Results of Environmental Monitoring at an Experimental Offshore Farm in the Gulf of Maine: Environmental Conditions after Seven Years of Multi-Species Farming

13

Richard Langan

Atlantic Marine Aquaculture Center
University of New Hampshire, 35 Colovos Road, Durham, New Hampshire 03824 USA
E-mail: rlangan@unh.edu

The University of New Hampshire, in partnership with local fishing cooperatives and a commercial marine fish hatchery, and with collaboration from several regional research institutions, established an offshore aquaculture research and development facility in the Gulf of Maine in 1999. The offshore platform, located 9.66 km (6 miles) off the New Hampshire coastline in 56.39 m (185 feet) of water, is fully permitted for commercial production. It consists of a submerged grid mooring system that can accommodate four submersible cages for finfish culture, two submerged longlines for suspended molluscan shellfish culture, and surface structures that include remotely operated feeders, acoustic biotelemetry systems, and oceanographic instrumentation. The facility serves as the field site for applied research and technology development, evaluation, and technology transfer for the Open Ocean Aquaculture Project funded by the National Oceanic and Atmospheric Administration. The goal of the project is to stimulate the development of an environmentally sustainable offshore aquaculture industry, thereby increasing seafood production, creating new employment opportunities, and contributing to regional and national economic and community development. To date, fish species cultured at the site have included summer flounder (*Paralichthyus dentatus*), Atlantic halibut (*Hippoglossus hippoglossus*), haddock (*Melanogrammus aeglefinis*), and Atlantic cod (*Gadus morhua*). In addition, blue mussels (*Mytilus edulis*) and Atlantic sea scallops (*Placopecten magellanicus*) have been grown on the adjacent submerged longlines.

Aquaculture, similar to all other methods of food production, will have some effect on the surrounding environment. The past three decades of development of nearshore cage culture for finfish has shown that if done correctly, the effects are localized and negligible. There is also evidence that poorly sited and poorly managed fish farms can result in environmental impacts. These include deposition of uneaten feed and feces on the seafloor that can alter bottom sediments and benthic communities, enrichment of the water column with dissolved nutrients that can stimulate increased primary productivity, escapement of captive fish, and negative interactions with marine mammal predators. In the past decade, environmental conditions in the vicinity of farms has greatly improved due to changes in husbandry practices and feed formulations, better fish health management through vaccine development, and more robust engineered systems have reduced catastrophic fish escapes. These issues, however, continue to be raised by opponents of sea cage culture. In addition, critics also cite overexploitation of lower trophic levels of fish for feed ingredients, transfer of diseases and parasites from farmed to wild fish, and genetic pollution and competition with wild stocks by escaped fish as the negative consequences of sea cage culture, though the actual risk and impacts of these issues are subjects of continuing debate within the scientific community. Regardless of whether the severity of the effects are real or exaggerated and whether some are even relevant to native marine fish farming in offshore environments, these issues must be addressed and successful management of environmental impacts must be demonstrated for open ocean aquaculture to gain "social license" to operate in the United States.

The approach adopted by the Open Ocean Aquaculture Project includes implementation of management practices that are designed to minimize potential impacts and a rigorous environmental monitoring program to measure any changes to the surrounding environment. To address escapes, the project has developed a suite of engineering tools to design and evaluate mooring systems and cages that can withstand extreme environmental conditions and avoid catastrophic losses due to storm damage. Sea cages are submerged 12-15 m below the sea surface to reduce the risk of ship collisions. A containment management plan, based on the principles of a Hazard Analysis and Critical Control Point risk analysis program, includes frequent inspection and maintenance as well as procedures to prevent escapement during stocking, sampling, harvesting, and transport operations. All fish cultured at the site are native to the area, and to date, all juveniles stocked in the sea cages have been the offspring of wild parents. Therefore, any escapees would be genetically identical to local stocks. Waste feed is managed by the use of remote, real-time video monitoring and control of feeding operations, so that feed delivery can be stopped when the fish are satiated. While the project's location in the Gulf of Maine is a low risk area for enrichment from dissolved nutrients, the adjacent culture of extractive species such as mussels and scallops is used to balance the inputs of nitrogen and phosphorus from fish culture. Fish health is managed using vaccination prior to stocking, and by maintaining optimal environmental conditions (e.g., temperature, dissolved oxygen, etc.) to minimize stress. Dead or moribund fish are promptly removed to reduce the risk of developing any reservoirs of pathogens resulting from decomposition. To date, no antibiotics or parasite treatments have been administered.

Eighteen months prior to stocking the first production run of fish in 1999, a detailed hydrographic and environmental assessment of the site was conducted to establish reliable reference conditions[1]. Using high resolution side scan and multi-beam sonar, underwater videography, multi-parameter in situ instrument packages, and traditional water column and benthic sampling and analytical methods, a baseline of seafloor, oceanographic, and environmental conditions for the proposed site was established. Numerical models were used to predict the dispersion and deposition of particulates and dissolved constituents, and 20 monitoring stations were established to represent impact (4), mixing (6), far field (5) and distant far field (5) zones. The parameters measured include benthic community characteristics (e.g., density, biomass, species diversity, and evenness), sediment organic content and redox potential discontinuity (RPD) layer, and water quality (dissolved oxygen, dissolved inorganic nutrients, and chlorophyll). A towed video camera is used to further assess sediment characteristics and provide data on epibenthic fauna. In situ instrumentation at a fixed location at the farm provides continuous measurements

[1] Grizzle, R., L.G. Ward, R. Langan, G. Schnaittacher, J. Dijkstra, and J.R. Adams. 2003. Environmental monitoring at an open ocean aquaculture site in the Gulf of Maine: Results for 1997-2000. Pages 105-119 *in* C.J. Bridger and B.A. Costa-Pierce, editors. Open Ocean Aquaculture: From Research to Commercial Reality. The World Aquaculture Society, Baton Rouge, Louisiana, USA.

of temperature, salinity, dissolved oxygen, turbidity, and fluorescence at three depths (1, 20, and 50 m), wave height and period, and current velocity and direction throughout the water column using Acoustic Doppler Current Profilers (ADCP) current meters.

Though analysis of environmental data has been conducted annually since 1999, only the data collected in late spring 2005 (Ward et al. unpublished report) was used in the analysis presented here to examine the worst case scenario in terms of organic loading. The 2005 water column and benthic sampling was conducted when the farm was stocked at maximum fish biomass with three sea cages stocked with cod, haddock, and halibut, respectively, containing approximately 25,000 kg of fish. Fish had been fed daily rations of pelletized feed formulation at a rate of 1.5% to 2% fish weight per day, therefore during this period, 500 kg of food was dispensed daily.

Analysis of sediment organic content (loss on ignition), showed very low organic content (1.2%-1.4%) and no differences as determined by one-way ANOVA between projected impact, mixing, and farfield zones. RPD analysis was incomplete due to difficulty recovering undisturbed samples from all stations. For those, however, that were recovered, there were no differences by one-way ANOVA in the depth of oxygenated sediments between impact, mixing, and farfield zones.

Univariate statistics were used to assess differences in density, biomass, and diversity (number of taxa) of infaunal benthos, and no differences (by one-way ANOVA) between the four zones were found. In addition to univariate community assessments, potential changes in taxonomic composition of the infaunal communities that might be pollution-related were examined in two ways. First, ratios of the densities of "pollution tolerant" taxa (oligochaetes, capitellids, cirratulids, ampeliscids) and "pollution intolerant" (nuculids, paraonids, ampharetids) taxa were calculated and compared. Pollution intolerant taxa were in the majority at all 20 sites, with no differences between zones. These data suggest that the infaunal benthic communities in all four zones were dominated by taxa that are relatively intolerant of organic pollution, providing additional evidence of no detectable impacts on the seafloor.

The second taxonomy-based approach involved calculating ecological indices of diversity (e.g., Shannon-Weaver, Simpson) and evenness (relative distributions of taxa, e.g., Pielou, Marginet). Each index distills the community taxonomic composition data into a single number that represents a measure of community characteristics. No differences in the calculated indices for diversity or evenness were found for samples from all four zones, again, suggesting that there were no detectable impacts on the infaunal benthic community.

Epibenthic fauna were sampled using bottom video that captures images of seafloor features such as surficial sediments, sediment texture, bedforms, and borrows for qualitative analysis; and generates quantitative data for epifauna. The video from each station is analyzed by clipping the video to isolate the highest quality segments, subsampling the video frames from ~30 to 1 per second to match the GPS positioning information, and subsequently analyzing each scene in the video for bottom characteristics (sediment type, roughness), visible burrow characteristics (size, density), and epifauna (taxa, density). The inclusion of laser beams at known distances apart in each scene allows the total area of the bottom viewed to be determined. The results of the video surveys in 2005 indicate no differences in density or taxa for benthic epifaunal communities located at stations within the predicted impact, mixing, and farfield zones, therefore, no indication of pollution effects on the seabed were detected in the epifauna data.

The water column was sampled in each zone at three depths (1, 20, and 50 m) and analyzed for suspended particulates (TSS), dissolved nutrients (NO_2, NO_3, NH_4, PO_4), and chlorophyll a. Simultaneous measurements of temperature, salinity, turbidity, fluorescence, and dissolved oxygen were obtained by vertical Conductivity-Temperature-Depth (CTD) casts. "Downstream" sampling locations were determined by the direction of flow at each depth by an ADCP current meter. Analysis indicated no differences (by one-way ANOVA) in any of the measured water column parameters between impact, mixing, or farfield zones.

Collectively, the sediment, benthic community, and water quality data suggest that there are no detectable effects of the offshore fish farming on the seafloor or water column at the level of production at the site. The project will continue to increase production levels and continue monitoring to determine the level of production at which environmental changes may occur.