The Role of Offshore Aquaculture in Ecosystem-Based Approaches to Coastal Management

1

James P. McVey

National Sea Grant College Program, Office of Oceanic and Atmospheric Research
National Oceanic and Atmospheric Administration, Silver Spring, Maryland 20910 USA
E-mail: jim59@comcast.net

The National Oceanic and Atmospheric Administration (NOAA) National Sea Grant College Program has been funding marine aquaculture projects since the inception of the program in 1968. Early funding emphasis was on disciplinary studies such as nutrition, pathology, genetics, systems engineering, and life history studies of promising candidate species for aquaculture. In the early 1990s, additional focus was placed on developing production systems that had the best potential for application in the environmentally conscious United States. These aquaculture technologies included recirculation system technologies, offshore aquaculture, and marine fisheries enhancement. Sea Grant funded several symposia on these subjects and proposed increases in funding through the NOAA budget process and this helped to further focus the research efforts for the NOAA based program.

The first Sea Grant sponsored workshop on the topic of offshore aquaculture was held at the University of New Hampshire in 1995. This time period coincided with the collapse of fisheries in northeastern United States. Fishermen and processors were desperate to find an alternative source of seafood. Because of the tremendous interest in the topic of offshore aquaculture, a second meeting on the promise and technology for offshore aquaculture was held in Hawaii in 1997. A third Sea Grant sponsored workshop was held in Texas in 1999 and a fourth was held in conjunction with Canada at St. Andrews, New Brunswick. All of these meetings were well attended by representatives from many nations from around the world.

NOAA Sea Grant began the National Marine Aquaculture Initiative in 1999 and this program has continued through 2006. In this 8-year period, NOAA Sea Grant has competed approximately $14 million of federal funds and funded a broad range of projects including a considerable portion of offshore aquaculture projects. Funding for the individual years of support varied, depending upon Congressional budget marks. The loss of funds in 2002, 2003, and 2005 caused NOAA to reduce or discontinue funding to projects that had already begun. This variability indicates the uncertainty of the national opinion about offshore aquaculture resulting in the reduced the level of effort for key industry technologies.

A progression of research topics through the years, with initial projects starting in 1999, focused on policy, regulatory, and environmental issues as well as life histories and technologies of new candidate species for marine aquaculture. In 2000, additional projects were added to expand the work on regulatory, policy, codes of practice, and Geographic Information Systems (GIS) issues. With the increase of funding in 2001 to $5.6 million, more than 20 projects were funded. The policy, regulatory, and environmental projects were continued and new projects on more species for culture, the use of alternative sources of protein meal, and demonstration of offshore and recirculation technology were begun. In 2002, funding was reduced by 60%, so ongoing projects were partially funded waiting for additional funds in 2003 to round out the projects. In 2003, all funds were lost for the program. All projects had to be terminated, with serious impacts on the end results of the research. In 2004, Congress provided only $700,000 for the program. NOAA called for projects to maintain the environmental monitoring studies on ongoing offshore projects. In 2005, all funds were lost again. In 2006, funding jumped to $4.6 million and it was decided to fund as many projects as possible for a full 2-year period from the 2006 funds rather than depending on year two funding from the 2007 budget. Thus, only 11 projects were funded in 2006; but if full funding was obtained for 2007 there would be additional projects started in that year. Table 1 provides a listing of projects for 2006.

Lead State	Principal Investigator	Affiliation	Project	2006-2007 Grant
California	Mark Drawbridge	Hubbs-SeaWorld Research Institute	Yellowtail as a Model for Marine Aquaculture	$505,553*
South Carolina	Craig Browdy	South Carolina Department of Natural Resources	Commercialization of Bait Shrimp Farming Based on Specific Pathogen-Free Stocks	$500,000*
Florida	Daniel Benetti	University of Miami	Demonstrating Technological and Economic Feasibility of Cobia	$400,000*
Hawaii	Charles Laidley	Oceanic Institute	Hawaii Offshore Aquaculture Research Project	$400,000*
North Carolina	Wade Watanabe	University of North Carolina Wilmington	Commercialization of Black Sea Bass	$400,000*
South Carolina	Theodore Smith	South Carolina Department of Natural Resources	Aquaculture Development and Fishery Enhancement of Cobia	$356,337
Washington	Daniel Cheney	Pacific Shellfish Institute	Alternative Shellfish Production Methods	$285,583
New Hampshire	George Nardi	GreatBay Aquaculture	New Technologies for Cod Culture	$248,952*
North Carolina	Craig Sullivan	North Carolina State University	Genome Mapping for Selective Breeding of Striped Bass	$202,578
Texas	Delbert Gatlin	Texas A&M University	Improved Diets for Warmwater and Coldwater Marine Fishes	$199,103
Florida	Larry Brand	University of Miami	Assessment of Environmental Impacts of Offshore Cage Culture	$150,000*

Table 1. NOAA-funded projects for 2006.

* Some project money to come from 2007 if available.

Despite the problems with funding for the program, a large number of marine aquaculture publications from the United States have appeared in statistics published by the Food and Agriculture Organization of the United Nations (FAO 2004). In 2004, the United States had 28 of the 97 publications representing the top 15 institutions in the category of marine aquaculture.

The impact of the research programs can also be seen in the establishment of new companies for offshore aquaculture and in the increase in seafood supplies. Two companies for marine fish production now exist in Hawaii and two more are in the permit process. In Puerto Rico, one company is producing cobia *(Rachycentron canadum)*, another just received the permits to begin operation, and another company is in the permit process. In New Hampshire, two companies have started up the production of blue mussels *(Mytilus edulis)* based upon the work of the New Hampshire offshore aquaculture project. In Hawaii, the production of moi *(Polydactylus sexfilis)* jumped from 0.91-1.37 metric tons (2,000-3,000 lbs.) per year to 15 metric tons per year as a result of the first offshore aquaculture company there. In Puerto Rico, the production of the single cobia farm of 5 metric tons equaled about 40% of the wild catch for that species in the southeast United States.

Even more importantly, the availability of moi and cobia in their respective regions invigorated the seafood supply line, providing communities with seafood supplies of top quality, traditional species. In Hawaii, farm-raised moi are served in many of the top tier restaurants. Visitors can enrich their vacations by trying a new fish representative of the locality.

Many countries around the world are moving toward the concepts of ecosystem based management. The new offshore aquaculture technology effectively opens up large areas of ocean to improve seafood supplies and to provide improved locations, ecologically, for the conduct of aquaculture. In terms of ecological function there are two types of aquaculture: extractive aquaculture, where the species being cultured serve to remove nutrients from the water (filter feeders and algae) and fed aquaculture, such as fish and shrimp, in which nutrients are added in the form of feeds. Coastal managers make use of this knowledge to consider aquaculture within models for improving ecological balance.

Addition of nutrients can be beneficial or detrimental, depending upon amount and location. Biological communities depend upon nutrients and they adapt to different levels of nutrients. Higher nitrogen levels lead to higher processing rates for nitrogen (Livingstone 2000). Carrying capacity for nutrients depends upon the combination of physical, chemical and biological factors. Offshore locations, because of their stronger currents, greater depths, and better mixing, have a greater carrying capacity for nutrients. Nutrients in offshore locations can stimulate fisheries. This can be seen in areas of upwelling of nutrients off of Peru, the U.S. Pacific Coast, and other locations where there are productive fisheries. NOAA based research has shown that natural biological communities in offshore locations quickly adapt to additional nutrients and fish and invertebrate communities increase as long as the nutrient does not cause negative effects on physical factors such as low dissolved oxygen or a build up of sulfides in sediments to unhealthy levels. All locations have a carrying capacity for nutrients. Five fed aquaculture farms may be acceptable but ten farms may be too many. This can be determined through experience and constant monitoring of environmental conditions. Research is being funded by NOAA on determining which environmental factors are the best indicators.

The development of management models for coastal ecosystems depends upon knowledge of the ecological roles of the biological communities, both wild and those represented by aquaculture.

This information must be coupled with additional data on the inputs of nitrogen from human sources such as agricultural run off, aquaculture, domestic waste treatment plants, and atmospheric deposition. It is also necessary to know the removal rates of nitrogen as a result of biological activity.

Several studies have provided some estimates of the removal rates of nitrogen for different biological communities. Production of seaweeds and animals compliment one another (Chopin 2002). The 4.8 million tons of marine algae produced annually by China removes 60-100,000 tons of nitrogen upon harvest (Fei 1998). One type of seaweed, Porphyra (nori), responds to higher levels of phosphorus and nitrogen in the environment by absorbing more (Fei 1998). Individual bivalves, which filter particles including phytoplankton, detritus, silt, and clay, can filter 1 to 4 L per individual per hour (Jorgensen 1966). Quahog clams were estimated by Rice (2001) to filter 21% of the tidal volume of the Providence River in Rhode Island, United States, on each tide, thus increasing light penetration. Hard clams excrete about 9 mg NH_3 per kg of soft tissue per day, but for every kg of shellfish meat harvested, about 16 g of nitrogen are removed (Rice 1999). This knowledge allows modeling.

NOAA maintains technical exchange programs with international partners:

- United States/Japan Cooperative Program in Natural Resources (UJNR) Aquaculture Panel
- United States/China Living Marine Resources Joint Coordination Panel
- United States/Korea Joint Coordination Panel, Aquaculture Sub Panel

These programs have been long term, and they provide U.S. researchers and those from the participating countries with an opportunity to exchange information on aquaculture science and technology of mutual interest. Activities include scientific symposia, exchange of scientists between countries, training of students in a broad range of topics, literature exchange, and development of web pages concerning the activities of the exchange programs. These web pages can be found on the web through the NOAA Central Library.

Discussions with NOAA's international partners have shown that they are also moving toward ecosystem based management for aquaculture. This universal move to looking at coastal ecosystems in a more holistic way prompted NOAA to bring its international partners to Hawaii in April of 2005 to discuss the role of offshore aquaculture in integrated coastal and ocean management. Representatives from Canada, China, Japan, Korea, the United States, and Vietnam presented country scenarios for ecosystem based coastal aquaculture, and were joined by participants from other countries and international organizations to discuss the dramatic effect offshore aquaculture is having on the management of coastal zones. China is rezoning some bays to move fed aquaculture activities offshore while employing filter feeders and macroalgae at appropriate levels to improve water quality. The European Union is using GIS based models to help place offshore aquaculture in proper context with other coastal uses. Canada is testing multi-trophic marine aquaculture or polyculture to minimize environmental impacts. The United Nations Development Programme has asked for assessment of aquaculture and fisheries in the Yellow Sea and the draft copy includes offshore technologies and ecosystem based management. South Korea has put a moratorium on nearshore and onshore aquaculture pending legislation that will facilitate offshore technologies. NOAA is supporting coastal ecosystem models incorporating GIS, benthic impacts, feed characteristics, and hydrography to predict impact of offshore aquaculture facilities. NOAA is also proposing a major study on coastal management that includes offshore technologies.

Possible benefits of offshore aquaculture technology include the following:

- Allows placement of ecological function at appropriate locations in coastal waters.
- Allows fishery managers to set different quotas for wild stocks for recovering fisheries and ecosystems.
- Allows alternative sources of seafood products when National Marine Protected Areas are created.
- Allows market planning and timing for selected seafood products thus contributing to expanded markets.
- Provides commercial quantities of popular species that are not available in the retail or wholesale markets today.
- Provides alternative source of tropical reef species that cannot be harvested commercially (contributes to coral reef community stability).
- Provides a larger scale of production to meet expected market demands.
- Opens up true open ocean/offshore areas for aquaculture, allowing countries and coastal managers to optimize the value of ocean resources while preserving ecological sustainability.

It is widely acknowledged that fish supplies from traditional capture fisheries are unlikely to increase substantially and that projected shortfalls in fish supply will probably be met mainly from expansion within the aquaculture sector (FAO 1997).

Recent statistics published by the Food and Agriculture Organization of the United Nations (FAO 2006) indicate that world aquaculture is now contributing 45.5 million metric tons (43%) of fish consumed. The actual amount of edible fish from wild fisheries is about 60 million metric tons. Aquaculture production is nearing that of wild fisheries. To supply world seafood protein demand, world seafood production is predicted to add 40 million metric tons by 2030, based on present per capita consumption.

In the opinion of this author, the development of offshore aquaculture is a revolutionary technology that begins to open up open ocean locations for aquaculture and expansion of seafood supplies. The more dynamic conditions of the offshore environment provide a better carrying capacity for the processing of nutrients, and this factor makes the open ocean a more appropriate location for fed aquaculture activities. Inshore locations are better for extractive forms of aquaculture that can process and balance nutrients coming in from human sources. Acceptance is growing for the concept of using the natural ecological functions of cultured species to place ecological function in the ecosystem that can lead to improving water quality and overall ecosystem health.

Literature Cited

Chopin, T., C. Yarish, and G. Sharp. 2002. Beyond the monospecific approach to animal aquaculture. The light of integrated aquaculture. In T.M. Bert, editor. Ecological and Genetic Implications of Aquaculture Activities. Kluwer Academic Publication Series (Reviews in Methods and Technologies in Fish Biology and Fisheries). Kluwer Academic Publishers, Norwell, Massachusetts, USA. 400 pp.

FAO (Food and Agriculture Organization of the United Nations). 1997. FAO Technical Guidelines for Responsible Fisheries, Aquaculture Development No. 5. Food and Agriculture Organization of the United Nations, Rome, Italy. http://fao.org/DOCREP/003/W4493E/W4493E00.HTM.

FAO (Food and Agriculture Organization of the United Nations). 2006. State of World Aquaculture (2006). FAO Fisheries technical paper No. 500. FAO Fisheries Department, Food and Agriculture Organization of the United Nations, Rome, Italy. ftp://ftp.fao.org/FI/DOCUMENT/t500_advanced/advanced_t500e.pdf.

Fei, X. 1998. Seaweed cultivation in large scale-a possible solution to the problem of eutrophication by the removal of nutrients. World Aquaculture 29(4): 22-24.

Jorgensen. C.B. 1966. The Biology of Suspension Feeding. Pergamon Press, Oxford, U.K. 357 pp.

Livingstone, M.W., R.V. Smith, and R.J. Laughlin, R.J. 2000. A spatial study of denitrification potential of sediments in Belfast and Strangford Lough and its significance. Science of the Total Environment 251-252: 369-380.

Rice, M.A. 1999. Control of eutrophication by bivalves: Filtration of particulates and removal of nitrogen through harvest of rapidly growing stocks. (abstract only.) Journal of Shellfish Research 18(1): 275.

Rice, M.A. 2001. Environmental impacts of shellfish aquaculture: Filter feeding to control eutrophication. Pages 77-84 *in* M. Tlusty, D. Bengtson, H.O. Halvorson, S. Oktay, J. Pearce, and J.B. Rheault, Jr., editors. Marine Aquaculture and the Environment: A Meeting for Stakeholders in the Northeast. Boston, Massachusetts, USA, 11-13 January 2001. Cape Cod Press, Falmouth, Massachusetts, USA.