centers

Northcentral Regional Aquaculture Center (NCRAC)
101 Science II Bldg, Ames, Iowa 50011
515-294-5280 • **https://www.ncrac.org/**

Northeastern Regional Aquaculture Center (NRAC)
2113 Animal Sciences Bldg 162, College Park MD 20742
301-405-6917 • ssadams@umd.edu
https://agresearch.umd.edu/nrac

Southern Regional Aquaculture Center (SRAC)
127 Experiment Station Road
PO Box 197, Stoneville, MS 38776
662-686-3269 • **https://srac.msstate.edu/**

Western Regional Aquaculture Center (WRAC)
University of Washington School of Aquatics and Fishery Science
Box 355 020, Seattle, WA 98195
206-685-2479 • **https://depts.washington.edu/wracuw/**

Resources/Other Information Sources

Alternate Farming Systems Information
https://www.nal.usda.gov/afsic/aquaculture

Aquaculture Information/Resources
https://www.usda.gov/topics/farming/aquaculture

Ecotao's Aquaculture Links
http://www.ecotao.com/holism/agric/aqua.htm

Missouri Alternatives Center
http://agebb.missouri.edu/mac/

U.S. Department of Agriculture
National Agricultural Library: Lists of Aquaculture Statistics, Data, State, Federal and International Research
https://www.nal.usda.gov/afsic/aquaculture-data-statistics-and-research-organizations

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Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Produced by Ag Communications and Marketing

Code UA297 05/19pod