Authors' Commentary: The Outstanding Coral Reef Papers

Melissa Garren
Center for Marine Biodiversity and Conservation
Scripps Institution of Oceanography
University of California–San Diego
La Jolla, CA

Joseph Myers
Dept. of Mathematical Sciences
U.S. Military Academy
West Point, NY

Introduction

According to the Food and Agriculture Organization of the United Nations, aquaculture is the fastest growing sector of animal-based food production for human consumption. As the global population increases, pressure on coastal ecosystems and the need to produce food also grow. More than half of the world's population lives within 200 km (120 mi) of a coast, and many natural fisheries are already fished at or over capacity. Within this context, the influence of aquaculture on coastal ecosystems is a topic of social, environmental and scientific concern and the subject for this year's problem in the Interdisciplinary Contest in Modeling (ICM)®.

Coral reefs are delicate and valuable ecosystems that only thrive in shallow, tropical, nutrient-poor waters. They cover less than 1% of the ocean's floor but harbor 25% of marine biodiversity. Many people depend on these ecosystems for food, trade, tourism, shoreline protection, and new sources of medicinal compounds. The majority of coral reefs on this planet grow along inhabited tropical coastlines of developing countries. Thus, as an ever-growing number of aquaculture facilities are installed in coastal waters, the interactions between coral reef ecosystems and fish farms are of particular interest.

There are many forms of aquaculture practices, but the more environmentally compatible versions tend to be more costly to set up and operate than their

The UMAP Journal 30 (2) (2009) 159–162.

less compatible counterparts. Developing methods that are both cost-effective and have a low impact on the surrounding ecosystem is an important issue and a complex and timely challenge. A common method is simply to raise one species of carnivorous fish in pens set directly in coastal waters. Unfortunately, this method causes several environmental problems:

- There is no real barrier between the captive and wild populations, so any disease that occurs in the densely packed pens will flow directly into contact with wild populations.
- No filtration of effluent exists—all excess feed, fish feces, and microbial populations mix directly with natural waters.
- Living organisms can only use 10–20% of the energy they consume, so the other 80–90% goes to waste—raising an organism higher up the food chain (a carnivore) means that several rounds of 80–90% loss occurred to simply make the food that the target species will eat.

These practices are currently happening on and adjacent to many coral reefs. A growing body of scientific literature is demonstrating that these fish farms have a significant negative impact on the corals, and thus major improvements are needed to attain a viable industry and a sustainable coral reef ecosystem.

Formulation and Intent of the Problem

The goal of this year's ICM problem was for student teams to tackle the ecological and technological challenges of improving such practices within the tractable confines of one specific case study of milkfish (*Chanos chanos*) aquaculture directly next to coral reefs in Boliano, Philippines. There are many possible approaches to improving the current situation, but we asked teams specifically to come up with a polyculture scenario that would improve water quality sufficiently for corals to recolonize the areas close to the fish pens where they currently cannot survive. By adding more than one species to the industry, energy inputs can be reduced by growing food for the milkfish locally and water quality can be improved by filter feeders and algae that absorb excess nutrients without requiring major gear or technology shifts. This particular method of more environmentally responsible aquaculture also emphasizes the ecological links between different species and trophic levels. There are a number of potentially negative impacts associated with introducing new species into an ecosystem, so teams were also asked to evaluate the potential risks associated with their polyculture solution.

Teams were first asked to model the original, healthy coral reef ecosystem before the introduction of fish farms. For the purpose of modeling, the complex ecosystem was simplified to one member from each major trophic and phylogenetic guild. The purpose was to identify how the natural system's organisms interact to control water quality in the area.

The second task was to model the current system with the monoculture of milkfish present. Since the natural milkfish food supply was removed by placing the animals in pens, feed must be purchased and added to the system. The idea was to see the effect of exogenous feeding on water quality. They compared the results of their model to actual observed water quality data from Bolinao. Next, teams were asked to model a remediation scenario. They chose the species they wanted to include in their polyculture system and modeled the effects on water quality, harvest, and economic value. They were asked to discuss the harvesting of each species and what parameters they would use to determine the value of the harvest. The last modeling challenge was to maximize the value of the total harvest while maintaining sufficient water quality levels for corals to grow.

The end result of modeling was to write recommendations to the Pacific Marine Fisheries Council regarding the management of the Bolinao milkfish aquaculture industry. This is where the teams evaluated the ecological pros and cons of the species chosen for their particular polyculture system, the economic trade-offs of improving water quality, and how long the remediation of Bolinao coral reefs can be expected to take.

A major goal of this contest problem was for teams to relate the modeling choices they made to realistic ecological and biological processes. Teams were asked to use realistic parameters for their models based on actual ecological and physiological data and to justify any assumptions made. Fundamental understandings of primary production, trophic interactions, and energy transfer were essential for building and critiquing their own models.

This year's ICM problem is based on research being done by the World Bank and Global Environment Facility's Coral Disease Working Group. This international group of scientists has been working to understand the ecological consequences of this fish farm industry on coral health. The first phase of the project was to identify some of the mechanisms by which fish pens are negatively impacting corals. This is the final year of phase one, and much progress has been made. As we enter phase two of the project, we move forward with a goal of testing and implementing alternative methods of farming in this area. Polyculture is one of the alternatives currently being discussed.

References

Hinrichsen, D. 1998. *Coastal Waters of the World: Trends, Threats, and Strategies.* Washington, DC: Island Press.

United Nations Food and Agricultural Organization (FAO). 2006. State of World Fisheries and Aquaculture 2006. `http://www.fao.org/docrep/009/a0699e/A0699E00.htm`.

About the Authors

Melissa Garren is currently a Ph.D. candidate in marine biology at Scripps Institution of Oceanography in La Jolla, CA. She earned her B.S. in molecular biology from Yale University and her M.S. in marine biology from Scripps Institution of Oceanography. Her research focuses on the ecological response of microbes to organic coastal pollution, particularly in coral reef environments, with the aim of understanding the effects on coral health and disease.

Joe Myers has served for two decades in the Dept. of Mathematical Sciences at the United States Military Academy. He holds degrees in Applied Mathematics and other disciplines and is a licensed Professional Engineer. He currently serves as a Professor, having directed freshman calculus, sophomore multivariable calculus, the electives program, and the research program. He has been involved in several major initiatives to improve teaching and learning, including building interdisciplinary activities and programs under the NSF-sponsored Project Intermath; integrating technology and student laptop computers into the classroom; and weaving modeling, history, and writing threads into the mathematics curriculum. He enjoys modeling and problem solving, has posed and guided the research of dozens of math majors, and has been involved in several research projects with the Army Research Laboratory.