Northeast Fisheries Science Center
Milford Laboratory, Milford, CT

1) Most Recent Evaluation of the Lab

The most recent review of Lab research was conducted by an external independent panel in August of 1990. This document is attached (ExpBiology Review.pdf).

2) Brief History and Mission

The Milford Marine Biological Laboratory was created in 1931 under the U. S. Bureau of Fisheries. At first, the Milford Laboratory's sole purpose was to study the biological problems of Connecticut's oyster industry. Since then, Laboratory scientists have made outstanding contributions to the understanding of basic shellfish biology and reproduction and have pioneered methods to increase productivity through aquaculture. Techniques for bivalve and algal culture developed in Milford are used extensively by the shellfish aquaculture industry, and the laboratory has won international recognition for its expertise and innovative research.

During the past two decades, research at Laboratory has broadened to reflect NOAA Fisheries' priorities. Specific research areas include physiology, ecology, biochemistry, immunology, algology, culture methodology, chemistry, genetics, bacteriology and pathobiology. Available tools for research include a variety of analytical scientific instruments, including a genetic analyzer, PCR, micromanipulator, two flow cytometers, a variety of microscopes and centrifuges, spectrophotometers, nutrient analyzer, computer access and an excellent library.

The facility faces Milford Harbor, close to the open waters of Long Island Sound. Researchers have ready access to mud flats, salt marshes, and tidal and subtidal estuaries as well as the Sound itself. Well-equipped for field studies, the laboratory operates several small boats and a 49-ft. vessel, the R/V Victor Loosanoff. This vessel has hydrographic-, dredge-, and net-sampling gear used to collect specimens for assessing the natural environment. SCUBA divers perform specialized field sampling. Milford scientists also participate in offshore, working cruises along the Atlantic Coast on NOAA's larger research vessels.

Since 1931, the laboratory has grown from a small wooden building to a facility well-equipped to perform modern marine biological research. Two buildings house 30 individual offices and laboratories. Seawater from Milford Harbor is continuously pumped into the laboratory and, there, heated, cooled, or filtered according to need -- a major asset in marine biological research. Seawater is also pumped directly to an outdoor tank system used for experimentation and holding of marine animals. One row of 18 tanks is enclosed and heated to permit year-round operation. The laboratory's specialized fiberglass tables, trays, and tanks were designed to enable spawning and rearing of marine animals through their several life stages. One room is dedicated to the mass culture of unicellular algae, the main food source for bivalves. A highly regarded collection of more than 200 cultures of individual algal species continuously maintained, has supplied monocultures to marine biologists around the world. Several rooms are equipped to perform cytogenetic analysis and assays for disease pathogens.

Researchers at the Laboratory have made significant contributions to marine science, with many hundreds of publications in the literature of marine biology. Technology developed at Milford has helped the growth of marine aquaculture, leading to new industries throughout the world.

Mission: Use experimental biology to gain insights that promote sustainable fisheries and demonstrate technologies and strategies for environmentally-compatible marine aquaculture of shellfish and finfish for both production of high-quality seafood and enhancement of wild stocks.

The Laboratory conducts research on the aquaculture of marine shellfish and finfish that are economically important in coastal areas of the Northeast region; in addition related studies are conducted to determine how habitats function as nurseries for young fish and shellfish that might be used in stock enhancement projects. Methods for the rearing of finfish and shellfish to market size are being developed using various technologies, including flow-through systems and recirculating seawater systems. The particular species of interest at this time include the bay scallop, black sea bass and tautog. Along with these studies strategies to re-introduce hatchery-produced finfish and shellfish into the natural environment are being evaluated. Technological tools are being developed to better understand and manage marine aquaculture methods and practices. Specific areas of application include marine livestock health management and disease diagnosis and treatment (including effects of harmful microalgae and biotoxins); selective breeding of shellfish for desired traits; and production and effective use of microalgal feeds for shellfish and for invertebrate animals fed to cultured larval finfish. Directed experimental studies are conducted to develop and evaluate technologies, and methods and tools are tested in practice.

Development of environmentally-sound aquaculture methodologies is of prime concern to NOAA/NMFS. The Aquaculture and Enhancement Division conducts research to develop the necessary technologies for rearing marine finfish and shellfish to marketable size. The Division supports the Biotechnology Branch and Culture Systems and Habitat Evaluation Branch, which conduct these studies. The Culture Systems and Habitat Evaluation Branch develops methods for the rearing of finfish and shellfish using various technologies, including flow-through systems and recirculating seawater systems. The Branch also assesses the functional value of habitats as potential nursery areas for the placement of finfish and shellfish in stock enhancement projects. The Biotechnology Branch applies the disciplines of genetics, immunology, microbiology, and pathology to improve the growth and health of marine species and uses microbiology to investigate phytoplankton culture, nutrition, and the effects of harmful algal blooms on marine species.

3) Major Customers of the Laboratory

Industry: For the past 24 years, the Milford Laboratory has sponsored the Milford Aquaculture Seminar, and for the past 4 years the Milford Microalgal Workshop has been held as outreach activities for the aquaculture industry. Milford Laboratory staff and resources have routinely been available to answer questions about aquaculture and advise or train commercial culturists.

Academia: Collaborations with over 30 universities have included grant proposals, research, publications, advising students, and adjunct professorships. Advisory Boards of Bridgeport Vocational Aquaculture High School (CT) and The Sound School, New Haven, CT.

International: Several ICES Working Groups, UJNR , LMR Cooperative Agreement with China, US-France Bilateral Agreement in Oceanography, ENSA France, and CIBNOR Mexico: Contributions to these customers include primary responsibility for agreements between federal organizations; participation on panels, committees, and commissions; and program and research evaluations.

NOAA's Restoration Center: We assessed bay scallop restoration after the North Cape oil spill.

NOAA's NURP: Fisheries habitat projects.

EPA Office of Long Island Sound: Programs on environmental quality and lobster disease issues; also representation on the Management Committee..

EPA, Narragansett RI: Coastal eutrophication project and assessing the impact of the North Cape oil spill on young winter flounder in coastal ponds.

CT Department of Environmental Protection, Marine Fisheries Division: Milford Laboratory staff has collaborated with personnel on numerous projects on the habitats of fishes in Long Island Sound.

CT Department of Agriculture, Aquaculture Division: Collaboration on oyster health projects.

Local Government: Lab staff advise local towns and shellfish commissions in the Northeast.

4) Research Summary

Aquaculture Theme

Genetics

A long-standing and productive avenue of research at the Laboratory has examined the selective breeding of shellfish. Selective breeding can increase the frequency of genes for desirable traits, thus significantly enhancing the production of a species in an aquaculture system. A genetic selection and breeding program for bay scallops offers the possibility for increasing muscle-size by increasing the scallop growth rate. Selectively-bred scallops with distinctive shell markings have been developed at Milford and are now being used in bay scallop enhancement studies. Genetic considerations in producing cultured fish such as black sea bass and tautog include a concern that a genetic hybridization risk can occur if wild fish are supplemented with hatchery animals. Application of genetic techniques for selection of brood stocks for aquaculture can assure sufficient diversity to avoid restricted gene pools in hybridized stocks.

Culture – Husbandry

Decreased fishery landings have convinced many managers and scientists that the ocean's annual harvest has now exceeded its maximum sustainable yield. Capture fisheries can no longer meet the rising demand for fishery products, and imported seafood now far out-values exported fish products from US sources. Aquaculture of marine species has been identified as a major component in solving these deficiencies. Aquaculture-development policies have been adopted by NOAA and NMFS. The US lags behind other nations in the use of aquaculture to meet the growing demand for seafood in the global marketplace, and NOAA is committed to promoting the commercial rearing of a least seven new species within the next five years. The Laboratory has been identified as one of the key facilities for research in this priority area. Staff members have developed position papers outlining the benefits of three species for initial research: a bivalve mollusk, the bay scallop, and two finfish species, the blackfish or tautog, and the black sea bass. The bay scallop has considerable commercial value but there is limited production of this species in the US. American consumers depend mainly on imported scallops of several species to meet the market demand. Current technology is insufficient for scallop production to be profitable in the Northeastern US. By addressing seasonal limitations on growth and survival, labor costs, and environmentally-responsible culture practices, Milford is developing modern technology for commercial production of the bay scallop. In a similar fashion, Milford is developing modern, recirculating seawater systems for culturing tautog and black sea bass. These two species have a high market value and the wild populations are declining rapidly. Only the development of commercial aquaculture production will close the gap between demand and the wild catch.

Culture – Stock Enhancement

Declines in finfish and shellfish populations from historically-productive levels suggest exploration of the potential for stock enhancement. Planting aquaculturally-reared (hatchery-reared) juveniles in selected areas may help to re-establish self-sustaining, reproductive populations for recreational and commercial fishing. Enhancement programs currently are being used worldwide to assist in the restoration of finfish species to rebuild stocks and for bay scallops in areas where populations have suffered high mortalities associated with the brown tide or other factors. Success of these and other programs will depend upon improved knowledge of the life history, ecology and habitat requirements of the target species. We have been focusing on nursery habitats, which provide insights into natural recruitment processes, as well as toward initiating pro-active enhancement strategies. We have investigated strategies for bay scallop enhancement in coastal estuaries. Decreasing black sea bass and tautog stocks, and expectation of sustained exploitation, have prompted us to explore the potential for stock enhancement. Since these are structure-oriented species, seeding natural habitats or artificial ones with hatchery-reared fish is a promising strategy. Modern techniques for the identification (molecular genetic markers or implanted tags) of cultured stocks are being investigated to assist in the determination of the benefit of such releases. Rigorous experimental design is employed to identify strategies and document success or failure.

Nutrition

Microscopic algae, or phytoplankton, are the natural foods of many invertebrates cultured as human foods, including bivalve mollusks such as scallops, oysters, and clams, and are used in production and nutritional enhancement of live feeds used in marine finfish hatchery production. The Phytoplankton Trophic Interactions Project has two ongoing research objectives addressing knowledge and technology needs for the effective use of microalgae in aquaculture production: 1) To develop cost-effective technologies for production of high-quality microalgal feeds at commercial scale, and 2) To define nutritional requirements of aquaculture food chains employing microalgal feeds. To address the first objective of culture system development, we work in a unique facility designed specifically for this purpose, the Greenhouse for Research on Algal Mass Production Systems (GRAMPS). Research in GRAMPS is driven by a bioeconomic model and employs contemporary, process-control technologies to optimize culture performance, quality, and cost-effectiveness. Current research is focused on management of chemical water quality within algal production tanks to support maximal production of the intended algal crop, while suppressing living contaminants, such as "weed" algae and harmful bacteria, that may affect animals being fed. Customers for this research include all marine aquaculture concerns, including commercial, government, and academic, as essentially all require microalgal feeds for some portion of the production process. Technologies are transferred to users in peer-reviewed publications, presentations at various meetings, and an annual, 3-day, hands-on training course, the Milford Microalgal Culture Workshop. The second objective to define nutritional needs of aquacultured animals fed microalgae has been pursued in collaboration with academic partners contributing capabilities in biochemical analysis. Using a culture collection of over 200 pure strains of microalgae and a unique facility for production of pure, research-quality algae in large quantity, we have conducted controlled feeding experiments with several commercially-important molluscan shellfish to answer the three fundamental questions needed to feed them: "What? How much? And how often?" This research has transformed the selection of microalgal strains being used in US aquaculture from "species" to "biochemical" criteria and changed how marine hatcheries use microalgae. Knowledge gained from this research is communicated to customers as mentioned above, and also through direct provision of microalgal "seed" cultures to hatcheries and advice on their use to hatchery personnel.

Ecosystems Theme

Genetic Stock Identification

As part of a holistic approach to ecosystems-based management, accurate identification of genetic stocks of marine species is required to provide a view of the relationships between and within populations. Using a variety of methods (microsatellite DNA, AFLP, allozyme analysis), and in collaboration with researchers at the University of Connecticut, the University of Rhode Island, and the Chinese Academy of Sciences, the staff at the Laboratory has been investigating the genetic stock structure of the bay scallop, tautog, and black sea bass. Another objective of stock identification is to provide essential information for use in stock enhancement. It is desirable to use as brood stock only those animals whose genotype is essentially the same as the population to be enhanced, thereby preserving the diversity of the wild stock. A slight, but detectable, difference in genotype, or the use of a molecular or implanted tag also serves the purpose of making the cultured sock used for enhancement readily identifiable to determine the benefit of such releases and allows for the detection of hybridization between the wild and cultured groups.

Essential Fish Habitat (EFH)
Better understanding of the habitat requirements of young fishes is essential to make wise decisions about habitat protection and conservation. Fish survey and mark-recapture data, and spatially oriented Geographic Information Systems, are used to map fish distribution and abundance over time. These maps are overlaid with habitat characteristics that can clearly define EFH. For example, coastal stocks of winter flounder are estuarine-dependent during their first year of life and often must use highly perturbed, nearshore habitats as nursery areas. Unrealized fish production within this first year clearly results in a smaller harvestable stock. It is critical to determine how both the quality and quantity of our coastal habitats determine the size of fish populations. Laboratory staff have published research on habitat requirements and health of young fish in relation to eelgrass beds, marsh creeks, macroalgal depositional areas, and urban harbors. Recent research has focused on the role of natural hard-substrate reefs as fish settlement sites and habitat of young fishes.

Harmful Algae
Toxic and otherwise harmful algae are increasingly recognized as disruptors of marine food webs supporting production of living marine resources (LMR's). While accumulation of toxins affecting human consumers of shellfish has been studied extensively, direct effects of harmful algae upon marine organisms remain poorly understood. The Phytoplankton Trophic Interactions Project, within the Biotechnology Branch, has an ongoing research program addressing questions about how trophic interactions between harmful algae and the animals that eat or are otherwise exposed to them affect the physiology and population biology of consumer organisms. Further, we wish to understand how changes in marine food webs may be related to increases in the proliferation of harmful algal blooms worldwide. We are applying the same culture capabilities as used in aquaculture research to conduct experimental exposures of animals to harmful algae, and work in collaboration with academic and other colleagues to determine physiological, pathological, and other responses. Further, we conduct field experiments in harmful algal bloom-prone waters to ascertain that effects seen in laboratory exposures are relevant to natural interactions. We are applying advanced, biomedical tools to this research, especially fluorescence-linked, physiological probes analyzed by flow-cytometry, to measure nutrient status of individual phytoplankton cells, as well as to evaluate immune-system status of shellfish exposed to harmful algae. We were the first to demonstrate immune- system suppression in shellfish resulting from harmful algal exposure, both in the lab and in the field, and, working closely with colleagues in France, have developed and published many of the methods being used in

flow-cytometric analysis of shellfish immune status. Customers for this research include the international harmful algal research community, coastal resource managers, and those seeking to understand how trophic interactions affect ecosystems supporting LMR's.

Effects of Environmental Degradation on LMR's
Another research effort in this category is seeking to understand the effects of persistent organic pollutants (POP's) upon immune-status, and hence disease resistance, in oysters. Survival constrains production of molluscan shellfish worldwide, and diseases and parasites are a major source of mortality in both aquacultured and wild populations of many species. There is a strong suspicion that environmental degradation is related to disease resistance, but few studies have addressed this question directly. We are conducting laboratory and field studies to understand vectors of POP's from contaminated environments into oysters and how these compounds affect immune status of exposed oysters, using flow-cytometric, hemocyte analysis methods developed in our harmful algal program. Other recent disease-related studies have investigated possible causes of a large die-off of lobsters in Long Island Sound and have determined the frequency of skeletal anomalies in flatfish in relation to capture site. Customers for this research include coastal resource managers and organizations involved in restoration of impacted coastal waters.

5) Major Accomplishments in the Last 5 Years

- Demonstrated the successful application of genetics for stock enhancement and restoration efforts through selective breeding, by increasing the frequency of genetic markers or striped shells in bay scallops from 1-5% occurring naturally in a population to 50% in the selected population in just one generation.

- Demonstrated that a harmful algal bloom can affect the immunological, disease-resistance system in eastern oysters.

- Completing development of flow-cytometric methods for determining the nutrient status of individual phytoplankton cells in aquaculture-production cultures and in natural seawater samples.

- Conducting laboratory and field studies of the immune-system status of bivalve mollusks, with specific projects addressing effects of toxic algae and persistent organic pollutants upon disease resistance of oysters.

- Completing the development of a molecular probe for the detection of a fungal parasite in bivalve larvae.

- Inducing spawning of black sea bass by using only temperature and light manipulation

- Optimizing physical and water-chemistry parameters for microalgal mass cultures and an intensive, recirculating seawater system for nursery culture of bay scallops.

- Describing the ecological functions of a hard substrate reef as a larval fish settlement site and habitat for young fish.

6) Legal Mandates

National Aquaculture Act of 1980
Presidential Proclamation #5030, 1983 (U.S. jurisdiction over aquaculture development in the Exclusive Economic Zone
Coastal Zone Management Act
NOAA Aquaculture Policy (1998)
Department of Commerce Aquaculture Policy (1999)

Contact Person: Ronald Goldberg, 203-882-6546, Ronald.Goldberg@noaa.gov