Growing Seafood in the Open Ocean

Offshore Aquaculture in the United States

By Rollie Barnaby

New Hampshire Sea Grant
Technical Report

"I am convinced that the United States must explore the potential of offshore aquaculture to help meet the growing demand for seafood in this country and to create jobs and economic opportunity for coastal communities. To support that, we are making the National Offshore Aquaculture Act of 2005 a priority for this department and this country. We need to create this opportunity now."

– Carlos Gutierrez, U.S. Secretary of Commerce
February 13, 2006

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by Rollie Barnaby
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Introduction

Aquaculture is the farming of freshwater or marine plants and animals for human use. In traditional marine finfish aquaculture, fish have been grown in cages close to shore, taking advantage of inshore land masses for protection from the sea. Norway, Chile, Canada and Maine have large salmon farms in protected fjords and bays. Most of these sites are located in rural areas with little competition from other users. Unfortunately, good inshore sites – with requirements such as good tidal flushing, access to markets, accessibility to hatcheries and a capable workforce – are very rare. In fact, most of the inshore waters in the United States are already overcrowded with multiple users.

Young haddock swim inside a submersible fish cage in waters off the coast of New Hampshire.

The logical next step in the development of marine aquaculture is to move offshore, where the deeper water and stronger currents make aquaculture more environmentally sustainable and fewer users compete for access. The cultivation of marine organisms away from the coast, bays, harbors, fiords or similar protection is known as open ocean aquaculture or offshore aquaculture.

No open ocean aquaculture operations existed in the U.S. prior to 1996, other than an unsuccessful attempt to attach fish cages to oil rigs in the Gulf of Mexico and some experimental cage projects at the University of New Hampshire (UNH), the Massachusetts Institute of

Technology (MIT) and Ocean Spar Technologies, a company based in Bainbridge Island, WA.

In May 1996, with funding from Sea Grant and the National Marine Fisheries Service (NMFS), NH Sea Grant and UNH Cooperative Extension hosted the three-day International Symposium on Open Ocean Aquaculture in Portland, Maine. More than 200 people from 13 countries attended. This meeting was instrumental in the creation of the U.S. offshore aquaculture industry and led to other meetings in Maui, San Antonio and St. Andrews, New Brunswick. In U.S. waters today, there are three active commercial farms, an experimental demonstration project in New Hampshire, and at least five companies awaiting permits.

The Need for Offshore Aquaculture

The demand for seafood in the U.S. is increasing and will continue to increase. Recent federal health guidelines call for Americans to double their consumption of seafood. To do so, the U.S. would need an additional four to six million metric tons of seafood per year. Even if the current per capita levels of seafood consumption were to stay the same, the U.S. would still need an additional two million metric tons per year by 2025 as the population grows. The country is making good progress rebuilding wild fish and shellfish stocks that were over-fished in the past – but the harvest of wild-caught seafood will never keep pace with demand.

The Atlantic cod is a popular fish that has been overharvested in the wild. Cod is one of the species now being farmed offshore as part of UNH's Open Ocean Aquaculture Demonstration Project.

When submersible cages are used for offshore aquaculture, only a few small buoys are visible at the surface, as seen here at UNH's Open Ocean Aquaculture site.

Between 60 and 70 percent of all seafood consumed in the U.S. is imported, creating a trade deficit of nearly $8 billion annually. Forty percent of the imported seafood is farm raised, primarily in South America and Asia. Reducing dependence on seafood imports will help reduce the U.S. trade imbalance, provide jobs in coastal communities and contribute to overall food security. Open ocean aquaculture is one of the obvious solutions available to address this need.

Most of the inshore waters in the U.S. are unavailable for marine aquaculture because of coastal development and competition from multitudes of other users, including recreational boaters and fishermen, commercial shipping, commercial fishermen, wind surfers and kayakers. Moving aquaculture offshore avoids many of these user conflicts. It also reduces coastal landowners' aesthetic objections, especially when submersible cages are used.

Concerns about environmental impacts and the health of farmed fish also lend support for the development of open ocean aquaculture. In most of the U.S., inshore waters are already under stress due to nutrient loading from human activities. The most important feature for any aquaculture activity is the availability of good water. The open ocean guarantees large volumes of high quality water. By using submersible fish cages that can be set to various depths, fish farmers also have some control over water temperature. Recent open ocean demonstration projects have shown that both finfish and shellfish do very well in the offshore environment.

In September 2004, the U.S. Commission on Ocean Policy issued its final report, *An Ocean Blueprint for the 21st Century.* In that report the commission identified the need for a comprehensive offshore aquaculture framework in the United States. On June 7, 2005, NOAA submitted The National Offshore Aquaculture Act of 2005 to Congress for consideration and action. The act responds to the Commission's recommendations for NOAA to develop a comprehensive, environmentally sound permitting and regulatory program for offshore aquaculture. These actions acknowledge the need for increased sustainable production of seafood in the U.S.

Divers assemble a fish cage off the coast of New Hampshire. After construction, the cage is completely submersed.

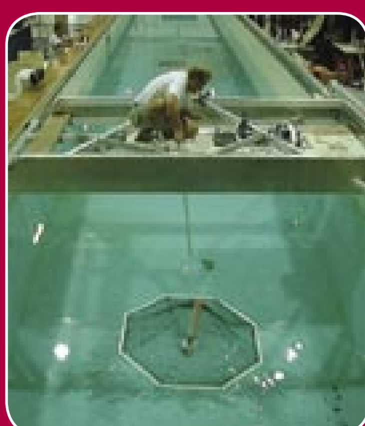
Progress in the Development of Open Ocean Aquaculture

Just 10 years ago, a long list of engineering and biological questions dominated discussions on the feasibility of open ocean aquaculture. Thanks to several university-based demonstration projects and a handful of private/public start-ups, many of those questions have been answered. We can now safely say that open ocean aquaculture is feasible – economically, biologically and environmentally.

Perhaps the most important development in offshore aquaculture in the past decade was the introduction of a submersible fish containment device, or cage. In 1994, Ocean Spar Technologies received a National Marine Fisheries Service Saltonstall-Kennedy grant to design and build a "towable" fish cage for the salmon industry. The result was the original SeaStation, a 50-foot by 80-foot rigid biconical sea cage with a center spar. When water accidentally seeped into the spar and the cage sank below the surface, Ocean Spar engineers realized that they could modify their design to allow operators to control the depth of the cage by adding or releasing air in the spar.

Traditional inshore fish cages typically consist of bag-shaped nets held open by gravity. The cages are maintained on the surface and are therefore at the mercy of high winds and strong waves. Submerging cages in the open ocean eliminates the problem of high-energy surface conditions, and the rigid nets on submersible cages are not adversely affected by currents.

After a suitable cage was designed, UNH engineers developed a multi-cage mooring system for SeaStation. Working with several other institutions, including MIT, UNH engineers used computer modeling to predict the action of the cages under different conditions and tested model cages in flume tanks. These cages, with some improvements, are now the cages of choice for all of the offshore aquaculture projects currently operating in the U.S. In 2005, Ocean Spar Technologies had 35 SeaStation cages in use worldwide, including 12 in the U.S. The company expects to have 12 new cages in operation by the end of 2006 and 70 more by the end of 2007. They presently build two versions of the SeaStation, a large 3,000-cubic-meter cage and a smaller 600-cubic-meter cage.



A UNH scientist tests a model cage in a flume tank. Engineers at Ocean Spar Technologies worked with researchers at UNH to test the SeaStation fish cages.

Once the SeaStation cage had proven it could survive in the open

The SeaStation cage, developed by Ocean Spar Technologies, is presently the cage used by all of the offshore aquaculture projects in the U. S. The 3,000 cubic-meter cage shown here holds tens of thousands of fish.

ocean environment, a whole new suite of operational challenges presented themselves. A partial list includes:

♦ **Identifying suitable sites**

When choosing a site, the depth, bottom type and proximity to competing users and shipping traffic must be considered. Some onshore space is usually necessary to store feed, nets, diving gear, mooring equipment and vessels. Proximity to hatcheries and markets is also an important consideration. Still, identifying an appropriate site is relatively easy. Getting a permit to utilize that site is not.

♦ **Survival and health of fish**

Researchers have determined that fish not only survive in the open ocean environment, but also thrive there. The species currently being grown in commercial farms – cobia in Puerto Rico and Pacific threadfin (moi) and amberjack (kampachi) in Hawaii – all have excellent growth rates and do well in open ocean cages. The UNH demonstration project has successfully grown flounder, halibut, cod, haddock and blue mussels at its offshore site. Growth rates have been excellent and the health of the fish has been very good.

♦ Identifying appropriate species

Only native species are considered for open ocean projects, ensuring that non-native species will not be accidentally introduced into offshore waters. All of the fish that have been farmed offshore have previously been studied and cultured successfully in onshore research facilities. Much was known about their behavior, growth rates, feed conversion rates and resistance to disease before they were introduced to open ocean cages.

♦ Transporting juveniles

A critical component in any aquaculture operation is a hatchery that can supply the necessary juvenile fish for growout. The degree of difficulty in transporting juveniles from the hatchery to the offshore cages depends, of course, on the proximity of the hatchery to the cages. Yet even if the hatchery is only a few miles from the cages, (as is the case at the Hawaii-based Kona Blue Water Farms, the only company that currently owns both its hatchery and growout cages) transportation still presents a logistical and often costly challenge.

♦ Developing methods of feeding

Researchers with UNH's Open Ocean Aquaculture Demonstration Project transfer juvenile cod into a submerged offshore fish cage.

Feeding fish in traditional surface cages is relatively simple. An automatic feeder can be used to spray feed, or workers can throw the feed directly into the cages. Moving the cages 30 feet below the surface presents a new set of problems. All of the farms in operation are now using some sort of system that puts feed into a 6- or 8-inch hose. Seawater is pumped through the hose, washing the feed into the cage.

This method, however, is labor intensive. Moreover, if bad weather or other problems prevent workers from traveling to the site, the fish don't eat. In New Hampshire, where a winter storm can last a week or more, UNH engineers have built and deployed an automatic feeder that holds one ton of feed and can feed a single cage for an entire week. They are now working on developing a 20-ton automatic feeder that can feed four cages at a time.

♦ Maintaining and cleaning cages

Any equipment that is left in the ocean for months or years requires a lot of maintenance and care. When those structures are kept below the surface, the process becomes even more complex. Offshore aquaculture requires highly trained divers to accomplish tasks such as examining and cleaning the cages and the mooring hardware.

♦ Monitoring fish behavior

Every farmer wants to be able to see his or her livestock, and fish farmers are no different. With surface cages this was not a problem. To address the problem offshore, UNH has installed small cameras, each

Michael Chambers, the project manager for UNH's Open Ocean Aquaculture Demonstration Project, sends cod feed via a pipe to the submerged fish cage.

about the size of a cigar, in its cages. Researchers can observe video of the fish before, during and after feeding from computer monitors aboard the research vessel or on shore. UNH researchers also use ultrasonic transmitters and underwater hydrophones to track the fine-scale movements of caged cod. Combining biotelemetry and video techniques allows researchers to study cod in their natural habitat. Commercial farms have not yet adopted this biotelemetry and video technology; they employ divers to observe the fish during feeding.

At UNH, video cameras installed in the submersible cages allow researchers to monitor the fish remotely – from aboard the research vessel, on campus or beyond.

♦ Safety

The biggest operational difference between traditional surface cages and submersible open ocean cages is the amount of diving required. Once traditional inshore cages are in place, a farm can go for months without needing a diver. Currently, the open ocean farms require one or more divers for everything they do. Much of the research being done at UNH and Ocean Spar Technologies aims to reduce diving time. Operator safety is a major consideration when new gear and technologies are being designed.

♦ Harvesting fish

Ocean Spar engineers and fish farmers have been working together to develop harvesting methods. Surface cages have nets on the cage rim that can be pulled up, crowding the fish into a smaller area where they can be harvested by a fish pump or a dip net. The SeaStation's net is attached to a rigid structure, requiring a new method of harvesting fish. Cates International, an offshore fish farm in Hawaii, has had success harvesting moi using divers and a commercial fish pump. But each farming operation is developing its own methods, learning as it goes.

♦ Monitoring environmental impacts

Traditional coastal fish farms have often been accused of negatively impacting the environment, creating a build-up of waste that harms native species. Such negative impacts are less likely in an open ocean environment, where waters are much deeper and waste is more widely dispersed.

Each open ocean aquaculture operation was required to have a comprehensive monitoring plan in place before receiving a permit. All but one of the projects have partnered with universities to design and implement their monitoring plans. To date, UNH's stringent monitoring program has found no measurable environmental impacts in the Gulf of Maine.

Pacific threadfin, known locally as moi, are harvested at Cates International, Inc., an offshore aquaculture company in Kailua, Hawaii.

Open Ocean Aquaculture Farms and Hatcheries

Despite the challenges inherent in getting new offshore aquaculture projects off the ground, a number of facilities have had success in U.S. waters.

Cates International, Inc., located in Kailua, Hawaii, is a spin-off of a project initiated in 1999 by Chuck Helsley, then the Sea Grant director at the University of Hawaii. The Hawaii Offshore Aquaculture Research Project (HOARP) was a partnership between the University of Hawaii and the Oceanic Institute in Waimanalo, Hawaii. The project hired Randy Cates, a local fisherman and salvage expert, to use his vessel to move fish and equipment and provide operational support. In 2001 the University of Hawaii turned the project over to Cates.

Cates International produces moi, also known as Pacific threadfin, a fish highly prized in Hawaii. The University of Hawaii still runs the environmental monitoring program, and the Oceanic Institute continues to serve as a hatchery, supplying the company with juvenile fish. Cates is presently producing six to seven thousand pounds of moi a week and is working on an expansion plan that includes a company-owned hatchery and four to eight new cages.

Kona Blue Water Farms, LLC, based in Kona, Hawaii, was culturing pearl oysters and finfish in land-based tanks before it ventured into the offshore finfish business. It is the only open ocean aquaculture company that currently operates both a hatchery and an offshore growout site.

Partners Neil Anthony Sims and Dale Sarver have extensive backgrounds in aquaculture research. They have four cages on their 80-acre site, located a half mile offshore in water 180 to 200 feet deep. They plan to add two more cages in 2006. Sims and Sarver did extensive research on several finfish species before deciding to grow kampachi, a popular sushi-grade Pacific fish. They had successfully grown kampachi in a tank farm, but the onshore growout proved too expensive. After a thorough study, Kona Blue Water decided to take their kampachi operations offshore.

Snapperfarm, Inc., a five-year-old company, is located in Culebra, Puerto Rico. Snapperfarm is raising cobia, an incredibly fast growing warm-water fish. Snapperfarm president Brian O'Hanlon and his small but dedicated team have overcome many operational obstacles, learning as they go with help from Ocean Spar Technologies and the University of Puerto Rico Sea Grant Program. Snapperfarm began as the industry partner in a Sea Grant-funded project with Dan Benetti (at the University of Miami) and the Aquaculture Center of the Florida Keys (ACFK). Snapperfarm has two cages at its site and hopes to eventually produce additional species.

The Aquaculture Center of the Florida Keys provides juvenile cobia to Snapperfarm, an open ocean aquaculture company in Culebra, Puerto Rico.

The ACFK supplies juvenile cobia to Snapperfarm. The challenge for ACFK and Snapperfarm has been in devising a way to transfer the fish safely from the hatchery in the Florida Keys to the cages in Culebra. The process involves trucking the fingerling fish from the Florida Keys to Miami, flying them to San Juan, Puerto Rico, and delivering them by boat to the island of Culebra.

The **University of New Hampshire** received NOAA funding for its Open Ocean Aquaculture (OOA) Demonstration Project and put its first fish, summer flounder, into a SeaStation submersible cage in 1999. Since then the collaborative UNH/NOAA project has successfully grown halibut, haddock and cod. In 2003, researchers stocked their 3,000-cubic-meter cage with 32,000 30-gram cod. In late 2005, some of those fish, weighing an average of three to five pounds each, were harvested and sold. GreatBay Aquaculture, a private hatchery in Newington, NH, has supplied juvenile summer flounder and cod to the OOA.

UNH has also developed a technique for growing mussels offshore on submerged longlines. The longline site is seven miles from shore in 180 feet of water. This technology has been transferred to a local fisherman, who will harvest his first crop in 2006.

The environmental conditions at the UNH site are quite different from those of the warm-water commercial farms operating in Hawaii and Puerto Rico. During a winter storm in 2003, a UNH monitoring buoy recorded a 12-meter wave. Heavy icing on the vessel and surface equipment is common during the winter months. When the project began, no one was certain that open ocean aquaculture was feasible. In the years since, the demonstration project has addressed many of the problems facing the development of an offshore aquaculture industry.

Conclusion

The individuals who are growing fish in the open ocean are breaking new ground everyday. They are all entrepreneurs and problem-solvers with a vision. All of the active farms will need to grow if they are going to survive. Yet all of them are having trouble getting the permits needed to expand.

Permitting is the greatest impediment to the development of open ocean aquaculture. All of the open ocean farms in operation are located in state waters, and each farm has had to deal with a unique permitting process within its state. In most cases, the states had never issued an open ocean permit before. In each instance, many different agencies were involved in permitting, which really slowed the process down.

There are at least five companies now waiting for permits in the U.S. Some of them have been waiting for several years, and all of them have invested thousands of dollars in the permitting process. All of the companies are investigating the possibility of taking their businesses to other countries because of difficulty obtaining permits.

In New England, nasty winter storms and heavy icing on buoys and vessels are common. Yet the UNH project has demonstrated that offshore aquaculture is possible even in this challenging environment.

To date, the UNH Open Ocean Aquaculture Project has succesfully grown halibut (shown here), haddock, cod, flounder and blue mussels.

All of the companies currently operating, as well as all of the companies waiting for permits, are attempting to grow native fish from local brood stock. Any escapees are not a threat to the ecosystem. There have been no records of marine mammal interactions with the Ocean Spar cages since their first deployment seven years ago. The UNH Open Ocean Aquaculture Demonstration Project has found that impacts on water quality and the seafloor community have been negligible. Hundreds of thousands of gallons of seawater flow through these cages daily, and the Project's environmental monitoring program has not been able to detect any measurable impact on the surrounding environment.

NOAA has now submitted the National Offshore Aquaculture Act of 2005 to Congress for consideration and action, a positive step that will hopefully lay the groundwork for the development of the offshore aquaculture industry in the U.S. An enormous amount has been learned about offshore fish farming in just the last 10 years. With careful action, the next 10 could see great progress in open ocean aquaculture, a field poised to take off as a valuable and sustainable domestic industry. ❖

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