
CHAPTER 1

STATUS OF UNITED STATES AQUACULTURE & WHY MOVE OFFSHORE

Robert R. Stickney

Texas A&M University
2700 Earl Rudder Freeway S., Suite 1700
College Station, Texas 77845

ABSTRACT

Aquaculture arose in the United States during the mid-1800s, with most of the effort being placed on the production of fish and shellfish for stocking both inland and coastal waters. Commercial aquaculture production was insignificant until the 1960s when channel catfish farming led the way, followed by a host of other species. The first salmon cages were developed during the 1970s, and the net pen Atlantic salmon industry arose during the 1980s in Puget Sound, Washington and in some of the protected coastal waters of Maine. Other users existing in those waters prompted aquaculturists to look to the offshore environment as an alternative, and while that approach has significant merit, it has been slow to develop. The federal government is only now promulgating regulations for aquaculture in the Exclusive Economic Zone, so no permit system is available, which is a major limiting factor. There has been some activity in exposed waters in states that have regulations in place. A major constraint to open ocean aquaculture development is the cost associated with moving offshore. Facilities that can withstand the hostile ocean environment are much more expensive to construct, install, and maintain than those employed in protected coastal waters. Various cages have been designed for offshore use, but it is only within the past few years that the majority of the engineering problems have been resolved. Logistical problems become more and more significant as distance from shore increases. Travel time, the need for seaworthy vessels, and the fuel to run them all add to the expense. Finding a species that can be sold at a profit has been a major issue, particularly in the face of imported fish that are raised in ponds or protected coastal waters where regulations are often lax or lacking, labor is inexpensive, and overall production costs are much less than those required to rear the same species offshore. Finally, open ocean aquaculture has opponents who argue that such facilities will pollute the environment and may spread disease to wild populations, among other things. Despite the obstacles, interest in developing an offshore aquaculture industry in the United States remains strong and the government recognizes the inevitability of its development. There remains only the questions when and where the industry will develop, and with which species.

DEVELOPMENT OF UNITED STATES AQUACULTURE

Origins

Aquaculture was developed in the U.S. largely in response to the observation by Spencer F. Baird that the nation's fisheries were being overexploited (Stickney 1996). In 1871, Baird, a respected naturalist and then

Secretary of the Smithsonian Institution, convinced Congress to establish the U.S. Fish and Fisheries Commission. Baird was named as the first Commissioner. One of his early actions was to seek out the few established fish culturists in the nation and employ them to produce fish for distribution into the fresh-water and marine areas of the country. Those early fish culturists included such legendary

figures as Seth Green, Livingston Stone, and Charles Atkins. All of them had been involved with salmonid culture (brook trout and Atlantic Salmon), but soon they, and others that followed, were spawning a wide variety of both marine and freshwater fishes. The activities of those early American fish culturists were augmented by crews that captured wild fish from areas where the fish were plentiful and distributed them into areas where populations of the same species had been greatly reduced, as well as, into areas outside the native range of the fishes. Distribution involved the use of railroad baggage cars modified to haul live aquatic animals.

Over several decades, billions of fish were captured or produced in hatcheries and stocked throughout the nation, and in some instances around the world. Nations that were supplied with U.S. fish often reciprocated, which is how brown trout and common carp became established in U.S. waters. Attempts were made to introduce Pacific salmon to the east coast and Atlantic salmon (along with American oysters, striped bass, American lobsters, and a variety of other species) to the west coast. Striped bass did become established in California, while rainbow trout (native to the region west of the Rocky Mountains) were established in nearly every state.

While the numbers of fishes and invertebrates hatched and distributed throughout the nation were almost inconceivable, successes in terms of increasing existing or establishing new populations were few. Most of the animals were released as larvae or fry since the technology required to feed the young stages of many species was not developed until many years after the program was initiated. Thus, it is a fair assumption that most of the animals that were stocked served as food for indigenous species or died to become animal detritus.

Be that as it may, many of the techniques that are still in use today can be traced back to the work of the pioneer fish culturists of the late 19th and early 20th centuries. Many of the methods required for spawning and hatching some of the species produced during the early years of the Fish and Fisheries Commission and its successor organization, the Bureau of Fisheries, were not written down and were thus lost. It has not been until the past few years that modern fish culturists have redeveloped the techniques required to spawn several species that the early culturists had pioneered.

Commercial Aquaculture

While a few of the early fish culturists produced modest quantities of fish commercially—sometimes while also producing fish on behalf of state or local government—it was not until the 1960s that private aquaculture of foodfish began rapid expansion to become the industry that exists today. Rainbow trout culture developed in the west, with the focal point becoming the Thousand Springs area on the Snake River in Idaho. That region produces the vast majority of the rainbow trout marketed today. The enormous quantities of high quality water of the proper temperature that flow from the north side of the canyon walls is diverted through raceways before entering the river. Modest production levels of rainbow trout can be found in many other states.

Channel catfish are the backbone of the freshwater cultured fish production industry in the U.S. Farmers in the south-central states first focused their attention on buffalo fish (*Ictiobus* spp.) as potential culture species. In the 1950s, Dr. Homer Swingle at Auburn University published a paper indicating that channel catfish could be reared to market size and that a profit could be made if farmers were able to obtain \$1.20/kg at the pondbank (Swingle 1957, 1958).

The commercial culture of anadromous salmonids, in particular chinook, coho, and Atlantic salmon arose as a natural offshoot of the intensive hatchery programs developed by various states and the federal government, primarily in Washington, Oregon, Alaska, and Maine. Hunter and Farr (1970) described the first salmon net pen in Puget Sound, Washington (designed to hold adult fish) and Novotny (1975) described the process of producing salmon in net pens. Within several years the emphasis in the Puget Sound region shifted from native species to Atlantic salmon. While a modest Atlantic salmon culture industry has been developed on both the Atlantic and Pacific coasts, the vast majority of the salmon produced in the world come from Norway and Chile. Scotland and Canada are also significant producing nations. Permitting problems and objections to salmon culture in the U.S. have largely stifled further development of the industry.

Aquaculture in the U.S. was largely restricted to mollusks, and in particular, oysters until the latter two or three decades of the 20th century. Shellfish aquaculture then expanded into the production of mussels, clams, and abalone. Of much more interest and receiving the bulk of the attention by researchers looking for new shellfish species to rear, were shrimp—both marine and freshwater. Beginning with research in the 1970s, shrimp culture began to be developed, with commercialization being achieved and developing rapidly in the 1980s. Two approaches for rearing the larvae of marine shrimp were developed—one in the United States, the other in Asia—and both technologies were applied as the industry developed. Freshwater shrimp received a great deal of attention in the 1980s as well, but various problems led to the virtual demise of that industry, not only in North America but throughout the world

where production is insignificant compared with the marine species.

Commercial production developed primarily in Latin America (in particular, Ecuador) and Asia (with Thailand and China being major producing nations). Texas leads the nation in U.S. commercial shrimp production today, and there are modest amounts produced in a few other states. The food shrimp industry in the U.S. is based exclusively on exotic species, so biosecurity has been a major issue and some have expressed concerns that escapees could reproduce and threaten the survival of native species, though no sign of that happening has been observed to date.

Marine fish culture is the most recent area under development. Commercial culture of red drum began in the 1980s, and was preceded by a few years by commercial hybrid striped bass culture. Both species were originally produced by government agencies, so the technology of spawning and rearing the early life history stages was in place prior to commercialization.

University and government researchers have been actively developing the procedures for culturing a number of other marine species. Included are red snapper, cobia, dolphin (mahi-mahi), Pacific threadfin, tuna, cod, ling cod, flounders, and halibut (Pacific and Atlantic). Some of those species enjoy at least a modest level of commercial production in the U.S. or elsewhere in the world.

U.S. AQUACULTURE PRODUCTION AND WHAT IS HOLDING IT BACK

According to the Food and Agriculture Organization (FAO) of the United Nations (<http://www.fao.org>), the United States is

responsible for only about two percent of the world's aquaculture production, though the potential for increasing output from aquaculture is significant. Government statistics for 2001 (U.S. Department of Commerce 2003) show that the total amount of foodfish and shellfish produced was nearly 355,000 metric tons valued at over U.S.\$786 million. Those figures exclude baitfish, algae, aquatic plants, alligators, eels, scallops and a few other miscellaneous items. A breakdown by species group of the animals that contribute to the totals mentioned is presented in Table 1.

While aquacultural production has expanded rapidly in many nations, the United States, despite its enormous potential for producing aquacultured products, seems to lag further and further behind. That outcome is not because of lack of interest. There are certainly plenty of entrepreneurs and venture capitalists interested in becoming involved in U.S. aquaculture, the technology to produce a variety of species exists, and the U.S. market for aquacultured products continues to expand. However, further development of U.S. aquaculture has been limited by a number of factors. Among the most important are the legal and regulatory framework, the inability of domestic aquaculturists to compete with cheap imports in some instances, high overhead costs, and opposition.

Regulations

For inland aquaculture on private land, the regulatory environment is fairly benign in many states, though it can be quite imposing in others. Obtaining a permit to farm freshwater fish in a pond may be as simple as paying a license fee (though a much more arduous process is not uncommon). Developing an aquaculture facility in public waters tends to be much more difficult. In the marine environment the situation may involve working ones

Table 1. Estimated production (metric tons) and value (U.S. dollars) of major aquaculture food animal production in the U.S. in 2001 (U.S. Department of Commerce 2003).

Species or Species Group	Production	Value
Finfish		
Cattfish	270,846	386,329
Salmon	20,769	72,019
Striped bass	4,946	28,520
Tilapia	7,983	30,000
Trout	25,813	64,482
Shellfish		
Clams	4,525	35,404
Crawfish	13,847	40,545
Mussels	303	1,169
Oysters	7,629	39,886
Shrimp	3,607	27,808

way through upwards of a dozen state and federal agencies during the permitting process. The court system has increasingly become involved in the process as opponents file lawsuits against aquaculture projects. For development of aquaculture in state waters and in the Exclusive Economic Zone (EEZ) of the United States—the topic that is the primary focus of this book—the permitting process is still under development in some coastal states and at the federal level.

While often not onerous to inland aquaculturists on private land, state regulations for those operating in public fresh, estuarine or coastal waters can be extremely rigorous. This has been particularly true in the case of salmon aquaculture, both in Maine and in the Pacific Northwest (commercial salmon farming is outlawed in Alaska except for not-for-profit ocean ranching operations in which some returning fish are utilized as broodstock while most are taken in the commercial fishery). Prior to establishing a facility, the applicant may be required to gather a significant amount of information to demonstrate that the proposed site is appropriate in that environmental degradation appears to be largely

avoidable. Once a facility is established, frequent monitoring of water and sediment quality may be required, special and costly efforts may be mandated to ensure, to the extent possible, lack of escapement of the cultured species, and tagging of individual animals may be required so escapees can be identified. Other requirements regarding the genetics of the animals being reared and/or stocking of sterile or unisex fish have been proposed or implemented in some cases. The costs of meeting the regulatory requirements can be significant, though the intent of governments to maintain environmental quality and avoid negative impacts on native fauna by cultured animals is a goal that is understood and supported by society and, for the most part, those involved in the aquaculture enterprise. There is a point, however, where meeting the regulatory requirements can mean loss of any chance for profitability.

Most aquaculturists profess to be environmentalists in that they take their responsibilities for environmental stewardship very seriously. They also are dedicated to maintaining an excellent environment for their charges since degradation of the culture environment can only lead to problems for the species under culture. Maintaining a healthy culture environment usually translates into maintaining a good environment in the adjacent waters. That does not mean that aquaculturists are always being unfairly criticized. More on that subject is discussed below.

Imports

The United States channel catfish and Atlantic salmon culture industries, along with both the commercial and aquacultured shrimp industries, are suffering from the import of products that are being produced and sold at lower prices than must be obtained by the domestic producers if those producers are to

stay in business. In the case of catfish, the primary competition is unrelated catfishes from Viet Nam. The U.S. farmed salmon industry is in competition primarily with Chile, though farmed salmon from Canada and elsewhere also enter the domestic market. Both captured and cultured shrimp from Asia and Latin America have caused many shrimp boat owners to tie up their boats during the 2003–2004 seasons as they cannot operate at a profit even with an abundant wild shrimp population. Similarly, cultured shrimp are more costly to rear in the U.S. than abroad so shrimp culturists are having difficulty breaking even, let alone making a profit in the face of inexpensive imports.

Aquaculturists have sought relief in various ways, including recommending tariffs on selected imported seafoods and searching for subsidies under the 2002 Farm Act legislation. In 2003, a tariff of up to 64% was placed on catfish called basa that are being imported from Viet Nam by the U.S. International Trade Commission. Basa compete directly with channel catfish though the two are members of different families. While the tariff led to a sharp decline in imports of basa, that did not lead to higher prices being paid to domestic catfish farmers. In fact, the average price of fresh channel catfish actually fell. Processors also claim that they are suffering from low prices. In the meantime, domestic catfish production continued to increase. The latest fear is that China, which has begun producing channel catfish, will begin flooding the U.S. market with fish in the future (<http://www.seafoodbusiness.com>).

Shrimp culturists and harvesters have also been seeking government intervention through the tariff process and for relief through subsidies through the U.S. Department of Agriculture Farm Bill.

Legislation was passed in 2004 to put import tariffs on shrimp exported by certain companies in some nations.

Support by culturists and wild harvesters for country of origin labeling legislation has also been strong. The assumption is that Americans will select the domestic product over imports even if the price of the former is higher. That theory remains to be tested in the marketplace.

Overhead

The cost of doing business can be significantly higher for U.S. aquaculturists compared with their counterparts in much of the rest of the world. Subsidies, tax breaks, low land and labor costs, disregard for environmental impacts, and in many cases, more suitable climates for aquaculture may all mitigate against the domestic producer. The cost of developing a culture system on private land one already owns is much less than that required for purchase and development of the same amount of land on the coast, yet costs in both cases can mean economic failure when the margin between cost of production and farm gate price is very low and can even be negative.

Opposition

Many chose to either disregard or elect to develop facilities in spite of the above-mentioned problems. However, those who proceed with plans to establish facilities in public waters cannot often ignore the opponents to aquaculture. Opposition takes multiple forms and is most aggressive and effective in coastal waters with regard to net pen and cage culture operations. The list of objections is long and includes:

- visual pollution;
- pollution of the water column with waste feed and feces;
- creation of anoxic zones due to deposition of waste feed and feces on bottom sediments;
- transmission of disease from cultured to wild fish;
- escapees interbreeding with native animals of the same species and reducing genetic diversity in the local population;
- use of antibiotics;
- noxious odors;
- excessive noise;
- interference with navigation;
- interference with fishing;
- use of exotic species; and,
- interactions with threatened or endangered species.

Broader issues include the use of fishmeal to feed fish and in the case of shoreside facilities, destruction of valuable wetlands such as mangrove swamps. The issues and what is being done and can be done to address them are considered in detail in a book edited by Stickney and McVey (2002).

NEW DIRECTIONS FOR COASTAL REGIONS

Appropriate space in coastal areas is limited in the United States, or in many cases

where space is not an issue, competition with other users—many of whom are willing to pay much higher prices than can be afforded by the aquaculturist—makes establishment of fish farms impractical. The National Research Council of the National Academy of Sciences (NRC 1992) looked at the situation with respect to marine aquaculture in the U.S. over a decade ago and concluded that there were two options that represent the best possibilities for expansion of finfish aquaculture. The recommendations of the Council were to develop onshore recirculating water systems and establish offshore facilities. Since this book focuses on offshore aquaculture, that option is the one emphasized here, though there are a few words on recirculating systems at the end of this chapter. In addition, the discussion is directed toward finfish aquaculture in net pens and cages. Bottom culture of mollusks is somewhat less controversial in that it avoids many of the problems associated with aquaculture in the water column and does not require the use of prepared feeds.

Advantages of Moving Offshore

Offshore aquaculture facilities have a distinct advantage in having virtually unlimited space available for the activity. With proper attention to the density of fish per unit area (controlled by the number of cages or net pens allowed and control of total stocking density), impacts on water quality and the benthos can be avoided due to broad dispersal of waste products due to currents. Impacts on the culture species from pollution that might be present in protected bay and estuarine waters are obviated and, significantly, upland landowners do not object to offshore facilities if those facilities are located sufficiently offshore to be out of sight from land.

Fluctuations in water quality tend to be reduced in offshore areas. Daily and seasonal

temperature fluctuations are somewhat dampened, dissolved oxygen tends to be more than adequate for good growth of the species under culture, pH is highly regulated by the oceanic buffer system, salinity remains highly stable, and nutrient levels are often quite low.

Offshore culturists may be able to take advantage of existing offshore structures as support facilities. The Gulf of Mexico, particularly the western Gulf, contains thousands of oil and gas platforms, many of which would be suitable as support facilities. While there remain issues associated with having ancillary personnel on active platforms and the conveyance of ownership of non-producing platforms to aquaculturists from the oil and gas companies, the potential for conversion of platforms from their original use to support aquaculture is attractive. Many platforms are sufficiently large to have living accommodations, helicopter landing pads, and plenty of room for feed storage. Platforms could also be used as hatcheries and early rearing facilities, thereby providing support for the entire life cycle of the species under culture.

Disadvantages of Moving Offshore

Being offshore in the EEZ also has some distinct drawbacks. A major one is logistics. People must be routinely present to inspect, clean, and repair net pens and cages, provide feed or fill feed bins if automatic feeding systems are employed, remove mortalities, stock and harvest fish, collect water quality and growth data, and perform various other duties associated with maintaining the facility. Having a suitable structure available such as an oil and gas platform or anchored barge large enough to house personnel will remove the need to service the facility from shore on a daily basis. In either case, working offshore is much more expensive than would be the case in bays and estuaries. Because of the

exposure of offshore facilities to the elements, the cost of the cages or net pens is considerably higher than for similar culture chambers in the inshore environment.

Some of the early work with offshore containment structures showed that random wave motion wreaked havoc with shackles and other components. Storms accounted for more immediate failure and loss of fish and even the cages or net pens themselves. Advances in engineering technology have overcome some of the problems, and cages designed to be submerged at all times or at least during periods of storms have been developed and are currently in use in some places. Still, not all the engineering challenges have been overcome and work continues to be conducted in that arena. That work includes development of feeding systems for submerged cages.

Issues surrounding logistics were mentioned above with regard to the discussion on use of offshore platforms, but it is worth bringing the subject up again. If a facility is located in the EEZ, it could take up a considerable amount of time to travel by boat from shore to the cage or net pen system. Taking a helicopter would shorten the time considerably but would significantly elevate the cost involved. Having a support facility that would allow personnel to remain on station for extended periods (perhaps up to a month) would reduce transit costs, though premium wages would undoubtedly have to be paid.

Challenges to Overcome

Putting technological and sociological issues aside, the most immediate need is to get a permitting process in place that covers all state waters and the EEZ. Obviously, this will involve development of permitting policies by the individual coastal states and by the federal government, though there may also be

straddling issues that need to be considered. It is easy to envision a request for permits of a site that is partially in two states, partially in one state and in federal waters, and even split among two states and federal waters.

Several states have developed a marine aquaculture permitting process, though the present processes may not always be applicable to offshore waters as the initial focus has been on aquaculture in intertidal and protected areas. Each state's permitting system should be re-evaluated with consideration given to whether it would be applicable to offshore areas within state waters.

With regard to the federal government, permitting has only been well developed for oil and gas drilling and for mining of the seafloor under a system overseen by the Minerals Management Service. When that process was developed, there was no interest in aquaculture in the EEZ, so no provision was made. Stickney (1997) reviewed the situation as it existed a few years ago and apparently continues to exist today.

Enormous economic benefit to the government has been obtained from leases of oil and gas blocks in the nation's state waters, and in particular, in the EEZ. Such will not be the case with respect to offshore aquaculture. Profit margins tend to be quite low to producers who have little or no control on the consumer prices paid for their products because the control lies at one or more other levels (among which are processors, wholesalers, and retailers) in the chain of custody. Imported competing seafood products that can be captured or raised at substantially reduced costs compared with those produced in the U.S. also mitigate against high profits for the industry overall, and in particular, for the nearly non-existent offshore industry. When

the added costs involved in locating facilities offshore are taken into account, the bottom line is often not competitive with sources of the same product from other sectors of the industry.

One can argue that luxury products such as sushi-grade tuna could be the source of prodigious profits. Putting aside the technological development needs associated with producing such a product on a routine and sustainable basis, in all likelihood the process would unfold similar to that associated with predecessor species. That is, the first successful individuals or companies that produce a particular species or product may be able to demand very high prices. However, as others begin to compete, the price falls until—at least one would hope—everyone makes some profit, but no one receives a windfall any longer. Overproduction can, of course, lead to price collapse to the point that no one profits. As we are seeing with respect to channel catfish, shrimp, and salmon, foreign competition can also be a factor in driving down prices to domestic producers.

The regulators should recognize all of this as a signal for them to keep the costs of obtaining permits and leasing offshore sites to a minimum. States and the federal government are not likely to realize any more than the administrative costs associated with overseeing their programs. If high lease costs are imposed, those interested in the offshore aquaculture industry will either not proceed to the development phase, or if they do, could in many cases be forced into bankruptcy. Until those interested in the offshore industry have a clear set of running rules and associated costs, many will be reticent about proceeding with development even under research permits (which apparently can be obtained at present).

Closed Systems

The NRC report (NRC 1992) indicated, as previously mentioned, that more consideration should be given to recirculating water systems on land, as well as, to development of offshore systems. While recirculating system technology has developed to the point where such systems are highly dependable and can produce aquatic animals quite effectively, they have largely been economic failures in cases where the entire life cycle of a species, or even rearing from juvenile to market size are undertaken. Exceptions occur with respect to unique situations such as when water of the proper temperature is available at virtually no cost and a considerable amount of water exchange (partial recirculation) is employed. Another exception has been associated with at least some tropical fish producers. Polyculture systems that incorporate high cost plants or other valuable specialty items have also sometimes been economic successes.

Since fish stocked in offshore facilities must be large enough to remain contained within the mesh of the cages or net pens, it will be necessary to either purchase fingerlings or grow them at a second facility. That facility could be established on an offshore platform or floating facility (an anchored barge for example) or on land. (An offshore facility could also be operated as an open system.) Logistics and costs associated with an on land recirculating facility might make that the most attractive option. Such a facility (whether at sea or on land) could maintain broodstock, provide spawning and hatching facilities, and house larvae, fry, and early juveniles until they are large enough for stocking offshore. When employed in that fashion, recirculating systems can be economical and may be necessary in order to ensure a continuous supply of animals to stock out in the offshore location.

CONCLUSIONS

Open ocean aquaculture facilities offer another choice that may be available to the aquaculturist, but while there are some significant benefits associated with employing that option, there are also negatives that must be given due consideration. A few successes and many failures associated with past attempts at moving aquaculture offshore have been seen and it is clear that the risks are high. As research produces new technology and expands the number of species that are suitable for offshore culture, and as the permitting situation becomes resolved, the risks and other negative aspects of establishing aquaculture facilities in the open ocean may be reduced considerably. In the meantime, risk-takers will continue to push the proverbial envelope and can be given credit for having the intestinal fortitude to stand up to the challenges. While many may fail, adaptive learning obtained from their experiences will help others to succeed. Marine aquaculture has entered a new phase—one that holds a great deal of promise and may provide one mechanism whereby the United States can expand production and begin to meet domestic demands.

REFERENCES

- Hunter, C.J. and W.E. Farr. 1970. Large floating structure for holding adult Pacific salmon (*Oncorhynchus* spp.). *Journal of the Fisheries Research Board of Canada* 27:947–950.
- Novotny, A.J. 1975. Net-pen culture of Pacific salmon in marine waters. *Marine Fisheries Review* 37:36–47.
- NRC (National Research Council). 1992. *Marine Aquaculture*. National Academy Press, Washington, DC. 290 p.
- Stickney, R.R. 1996. *Aquaculture in the United States: A Historical Survey*. John Wiley & Sons, New York, NY. 372 p.
- Stickney, R.R. 1997. Offshore mariculture. Pages 53–86 in J.E. Bardach, editor. *Sustainable Aquaculture*. John Wiley & Sons, New York, NY.
- Stickney, R.R. and J.P. McVey. 2002. *Responsible Marine Aquaculture*. CABI Publishing, Oxon, United Kingdom. 391 p.
- Swingle, H.S. 1957. Preliminary results on the commercial production of channel catfish in ponds. *Proceedings of the Southeastern Association of Game Fish Commission* 10:160–162.
- Swingle, H.S. 1958. Experiments on growing fingerling channel catfish to marketable size in ponds. *Proceedings of the Southeastern Association of Game Fish Commission* 12:63–72.
- U.S. Department of Commerce. 2003. *Fisheries of the United States, 2002*. U.S. Government Printing Office, Washington, DC. 126 p.