Aquaculture in Delaware: Its Potential, Its Future Prospects

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Aquaculture, the husbandry or controlled cultivation of aquatic plants and animals, can be traced back thousands of years to early civilizations in Europe, the Middle East, and Asia. Historical accounts from ancient Greece and the Roman Empires describe the use of ponds to grow and hold fish for food, and simple methods for cultivating oysters. The Chinese are recognized for establishing the basic principles of fish culture and for creating techniques integrating aquatic and agricultural production that are still in use today.

Despite similar beginnings, aquatic and terrestrial approaches to food production have progressed independently. While agriculture has undergone revolutionary advancements through years of scientific and applied research, aquaculture remains relatively undeveloped and is still as much an art as a science.

Most of the world's aquaculture production comes from China and other Asian countries where aquaculture is widely used to increase the productivity of marginal farmland. Low-technology methods for growing aquatic plants and animals have traditionally been applied in this part of the world to provide an inexpensive, local source of protein. However, there is increased recognition of the potential of rural economic development through aquaculture, and Japan's and Taiwan's successful commercial aquaculture operations, which use more technology-dependent methods, are serving as models for the rest of the world. Commercial aquaculture production is increasing in the United States, and interest in aquaculture is growing in Delaware and throughout the Mid-Atlantic region.

Today, capture fisheries account for approximately 85% of aquatic food production. Advances in fisheries technology through use of larger vessels and more efficient methods and gear have improved yields to the point where it is now believed that harvests of world fishery resources are approaching or, in some cases, have exceeded sustainable biological limits. As world population and consumption of fishery products continue to grow, aquaculture is emerging as an important means of bridging the widening gap between supply and demand. Estimated by the United Nations Food and Agricultural Organization (FAO) to reach nearly 21 million metric tons by the year 2001, the international aquaculture industry more than doubled production over the last decade and currently supplies nearly 15% of total world fishery landings.

U.S. Aquaculture Development

Aquaculture began in the United States as a conservation tool. Federal and state fish and wildlife agencies have operated finfish hatcheries since the mid-1800s to stock public waters with different species of game fish and to improve the management of our freshwater resources.

In the 1940s, knowledge about fish hatchery technology and culture requirements, plus growing public interest and involvement in recreational fishing, led to the onset and gradual expansion of fish-farming industries for rainbow trout and bait fish. A similar combination of market demand, adequate natural resources, and technical information has resulted in the extraordinary growth of the catfish and crawfish industries since the 1960s and to expanded commercial production of salmon, oysters, and clams in the 1980s.

Fueling aquaculture's growth has been the increasing consumption of seafood in the U.S. Despite substantial growth in domestic commercial fishery landings since...
1975, the U.S. seafood industry must supplement its supply with products from foreign fishery and aquaculture sources that account for, in some cases, as much as 70% of U.S. market demand. Imports have contributed to a consistent year-round supply and, because they are generally less expensive, have helped stabilize market prices, making seafood affordable to more people. Increased reliance on imports, however, has fostered a significant trade imbalance in some fishery products, particularly shrimp and other shellfish. Although in the last few years the combination of increased U.S. fish exports and a leveling off or slight decline in imports has reduced the deficit for edible fishery products ($3.3 billion in 1988, down 20% from 1987), the prospect of persistent fishery deficits remains.

This gap between consumer demand and domestic production was the stimulus that increased federal support to identify ways to reduce reliance on imported seafood. Passage of the National Aquaculture Act in 1980 by Congress and subsequent release of a National Aquaculture Development Plan in 1983 outlined the federal government’s commitment to foster growth and development of a domestic aquaculture industry. Title XIV of the Agriculture and Food Act of 1980 and the Food Security Act of 1985 provided for establishment of five Regional Aquaculture Centers in 1987 to encourage industry development by supporting priority research, extension education, and demonstration projects. Many state governments have enacted legislation promoting aquaculture or now are drafting aquaculture plans that identify and address constraints to industry development.

Although it is the fastest growing domestic source of fish and shellfish, commercial aquaculture in the U.S. has, until recently, largely been a private sector initiative that has progressed slowly and experienced more than its share of setbacks. Scientific and technical obstacles, high start-up and production costs, ill-defined markets, and other social and political constraints all contributed to the unprofitability of many early commercial operations in the 1960s and 1970s.

Improvements in production technology, a gradual shift from competition with, to supplementation of, commercial fishery landings, higher prices, and steadily increasing and diversified markets for “high-value” species have all enhanced economic prospects of aquaculture and explain the recent growth of an industry that is projected to account for as much as 25% of U.S. seafood consumption by the turn of the century. Despite this promising outlook, however, aquaculture in the U.S. remains a high-risk business. Potential “fish farmers” must understand that the scientific development of aquaculture is only in its infancy, and numerous obstacles limit industry expansion.

Culture System Technology

Virtually every type of production system for fish and shellfish requires some containment device such as a pond, tank, raceway, tray, cage, or nets. Production systems generally are classified as open, flow-through, or closed, based on the degree of water interchange between the system and the natural environment; and extensive or intensive based on the density or concentration at which fish or other species are grown and the extent to which environmental factors are externally controlled or managed.

In an extensive system, such as crawfish stocked in a pond or drainage ditch, management is minimal and animals are maintained at low densities. Much or all of the food may come from natural sources with only supplemental feeding by the culturist. Yields from extensive systems are often higher than unmanaged areas and can be achieved with low to moderate risk due to lower start-up and operational costs. Semi-intensive culture systems are generally defined as extensive systems that have additional inputs to improve management options and/or production. Fish raised on formulated feed in cages in a pond kept well-mixed with an aerator would be a good example.

Intensive systems represent the other extreme, where animals are concentrated at very high densities and the culturist must supply all the organism’s food requirements through nutritionally complete feeds. Because of high stocking densities in these systems, water quality becomes critical and must be maintained either by large volumes of water flow (such as in open or flow-through systems) or by purifying and reusing the water (closed or recirculating systems).

A trout hatchery is an intensive flow-through system where fish are maintained in concrete raceways with large volumes of well-aerated spring water. Indoor culture of tilapia in tanks with mechanical and biological filtration (particle removal and water purification) and advanced aeration technology (oxygen injection) is an example of an intensive, closed system. Intensive systems require less area and can support significantly higher yields, but they are expensive to build and operate and require detailed information on all aspects of the biology of the culture organism. Improper management, equipment failure, or power loss can increase the chances of a catastrophic crop loss. Intensive production technology is still experimental. However, this approach holds much promise for future expansion of a domestic aquaculture industry faced with increasing competition for available land and sources of high-quality water.

Regulations Affecting Aquaculture

The legal and regulatory framework governing aquaculture at the local, state, and federal level originally was developed to protect and manage freshwater and marine resources, including commercial and recreational stocks. Since these laws and regulations were not designed with regard to cultivation of aquatic species, they are
often confusing and difficult to interpret when applied to aquaculture development.

New projects often involve overlapping government jurisdictions and must satisfy extensive permit requirements for items such as siting, water use, environmental discharges, diseases and health, use of exotic or non-native species, and transport and/or sale of live animals within or across state borders. Other regulations, for protection of navigable waters, wetlands, potential archaeological sites, zoning, and land use, may also apply. Compliance with local, state, and federal regulations is often expensive and time-consuming. Gradually, however, the legal climate for aquaculture nationwide is starting to improve as many states reevaluate and modify laws and regulations identified as constraints to aquaculture development. One widely used response has been to recognize aquaculture as a specialized form of agriculture, thereby providing “fish farmers” with much of the same legal protection available to farmers and their agricultural operations.

Financing Aquaculture Operations

Aquaculture is a form of agriculture and, like any business, requires sufficient capital to cover both anticipated and unexpected start-up and operational costs. In a commercial aquaculture enterprise, these can vary from several thousands of dollars to hundreds of thousands or even depend on the cost of land, water, and other resources, the species’ biological and technical requirements, the production technology used, and the costs associated with regulatory compliance.

Unlike agriculture, aquaculture is seen as an emerging industry still working its way through an array of technical, legal, and political barriers that present significant financial risks to entrepreneurs and other investors. A general lack of information on production costs and performance, prices, markets, and profitability has restricted development of an accurate method of risk assessment for commercial lending institutions and insurance underwriters. As a result, most aquaculture financing is provided through equity ownership or self-financing rather than through commercial lenders. Some federal programs in the Farmers Home Administration (FmHA), Small Business Administration (SBA), and Farm Credit Administration (FCA) also provide limited financial support.

Delaware Aquaculture Development

Commercial aquaculture in Delaware presently is limited, but rising public interest and initiation of several small-scale culture efforts has led to formation of the Delaware Aquaculture Association and planning at the state level to promote additional development. This interest reflects national trends and is further reinforced by aquaculture development in neighboring Maryland and Virginia, where major initiatives are underway. Both states have recognized aquaculture as a form of agricultural production, have appropriated funds to plan and support future development, and have enlisted the resources of their respective agriculture and natural resource departments and academic institutions to address regulatory, technical, and economic factors limiting the expansion of aquaculture as an industry.

As in neighboring states, aquaculture development in Delaware depends on successful integration of a number of technical requirements with other economic and regulatory considerations. Sufficient resources such as land, energy, labor, and a reliable source of high-quality water all must be available. Culture systems, species grown, and management protocols must be compatible with local climatic conditions and growers must have the experience, time, and technical skills needed to manage the crop. Production and processing facilities must be able to recycle or otherwise dispose of processing wastes with minimal environmental impact. Markets must be developed that are reliable and specific for the cultured species. Capital must be available from banks and other lending institutions for purchases of equipment, facilities construction, and operating expenses. Social and regulatory issues concerning land use, wetlands, water allocation and effluent discharges, bottom and water column leasing, introduction of exotic species, bird predation, and government inspection of fish and/or fish processing plants, among others, must be addressed equitably. And institutional support from appropriate state agencies, universities and colleges, and agribusiness must be obtained and coordinated.

Natural Areas in Delaware With Aquaculture Potential

Natural areas that have potential in supporting aquaculture activity in Delaware can be subdivided into the subtidal zone (subaqueous bottom) and water column in coastal and nearshore areas, tidal waters, and upland locations that often include fresh and occasionally brackish waters. Examples include the Delaware Bay, tidal creeks, Inland Bays, or coastal lagoons (Rehoboth Bay and Indian River Bay), and a variety of ponds, drainage ditches, and other marginal water-retaining areas on farms throughout the state.

The Department of Natural Resources and Environmental Control (DNREC) has primary responsibility for the allocation and management of these public resources. The Development Advisory Service (DAS), comprising representatives from DNREC, Division of Public Health, Division of Historic and Cultural Affairs, Department of Agriculture, Delaware Development Office, and other agencies, was established to provide information on federal, local, and state environmental permit requirements. Depending on the aquaculture project proposed, the DAS will advise applicants of all permit requirements, standards, and procedures and will refer them to the appropriate federal, state, and local agencies.
Aquatic Species with Aquaculture Potential in Delaware

Delaware, as part of the Mid-Atlantic region, rests in a transition zone between cold-water and warm-water adaptation areas. Aquatic species with commercial value that have good potential for culture in Delaware include hybrid striped bass, crawfish (red swamp and white river), catfish, blue crabs (soft-shell), hard clams, oysters, freshwater bass, bait fish, and other sport or ornamental fish. Culture systems and production protocols for tilapia and other species are being developed; some of them may adapt well to Delaware.

Striped Bass or Hybrid Striped Bass

The striped bass (Morone saxatilis), or rockfish as it is known locally, has been a major food and sport fish on the Atlantic coast of North America. A virtual disappearance of the species in the late 1970s led resource managers to close the fishery and helped stimulate increased research on hatchery production of striped bass and hybrids (striped bass crossed with the white bass, Morone chrysops). Both approaches have proven to be worthwhile, with signs of recovery in natural stocks and successful development of commercial production of hybrid bass.

Hybrid striped bass culture has been expanding in the southern states and offers good potential for development of a viable food-fish industry in Delaware because of strong consumer familiarity and preference. Striped bass are indigenous to the Mid-Atlantic region and are adapted (as are hybrids) to conditions in freshwater and estuarine (brackish and saltwater) environments. However, the Department of Natural Resources and Environmental Control limits cultivation of hybrids to pond or tank culture to prevent the fish’s accidental escape into natural habitats.

Commercial production of hybrid bass on Delmarva is just getting started and will become more established as the technical aspects of brood stock management, fingerling production, and nutrition (specific feed formulation) are improved and regulatory questions regarding brood stock acquisition, disease certification, and interstate transport and sale are resolved.

Channel Catfish

Channel catfish (Ictalurus punctatus) farming has become a successful aquaculture industry in many of the southern states with well-developed culture technologies and domesticated strains available.

Although catfish culture in Delaware is technically feasible, the cooler climate of the Mid-Atlantic region could significantly influence production volume and costs by prolonging the growing season. Commercially viable catfish production on Delmarva will probably be related more to consumer demand and market economics than to technical considerations. Close proximity to major markets and successful development of specialty products may make catfish culture on Delmarva competitive with that of the southern states.

Game Fish, Ornamentals, and Bait Fish

Hatchery technology and other aspects of these species’ life history and biology have been sufficiently developed to permit institutional (state and federal hatcheries) and commercial production using extensive culture techniques. Commercial operations are located in various parts of the country, including Delaware, but are concentrated predominantly in several southeastern and mid-western states. Successful techniques for more intensive production of these species have not yet been developed. Rising interest in recreational fishing, increased stocking of game fish for conservation, and development of feedfishing operations may further develop local or regional markets for small-scale or part-time producers.

Tilapia

Several species or varieties of fish of the family Cichlidae, belonging to one of three genera—Oreochromis, Sarotherodon, or Tilapia—are collectively known as tilapia. Tilapia are considered by many to be a food fish with considerable potential for commercial production on Delmarva. They are one of the most widely cultivated fish in the world, especially in developing countries and/or tropical environments.

Although tilapia are not native to the United States, they are being cultivated commercially on a limited basis. Rapid growth and reproductive rates, high tolerance of marginal water quality, appealing meat texture and taste, and efficient energy conversion indicate good technical potential for successful culture. Tilapia are unable to survive in water temperatures below 10–14°C (50–55°F), however, and, in Delaware, this species would have to be grown indoors using intensive production methods which are not yet commercially viable. Consumer unfamiliarity with the product and undefined market potential in the region must also be addressed before the commercial potential of tilapia culture on Delmarva can be fully realized.

Crawfish

Two species of crawfish cultured in the U.S. with good production potential for Delaware are the red swamp (Procambarus clarkii) and the white river (P. zonan-
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Shellfish with Aquaculture Potential in Delaware

Standing of the crawfish reproductive cycle in the Mid-Atlantic region will help further define effective production techniques. Current market opportunities for crawfish as food or bait are localized and must be actively developed by growers. Market prospects, however, are expected to improve as supplies of locally produced crawfish increase and become more consistent.

Oysters

The Delaware Bay’s once-thriving Eastern oyster (Crassostrea virginica) industry was decimated by MSX, a single-celled parasite, in the late 1950s. Harvests in subsequent years have been limited by a combination of continued sporadic MSX disease activity and inconsistent natural recruitment. In the early 1980s, several seasons of drought raised average salinities in the bay and revived MSX activity to epidemic levels, eventually leading to suspension of commercial seed planting and harvesting in 1985.

The state of Delaware has expended considerable effort to plant shell and otherwise prepare traditional seed beds to maximize natural spatfall. However, annual oyster recruitment patterns in Delaware Bay are poorly understood and the natural spatfall that has occurred has not been sufficient enough to support sustained commercial oyster operations.

While research to produce and plant oysters with increased resistance to MSX disease has shown some progress, logistical problems associated with the economical production and handling of seed oysters (nursery culture) on a commercial scale remain as obstacles, requiring additional research and development. Other successful techniques for off-bottom culture of cultchless or single oysters for the premium-quality market are available and need to be evaluated for their applicability to conditions in Delaware Bay.

Delaware and New Jersey recently began a joint effort to develop a comprehensive management plan for the Delaware Bay oyster resource. One component of this plan will address the role of hatcheries, selective breeding, introduction of exotic species, and other aquaculture technologies in the overall strategy of managing and improving the oyster fishery during the next decade.

Clams

Hard clams (Mercenaria mercenaria) have excellent potential for aquaculture in Delaware and the Mid-Atlantic region. Consumer demand for hard clams is high, with an increasing percentage of cultured clams entering the market each year, supplementing production from natural stocks.

Culture technology for commercially viable production is well established, and clam aquaculture constitutes a growing industry in neighboring states (New Jersey and Virginia) and many other states along the eastern seaboard from Massachusetts to Florida. Portions of Delaware’s Inland Bays (Indian River and Rehoboth bays) and possibly certain sites in Delaware Bay have the capacity to support commercially viable operations using current clam production technology.

Information on the total acreage of subaqueous (submerged or subtidal) lands in Delaware available to support commercial clam aquaculture, however, is not known and needs to be determined to evaluate future industry potential. While some additional technical information is needed, other social and legal/regulatory issues such as conflicting use of the bays for development versus recreation, declining water quality, and lack of a state program for leasing subaqueous lands in the Inland Bays constitute major constraints to development of clam culture as an industry in Delaware for the foreseeable future.

Blue Crabs

The blue crab (Callinectes sapidus), like all crustaceans, must frequently undergo molting, a growth process whereby the crab sheds or vacates its old shell, or "exo-skeleton." When this occurs, the crab expands in size and enters what is called a "soft-shell" stage for a few hours before a new inner shell gradually hardens to replace the one that was abandoned. Crabs that are harvested and chilled or frozen while in the soft-shell stage are considered a seafood delicacy and are the object of a growing domestic and export industry.

Blue crab shedding has developed into a significant industry in Maryland, Virginia, and other southern states. Increasing demand for soft-shell crabs for domestic and export markets and improved handling and storage techniques have led producers to seek out new sources of peeler crabs. Although in recent years, harvests of peeler crabs in the Delaware Bay have been some of the best on record, there has been no corresponding increase in the number of shedding operations. At present, crab shedding activity in Delaware is relatively low, with fewer than a dozen producers concentrated around Port Mahan and Little Creek supplying crabs for local markets.

Crab-shedding system technology (flowthrough and closed systems) has been significantly advanced in recent years. Improvements in closed, recirculating systems have made it possible for shedding facilities to operate at less costly inland
sites while maintaining consistent water quality and a controlled environment for the optimum production of soft crabs. Recent peeler crab harvests have stimulated renewed interest in crab shedding and the use of recirculating systems in Delaware. However, thus far, only a few new systems have been built and are in use. Additional information must be compiled on anticipated trends for the Delaware Bay crab fishery, and local, regional, and export markets, and prices to assess the economic and industry potential for expanded soft-shell crab production.

Future Prospects for Aquaculture

Considering the current market value of coastal property and the ongoing debate between developers and environmental groups, and commercial and sportfishing interests on the regulation and allocation of coastal land and fisheries resources, those interested in getting started in aquaculture may find that upland ponds and unproductive farmland provide the best initial prospect for aquaculture development. The state’s agricultural industry, looking for ways to diversify production, may find on-farm culture of hybrid striped bass and/or crawfish attractive alternative crops. Increased use of existing ponds and marginally productive land, watershed management advantages, recycling of agricultural wastes, an established industry infrastructure, and close proximity to urban markets between Washington, DC, and Boston are all compelling reasons to seriously consider the contribution of aquatic production to a successful, diversified agricultural operation in Delaware.

This is not to say, however, that marine or coastal environments will be excluded from future aquaculture development. Commercial cultivation of striped bass, oysters, clams, soft-shell crabs, and other marine finfish and shellfish can and should be integrated, wherever possible, with existing traditional fisheries which have been in serious decline in Delaware and the Mid-Atlantic region. A major educational effort to demonstrate the economic, conservation, and ecological benefits of aquaculture will be required to offset current socioeconomic and regulatory obstacles that restrict aquaculture development in the coastal zone.

While there is certainly strong evidence that aquaculture’s potential future contribution to the economy of Delaware and the Delmarva Peninsula can be significant, much needs to be done before this potential can be fully realized. Like Maryland and Virginia, Delaware needs to decide on the future role of aquaculture in the state’s economic development and formulate a plan that addresses the need for technical information, continued basic and applied research and development, and extension education, as well as resolution of the regulatory and public policy issues limiting development of an aquaculture industry not only in Delaware, but nationwide.

The first step in this process was recently taken in December 1989 with the formation of the Delaware Aquaculture Task Force, which was appointed by Governor Michael N. Castle and chaired by Lt. Governor Dale Wolf. The task force, composed of individuals from government, industry, and the academic community, was asked to evaluate the current status and future potential of aquaculture in Delaware. The group concluded that the potential contribution of aquaculture to the state’s future economic development would be significant and recommended that Delaware develop a comprehensive program to promote and support growth of an aquaculture industry.

A bill entitled “The Delaware Aquaculture Act,” passed by the 135th General Assembly in June 1990 and signed by Governor Castle the following month, established aquaculture as an agricultural activity and named the Department of Agriculture as the lead agency responsible for promotion and coordination of aquaculture in Delaware. The legislation also authorized creation of an Aquaculture Advisory Council to work with the Secretary of Agriculture to resolve or otherwise address technical, economic, and legal regulatory issues affecting present and future industry development.

In the next decade, as the gap between consumption of seafood products and supply of high-value fish and shellfish from coastal fisheries continues to widen, aquaculture will be increasingly recognized as a specialized form of both agriculture and fisheries and as a consistent source of high-quality seafood products. Development of an aquaculture industry will require the same long-term commitment of state and federal support and cooperative interaction of industry, research, and extension that has enabled the expanded production of poultry and other agricultural commodities in Delaware.

REFERENCES


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