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# Aquaculture Systems for the Northeast

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## Introduction

Many systems are used to culture aquatic plant and animal organisms commercially in the northeastern United States. No single system is appropriate for all situations. Information on systems that are applicable to your area and species to be cultured may be obtained from your university extension agents and specialists. They can also identify contacts to assist with design and construction of your operation, and regulatory agencies that must be consulted for permits prior to beginning. This fact sheet gives a general overview of some common types of aquaculture systems that are used in the region.

## Culture Systems

Traditionally, aquaculture has been practiced in open, semi-closed, and closed systems. Open system aquaculture involves production at densities not greatly exceeding those found in nature. Generally, such systems receive little maintenance: bottom shellfish grounds are not managed, while farms ponds, which vary in size, are not fertilized or aerated, nor are fish given prepared feeds (Figure 1). At the start of the culture cycle, fingerlings or shellfish seed are stocked; at the end of the growing period, the fish or shellfish are harvested and sold.



**Figure 1.** Aquaculture ponds can be of varying sizes. (Photograph by Don Webster)

Semi-closed system culture aims at producing aquatic organisms at densities that exceed those in nature; consequently, production requires more hands-on management and investment of energy. Examples include fish fed in a pond, cage, or net pen culture, and managed shellfish culture. Sophisticated culture methods are employed such as pumping water, providing supplemental or continuous aeration, and adding commercial feeds. While semi-closed system culture can increase the biolog-

ical return from a given water resource, its use also increases production costs, chances for catastrophic loss, and increased wastes that such operations generate. Most growers in the region employ some form of semi-closed system culture.

Closed system culture employs intensive management of a production system. Culturists must provide for all the biological needs of the cultured organism, e.g., nutritionally complete rations, continuous aeration or oxygenation, biological filtration, waste management. Examples of such systems include recirculating aquaculture systems, hydroponics, and aquaponics. Yields from closed system aquaculture can greatly exceed those of open and semi-closed systems; however, the cost and management of such systems similarly increase, as does the potential for catastrophic loss. Over the last twenty years, closed systems have been evolving from research and demonstration setups to the establishment of several commercial operations in the Northeast.

Just what system to choose will depend on a number of factors: the culturist's resources, time, and willingness to take calculated risks as well as available sites and natural resources, species to be cultured, and regulatory concerns. Many successful culturists started with small operations and expanded them as they gained experience.

## Water Source and Supply

Regardless of the system or species cultured, good water quality and adequate supply are essential for success and must be a primary consideration from the earliest planning stage.

Groundwater can be obtained from aquifers. Useful information on groundwater is usually available from well drillers in the area or from the state geological survey. Many states have aquifer maps as well as other important information on water quantity and quality. Test wells may be necessary to ensure that a sufficient flow is available, especially for large operations where rapid filling or flushing will be required. Because well water is usually deficient in oxygen and is saturated with nitrogen it must often be aerated before being introduced into the system. Chemical analysis of all water for ammonia, pH, hardness and alkalinity, contaminants, dissolved oxygen, etc., is essential before it is used for aquaculture.

Surface water represents an alternative water supply. Though frequently less expensive to develop and pump than groundwater, there are often restrictions that present problems for the farmer. Surface water may be more variable with regard to flow, temperature, and quality; chemical and biological contaminants may also be present. In addition, water must be filtered or screened to eliminate

unwanted fish and insect larvae. Other treatments such as aeration or filtration to remove particulates may also be necessary.

Water from municipal systems may be used, but it is expensive and usually limited to recirculating systems because they require less water to produce high value products. Still, this water must often be treated to remove chemical agents such as chlorine, which is added in order to sanitize municipal supplies for human consumption.

In marine operation, proper salinity is critically important. Inflows of fresh water may stress or kill cultured animals. Both point and non-point runoff must be surveyed and the presence, or extent, of disease, fouling organisms, and predators determined. Potential problems must be addressed during site selection.

## Finfish Aquaculture Systems

**1. Pond Culture.** Today, most commercial fish and crawfish production in the United States is in ponds (Figure 2). While a few culturists utilize open-system technology, most provide some form of management and supplemental energy input. In some areas, coastal or ocean water may be used, but regulations and water quality must be considered. Most aquaculture ponds are less than 20 acres in size and have a maximum depth of 6 to 8 feet; they are not usually larger than 5 acres with smaller ponds more the norm. Ponds north of the mid-Atlantic region require water depths 6 to 8 feet or more so fish can safely overwinter. It is advisable to incorporate electrical access to each pond for aeration, pumping, etc. In wintertime, aeration and/or water pumping can reduce or eliminate ice formation, which will help prevent oxygen depletion and winter-kill.



Figure 2. Aquaculture ponds should be fillable, drainable, harvestable, and accessible as needed. (Photograph by Kaitlin Harrell)

Pond construction is expensive in the Northeast. Before construction, a soil profile must be taken. If the land had been used for agriculture, do not use the surface soil for the top or inside of the levees. While rectangular ponds are easier to harvest, other shapes can be used, especially if they fit the property better and allow for more acreage to be used. The primary concerns are that ponds conform to existing topography, available area, and anticipated use. The pond bottom should be smooth and without depressions to facilitate maintenance and harvest by seining. Pond liners, clay, and other materials can be used if soil conditions are a problem at an otherwise attractive site, but they significantly increase construction and maintenance costs. Control of water is highly desirable, so the choice of water control devices can be very important. Ponds should be designed to fill and drain easily: incorporating drains during pond construction is advised, though this will also add to costs. While few large ponds are less expensive to build, smaller ponds are easier to manage. The USDA Natural Resource Conservation Service (check the phone book or your county Extension Office) may be able to help with soil maps and surface water interactions and possibly with pond design.

Experienced culturists grow species appropriate for their regions, growing season, and markets. They use high quality feeds, provide continuous or supplemental aeration, and may practice topping (the selective removal of large, marketable fish and their replacement with smaller fingerlings) although this may not be possible with all species due to potential cannibalism of larger fish on smaller ones. Yields from culture ponds can range from a few hundred to several thousand pounds per acre, depending upon fish stocking density, feeding rate, and management ability.

**2. Flow-Through or Single-Pass Systems.** Raceways and tanks with water moving around them have been used to rear fish for over a century (Figure 3). High quality water continuously flows into these culture units and passes through the heavily stocked raceways, which hold the fish. Each raceway will have several feeding stations. Fish waste is discharged from the downstream end of the system. Federal, state, and local (zoning) laws (National Pollution Discharge Elimination System, NPDES; State Pollution Discharge Elimination System, SPDES) require that the effluent from these operations meet quality standards before being returned to public waters. Treatment of discharge waters should be incorporated into a flow-through system. Yields are dependent upon water flow, aeration, and water temperature. In the Northeast region, trout are the most common species cultured in these types of systems.

Annual yields can range from 10 to over 100 pounds per gallon per minute of waterflow to the raceway. High yields require large volumes of high quality water, stable cold temperatures, supplemental aeration and/or oxygenation, high quality feeds, and good management.



**Figure 3.** Raceways and tanks utilize a continuous inflow of high quality water to culture fish at high densities. (Photograph by Kenneth Semmens, West Virginia University Extension Service)

**3. Cage and Net Pen Culture.** Many natural bodies of freshwater can be unsuitable for aquaculture: they may be too deep, too large, or have irregular bottoms or obstructions. Many can be used, however, to culture fish confined in cages (Figure 4) or net pens. Cages are relatively small, rigid structures usually between one and approximately 20 cubic yards. Net pens in saltwater are usually large mesh enclosures up to several hundred cubic yards. Both cages and net pens must be anchored securely in an area where water flow and depth are sufficient to provide aeration and removal of wastes.



**Figure 4.** Fish cages can be used in small irregularly shaped ponds that would be hard to harvest otherwise. (Photograph by Craig Hollingsworth, University of Massachusetts)

Some successful small aquaculture businesses use cage culture, though it should be considered an entry level of aquaculture that may not lead to large-scale production. One or two cages placed into an existing pond can provide an excellent and relatively inexpensive introduction to aquaculture as well as a source of high quality fish. Annual yields can exceed 400 pounds per cubic yard of cage or net pen, depending upon water quality and the skill of the fish farmer. Use of public waters for cage culture requires careful investigation of social, regulatory, and technical issues. This form of aquaculture is not well suited for large-scale enterprises on land, but would do well for farmers with irrigation ponds or for niche marketers with limited resources.

Net pen culture commonly involves considerable investment of capital and other resources. It is commonly practiced in public waters, so regulatory concerns and interaction with other user groups are important considerations. Since net pens are designed to maintain fish at high densities, waste management, prevention of escapees, and transfers of disease and parasites are critical concerns. Net pen culture is well suited for rearing salmon in protected coastal waters and is an industry standard in Maine (Figure 5).



Figure 5. Net pen culture of Atlantic salmon is an important industry in Maine. (Photograph by Chris Bartlett, University of Maine)

**4. Recirculating (or Closed) Systems.** These systems support fish in an enclosed environment (Figure 6). Fish are raised in tanks where they live, eat, respire, and excrete. A primary filter removes particulate wastes; the water then passes through a biological filter where excretory wastes are detoxified by bacteria. Toxic ammonia and nitrites ( $\text{NO}_2^-$ ) are converted to nitrates ( $\text{NO}_3^-$ ), which

are non-toxic to fish at concentrations of several hundred parts per million. The now-cleansed water is returned to the fish holding unit.

Since most water is “recirculated,” the systems require relatively small additions of new water (<5 to 10% of the total culture volume daily). Water is added to replace that lost by evaporation and discharged to remove settled solids. Such closed systems require continuous aeration or oxygenation of both the fish culture tanks and biological filter to function properly. Water quality must be monitored closely and carefully managed; emergency back-up systems are essential.

Recirculating systems are potentially appropriate when water quality and quantity are insufficient, for example, if water must be cooled or warmed, or if discharge standards cannot be efficiently met. While the culture of fish in recirculating systems is biologically possible, the economics must be very carefully evaluated. These systems often require high value species and experienced operators for commercial success. It is imperative that near-constant attention from skilled labor be available to ensure the production system works well. Many have been tried at various scales but over the long run, only a few have been successful.

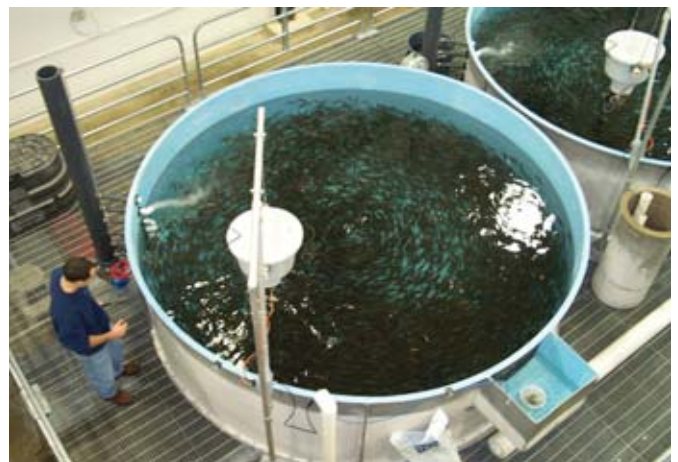


Figure 6. A variety of recirculating systems exist. Most include a fish holding unit, biological filter, removal mechanisms for particulates, and aeration systems. (Courtesy of The Conservation Foundation)

## Shellfish Aquaculture

**1. In or On Bottom.** If the estuary bottom will support oysters or is of a firmness that allows clams to burrow, then shellfish seed can be stocked directly in or on the bottom (Figure 7). Clam and oyster seed are routinely planted at 20 to 100 per square foot, depending on the site. Hard and soft shelled clams — from 10 to 15 mm SL (shell length) — will be planted in the bottom for growout;

oysters of a larger size may be laid out on the bottom after a longer nursery phase. In mussel culture, one technique involves harvesting small seed from dense beds and relocating them to a bottom site at a lower density. At harvest time, the mussels are brought ashore and purged of sand and other grit before sale.

Frequent maintenance is essential for commercial success of bottom shellfish culture. While predator controls are not used in mussel culture and rarely with oysters, culturists commonly protect seed clams by covering them with a light polyethylene plastic or nylon netting to control predation by crabs, drills, or rays. Nets used to control predators must be monitored and cleaned regularly to eliminate entrapped predators, repair holes, and remove fouling organisms that can inhibit water flow and prevent phytoplankton from reaching the growing seed.



**Figure 7.** Hard clams or Northern Quahogs are planted as seed in the bottom and covered with predator netting to help improve survival. (Photograph by Gef Flimlin)

**2. Near Bottom Culture.** Cages and boxes of plastic mesh are used to culture clams and oysters just off the bottom (Figure 8). These enclosures can be built by the culturist or purchased from commercial suppliers. Shellfish seed is put in the mesh bags or plastic boxes and sometimes placed on a rack. As the seed grows, oysters or clams are transferred to enclosures with increasingly larger mesh: a larger mesh provides better water flow, which delivers more food and oxygen, while removing wastes.

Most pre-fabricated units are about five square feet, though units over 30 square feet have been used. Units can be employed in the nursery phase for both clams and oysters. However, clams must be transferred to the bottom after 20 millimeters for growout to market size: clam seed held larger than that in mesh bags will become stunted and not grow as fast as those placed in the bottom sediments. Oysters will grow in bags and cages until harvest. Off bottom culture of oysters is typically better than plac-

ing bags directly on the bottom since sedimentation in the bags can reduce growth and potentially suffocate the growing oysters.



**Figure 8.** Oysters can be grown in polyethylene plastic bags on racks in shallow water. (Photograph by Gef Flimlin)

**3. Water Column Culture.** Lantern nets, cylindrical containers made of nylon netting divided into sections and hung from floats, can be used to culture scallops and oysters (Figure 9). Mussels are cultured in long, plastic mesh sleeves that are hung from longlines, usually in the ocean (Figure 10). This system requires onboard filling equipment to stuff the mussels into the “stockings or socks.” Weight is a consideration here: mussels can become so heavy that they could potentially fall through the socks onto the bottom. This type of rope culture, with mussels hanging down into the water column, is usually done in deep coastal waters.



**Figure 9.** Lantern nets are used to culture shellfish in the water column. (Photograph courtesy Fishers Island Oyster Company)



**Figure 10.** Mussels are grown in fabric socks suspended from long-lines in cold coastal waters (inset shows mussel seed to be placed in sock). (Photograph courtesy of the University of New Hampshire)

Water column culture is common in the northern states, but ice damage and vessel traffic can present problems, as can the potential controversies between shoreline residents and commercial shellfish operations. A boat larger than the normal shellfishing skiff is necessary for access and harvesting, and a good anchoring system is essential.

Water column culture will require permits, probably from both state and federal agencies — acquiring them may take a great deal of time, money, and involve lengthy public comment periods.

Oysters can be grown in sturdy plastic mesh bags that are either placed in racks in cages specially designed to hold a number of bags or cultured with plastic floats attached to the bags. The bags are held together in a ladder array with the system floating at the surface, where phytoplankton is dense, or sunk to the bay floor during the winter when ice damage can be problematic. Some growers overwinter their oysters on land in pits or other protected areas.

All gear placed in saltwater for shellfish culture will become fouled with various kinds of organisms. Some of this fouling may just be a nuisance but the growth can be so extensive, it may restrict water flow or even smother the animals. Periodic cleaning of shellfish bags, cages, and predator control screens is essential to the survival of cultured shellfish.

**4. Surface Systems.** At some locations, small mesh containers have been used to float shellfish seed near the warmer, surface waters. Phytoplankton, microscopic algae that shellfish feed on, are more abundant in shallow waters where water flow is usually greater. Surface culture is normally used in the nursery phase of shellfish culture and is occasionally used for final growout

Floating Upweller Systems (FLUPSYs), an in-water powered nursery system used to grow clam and oyster

seed to plantable size for the field, are becoming more popular since they can either be set up as a large floating box or concealed in a floating dock. Both configurations are designed to move a lot of water thus increasing growth rates because of intense feeding regimes. FLUPSYs are used as part of the nursery phase, from 2 to 10-15 mm SL for clams and even larger for oysters. These seed can then be moved into bottom culture for clams, while oysters can be placed in plastic mesh bags for further growout.



**Figure 11.** Floating Upweller Systems are becoming more common because of the large amounts of water that can be moved economically. (Photograph by Rick Bushnell, Reclam the Bay, Inc.)

**5. Land-based Systems.** These systems are used to culture early stages of shellfish. Upwellers and raceways are employed to raise juvenile clam seed from post set (~500 microns) to 10 to 12 mm before transfer to growout sites (Figure 12). Oyster seed will typically be grown only in upwellers — the raceway section will not be used but the oysters placed in mesh bags in the estuary for continued growth. Economic success in using land-based systems for growout has not been demonstrated, largely because of high energy costs of pumping the water until the shellfish reach market size. One exception is shedding units for holding crabs until they molt and become soft shell crabs. These are special cases as shedding takes only a few days, does not require feeding, and the finished product has a high value.

Crab shedding tanks are land-based systems that some may not consider true aquaculture: the shallow

shedding units are only used for holding blue crabs until they molt and thus become soft shell crabs. Shedding takes only a few days and does not require feeding — the systems can be closed or flow through.



Figure 12. Bivalves are grown in land-based systems such as upwellers that pump water to feed juvenile shellfish. (Photograph by Gef Flimlin)

## Aquatic Plant Aquaculture

The culturing of ornamental aquatic plants for use in backyard fish ponds has been increasing in recent years. Numerous types of plants can be grown, among them, hardy marginals, tropicals, lotus, and lilies. Known as hydroponics, the simplest culture process relies on raised raceways filled with water where plant seedlings are grown to marketable plants and sold as 2-inch plugs, or in 4 to 8-inch pots filled with media (Figure 13). These plants can be individually fertilized or fertilizer can be added to the entire system. Numerous aquatic plants will survive in your area, including invasive or exotic species. Contact your state department of agriculture to ensure the species you plan to grow are allowable.

Aquaponics is the culturing of terrestrial plants or aquatic autotrophs in conjunction with raising aquatic ani-



Figure 13. Ornamental aquatic plants are fairly easy to grow since most of them are actually weeds. (Photograph by Gef Flimlin)

mals, typically fish (Figure 14). Fish provide most of the nutrients that plants require, while plants remove nitrates and improve water quality. Various vegetables and herbs, such as lettuce, tomatoes, peppers, eggplant, and basil are commonly linked to fish production systems, and do quite well getting nutrients from the fish wastewater. Solid waste from closed systems that are usually linked to the hydroponic plant production can be applied as a fertilizer for vegetable or flower gardens.



Figure 14. Aquaponics links fish culture with plant culture. (Photograph by Gef Flimlin)

## For More Information

Extension agents and specialists, university personnel, and your state aquaculture association can provide more information on the systems described and their application. A list of state aquaculture extension personnel is contained on the NRAC website ([www.nrac.umd.edu](http://www.nrac.umd.edu)) or you can contact your local County Cooperative Extension Office for an initial contact.

A good place to start looking for more information is at the Aquaculture Network Information Center ([www.aquanic.org](http://www.aquanic.org)), which will lead you to many valuable websites and publications about aquaculture.

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