

# Can offshore aquaculture of carnivorous fish be sustainable?

## Case studies from the Caribbean

DANIEL BENETTI<sup>1</sup>, LARRY BRAND<sup>1</sup>, JAMES COLLINS<sup>1</sup>, REFIK ORHUN<sup>1</sup>, ANTONIO BENETTI<sup>2</sup>, BRIAN O'HANLON<sup>3</sup>, ANDY DANYLCHUK<sup>4</sup>, DALLAS ALSTON<sup>5</sup>, JOSÉ RIVERA<sup>6</sup> AND ALEXIS CABARCAS<sup>5</sup>

User conflicts and pollution concerns suggest that major environmental benefits are to be gained by moving cage aquaculture operations further offshore. The United States is paving the technological road to sustainable development of offshore aquaculture through university-industry-government partnerships. Emerging technology, in collaboration with the private sector, is being used to demonstrate the environmental sustainability and economic viability of raising hatchery-reared fish in submerged cages in exposed sites in the Caribbean. The University of Miami's Aquaculture Program has partnered with the private companies Snapperfarm, Inc. and AquaSense, LLC to transfer technology and develop offshore aquaculture demonstration projects in Puerto Rico and the Bahamas. The Island School and Cape Eleuthera Institute are also partners in the initiative.

The offshore areas of the southeastern United States and the Caribbean countries have extraordinary potential for the development of an environmentally sustainable mariculture industry (Benetti et al. 2003). Site selection is the first and most crucial step taken to ensure environmental sustainability and successful implementation of offshore aquaculture operations. Detailed site assessments were conducted to evaluate parameters related to infrastructure, topography, bathymetry, meteorology, hydrology, environmental and biological information, as well as the legal, social, economic and political framework. Areas of potentially conflicting use were avoided.

The offshore aquaculture demonstration projects currently being conducted in Culebra Island, Puerto Rico and South Eleuthera, Bahamas, are completely submerged, thereby preserving the aesthetic appearance of the areas. Systems clear at least 12m from the surface in order to avoid impediments to navigation. The depth of the site (25-30m)



A remora swims around a SeaStation 3000 stocked with cobia in South Eleuthera, the Bahamas. The cage (background) is tilted due to strong currents prevailing in the area. (Photo by Evan D'Alessandro, RSMAS/UM)

and steady current (0.5-1.5 knots) maintain water movement in a downstream direction, dispersing organic and inorganic materials that could potentially be associated with the operations. Considering cage volumes and the current velocity, approximately 2 billion liters of clean oceanic water flow through each cage daily.

The cages were stocked with hatchery-reared fingerlings of endemic, native species such as cobia (*Rachycentron canadum*) and snapper (*Lutjanus analis*) for growout. We hypothesized that the nutrients and suspended solids generated by the cage systems would not dramatically affect the oligotrophic offshore environment due to its carrying capacity. This premise is important because of previous

indications that inshore cage culture of marine finfish may be detrimental to coastal waters due to excessive nutrient loading, hypernutrification and eutrophication with subsequent harmful algal blooms (Beveridge 1984, Rosenthal 1994, Beveridge 1996, Benetti et al. 1999, Chen et al. 2000; Molina et al. 2001, Benetti et al. 2002).

The University of Miami and the University of Puerto Rico are conducting environmental assessments in the areas surrounding the cages in both Puerto Rico and the Bahamas. Sampling stations were set up at different distances and directions from the fish cages. Possible eutrophication of the local environment was evaluated monthly by measuring dissolved nitrogen and phosphorus, phytoplankton biomass, epiphyte growth potential, sinking flux of organic matter into sediment traps, organic content of the sediments, and benthic microalgal biomass. In no case were significant differences found as a function of distance from the cages or relative to upstream-downstream direction. Environmental data from Puerto Rico and the Bahamas indicate that the current regime and resulting dilution of nutrients from the submerged cages do not lead to a significant change in the ecosystem near the cages. There were no significant differences in any of the water quality parameters measured in the area surrounding and beneath the cages<sup>7</sup>, indicating that fluctuations appeared to be seasonal, affecting the cage and control site more or less equally. These findings are relevant because elevated nutrient concentrations are usually only found once the assimilation capacity of the autotrophic community has been exceeded (Bell 1991) or when large nutrient imbalances exist. The final report of the first two years of studies on the environmental impact of the offshore cages in Puerto Rico is under review and its findings will be published. Similar findings resulted from the environmental assessment conducted in the Bahamas project, in conjunction with which the final report by the authors is also in review.

In the summer and fall of 2004, the submerged cages (SeaStation) were exposed to severe storms, including category 4 hurricane Frances. Hurricane strength winds ranging from 100-160 km/hr prevailed for almost 24 hours in the area where one of the cages is deployed in South Eleuthera, generating high waves and strong currents (Benetti 2004). No damage to the cage or fish mortality was observed.

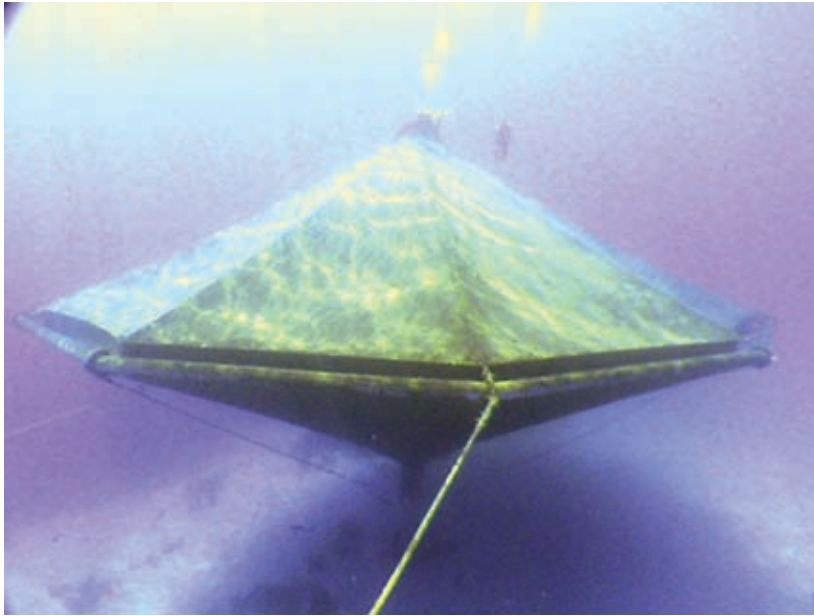
No coral reefs are present in the area near the cages. Rather, sparse patches of *Halimeda* sp., a macroalgae characteristic of an oligotrophic environment, are found at the predominantly sandy bottom. In the near future, to utilize the inorganic nutrients being released by the systems, rafts and longlines of filter feeder molluscs (scallops and oysters) and macroalgae will be deployed in the area surrounding the cages. The submergible cages provide ideal habitats and are also acting as fish aggregating devices, attracting a wide variety of transient and resident species of vertebrates and invertebrates. These organisms thrive on any feed pellets that



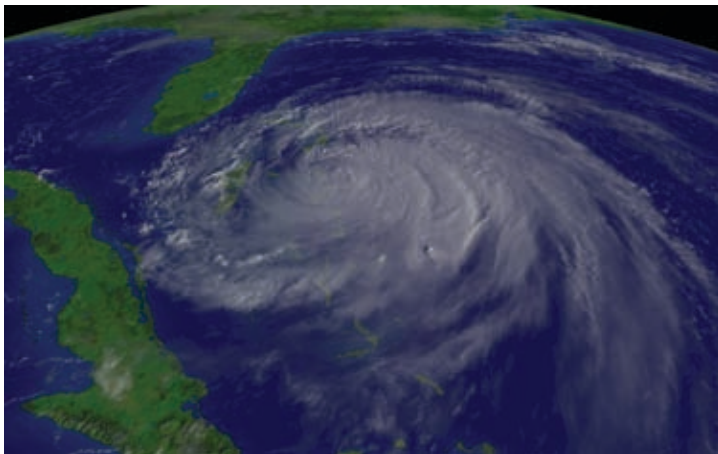
*Juvenile cobia swimming inside a SeaStation 3000 cage belonging to AquaSense Bahamas Ltd. in South Eleuthera, the Bahamas. The demonstration project was run by the Cape Eleuthera Institute in collaboration with RSMAS/University of Miami. (Photo by Daniel Benetti)*



*Anesthetized cobia (*Rachycedntron canadum*) broodstock undergoing prophylaxis. (Photo by Jorge Alarcón, Aquaculture Center of the Florida Keys, Inc.)*



*SeaStation 3000 cage submerged in the blue waters off Cape Eleuthera in the Bahamas. (Photo courtesy of The Island School/Cape Eleuthera Institute)*



*Hurricane Frances remained in the region where the SeaStation 3000 cage was deployed in South Eleuthera, Bahamas, for 24 hours with winds ranging from 100-160 km/hr. No damage to the cage or fish mortality due to the storm were observed. (Photo courtesy of NOAA)*

might occasionally have passed through the cages before being consumed by the cultured fish.

Mutton snapper grow relatively slowly, reaching approximately 500g from the egg stage in one year (Benetti et al. 2002). This is the average growth of most fish, such as grouper, snook or flounder. Conversely, cobia exhibit extraordinary growth (4-6 kg in 12 months), yielding 1 kg of fish biomass when fed 1.8 kg of pellets containing 50 percent fish meal (FCR = 1.8). Taking into account that energy loss between trophic levels in nature results in an ecological efficiency of only around 10 percent, our data show that using fishmeal to produce high value fish for human consumption in aquaculture can be 3.7 times more efficient than the transformation in nature. Nevertheless, the need to reduce and perhaps eliminate the use of fishmeal in aquaculture feeds is widely recognized. Among the best alternatives being investigated are the utilization of grain-based and alternative protein source feeds for carnivorous fish without resorting to genetically modified organisms (GMOs).

While research in this area progresses rapidly, cobia raised in our offshore projects are fed pellets containing fishmeal from a properly managed fishery resource, Atlantic menhaden, without the use of antibiotics, growth hormones, pigments or pesticides. Indeed, if it weren't for the use of ethoxyquin - a synthetically-derived antioxidant (stabilizer) required to prevent rancidity in the fishmeal - the cobia raised in these projects could be considered organic. The industry is currently investigating alternative sources of organic antioxidants, which at present, are of limited availability and of prohibitively high cost for use in fishmeal-based feeds.

Cobia growth rates in the demonstration projects are among the fastest ever recorded for teleosts. Results suggest that growing this species in exposed sites with adequate depth and currents can produce high yields of seafood for human consumption with low environmental impact.

Our research indicates that, when relying on fishmeal from sustainable fishery resources and properly sited and managed facilities, aquaculture of carnivorous fish can be conducted responsibly. However, the efficiency of fishmeal use in the culture of carnivorous fishes as it relates to long-term sustainability is a complex issue. It is dependent on the management of small pelagic fisheries, which in turn depends on fishing pressure, oceanographic and meteorological parameters, as well as long-term climate changes and anthropogenic factors.

Additionally, high risks associated with offshore operations may conspire against their economic viability. Operations that are economically unsound cannot possibly be sustainable in the long run. Indeed, when we began developing these projects, our primary concern was with the environmental impact that the cages could potentially cause



Sampling juvenile cobia in the Bahamas. (Photo by Daniel Benetti)

in the surrounding areas. Because, after conducting studies for three years, we could not measure or detect any harmful effects, our focus and attention have shifted to predator control and the economic viability of the operations. Particularly in the Bahamas, there have been episodes of sharks attacking dead fish and damaging the nets at the bottom of the cage. As a consequence, there have been fish escapements and production losses, compromising the economic viability of the operation. In addition, and also importantly, fish escapements from net cages could arguably be detrimental to the environment. Even though these fish are native, endemic to the region and healthy, many researchers believe that such escapements could compromise the genetic makeup of the local population of the species.

In collaboration with the Massachusetts Institute of Technology and the private sector, a major effort is currently being placed on anti-predator systems, including predator nets, solid barriers, electromagnetic and magnetic fields and chemical and electrical repellants.

The environmental assessment is ongoing. The latest results, summarized in this article, were presented at the American Association for the Advancement of Science Annual Meeting in Washington, D.C. in February 17-21, 2005.

## Notes

- <sup>1</sup>Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149, USA
- <sup>2</sup>Instituto de Pesquisas Hidráulicas, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9.500 Porto Alegre 91501-970 – RS, Brazil
- <sup>3</sup>Snapperfarm, Inc., Culebra, Puerto Rico, USA
- <sup>4</sup>Cape Eleuthera Institute, South Eleuthera, Bahamas
- <sup>5</sup>University of Puerto Rico, Mayaguez, P.O.Box 9084, Mayaguez, Puerto Rico 00681
- <sup>6</sup>National Oceanic Atmospheric Administration, NMFS, CARR 102, Cabo Rojo, PR 00623
- <sup>7</sup>Alston, D.E., A. Cabarcas, J. Capella, D.D. Benetti and R. Cortés (In review). Environmental impact of sustainable offshore cage culture production in Puerto Rican waters. Final Report, National Marine Aquaculture Initiative, Mayaguez, Puerto Rico: 138 p.

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