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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: CONNECTICUT

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Industry Trends and Outlook

Connecticut is a major producer of farm-raised shellfish, including eastern oysters (*Crassostrea virginica*) and northern quahogs (*Mercenaria mercenaria*), valued at greater than $16 million in 2006. The northern quahog (hard clam) is the number one product in terms of production and value. There are 46 companies cultivating shellfish on over 77,000 acres of town and State grounds in Long Island Sound. Two commercial hatcheries serve as shellfish seed sources, though the majority of the industry still relies on natural recruitment.

Each coastal town in Connecticut has a municipal shellfish commission consisting of government-appointed members from its community. These commissions are responsible for managing their local shellfisheries resources, as well as recreational and commercial shellfishing activities. A number of these commissions grow shellfish for enhancement or restoration purposes.

A small, but expanding commercial freshwater finfish industry grows mainly trout and baitfish, and contributes approximately 5% of the aquaculture revenues. The Department of Environmental Protection operates two trout hatcheries for stock enhancement, and a salmon culture facility for restoration.

Several of the State's Regional Vocational Agriculture Schools and specialized marine and aquaculture high schools participate in husbandry and restocking efforts in cooperation with producers and state agencies.

Oyster culture bags in coastal Connecticut. (Photo: Tessa Getchis)

Commercial Species List

- Eastern oyster (*Crassostrea virginica*)
- Northern quahog (*Mercenaria mercenaria*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Brown trout (*Salmo trutta*)
- Brook trout (*Salvelinus fontinalis*)
- Golden trout (*Oncorhynchus aguabonita*)
- Largemouth bass (*Micropterus salmoides*)
- Bluegill sunfish (*Lepomis macrochirus*)
- Brown bullhead (*Ameiurus nebulosus*)
- Black crappie (*Pomoxis nigromaculatus*)
- Yellow perch (*Perca flavescens*)
- Pumpkinseed (*Lepomis gibbosus*)
- Fathead minnow (*Pimephales promelas*)
- Golden shiner (*Notemigonus crysoleucas*)
- Grass carp (*Ctenopharyngodon idella*)

Emerging Issues and Critical Needs

- Environmental effects of shellfish aquaculture
- Environmental effects of utility-crossing installations in Long Island Sound
- Innovative packaging, labeling and marketing for cultured shellfish
- Availability of disease-resistant oyster seed
- Economic impact of combined sewer overflows and weather events on shellfish production
- Negative public perception of aquaculture gear and associated marker buoys
- Streamlining the permitting process for coastal aquaculture
- Increased eligibility for USDA farm assistance programs (loans, grants, crop insurance, etc.)
- Impact of Viral Hemorrhagic Septicemia

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

Aquaculture Research

The University of Connecticut (UConn) is the Land Grant and Sea Grant Institution for the State of Connecticut. Aquaculture research is conducted within various departments within the Colleges of Agriculture and Resource Economics, and Liberal Arts and Sciences. The following projects are in progress:

- **The growth and feeding of *Strombidium stylifer*, a marine ciliate that may be of use as a live feed in mariculture** *Strombidium stylifer*, a planktonic oligotrich ciliate, has been selected for its potential use as a food organism for marine aquaculture. It holds promise, especially in parts of the world that do not have access to culture collections or funds to purchase and maintain commercially-available feeds.
- **The effects of oyster depuration gear on eelgrass, sediment and water quality parameters** Concerns have arisen over the potential effects of shellfish aquaculture gear on the marine environment, and in particular to sensitive species such as submerged aquatic vegetation. The objective of this study is to determine the degree of impacts of oyster depuration cages on sediment and water quality parameters, and eelgrass abundance in eastern Long Island Sound.
- **The effects of marine invasive species on the ecology of economically important shellfish species** The increasing number and high abundance of introduced fouling species, such as ascidians, are threatening both natural and cultured populations of commercially-important shellfish. Objectives are to determine the degree to which the invasive ascidians affect the growth and mortality of shellfish that they foul, and to determine the effectiveness of biological control to prevent or impede the recruitment of ascidians into shellfish populations.
- **Linking marine pathogens to molluscan shellfish** Within the past decade, several marine pathogens have caused high disease prevalence and mortality in cultured molluscan shellfish. Infections have led to widespread economic disaster when diseased shellfish have been transferred to naïve growing areas. This project will investigate the pathways associated with transfer of these disease agents, as well as methods to prevent the transfer of molluscan shellfish diseases.
- **Potential for transport of harmful algae via shellfish transfers** Restoration and aquaculture of bivalve shellfish frequently involves movement of the shellfish from one body of water to another. In collaboration with scientists from the National Marine Fisheries Service Milford Laboratory and North Carolina State University, researchers have been investigating the possible movement of harmful algal bloom (HAB) species via shellfish. It has been shown that HAB species pass intact and viable through the digestive system of shellfish. Researchers are working with the shellfish industry to develop best management practices to avoid unwanted introductions of HAB species.
- **Oyster immunology** A study on the defense mechanisms of oysters, in particular how they relate to resistance to *Perkinsus marinus*, has been conducted in collaboration with scientists from the Connecticut Department of Agriculture. Results to date have shown that apoptosis, the ability of cells to undergo “cell suicide” once infected, may be key in the resistance to *Perkinsus marinus*. Research is also being performed on the effects of pollutants on those defense mechanisms.
- **Development of an integrated recirculating**

aquaculture system for nutrient bioremediation in urban aquaculture The objectives of the project are to: 1) demonstrate the performance of a continuously operating, integrated recirculating aquaculture system, from which finfish and marine plant biomass can be harvested; 2) demonstrate that acceptable water quality can be maintained and that effluent nutrient levels are well below guidelines being developed by the Environmental Protection Agency (EPA); 3) compare four candidate native species of *Porphyra* to act as biofilters and as crops; and 4) examine nutrient dose-response relationships to determine the maximum finfish biomass that can be maintained for a given marine plant biomass (and biofilter area).

The Connecticut Department of Agriculture, Bureau of Aquaculture (DA/BA) is the lead State agency responsible for commercial shellfisheries and aquaculture. The Bureau of Aquaculture and Laboratory administers the following programs: shellfish sanitation, laboratory diagnostic services, shellfish habitat management and restoration, and aquaculture development and coordination. The following research and monitoring projects are in progress:

- **Clam disease monitoring** Samples of northern quahogs are collected each spring for pathological assessment. Prevalences of infectious agents such as QPX and *Chlamydia*, and histopathological changes are recorded.
- **Soft shell clam disease monitoring** Two types of neoplasia, a malignant (leukemia) and a benign tumor (papilloma), are studied in the soft shell clam.
- **Oyster disease monitoring** Sampling sites are monitored each fall for the presence of pathogens and histopathological changes in oysters. Prevalence of viral gametocyte hypertrophy, Rickettsia, *Roseovarius crassostrea* (JOD), *Haplosporidum nelsoni* (MSX), *H. costale* (SSO), *Perkinsus marinus* (Dermo), *Nematopsis ostrearum*, ciliates, trematodes, and pea crabs are recorded, as well as histopathological changes such as inflammatory responses, degenerations, cell and tissue death, growth derangements, hemodynamic and fluid derangements, and neoplasia.
- **Disease-resistant oysters** Disease resistant oysters (*Crassostrea virginica*) have been produced by selective breeding since the MSX epizootic of 1997. Broodstock are tested for disease resistance for MSX, Dermo and JOD. This year oysters will be grown and tested for pathogens as part of a collaborative study with scientists from Maine, Massachusetts, Rhode Island and New Jersey.

State Shellfish Pathologist Inke Sunila monitors disease prevalence and growth rates of cultured oysters in Long Island Sound. (Photo: Tessa Getchis)

- **Epizootic branchial adenocarcinoma in oysters** A collaborative study with Stony Brook University describes lesions in Long Island Sound oysters using light and electron microscopy.
- **Enteric adenocarcinoma in oysters** A collaborative study with the EPA Narragansett laboratory describes lesions recently found at low prevalence in Long Island Sound oysters. The study includes a ten-year sampling period in Connecticut and archived slides from EPA.
- **Apoptosis of *Perkinsus marinus* cells in oysters** This collaborative project with the Maryland Department of Natural Resources uses electron microscopy and *in situ* hybridization to study apoptosis, a type of cell death in cultured *P. marinus* (Dermo).
- **Immuno- and histopathological effects of toxic algal species (*Prorocentrum*, *Alexandrium*)** A study in collaboration with the National Marine Fisheries Service Milford Laboratory and scientists from Barcelona, Spain uses flow cytometry, histology, and *in situ* hybridization to determine the harmful effects of species which cause blooms on molluscan shellfish.

The National Marine Fisheries Service (NMFS) Milford 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.

The following include some of the major projects at the laboratory:

- **Cultivation methods for the rearing of finfish and shellfish to market size** These methods 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 reintroduce hatchery-produced finfish and shellfish into the natural environment are being evaluated.

- **Technological tools 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, methods, and tools, which are tested in practice.

Aquaculture Extension

Connecticut has four full-time Extension faculty within the Sea Grant and/or Cooperative Extension Programs who are dedicated all or in part to programs in fisheries and aquaculture. These include finfish and shellfish aquaculture specialists, a resource economist, and a seafood safety specialist. These specialists, based at several campuses within the University of Connecticut, have statewide responsibilities. The following is a summary of the major outreach projects:

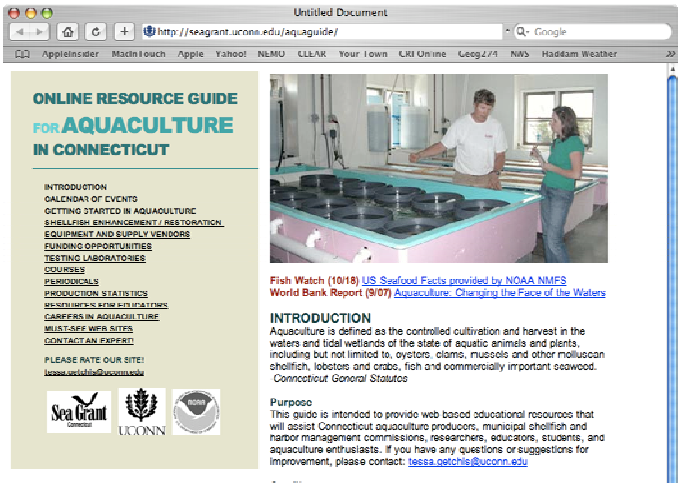
- **Online Resource Guide for Aquaculture in Connecticut** Connecticut Sea Grant has developed a comprehensive online aquaculture resource guide for stakeholders in Connecticut available at http://www.seagrant.uconn.edu/aquaguide. The guide includes practical information on aquaculture production, business development and seafood production tools, educational resources, journals and trade magazines, an event calendar, and contact information for extension, education and research specialists, as well as industry associations and private and government assistance agencies.

- **Partnering to streamline the marine aquaculture permitting process** Connecticut recently revised its marine aquaculture permitting process, which requires input and review by a number of local, state and federal agencies. The goal of this project was to familiarize growers with the new permitting system; to aid in streamlining the aquaculture permitting system in Connecticut. Three products have been drafted including: a new marine aquaculture application, a guide to the marine aquaculture permitting process, and a manual of standard operating procedures for permitting review for regulators.

- **New gear and species development** To contribute to the expansion of environmentally- and economically-sustainable freshwater and marine aquaculture industries in Connecticut and the Northeast, extension specialists and industry members have undertaken small-scale projects to investigate culture methods for new species including blue mussels, razor clams and ornamental corals. These projects have provided a new source of revenue to producers.

- **Hazard Analysis and Critical Control Points Program** HACCP is a food safety management program that first identifies and evaluates the risk of biological, chemical, or physical food safety hazards that may be associated with a particular species of fish or seafood product. The Connecticut and Rhode Island Sea Grant programs serve the seafood industry by jointly offering seafood HACCP training courses two to four times a year. Since 1997, we have trained more than 600 seafood processors, dealers, importers, and state and federal regulators in the principles and application of HACCP to seafood processing.

- **Northeast Aquaculture Conference & Exposition (NACE)** The biennial NACE, chaired by Connecticut extension specialists, is the premier event to learn about the Northeast region's aquatic farming industry. The program for NACE 2006



The Online Resource Guide for Aquaculture is a collaborative effort among Extension personnel, researchers and resource managers.

reflected the diversity of the aquaculture industry in the northeast U.S., with programs on shellfish, finfish and ornamentals, that suit both freshwater and marine businesses. The format combined over 100 traditional presentations, panels and poster sessions, along with the more informal and hands-on Technology Transfer sessions. More than 350 attendees from 20 U.S. states and Canada participated in NACE 2006. The top three attendee groups were industry, students and government officials. The trade show attracted 30 aquaculture equipment vendors and suppliers from across the country.

- **Increasing producer eligibility for USDA farmer assistance programs** Following a nationwide survey, it was determined that many shellfish aquaculture producers were ineligible for USDA farmer assistance programs such as non-insured crop disaster assistance, crop insurance, loans, grants or incentive programs. Extension is leading an effort, in collaboration with state and federal officials, to increase the eligibility of producers for these programs by revising eligibility requirements.

- **Northeast Aquaculture Extension Network (NAEN)** Connecticut Extension staff members lead the Northeast Aquaculture Extension Network, which is group of aquaculture extension specialists from throughout the northeast region. The goal of this NAEN is to produce and deliver accurate and credible science-based aquaculture information, educational materials and outreach activities to key stakeholders in a manner that is efficient and effective. The vision is to develop and disseminate high-quality outreach products that will facilitate NRAC's goal to increase public awareness of the social, economic and environmental importance of commercial aquaculture in the northeast U.S., and to increase the value and volume of aquaculture products cultured in the region.

- **Municipal shellfish commission assistance** Shellfisheries and aquaculture in town waters are managed by municipal shellfish and harbor management commissions in Connecticut. Commission members are volunteers appointed by town leaders. There is an ongoing need for training and the provision of educational resources to this user group. To this end, Extension has formed a partnership with municipal shellfish and harbor management commissions statewide and has established several avenues for communication within and among the commissions. Extension hosts an annual gathering and SHELLCOMM, a list-serve for these stakeholders. In 2008, Extension staff will provide Geospatial Information Systems (GIS) training to municipal officials so that they can use this tool to better plan for aquaculture activity within their local town waters.

The Northeast Aquaculture Conference & Exposition, held in Mystic, Connecticut, attracted 350 participants. (Photo: Tesssa Getcjos)

Aquaculture Education

Several specialized secondary schools offer aquaculture and/or marine science education, including the Bridgeport Regional Vocational Aquaculture High School and The Sound School in New Haven. A third school, the Marine Science Magnet High School, will have an aquaculture focus and is scheduled to be built in eastern Connecticut. Several Vocational-Agricultural and Vocational-Technical programs throughout the State offer coursework in aquaculture as well.

Currently, the University of Connecticut (UConn) and the University of New Haven offer minors in aquaculture business management. UConn also offers an aquaculture biology minor, and there is interest in developing an aquaculture major.

Mussel seed growth rates have been measured in several locations throughout Long Island Sound. (Photo: Larry Williams)

Research Contact Information

Name	Address	Specialty:
Walter Blogoslawski	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 walter.blogoslawski@noaa.gov	marine bacteriology, with specialty in shellfish hatchery diseases, including vibriosis
Diane Brousseau	Fairfield University (203) 254-4000 Ext. 2739 brousseau@mail.fairfield.edu	marine invertebrate ecology with a special interest in the ecology and pathology of commercial shellfish species
Christopher L. Brown	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6540 christopher.L.brown@noaa.gov	fish endocrinology, larval development, and molecular biology; aquaculture technology in developing nations
Thomas Chen	University of Connecticut Department of Molecular & Cell Biology (860) 486-5481 thomas.chen@uconn.edu	structure, evolution and regulation of growth hormone and growth factor genes in finfish and shellfish
Sylvain De Guise	University of Connecticut Department of Pathobiology (860) 405-9138 sylvain.deguise@uconn.edu	immunology and immunotoxicology of bivalve shellfish, crustaceans; defense mechanisms of oysters; effects of pollutants on oyster defense mechanisms
Salvatore Frasca	University of Connecticut Department of Pathobiology (860) 486-1138 salvatore.frasca@uconn.edu	mechanisms of disease principally by infectious agents involving aquatic animal species; investigation of disease pathogenesis and virulence factors
Richard French	University of Connecticut Department of Pathobiology (860) 486-5370 richard.french@uconn.edu	diseases and pathogenesis in wildlife species including fish, and some invertebrates; areas of study include neuropathology, neuroimmunology, dermotopathology and parasitology
Ronald Goldberg	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6546 ronald.goldberg@noaa.gov	molluscan aquaculture and habitat ecology
Robert Johnston	University of Connecticut Department of Agriculture & Resource Economics (860) 405-9278 robert.johnston@uconn.edu	environmental economics, natural resource economics, economics of marine and coastal resources, and non-market valuation
Hans Laufer	University of Connecticut Department of Molecular & Cell Biology (860) 486-4117 hans.laufer@uconn.edu	crustacean endocrinology

Research Contact Information (continued)

Name	Address	Specialty:
George McManus	University of Connecticut Department of Marine Sciences (860) 405-9164 george.mcmanus@uconn.edu	plankton ecology; aquaculture feeds
Shannon L. Meseck	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 shannon.meseck@noaa.gov	chemical oceanography, phytoplankton nutrient utilization
Lisa Milke	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 lisa.milke@noaa.gov	molluscan physiology and nutrition
Dean M. Perry	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 dean.perry@noaa.gov	finfish aquaculture: blackfish, black sea bass, scup culture. Live feeds culture: rotifers, brine shrimp
Robert Pomeroy	University of Connecticut Department of Agriculture & Resource Economics (860) 405-9215 robert.pomeroy@uconn.edu	financial analysis, marketing, production economics
Sandra Shumway	University of Connecticut Department of Marine Sciences (860) 405-9282 sandra.shumway@uconn.edu	shellfish biology, harmful algal blooms and impacts of biofouling on shellfish and aquaculture
Barry C. Smith	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 barry.smith@noaa.gov	microalgal mass culture, automation and control systems
Sheila Stiles	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 sheila.stiles@noaa.gov	genetics and breeding of fish and shellfish
Inke Sunila	Connecticut Department of Agriculture Bureau of Aquaculture (203) 874-0696 isunila@snet.net	shellfish pathology

Research Contact Information (continued)

Name	Address	Specialty:
Kumar Venkitanarayanan	University of Connecticut Department of Animal Science (860) 486-0947 kumar.venkitanarayanan@uconn.edu	inactivation of pathogenic microorganisms in foods using antimicrobials; development of molecular methods for rapid detection of food-borne microorganisms
Jason Vokoun	University of Connecticut Department of Natural Resource Management and Engineering (860) 486-0141 jason.vokoun@uconn.edu	kernel estimation of fish space and habitat use; conservation of fish habitat in stream ecosystems; fish species of special conservation concern
J. Evan Ward	University of Connecticut Department of Marine Sciences (860) 405-9073 evan.ward@uconn.edu	endogenous and exogenous factors that mediate the behavior and physiology of benthic, particle-feeding invertebrates
Robert Whitlatch	University of Connecticut Department of Marine Sciences (860) 405-9154 robert.whitlatch@uconn.edu	marine benthic population and community ecology; invasives and aquaculture
James Widman	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6508 james.widman@noaa.gov	shellfish culture, shellfish hatcheries, hatchery automation, recirculating culture systems, bay scallops, hard clams, oysters, winter flounder
Gary H. Wikfors	Northeast Fishery Science Center Aquaculture & Enhancement Division Milford Laboratory (203) 882-6500 gary.wikfors@noaa.gov	microalgae, molluscan nutrition, cellular immune function in molluscs
Charles Yarish	University of Connecticut Department of Ecology & Evolutionary Biology (203) 251-8432 charles.yarish@uconn.edu	seaweed aquaculture (open water and land-based); integrated multi-trophic aquaculture (IMTA) systems; bluefin tuna ranching

Extension Contact Information

Nancy Balcom	University of Connecticut Connecticut Sea Grant/ Cooperative Extension (860) 405-9107 nancy.balcom@uconn.edu	seafood safety; HACCP training; invasive species
Tessa Getchis	University of Connecticut Connecticut Sea Grant/ Cooperative Extension (860) 405-9104 tessa.getchis@uconn.edu	effects of shellfish aquaculture on the environment; permitting and policy; business planning

Extension Contact Information (Continued)		
Name	**Address**	**Specialty:**
Robert Pomeroy	University of Connecticut Connecticut Sea Grant (860) 405-9215 robert.pomeroy@uconn.edu	financial analysis; marketing; business planning
Lance Stewart	University of Connecticut Department of Extension (860) 405-9284 lance.stewart@uconn.edu	fisheries management
Education Contact Information		
Diana Payne	University of Connecticut Connecticut Sea Grant (860) 405-9278 diana.payne@uconn.edu	marine education; k-12 teacher training
State Aquaculture Coordinator		
David Carey	Connecticut Department of Agriculture Bureau of Aquaculture (203) 874-0696 davcarey@snet.net	aquaculture permitting
Aquaculture Industry Association(s)		
Barbara Gordon	Connecticut Seafood Council (860) 521-0545 ctseafoodcouncil@aol.com	seafood promotion and marketing
Testing Laboratories		
Inke Sunila	Connecticut Department of Agriculture Bureau of Aquaculture (203) 874-0696 isunila@snet.net	shellfish pathology
Rick Van Nostrand	Department of Environmental Protection Inland Fisheries Division (860) 622-2200 richard.vannostrand@po.state.ct.us	finfish pathology

Aquaculture Resources

Department of Agriculture, Bureau of Aquaculture
Leasing and permitting information for Connecticut aquaculture operations, education and research projects. http://www.ct.gov/doag

AQUAGUIDE—Online Resource Guide
Online resource guide for Connecticut producers, researchers, resource managers, municipal commissions, teachers, students, etc. http://www.seagrant.uconn.edu/aquaguide/

AQUACONN—Aquaculture Producer ListServ
Connecticut aquaculture producers may subscribe to the listserv by contacting tessa.getchis@uconn.edu
Post to: *AQUACONN-L@listserv.uconn.edu*

SHELLCOMM—Shellfish Commission ListServ
Shellfish and Harbor Management Commission members statewide may subscribe to the listserv by contacting tessa.getchis@uconn.edu
Post to: *SHELLCOM-L@listserv.uconn.edu*

Northeastern Regional Aquaculture Center
The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: DELAWARE

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Industry Trends and Outlook

Aquaculture production in Delaware is limited in terms of commercial producers. There are a handful of individuals involved with the industry to varying degrees. The largest single producer in the state (Blessing Aquaculture Farm in Houston) is growing tilapia for the live market and currently there is only one farm in production in this sector. Another established company (Delmarva Aquatics in Smyrna) specializes in the production of eggs, fry and fingerlings of hybrid and straight striped bass and yellow perch, and distributes a variety of other culture and wild finfish species. In addition to this operation, there are individuals involved with smaller scale production/distribution of various pond stocking species, American eel capture/hold/live-haul and crab peeling (shedding) operations. Delaware currently has no commercial shellfish or marine aquaculture, but oyster and hard clam aquaculture is part of a shellfish research, restoration and demonstration program being conducted by the Delaware Center for the Inland bays (CIB) with technical assistance from the Delaware Sea Grant Marine Advisory program and Delaware State University. Also, the Delaware Bay Oyster Restoration Task Force is working to revitalize the oyster population in the Delaware Bay.

Despite the small size of the current industry, interest in aquaculture as an alternative to, and diversification from, traditional agriculture production continues from both the Delaware Department of Agriculture and potential producers; however, the number of serious inquiries from prospective producers remains low. Identification of suitable species that can be raised in an environmentally sustainable and economically viable way in Delaware will likely change this.

The Delaware State University Aquaculture Research and Demonstration Facility in Dover. (Photo: Lori Brown)

The Delaware Aquaculture Act http://www.delcode.state.de.us/title3/c004/index.htm enacted in 1990 designates the Delaware Department of Agriculture as the lead state agency for aquaculture development. The Department has proposed a series of regulations for aquaculture in non-tidal waters http://www.state.de.us/research/register/april2002/proposed/5%20DE%20Reg%201864%2004-01-02.htm

Emerging Issues and Critical Needs

- Delaware does not have a state aquaculture plan or formally adopted regulations in place for either freshwater or marine aquaculture.
- No state policy has been developed for either shellfish or finfish in tidal (marine) waters.
- Federal and state policies on containment of Viral Hemorrhagic Septicemia (VHS) affecting live transport of fish is a significant concern.

that have not been formalized. No specific regulations exist for aquaculture in tidal waters. Shellfish or finfish aquaculture in tidal waters is presently subject to governance on a case-by-case basis under existing fishery statutes and regulations by the Delaware Department of Natural Resources and Environmental Control (DNREC).

Commercial Species List

- Channel catfish (*Ictalurus punctatus*)
- Crappie (*Pomoxis* spp.)
- Koi (*Cyprinus carpio*)
- Largemouth bass (*Micropterus salmoides*)
- Smallmouth bass (*Micropterus dolomieu*)
- Striped bass (*Morone saxatilis*)
- Sunfish (*Lepomis* spp.)
- Tilapia (*Oreochromis niloticus*)
- Yellow perch (*Perca flavescens*)
- Various minnows

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

Aquaculture Research

Delaware State University (DSU) operates an Aquaculture Research and Demonstration Facility on its campus in Dover, Delaware. The facility includes 34 ponds and a temperature and humidity controlled 14 m x 20 m wet laboratory. The lab houses five independent systems, in three configurations enabling rearing various life stages of many marine or freshwater species. Research efforts include:

- **Baitfish Aquaculture** As part of a continuing effort to foster the development of an environmentally and economically sustainable aquaculture industry in Delaware, baitfish aquaculture husbandry techniques are being developed for the saltwater baitfish, *Fundulus heteroclitus*, or mummichog.
- **Weakfish Aquaculture** Weakfish, a popular food fish, are impacted by fisheries and habitat loss in their nursery habitats in the mid-Atlantic region. The potential for captive rearing programs for weakfish warrants serious consideration, and efforts are underway. Therefore, to determine experimentally derived, baseline information on weakfish production is fundamental to captive rearing (larval rearing, weaning, growth).

The USDA Agricultural Research Service (ARS) maintains an Oyster Virology Laboratory (Microbial Food Safety Research Unit) on the DSU campus. http://www.ars.usda.gov/SP2UserFiles/Place/19353000/PDFFiles/CRIS045.pdf. The research program is focused on the development of molecular and biochemical detection, and intervention methods for bacterial and viral pathogens in oysters and other aquaculture products.

Research at the University of Delaware Graduate College of Marine and Earth Studies (CMES) in Lewes, Delaware includes the following:

- Development of genetic markers in eastern oyster (*Crassostrea virginica*) for breeding programs
- Mapping of disease-resistance genes for aquaculture and fisheries restoration and stock enhancement
- Applied field research and demonstration to evaluate the use of aquaculture methods for

Disease-resistant oysters are being used for stock enhancement and restoration. (Photo: John Ewart)

shellfish restoration and stock enhancement

- Oyster disease research (pathogen detection and diagnostics using PCR methods)
- Development of a governance framework for marine aquaculture in the U.S. Exclusive Economic Zone (EEZ)
- Seafood safety and post harvest treatment using high hydrostatic pressure.

Aquaculture Extension

Delaware Cooperative Extension and Delaware Sea Grant Marine Advisory Program both have aquaculture extension responsibilities in Delaware. Delaware Cooperative Extension and Sea Grant are separate, independent programs, but both specialists collaborate to provide information and other extension services to current and prospective aquaculturists, state agencies and decision makers, Agriculture Education program secondary school students, and the general public. A Seafood Technology Specialist for the Delaware Sea Grant Marine Advisory program conducts public outreach and training on Hazard Analysis and Critical Control Points (HACCP) program and seafood nutrition, preparation and safety.

Delaware State University

Over the last two years, DSU has organized aquaculture sessions for current and prospective producers at the Delaware Agriculture Week (2006 and 2007), and taken their traveling display to the East Coast Commercial Fishermen's and Aquaculture Exposition sponsored by the Maryland Watermen's Association, the Delaware State Fair and University of Delaware's Coast Day annual open house at the College of Marine and Earth Studies campus in Lewes, Delaware.

Beginning last spring, Delaware State University has partnered with the University of Maryland and West Virginia University to obtain funding through the USDA's Sustainable Agriculture Research and Education (SARE) program to demonstrate the economic and environmental benefits of integrating aquatic plant culture with aquaculture. The project seeks to provide several educational opportunities around the region via workshops, tours of integrated culture systems in all three states, and individual technical support to assist in implementation. After the first field season, DSU has developed a Web site, hosted a technology transfer session at NACE 2006 and have expanded the scope to evaluate additional plant species.

Hatchery-raised clam seed. (Photo: John Ewart)

Delaware Sea Grant Marine Advisory Program Activities

The Delaware Aquaculture Resource Center (DARC) Home page http://darc.cms.udel.edu is an expanding archive of links, resources and other information about aquaculture in Delaware and the Mid-Atlantic region. The Web site is a member of the DOC/NOAA Sea Grant Network of Aquaculture Information Services (NAIS). Other NAIS collaborators include the Aquaculture Network Information Center (AquaNIC), the National Sea Grant Library, DOC/NOAA Aquaculture Information Center, Maryland Sea Grant, Illinois-Indiana Sea Grant and the Mississippi-Alabama Sea Grant Consortium.

The Delaware Sea Grant Marine Advisory program has been conducting field research and demonstration work since 1998 in collaboration with the Delaware Center for the Inland Bays (CIB), a non-profit community-based organization and member of the National Estuary Program. The goal of the program is to determine how best to integrate the use of aquaculture technologies for shellfish restoration and stock enhancement into the overall management of Delaware's three coastal (known locally as "inland") bays. Other program participants include the University of Delaware College of Marine and Earth Studies, Delaware State University, Delaware Department of Natural Resources and Environmental Control (DNREC) and the regional office of the U.S. Environmental Protection Agency (EPA) in Philadelphia. Sussex County government, local municipalities such as Fenwick Island, Delaware and other community groups and volunteers are also actively involved with funding support, donations, materials, supplies, and other in-kind services.

As part of the cooperative shellfish research and demonstration effort, a pilot-scale oyster gardening project was initiated during summer 2003 to produce juvenile oysters for field restoration. Fifteen Inland Bay gardening sites were established in residential lagoon communities around the estuary and twenty-one coastal resident volunteers were trained to raise oysters in floating baskets (Taylor floats) attached to their docks. As of 2007, oyster gardening has expanded rapidly into a community-based program with 105 locations involving 150 volunteers. The program has demonstrated that environmental conditions in all areas of the estuary will support oyster growth, especially in residential lagoon systems, generally characterized by degraded water quality. Oyster gardens perform well in these marginal environments, and also provide excellent local habitat for juvenile fish and other macro-invertebrates. Volunteers and middle/secondary school students participating in the program and coastal community residents are also educated about the impacts of excess nutrient input (eutrophication) on estuarine water quality and the important ecological role of filter feeding bivalve shellfish. A Web site http://darc.cms.udel.edu/ibog provides additional information about the program and related shellfish research, demonstration and restoration work.

Aquaculture Education

Neither the University of Delaware nor Delaware State University offer degrees in aquaculture, although DSU's Department of Agriculture and Natural Resources offers both graduate and undergraduate degrees in related subject areas (see table 1).

Table 1. DSU Degree Programs

Degree	Course Title
B.S. in Fisheries / Wildlife Management (Fisheries Option)	Aquaculture Fish / Wildlife Management Ichthyology Fisheries Science Environmental/Wildlife Law Fisheries Management
M.S. in Natural Resources (Thesis)	Population Biology Ichthyology Fisheries Policy Thesis Research

In addition to the formal educational opportunities listed here, the DSU Aquaculture Research and Demonstration Facility relies heavily upon students to manage and conduct the various research and demonstration projects, affording them the opportunity to learn aquaculture 'hands-on.' Similar hands-on aquaculture learning opportunities exist throughout the state at the high school level through the AgriScience education program administered by the Delaware Department of Education.

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Pat Gaffney	College of Marine and Earth Studies University of Delaware (302) 645-4364 pgaffney@udel.edu	oyster genetics and development of genetic markers for disease resistance and restoration/stock enhancement
David H. Kingsley	USDA Agricultural Research Service Eastern Regional Research Center Microbial Food Safety Research Unit (302) 857-6406 dkingsley@desu.edu	molecular & biochemical detection and intervention methods for bacterial and viral pathogens in oysters and other aquaculture products

Research Contact Information (continued)

Name	Address	Specialty:
Adam Marsh	University of Delaware College of Marine and Earth Studies (302) 645-4367 amarsh@udel.edu	impact of Dermo on larval recruitment; characterization of the molecular response of a larva to the presence of *Perkinsus. marinus*, to identify biochemical markers that may provide disease resistance
Dennis McIntosh	Delaware State University (302) 857-6456 dmcintosh@desu.edu	freshwater and marine aquaculture; water quality; integrated aquaculture/agriculture systems; aquaculture effluents; recirculation technology
Gulnihal Ozbay	Delaware State University (302) 857-6476 gozbay@desu.edu	shellfish, water quality, harmful algal blooms
Gary Richards	U. S. Department of Agriculture Agricultural Research Service Eastern Regional Research Center Microbial Food Safety Research Unit (302) 857-6419 grichard@desu.edu	molecular & biochemical detection and intervention methods for bacterial and viral pathogens in oysters and other aquaculture products

Extension Contact Information

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Doris Hicks	University of Delaware Delaware Sea Grant Marine Advisory Service (302) 645-4297 dhicks@udel.edu	seafood safety and processing, sensory evaluation, and product development
Dennis McIntosh	Delaware State University (302) 857-6456 dmcintosh@desu.edu	freshwater and marine aquaculture; water quality; integrated aquaculture/agriculture systems; aquaculture effluents; recirculation technology

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State Aquaculture Coordinator(s)

Orlando Camp	Delaware Department of Agriculture (302) 698-4600 orlando.camp@state.de.us	

Aquaculture Resources

Delaware Aquaculture Resource Center (DARC) An expanding archive of links, resources and other information about aquaculture in Delaware and the Mid-Atlantic region. http://darc.cms.udel.edu

Delaware Aquaculture Act (1990) http://www.delcode.state.de.us/title3/c004/index.htm

Delaware Bay Oyster Restoration http://www.delawareestuary.org/onthegroundactivities/oysterrevitalization.asp

Delaware Center for the Inland Bays (CIB) http://www.inlandbays.org/

Delaware State University Aquatic Sciences Program http://cars.desu.edu/aqua-sci/

Partnership for the Delaware Estuary http://www.delawareestuary.org/

Northeastern Regional Aquaculture Center The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: MASSACHUSETTS

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Industry Trends and Outlook

Commercial aquaculture in Massachusetts occurs in freshwater and marine waters. Freshwater finfish and marine shellfish are also cultured by governmental agencies for release into public waters. In 2005, Massachusetts was the seventh largest producer of cultured shellfish in the U.S. with almost 1,000 acres cultivated, reported sales topping $5.2 million, and over 30,000 bushels of oysters, and 25,000 bushels of quahogs marketed by over 250 shellfish farmers. According to the last Census of Aquaculture, the number of shellfish farms in Massachusetts has grown by 47% from 1998 to 2005 with an increase in sales of 57% over the same time period. Oyster sales, in particular, exploded, increasing 165% during that time, reflecting production from both established and new farms. Since 1996, oysters have been the primary species contributing to the establishment of a number of new shellfish farming communities in Barnstable Harbor, Duxbury Harbor, Katama Bay in Edgartown and the Dennis flats, as well as by the Wampanoag Tribe of Aquinnah. A modest, but growing commercial production of soft-shell clams is also being pursued. Production of freshwater finfish targets food fish, live bait, ornamental and recreational markets. Total value of the industry in 2005 exceeded $9 million.

An oyster farmer checks his oyster seed (Photo: Diane Murphy)

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations, and concerned stakeholders all play a role in addressing industry needs. The following sections outline new initiatives and recent accomplishments in these areas.

Emerging Issues and Critical Needs

- Public perceptions of aquaculture and aquaculture products have been tainted by misinformation generated by special interest groups. As a result, there is resistance to industry growth as well as market barriers. Public education and informing/enlisting policy-makers are crucial to continued growth of aquaculture in Massachusetts and elsewhere.

- Because of coastal demographics and current use patterns, significant industry growth in Massachusetts will require (1) recognition that a working waterfront is integral to coastal states and aquaculture is a proper, sustainable pursuit and (2) the adoption of offshore techniques. Opportunities currently exist that produce high value products for niche markets such as oysters and quahogs, and for larger-scale production such as submerged longline mussel culture, but technology transfer and candid dialogue are needed.

- Space allocations will be needed for any activities in State waters and will require outreach to other user groups and to the general public. Partitioning a traditionally, and often constitutionally, designated common resource into portions for the greater common good is needed and will require candid discourse and compromise.

- As the farmed oyster industry has grown, aquaculturists have become increasingly concerned about finding and maintaining markets. It will be critical that Massachusetts shellfish producers establish a niche as a premium product with a high market value.

- The majority of the members of the Massachusetts aquaculture community are small, family-run farms, often operated on slim margins. Any improvements in profitability (e.g., production of triploid oysters, disease resistance stocks) can have dramatic effects upon this community, and therefore warrant our attention.

Commercial Species List

- Eastern oyster (*Crassostrea virginica*)
- Northern quahog (*Mercenaria mercenaria*)
- Soft-shell clam (*Mya arenaria*)
- Bay scallop (*Argopecten irradians*)
- Barramundi (*Lates calcarifer*)
- Brook trout (*Salvelinus fontinalis*)
- Brown trout (*Salmo trutta*)
- Brown bullhead (*Ameiurus nebulosus*)
- Largemouth bass (*Micropterus salmoides*)
- Golden shiner (*Notemigonus crysoleucas*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Tilapia (*Oreochromis niloticus*)
- Yellow perch (*Perca flavescens)*

Aquaculture Research

Commercial aquaculture was largely confined to small-scale shellfish farming up until the early 1990's with most farms located within Barnstable County. Cape Cod Cooperative Extension's (CCCE) Marine Program has been working with these shellfish farmers for almost 40 years with most research being field based. With the increase in offshore fishery closures and mounting interest in aquaculture, the Commonwealth of Massachusetts established and funded three aquaculture centers in 1996: the Southeastern Massachusetts Aquaculture Center (SEMAC), the Northeastern Massachusetts Aquaculture Center (NEMAC), and Western Massachusetts Center for Sustainable Aquaculture (WMCSA). In addition, the Massachusetts Institute of Technology Sea Grant Hatchery and Marine Education Center (MITSGH/MEC) is located in Gloucester, MA, and aquaculture research is conducted at Woods Hole

Scallops cultured on Martha's Vineyard. (Photo: Amandine Surier)

Oceanographic Institution (WHOI), the University of Massachusetts (UMASS) at Dartmouth's School for Marine Science and Technology in New Bedford, the Martha's Vineyard Shellfish Group (MVSG) in Tisbury, the Wampanoag Aquinnah Shellfish Hatchery, and at the Marine Biological Laboratory (MBL) Marine Resources Center. There are several private hatcheries that conduct their own research. In 2007, SEMAC and NEMAC partnered with the Massachusetts Aquaculture Association, the Martha's Vineyard Shellfish Group, and the Marine Biological Laboratory to form the Massachusetts Shellfish Aquaculture Innovation Consortium (MSAIC).

NEMAC is based at the Cat Cove Marine Laboratory, operated by Salem State College. The 5,500 square foot laboratory rests on a 16-acre site adjacent to Smith Pond. The Laboratory includes a classroom, analytical lab, shellfish hatchery, algal culture room, and finfish culture system. Most research efforts have focused on soft-shell clams, but mussels, green crabs, urchins, striped bass, summer and winter flounder, cod, rainbow trout, tilapia, largemouth bass and yellow perch have been examined experimentally. The following research projects are being conducted (those marked with an asterisk(*) are major recent research accomplishments):

- Culture protocols for soft-shell clam spawning, nursery, and growout*
- Restoration and enhancement of soft-shell clam populations in Boston Harbor*
- Spawning and nursery success of soft-shell clams from Cape Cod and Cape Ann*
- Culture protocols for red hake
- Open ocean culture of blue mussels
- Characterization of green crab populations in the Rowley River
- Manipulation of green crabs to induce molting
- Use of macroalgae as a lipid and protein substitute in salmonid rations

CCCE and SEMAC have lab and work space at the Marine Program Field Station, primarily for conducting research in conjunction with shellfish farmers and local natural resource managers. In addition, SEMAC and CCCE maintain a shellfish research and demonstration site in the town of Dennis. Space is also utilized at the Massachusetts Maritime Academy shellfish hatchery, at the Eastham Aquaculture Technology Training Center, which houses a large recirculating system. SEMAC and CCCE also work closely with the Marine Biological Laboratory on a number of projects which allows for research access to a highly sophisticated marine animal holding facility and marine pathology lab. The following research projects are being conducted (those marked with an asterisk(*) are major recent research accomplishments):

The NorthEastern Massachusetts Aquaculture Center and Salem State College have collaborated to restore soft-shell clams to the North Shore region. (Photo : Joe Buttner)

- Development of a quantitative measure of shellfish habitat*
- Identification of factors affecting QPX prevalence*
- Utilization of microsatellite genetic markers to differentiate offspring of bay scallop broodstock*
- Shellfish research farm network, where research is conducted in collaboration with farmers. Projects include assessing triploid oyster growth, testing alternative species, and testing disease resistance in local strains of oysters
- Testing of barriers to oyster drills
- Test of factors affecting QPX disease in cultured quahogs
- Quantifying prevalence and intensity of shellfish diseases
- Use of pediveligers for onsite shellfish restoration projects
- Use of eelgrass seeding for habitat restoration
- Utilization of microsatellite markers to differentiate offspring of bay scallop broodstock
- Community-based oyster remote-set projects as a potential method to improve marine water quality
- Potential use of recycled plastic lumber in aquaculture applications
- Potential use of crabs and other grazers to control biofouling of shellfish gear
- Comparison of the various methods used for over-wintering oysters
- Identifying and monitoring the presence and abundance of phytoplankton communities at selected sites within the Cape Cod Region

WMCSA supports and promotes the development of the freshwater finfish aquaculture industry in the state, facilitating industry expansion and educating the public about the opportunities and benefits of aquaculture. Collaborations have been developed with U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey, Massachusetts Department of Agricultural Resources and Massachusetts Division of Fish and Game. WMCSA on-farm research projects have included:

- Cage culture feasibility studies
- Suitability of soy-based feeds for trout and largemouth bass
- Implications of vaccinations for furunculosis

MITSG/MEC develops and maintains recirculating and flow-thru aquaculture systems to conduct research on egg, larval and juvenile life stages of marine fishes. Winter flounder and black sea bass are the species of focus. MITSG has also developed an eelgrass cultivation program for Massachusetts.

MITSG's Offshore Aquaculture Engineering Center (OEAC) specializes in the development of production technology for offshore operations. The following research projects are being conducted (those marked with an asterisk(*) are major recent research accomplishments):

- Robofeeder: autonomous cage-mounted feeder for offshore aquaculture*
- Single-Point Mooring (SPM) for offshore cages that provides submergence in extreme current*
- Underwater acoustic deterrent against duck predation at mussel farms*
- Techniques for diverless rotation of an offshore cage for cleaning and harvesting*
- Pilot-scale tests of Ocean Drifter
- Auto-submerging 100 cubic meter cage for offshore aquaculture in China
- Diverless methods for offshore cage operations
- Methods to reduce duck predation on mussel farms

MVSG is a consortium of the Shellfish Departments of the six towns on Martha's Vineyard. It operates both a solar-assisted shellfish hatchery on Lagoon Pond in Tisbury and a shellfish nursery on Chappaquiddick Island in Edgartown. The following research projects are being conducted:

- Development of triploidy in bay scallops
- Production of a Dermo-resistant strain of oyster
- Development of cageless culture of shellfish with marine adhesives
- Investigation of the feasibility of offshore mussel culture

The MBL in Woods Hole has both a world-class pathology laboratory and an animal holding facility. The pathology lab is equipped for histopathology, disease testing and analysis. The Marine Resources Center of the Marine Biological Laboratory is a 32,000 square foot state-of-the-art facility capable of housing and culturing a number of vertebrate and invertebrate marine organisms. An 800 square foot research shellfish hatchery and floating upweller shellfish nursery is established at the MBL. The following research projects are being conducted (those marked with an asterisk(*) are major recent research accomplishments):

- Development of a fast, sensitive assay for QPX*
- QPX genetic analysis
- Locally developed oyster broodstock
- Restoration of the surf clam fishery
- Production of alternative species

Aquaculture Extension

Extension is the major focus of the three regional aquaculture centers, which often collaborate together on inter-regional projects. Extension activity is also an integral part of the MITSGH/MEC program.

NEMAC extension efforts focus on the North Shore of Massachusetts. With NEMAC assistance, a fledgling soft-shell clam aquaculture effort has materialized, initially on the North Shore and subsequently throughout the entire coastline. Best management practices for soft-shell clam culture as well as marketing materials have been developed by NEMAC with industry. A website and newsletter are produced and disseminated, and list-serves are managed by NEMAC staff.

WMSCA and NEMAC collaborate to assist growers producing fish in ponds and integrating bass culture into cranberry bogs. For instance, on-site assistance with stocking and water quality management are provided and fingerling bass are grown through a network of secondary schools from two to eight inches, when they attain a size suitable for stocking in cranberry bogs.

WMCSA provided leadership for the renovation of an abandoned USFWS hatchery in Monterey. The Berkshire Fish Hatchery, which cultures brown and rainbow trout and Atlantic salmon, is now the only USFWS hatchery staffed entirely by volunteers.

WMCSA also provides technical support for schools involved in the Atlantic Salmon Egg Rearing Program (ASERP) and coordinates field trips to the Berkshire Fish Hatchery. WMCSA has been active in the design and technical operation of two new

aquaculture facilities in the state: a largemouth bass fingerling operation in Northfield and a bass/trout aquaponics facility in East Sandwich. A publication, *Best Management Practices for Finfish Aquaculture*, was developed and published by WMCSA.

SEMAC, working with Cape Cod Cooperative Extension and Woods Hole Oceanographic Sea Grant, has offered a number of workshops specifically targeting shellfish farmers. This series, *Improving Shellfish Production*, focuses on applied information and has been very successful. SEMAC has also developed water-proof, glove-compartment-sized brochures for shellfish farmers, describing common predators, pests and diseases. Additionally, SEMAC and Cape Cod Cooperative Extension have provided workshops and meetings which allowed industry members to obtain information about the US Department of Agriculture Risk Management Agency (USDA RMA) crop insurance program for hard clams, and the potential use of USDA RMA Adjusted Gross Revenue-Lite insurance by shellfish farmers. SEMAC works closely with the region's shellfish farmers and natural resource managers to provide technical assistance. The first manual, *Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts*, was produced and distributed to the aquaculture industry as well as municipal offices throughout the southeastern Massachusetts region. SEMAC, along with CCCE, established three water quality monitoring stations outfitted with state of the art 'YSI' instruments to record water condition data every 20 minutes. Two of the sites relay real-time data via satellite to the Web. SEMAC publishes a periodic newsletter as well as maintaining it's presence through a website.

Since 1996, a large potion of the SEMAC outreach budget has been directed toward direct industry support with financial assistance provided through both mini-grant and scholarship programs.

MITSGH/MEC offers extension through demonstration of larval culture and the integration of aquaculture into classrooms throughout the state. Eelgrass culture has also become a large part of MITSG/MEC extension efforts due to the City of Gloucester's sewer pipe upgrades in Gloucester Harbor. In collaboration with the U.S. Environmental Protection Agency, the Massachusetts Coastal Zone Management and the Massachusetts Division of Marine Fisheries, MITSGH/MEC provides assistance in eelgrass culture and research protocols as well as facilitates the experimental systems used to over winter eelgrass. MIT Sea Grant's Offshore Aquaculture Engineering Center is a research and technology transfer center that focuses on the development of technologies for industrial-scale aquaculture in the U.S. Exclusive Economic Zone. OAEC provides engineering support to U.S. companies engaged in offshore fish and shellfish farming and to U.S. companies providing hardware and systems for offshore aquaculture worldwide.

Blue Streams, a trout farm in Barnstable, grows trout in raceways that were originally constructed one hundred-fifty years ago. (Photo: Craig Hollingsworth)

Aquaculture Education

Education is a critical component of each of the Massachusetts Aquaculture Centers and considerable collaboration occurs with workshops and demonstration projects. Each center maintains a website (see "Aquaculture Resources" at the end of this report) and several facilities open their doors for tours; for instance, MITSGH/MEC has over 10,000 visitors annually.

NEMAC, through Salem State College, offers undergraduate training in aquaculture as a concentration in the Department of Biology; graduate courses and opportunities for Directed Studies (for non-traditional students such as high school students, displaced fishers and pensioners) are also offered. A small grants program is available for teachers (K-12) to access for supplies, equipment and other resources to facilitate integration of aquaculture into the classroom. Over 90 teachers have participated in summer workshops and over a dozen schools have established some form of aquaculture-based instruction.

Essex Agriculture High School in collaboration with MITSG, is conducting aquaculture research on marine and freshwater fish and invertebrate species in their Fish Barn. They raise red bellied turtles, Atlantic salmon, winter flounder and large mouth bass. In

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Rebecca Gast	Woods Hole Oceanographic Institution (508) 289 3209 rgast@whoi.edu	QPX, genetics
Clifford A. Goudey	Massachusetts Institute of Technology Sea Grant College Program (617) 253-7079 cgoudey@mit.edu	aquaculture technology
Rick Karney	Martha's Vineyard Shellfish Group (508) 693-0391 mvsg@comcast.net	shellfish biology
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William C. Walton	Cape Cod Cooperative Extension & Woods Hole Oceanographic Institution Sea Grant (508) 375-6849 wwalton@whoi.edu	fisheries and aquaculture, shellfish biology, shellfish predators

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William C. Walton	Cape Cod Cooperative Extension & Woods Hole Oceanographic Institution Sea Grant (508) 375-6849 wwalton@whoi.edu	fisheries and aquaculture, shellfish habitat assessment
Brandy M. Wilbur	Massachusetts Institute of Technology Sea Grant (617) 253-5944 office / (978) 283-6275 hatchery bmmoran@mit.edu	K-12 marine education, finfish aquaculture
Education Contact Information		
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Brandy M. Wilbur	Massachusetts Institute of Technology Sea Grant (617) 253-5944 office / (978) 283-6275 hatchery bmmoran@mit.edu	K-12 marine education
State Aquaculture Coordinator		
Scott J. Soares	Massachusetts Department of Agricultural Resources (617) 626-1730 office scott.soares@state.ma.us	permitting and development
Aquaculture Industry Association		
Scott Mullin	Massachusetts Aquaculture Association (508) 362-8145 great.marsh@verizon.net	shellfish industry networking and information transfer
Testing Laboratory		
Roxana Smolowitz	Marine Biological Laboratory (508) 289-7400 rsmol@mbl.edu	pathology, shellfish diseases

Students transfer fish into a recirculating fish culture system. (Photo: Brandy Wilbur)

addition to the Fish Barn, an integrated polyculture system has been developed to grow fish and plants.

MITSGH/MEC in collaboration with the Gloucester Maritime Heritage Center strives to educate the public about aquaculture: what is it, how are species raised, what systems are used, and how is aquaculture part of our society? Education activities include: 1) field trips focusing on measurement, system design, water quality, animal husbandry, finfish development and eelgrass, and 2) teacher professional development workshops on eelgrass, marine finfish culture and monitoring the marine environment. MITSGH/MEC also hosts high school and undergraduate internships year-round for students seeking to learn more about aquaculture and the marine environment.

SEMAC, working with Cape Cod Cooperative Extension and Woods Hole Oceanographic Sea Grant, routinely gives lectures and hosts field trips. In addition, formal courses are offered periodically, often through Massachusetts Maritime Academy, including a state certification course for Massachusetts Shellfish Officers. Last year, the DVD *Shellfish Aquaculture: Tools, Tips, and Techniques*, was released as a tool for new shellfish farmers and others working with shellfish.

Extensive curricular materials for the integration of aquaculture into K-12 classrooms have been cooperatively produced (authored by New England Board of Higher Education, SEMAC, Roger Williams University, Massachusetts Department of Agricultural Resources) and published.

Aquaculture Resources

SouthEastern Massachusetts Aquaculture Center
http://www.capecodextension.org/semac/

NorthEastern Massachusetts Aquaculture Center
http://www.salemstate.edu/biology/aquaculture

Western Massachusetts Center for Sustainable Aquaculture
http://www.umass.edu/aquaculture

MIT Sea Grant Marine Education Center
http://web.mit.edu/seagrant/edu

Northeastern Regional Aquaculture Center
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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: MARYLAND

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Industry Trends and Outlook

Maryland has a small but diverse aquaculture industry with an annual farm-gate production of approximately $5 million annually. Growers produce a wide range of finfish, shellfish, aquatic plants, and reptiles. The largest contributing sectors currently are producers of ornamental fish and aquatic plants. Plants are produced for wholesale water garden trade, shoreline stabilization, and mitigation, with expected strong demand for the latter two in the near future. Growers of water garden plants have begun to cultivate alternative markets for their products such as the use of aquatic plants in the healthy management of stormwater ponds.

The second largest sector is shellfish production - Eastern oysters and hard clams. Disease epizootics have kept most bottom leases in the Chesapeake and coastal bays from maintaining their traditional productivity, but innovative growers have evolved techniques to manage their animals in areas of high disease prevalence. Recent development of selected oyster lines, and the production of triploids, has made it possible to raise native oysters in zones of high disease intensity. In addition, the states of Maryland and Virginia are actively investigating the use of a non-native oyster, *Crassostrea ariakensis*, for potential introduction. An Environmental Impact Study of this proposed introduction is expected in early 2008.

Aquatic plants are the largest segment of Maryland's aquaculture industry. Floating plant rafts serve to beautify community stormwater ponds while taking up nutrients, extending the life of the pond and minimizing weed problems. (Photo: Don Webster)

A small segment of the industry raises products in recirculating systems. These include organisms such as tilapia, shrimp, and ornamental fish. The market for live tilapia has peaked in recent years with remaining producers having become adept at business management and marketing in order to remain competitive.

Recent trends have included government interest in modifying laws and regulations that hinder or inhibit

Emerging Issues and Critical Needs

- Most recently the State has moved to renovate its aquaculture laws. Recent changes led by extension faculty resulted in speeding up of aquaculture permits and recognition by key political leaders of the benefits of aquaculture for the economy and the environment.
- Continued funding of positions is deemed to be the most critical need at this time so as to continue the work of the existing faculty while developing new programs and initiatives through access to additional funding.
- Development of shellfish aquaculture is critical to the health of the Chesapeake and coastal bays due to the importance of biological filtration and nutrient transfer. Solutions for the current oyster disease problem will require species, production systems, and genetic hybrids able to resist disease.
- Renovating state leasing laws for enhancement of shellfish production will be critical for development of the industry, as will enactment of programs through the U.S. Army Corps of Engineers for being able to utilize near-bottom and off-bottom production techniques.
- Continued support for research into defined industry problems and culture techniques for new and innovative species will be a priority.
- As the population expands, conflicts with aquaculture producers will become more prevalent, especially with methods that use public waters. Conflict management resolution will become necessary to help minimize these problems and allow production while protecting the environment.

aquaculture. The State renovated its permitting policy in 2005 to direct initial inquiries for aquaculture through the state Aquaculture Coordinator who tracks permits through agencies while chairing the Aquaculture Review Board. That body meets regularly to discuss applications and mediate differences between agencies. A state Aquaculture Coordinating Council is charged with recommending policy and legislative initiatives annually to the executive and legislative branches of state government. Other tasks include developing and maintaining current Best Management Practices and forming options to initiate Aquaculture Enterprise Zones for the enhancement of shellfish aquaculture.

Commercial Species List

- Eastern oyster (*Crassostrea virginica)*
- Northern quahog (*Mercenaria mercenaria)*
- Red swamp crawfish (*Procambarus clarkia)*
- Tilapia (*Tilapia* sp.*)*
- Striped bass and hybrids (*Morone* sp.*)*
- Diamondback terrapin (*Malaclemys terrapin)*
- Various turtle species (Chelydridae*)*
- Pennaeid shrimp (Penaeids*)*
- Soft corals (*Alcyonacea* sp.*)*
- Blue crab (*Callinectes sapidus)*
- Clownfish (*Premnas* sp.*)*
- Various aquatic plants cultured for shoreline protection and stabilization, ornamental use, pond management
- Various ornamental fish (freshwater and marine)

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

Aquaculture Research

The University System of Maryland (USM) includes thirteen institutions and campuses with aquaculture research conducted at several facilities.

The Center for Environmental Science includes the Aquaculture and Restoration Ecology Lab (AREL), at Horn Point on the Eastern Shore, which provides oyster larvae for large-scale restoration projects for the Eastern oyster, as well as quarantine facilities for non-native shellfish and finfish. In 2006, the AREL facility produced over 350 million spat for innovative projects

Oyster farm in Snow Hill, Maryland (Photo: Luke Breza)

such as managed reserves that combine ecological and economic benefits in carefully defined and regulated areas. The AREL also serves as a base for endangered species research on the sturgeon, and provides facilities for work on tropical ornamental fish like clownfish. Aquatic vegetation research conducted here is leading to advances in large-scale introduction of depleted plants important in maintaining the health of an estuary.

The Center of Marine Biotechnology (COMB), on the waterfront in the city of Baltimore, provides cutting-edge research that has closed the life cycle of the blue crab and provided production information important in the culture of sea bream. Other research teams at COMB are working to develop effective bacteria for the biological filtration used in recirculating aquaculture systems, which has led to recirculating technology that discharges no water.

The Biological Resources Engineering Department on the main campus at the University of Maryland College Park (UMCP) has a long history of research and development in seafood technology and aquaculture production systems. They have worked closely with extension faculty in applying science to industry problems for many decades.

The Animal Science Department at UMCP carries out breeding and selection projects, as well as feed and nutrition development, for the striped bass and hybrid industries. This program, first developed during the 1980s, has helped the annual growth of the striped bass and hybrid aquaculture industry in the nation.

The University of Maryland Eastern Shore (UMES) has done research on tilapia aquaculture as well as developed technology for recirculating systems. Some of their work on finfish systems has been adapted for use in the soft crab production industry. A new lab on Chincoteague Bay will provide an opportunity to work with hard clams and other shellfish in a high salinity environment.

Aquaculture Extension

Maryland has eight full-time extension faculty dedicated all, or in part, to programs in seafood and aquaculture. These include three regional specialists who are located in geographically distinct areas; statewide finfish and shellfish specialists with joint research and extension appointments; a resource economist; education specialist; and seafood technologist. The program faculty organizes state, regional, and national educational programs addressing aquaculture topics. They teach short courses, as well as evening or day-long programs in support of ongoing extension project areas.

Restoration aquaculture is a major thrust of Maryland programs. The F/V Robert Lee plants oyster spat produced at the UMD's Aquaculture and Restoration Ecology Lab on the Eastern Shore on managed reserves, an innovative concept that combines ecological and economic

The Extension program is administered by University of Maryland Cooperative Extension, with support from the Maryland Sea Grant College Program. The Extension faculty is located at labs and campuses throughout the state in places where they can more easily interact with industry. State specialists have joint research appointments, while regional faculty provide industry liaison and work with researchers in field demonstrations and application of technology. Maryland Cooperative Extension administratively ties the 1862 and 1980 programs together, which gives strong support through both the traditional programs as well as those aimed at minorities.

Aquaculture Education

The *Aquaculture in Action* program is a year-long K-12 outreach program emphasizing aquaculture as a dynamic tool for learning. The goal is to create a curriculum that integrates science skills of chemistry, physics, mathematics, ecology, and animal husbandry using hands-on learning sets. Teachers are assisted through biennial workshops, annual planning and development meetings, yearly fish deliveries and stocking events, and an interactive Web site for consultations and individual project reporting.

The *Aquaculture in Action* program consists of some fundamental pieces that are key to its success in the schools:

- One-week workshops that support teachers with an aquaculture companion manual and materials, and equipment for the construction of a 210-gallon recirculating aquaculture system.

Research Contact Information

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Reginal Harrell	University of Maryland Wye Research & Education Center (410) 827-8056 harrell@umd.edu	finfish research; genetics
Andy M. Lazur	University of Maryland Horn Point Environmental Laboratory (410) 221-8474 alazur@hpl.umces.edu	finfish research; aquatic plants
Kennedy Paynter	University of Maryland (301) 405-6893 paynter@cbl.umces.edu	shellfish ecology, restoration
Yossi Tal	University of Maryland Center of Marine Biotechnology (410) 234-8875 tal@umbi.umd.edu	aquatic microbiology, marine aquaculture
L. Curry Woods III	University of Maryland Department of Animal Science (301) 405 7974 curry@umd.edu	striped bass and hybrids
Yonathan Zohar	University of Maryland Center for Marine Biotechnology (410) 234-8803 zohar@umbi.umd.edu	fish reproductive endocrinology, aquaculture

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Dan Terlizzi	Maryland Cooperative Extension Center of Marine Biotechnology (410) 234-8837 dterlizz@umd.edu	water quality
Don Webster	Maryland Cooperative Extension Wye Research & Education Center (410) 827-5377 ext. 127 dwebster@umd.edu	general aquaculture; policy

Education Contact Information

Name	Address	Specialty:
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State Aquaculture Coordinator

Karl Roscher	Maryland Department of Agriculture 50 Harry S Truman Parkway Annapolis MD 21401 (410) 841-5724 RoscheKR@mda.state.md.us	permit coordination and tracking; chairman of Maryland Aquaculture Review Board; member of Maryland Aquaculture Coordinating Council

Aquaculture Industry Associations

(inactive at this time)

Testing Laboratories

Ana Baya	Regional Animal Health Laboratory Avrum Gudelsky Veterinary Center College Park, MD 20742 (301) 314-6837	diagnosis of fish disease and recommendation for treatment
Shawn McLaughlin	Cooperative Oxford Lab 904 South Morris Street Oxford, MD 21654 (410) 226-0078	diagnosis of shellfish diseases

Teachers build their own recirculating system for the classroom. (Photo: Jackie Takacs)

- A one-of-a-kind Web-based component that gives teachers and students the ability to enter project data related to their research in the classroom and communicate with one another about projects and ideas.
- Support throughout the school year including the coordination of obtaining native fish for culture and the release of fish at the end of the school year at Maryland Department of Natural Resources approved locations in Maryland.

Over the last ten years, the program has been: 1) incorporated into 43 schools in Maryland, one in Pennsylvania, and one in West Virginia; 2) used by over 10,000 students in the context of learning science; 3) developed into 50+ student projects; 4) presented at four national conferences (invited); and 5) used as a model by extension and education specialists from California, South Carolina, Louisiana, and Florida (for use in Costa Rica). Ten teachers in the program have successfully secured funding to expand their school's aquaculture program and two were named Maryland "Teacher of the Year".

Aquaculture Resources

Northeastern Regional Aquaculture Center
The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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A copy of this report may be downloaded from: http://www.nrac.umd.edu

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: MAINE

Dana Morse, University of Maine Sea Grant and Cooperative Extension
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Atlantic salmon culture in Maine (Photo: Chris Bartlett)

Industry Trends and Outlook

The Maine aquaculture industry is diverse with a variety of marine and freshwater species raised. Salmon production values are in the range of $48 million per year, with annual production ranging between 11-36 million pounds from 2000-2005; shellfish production throughout Maine is approximately $10 million annually (O'Hare et al. 2003). Recent reinvestment in the salmon industry will probably raise those values, as will husbandry practices that limit the adverse effects of disease. True North Salmon (Cooke Aquaculture) has publicly pledged to raise production levels sufficiently in the State to support the year round operation of a salmon processing plant in Maine.

Commercial Species List

- American shad (*Alosa sapidissima*)
- Atlantic salmon (*Salmo salar*)
- Atlantic cod (*Gadus morhua*)
- Atlantic halibut (*Hippoglossus hippoglossus*)
- Bay scallops (*Argopecten irradians*)
- Blue mussel (*Mytilus edulis)*
- Brook trout (*Salvelinus fontinalis*)
- Brown trout (*Salmo trutta*)
- Cinnamon clownfish (*Amphiprion melanopus*)
- Clarkii clownfish (*Amphiprion clarkii*)
- Common seahorse (*Hippocampus kuda*)
- Eastern oyster (*Crassostrea virginica*)
- Emerald shiners (*Notropis atherinoides*)
- European oyster (*Ostrea edulis*)
- Golden shiners (*Notemigonus chrysoleucas*)
- Green sea urchin (*Strongylocentrotus droebachiensis*)
- Neon dottyback (*Pseudochromis aldabraensis*)
- Nori seaweed (*Porphyra* sp.*)*
- Northern quahog (*Mercenaria mercenaria*)
- Orchid dottyback (*Pseudochromis fridmani*)
- Ocellaris clownfish (*Amphiprion ocellaris*)
- Percula clownfish (*Amphiprion percula*)
- Rainbow smelt (*Osmerus mordax*)
- Rainbow trout (*Oncorynchus mykiss*)
- Sandworms (*Nereis virens*)
- Sea scallops (*Placopecten magellanicus*)
- Softshell clam (*Mya arenaria*)
- Splendid dottyback (*Pseudochromis splendens*)
- Sunrise dottyback (*Pseudochromis flevivertex*)
- Tomato clownfish (*Amphiprion frenatus*)
- Whitenose sucker (*Catastomus commersonii*)

Critical Needs and Emerging Issues

- Workforce and professional development: Facilitation of the entry of new aquaculture professionals, and advancement of the skills and abilities of existing industry members
- Access to startup capital and tax incentives: Capital is limited in the aquaculture industry, especially so for new start-ups, and the earlier phases of commercial development
- Regulatory barriers to entry: The aquaculture industry is highly regulated, and in many cases regulation effectively constitutes an obstacle to entry, and to the development of new techniques, species and equipment
- Assessment of appropriate environmental indicators: Assessment of the scientific validity of existing environmental indicators and evaluation of new indicators which may be more valid
- Biofouling control for finfish and shellfish: Biofouling is a long-standing problem for aquaculture producers, and eradication remains an area of critical need
- Waterfront access for marine businesses: Despite many advances in waterfront access for marine businesses in Maine, access continues to be in critically short supply and is essential for a healthy mariculture industry
- Establishment of husbandry practices and equipment to minimize negative environmental effects and to accentuate positive effects: This ongoing need is front and center in the continued viability of the aquaculture industry, both for protection of the resources that producers depend on, and on the goodwill of other resource users, managers, and groups
- Eelgrass/shellfish culture management: The dynamics between eelgrass and shellfish aquaculture (suspended and bottom) is an area where study is strongly needed
- Marketing program to develop "Maine-brand" identity linked to sustainable farming methods
- Access to suitable growing sites continues to be a constraint to industry development
- Continued forums for public discussion and education about methods, practices and species being cultured in Maine are necessary
- Polyculture, or co-culture, of marine organisms can take many forms, including integrated, multi-trophic aquaculture. This strategy of production is in its early stages in Maine, but is expected to make stronger advances in the near future
- Predation by eider ducks continues to be a significant obstacle to higher production levels of blue mussels in suspended and bottom culture
- Macroalgae are expected to become more significant in the overall production of marine culture products in coming years
- Significant advances in the culture of various freshwater finfish species used as bait have been made and, with a vigorous market for such products, baitfish production is expected to be a growth industry
- Culture of the sea scallop has been limited in the recent past, but upcoming changes to regulation and permitting may allow greater experimentation and production of this valuable species
- Culture of the green sea urchin has been limited in the past, but new research and changes to regulations and permitting may allow greater experimentation and production
- Improved harvesting techniques and equipment are needed, to improve productivity and safety and to minimize the environmental impacts of mechanical and diver harvesting
- In recent years, most new shellfish growers have been commercial fishermen, either active or retired. This trend is expected to continue, and brings with it issues of access to production areas, and the transition of some submerged lands from open fishing areas to areas of limited access by others, e.g. leases
- New marine finfish species are being developed for commercial culture in the state. Due to the unique growing conditions in the Gulf of Maine stakeholders must adapt, develop and improve husbandry techniques from others locales
- Conflicting pressures between working waterfronts, recreational and residential users: As competition for water resources increases, it is becoming increasingly necessary to develop new management strategies that support and encourage multiple uses of areas while reducing conflicts

Salmon culture cages in Maine (Photo: Chris Bartlett)

Marine finfish culture is expected to grow in the future as current producers expand and diversify their production and new producers enter the State.

In recent years, shellfish production has been on a slow and steady increase, especially for blue mussels and oysters. Likewise, there is an increased interest in expanding the existing freshwater finfish industry, both in terms of new baitfish producers and fee fishing operations.

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections highlight the major aquaculture research, extension and education facilities and organizations in Maine.

Aquaculture Facilities

The University of Maine (UMaine) has a number of research facilities throughout the state including the Darling Marine Science Center, the Center for Cooperative Aquaculture Research (CCAR), the Aquaculture Research Center, the Food Sciences Lab and the Maine Aquatic Animal Health Lab (MAAHL).

Research at the Darling Marine Science Center, located in Walpole on the Damariscotta River, is focused on the development of sustainable shellfish culture techniques and is the home of the oyster broodstock program. This facility also has incubation space for aquaculture business that can house start-up shellfish, invertebrate, algal or finfish businesses.

The Center for Cooperative Aquaculture Research, located in Franklin on Taunton Bay, is a commercial scale applied aquaculture R&D facility and business incubator space. Facilities include a variety of rearing tanks, over a dozen marine and freshwater recirculating systems, a new state of the art multi-species marine finfish hatchery, and a water system that allows for rearing of marine, brackish and freshwater species. The facility currently houses halibut and cod broodstock and juveniles, the world's only indoor recirculating marine polychaete worm farm, a green sea urchin hatchery, and culture and net seeding facilities for nori.

The Aquaculture Research Center, located on the University of Maine campus in Orono, has a laboratory system used for small scale marine, brackish and freshwater research. It specializes in recirculation technology. The Center also houses a wave tank that is used for engineering and testing new aquaculture equipment. Current work at the Center includes breeding and rearing of new tropical marine species.

The Food Sciences Laboratory is a completely equipped facility including a twin screw extruder. This lab participates in fish nutrition studies and manufactures trial diets as needed. They work cooperatively with other university facilities to conduct feeding trials and develop new diets.

The Maine Aquatic Animal Health Lab is designed as a shared-user magnet research facility for aquatic animal health and disease research, and is located at the University of Maine Orono campus. The mission of the MAAHL is to foster applied aquatic animal health research and diagnostics along with providing outreach with education to address the needs of Maine's aquaculture and fisheries communities. Private and public entities are encouraged to collaborate in the activities of the MAAHL. The laboratory is equipped with state of the art imaging, culture and molecular equipment needed to conduct cutting edge research on aquatic animal pathogens of any nature. In particular, the lab is currently home to the only disease isolation wet lab in the state for conducting experimental infectivity trials. The MAAHL is a program of the University of Maine Cooperative Extension and the Department of Animal and Veterinary Sciences.

The Maine Aquaculture Innovation Center (MAIC) is housed at the University of Maine in Orono. The mission of MAIC is to assist in the development of economically viable aquaculture opportunities along the coast of Maine and at appropriate inland sites by:

- sponsoring and facilitating innovative research and development projects involving food, pharmaceuticals and other products from sustainable aquatic systems;
- investing in the enhancement of aquaculture capacity in Maine;
- serving as a clearing house of educational information to enhance public visibility and

acceptance of aquaculture; encouraging strategic alliances tasked with promoting research, technology transfer, and the commercialization of aquaculture research.

The U.S. Department of Agriculture operates its National Cold Water Marine Aquaculture Center research facilities in Franklin, with additional research facilities planned in Orono. Facilities in Franklin are located adjacent to the University of Maine Center for Cooperative Aquaculture Research (CCAR). Facilities in Orono will be located on the University of Maine campus. The Franklin facility is the home of the USDA Atlantic Salmon Broodstock program. The National Cold Water Marine Aquaculture Center (NCWMAC) has been conducting research since 2003 in Franklin using two temporary greenhouses prior to construction of permanent facilities. One greenhouse has 144 small 50-gallon culture tanks for rearing Atlantic salmon from fry to advanced parr stage. The second greenhouse has 4 larger 2,500 gallon tanks for rearing smolts prior to stocking into sea cages. This greenhouse also has a 4,000 gallon tank for culturing sub adult salmon prior to completion of permanent facilities. All research tanks are supplied with water from recirculating filtration systems. The permanent research facilities were completed in 2007 and consist of a 42,000 square foot main research building with approximately 300 research tanks and two approximately 3,000 square foot individual research buildings.

The Downeast Institute for Applied Marine Research and Education (DEI) is located on Great Wass Island in Beals. This education and research facility produces commercially important marine shellfish in a commercial-scale hatchery facility. DEI is best known for the annual production of millions of soft-shell clam seed for public stock enhancement for Maine coastal communities. In addition, research projects at the facility include regional growth of hatchery-reared lobster juveniles, growth/survival of hard clams in the cold waters of eastern Maine, and an examination of the efficacy of closed bottom areas with respect to managing wild populations of sea scallops. Downeast Institute staff work with scientists and students from the nearby University of Maine at Machias, which considers the facility its marine field station. In addition, DEI staff and UMM scientists work in conjunction with fishermen, entrepreneurs, and educators to help develop programs and projects that have both educational and economic benefits to the residents of coastal Maine. The Downeast Institute is a non-profit organization administered by a 15-member Board of Directors. The mission of DEI is to improve the quality of life for the people of downeast and coastal Maine through applied marine research, technology transfer, and public marine resource education.

The Maine Aquaculture Association's (MAA) conducts applied research on member farms that addresses industry issues and supports the development of sustainable husbandry techniques. Recent and on-going research includes: the development of an independent third party verified containment management system for all salmon culture facilities in the state, development of Best Management Practices, development of composting techniques for fish waste from freshwater hatcheries, demonstration of plant culture techniques to reduce nutrients in hatchery effluent and development of inventory system for bottom cultured oysters.

Lists of other aquaculture projects in Maine can be found by checking with the principal funding agencies which include the Northeast Regional Aquaculture Center, Maine Sea Grant, and the Maine Aquaculture Innovation Center. Projects range from deterrent devices for eider predation on mussels, to broodstock development in oysters, and improvements in baitfish production.

Extension Programs and Facilities

Centers of extension activity in Maine include:

- Maine Sea Grant at the Washington County Community College
- Maine Sea Grant at the Darling Marine Center
- Maine Aquaculture Innovation Center
- Maine Aquaculture Association
- University of Maine at Orono

Extension activities for Maine Sea Grant (ME SG) include: programs for technology transfer and

Oysters ready for planting. (Photo: Eric Horne)

professional development within the industry, and programs to educate or connect citizens to the aquaculture industry and its products in various ways. Partners in these efforts include the Maine Aquaculture Association, Maine Aquaculture Innovation Center, Maine Department. of Marine Resources, and other institutions and citizen groups. Examples of our activities include: hosting industry meetings to discuss important issues and solutions, collaborating with regional partners on the biannual Northeast Aquaculture Conference and Exposition (NACE) conference, convening forums where industry and concerned citizens can work on issues of concern, organizing visits to aquaculture sites and facilities, and various speaking engagements. ME SG also produces publications relevant to the aquaculture industry.

The Maine Aquaculture Association (MAA) focuses its extension and outreach efforts in two primary directions. First, we provide various professional development opportunities to existing growers in the state. These efforts focus both on improved husbandry and/or management skills and improved business skills. Often we will work with other partners such as Maine Sea Grant or the Maine Aquaculture Innovation Center in these efforts. MAA also directs significant efforts to educating the general public about aquaculture in the state. This is accomplished through several methods including our website, public presentations and outreach efforts at public trade shows and events. Staff members often lecture to various civic organizations or school groups, and we recently concluded a series of public lectures hosted along the entire coast. We can also be seen at numerous trade events such as the Maine Sportsman Show, The Agricultural Trade Fair, Fisherman's Forum, Tourism shows, Local Festivals and of course the Big E down in Springfield, Mass. Please visit our website for a list of up coming events http://www.maineaquaculture.com

There are many activities that fall into the category of extension by other groups throughout the state. Brief examples: the Maine Aquaculture Innovation Center hosts 'lunch and learn' professional development activities for growers throughout the state. The Downeast Institute transfers technology to others in marine industries regarding the culture of soft shell clams and development/operation of lobster hatcheries. The Center for Cooperative Aquaculture Research works with growers on culturing new species in Maine waters.

Education Facilities

The University of Maine in Orono has undergraduate and graduate programs in aquaculture, including freshwater and marine species, finfish, shellfish and algae. Faculty members within the School of Marine Science teach and conduct research in topics ranging from culture of marine macroalgae, to salmon feeds, oyster broodstock development, and design of aquaculture equipment.

Carter Newell examines blue mussels at his raft culture operation. (Photo: Dana Morse)

The Darling Marine Center is an established center for shellfish culture education, on formal and informal levels. Researchers, industry members, extension personnel, and members of the public are involved in such educational programs as a course on Shellfish Mariculture Techniques, Oyster Gardening, and lectures by guest speakers. The DMC also serves as a central meeting space where shellfish growers gather, to learn and discuss programs from Crop Damage Insurance to water quality, and the progress of the Oyster Broodstock Program.

A Maine Sea Grant College Program staff member is housed within the Washington County Community College (WCCC), and conducts a variety of aquaculture-related activities such as coordinating the Fish Health Workshop, conducting educational day trips to school and other groups, and participating in aquaculture research in finfish, shellfish and marine algae.

Southern Maine Community College (SMCC) offers the Applied Marine Biology and Oceanography (AMBO) program. This program provides students with the academic background and applied skills required for employment as research assistants and technicians or for transfer into a four-year baccalaureate program. The curriculum emphasizes hands-on laboratory and field procedures. Special attention is given to collecting and identifying marine organisms, oceanographic sampling aboard the school's

research vessel, aquaculture, and service projects in the southern Maine community.

Unity College has an integrated aquaculture and fisheries program that combines the tradition of preparing fisheries biologists and fisheries technicians for federal, state and private agencies and conservation groups with the education in the multi-faceted aspects of aquaculture. Students are sought by employers and graduate schools because the curriculum provides opportunities for students to become proficient in basic biological and physical sciences while giving them theoretical and practical exposure to the fields of aquaculture and fisheries sciences. Students also develop an appreciation for the intricacies of aquaculture production, fisheries management, and fish pathology.

The University of New England (UNE) has an Aquaculture and Aquarium Science major that is designed so that graduates will have the skills to either find jobs in the private or governmental sectors including owning their own businesses or working at a public aquarium. There are four dedicated classes and two business classes plus plenty of opportunity to gain hands-on experience maintaining both captive tropical reef fish and local Gulf of Maine species. The students learn to grow phytoplankton and zooplankton and to design and build recirculating systems and exhibit tanks. Students get a good overview of the state of aquaculture in Maine as well as the world, and also the role that aquariums and aquarium science will take in the future of marine science and conservation.

The University of Southern Maine (USM) has a modest link to aquaculture with some biology classes, and at least one faculty member involved in aquaculture research.

The Herring Gut Learning Center (HGLC) is a non-profit marine education and resource center located in the small fishing village of Port Clyde, Maine. Staff at HGLC teach marine science, aquaculture, geology, and coastal ecology to students of all ages through a variety of hands-on school-based, community outreach and summer camp programs.

Lubec Consolidated School Aquaculture Lab is a state of the art science center that teaches applied biological sciences to grades 6 through 12 students. The lab has over 7000 gallons of recirculating aquaculture systems raising tilapia, brook trout and various ornamental fishes. The tilapia system is an environmentally friendly simulated wetland aquaponics system, that utilizes plants growing in an 800 square-foot greenhouse to purify the fish water. The aquaponic greenhouse has the capability to grow enough vegetables to serve the students a salad bar in the cafeteria every day. The lab also conducts distance learning courses to any interested schools, and we are regularly hosting virtual field trips via a T.V. polycom system. Classes are very interactive utilizing five fixed and mobile cameras around the class in microscopes and in the tanks themselves. The students at Lubec Consolidated School and other interested schools can take courses in Vocational Aquaculture, Aquaponics, Botany, Aquaculture, Aquascience, and for the middle school Applied Science.

Presque Isle Regional Career and Technical Center offers a one-year elective course to tenth, eleventh, and twelfth graders. It is designed to introduce the students to growing freshwater and tropical fish under controlled conditions.

The Maine Sea Grant College Program (MESG) is involved in aquaculture education through the Marine Extension Team (MET -a partnership with Univ. of Maine Cooperative Extension), and through its Communications Department. The MET works with other groups and agencies to develop and implement information educational programs such as tours, workshops, seminars, speaking engagements and conferences, and collaborates with the Communications Department to produce items such as fact sheets, research briefs, and other documents and publications. The Maine Sea Grant Program also funds research in aquaculture through its bi-annual Research Program, and projects funded by MESG are required to have an extension and education component.

Aquaculture Resources

Maine Aquaculture Innovation Center
http://www.maineaquaculture.org

Maine Aquaculture Association
http://www.maineaquaculture.com

Maine Department of Marine Resources
http://www.maine.gov/dmr/

Red Tide and Shellfish Sanitation Hotline
http://www.maine.gov/dmr/rm/public_health/closures/shellfishhotline.htm

Maine Department of Environmental Management
http://www.maine.gov/dep/

Maine Sea Grant
http://www.seagrant.umaine.edu

Maine Oyster Broodstock Program
http://www.marine.maine.edu/~rawsonp/oyster_broodstock/start.htm

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Maine Legislature: Joint Standing Committee on Marine Resources
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Northeastern Regional Aquaculture Center The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: NEW HAMPSHIRE

Rollie Barnaby, University of New Hampshire Cooperative Extension, UNH Sea Grant
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Industry Trends and Outlook

New Hampshire has four trout farms that raise rainbow and brook trout. Most fish are used to stock public and private ponds. One farmer is raising brown bullheads, and there is great interest in baitfish culture.

Great Bay Aquaculture, the only commercial saltwater hatchery in New Hampshire, has been producing cod and summer flounder for many years. They shipped their first batch of cobia to Puerto Rico in 2006 and expect to have black sea bass on line in the near future.

The University of New Hampshire (UNH) Open Ocean Aquaculture Project has successfully grown blue mussels on submerged longlines for five years. A commercial fisherman has taken over six lines initially put in by UNH and added several others. He harvested his first mussels in December of 2006.

Commercial Species List

- Atlantic cod (*Gadus morhua*)
- Cobia (*Rachycentron canadum*)
- Summer flounder (*Paralichthys dentatus*)
- Blue mussel (*Mytilus edulis*)
- Brook trout (*Salvelinus fontinalis*)
- Brown bullhead (*Ameiurus nebulosus*)
- Rainbow trout (*Oncorhynchus mykiss*)

Addressing Industry Needs

Researchers, extension staff, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

New Hampshire salmonid farm. (Photo: J-J Newman-Rode)

Aquaculture Research

The University of New Hampshire has several researchers who focus on freshwater and marine aquaculture applications.

UNH has had an open ocean aquaculture project since 1997. The project is run by an interdisciplinary team of marine biologists, ocean engineers, benthic ecologists, extension educators and technical operations professionals based at the University. This team is recognized worldwide as a leader in open ocean aquaculture.

Emerging Issues and Critical Needs

- The most pressing need for marine aquaculture is a permitting process for conducting aquaculture in federal waters and a revamping of the process in state waters. These processes will facilitate and encourage additional entrepreneurs within the state to pursue marine aquaculture. The current displacement of the New Hampshire commercial fishing fleet makes marine aquaculture an attractive prospect.

The University‘s Open Ocean project is now called the Atlantic Aquaculture Center. The center’s offshore demonstration site, which can hold up to four cages, is secured by a submerged mooring grid 440 feet in perimeter and held fast to the sea floor by 12 anchors. The opposing forces of these anchors and submerged floats place tension on the structure, maintaining the desired geometry and preventing loose lines that could ensnare a whale or other marine mammal.

The project has successfully grown summer flounder, cod, haddock, and halibut in the open ocean site. The breakthroughs over the past eight years have been numerous. At the World Aquaculture Society meeting in March 2007, eight of the13 papers presented on open ocean aquaculture were given by researchers, graduate students, or graduates of UNH. Conclusions based on eight years of research:

- Farmed fish thrive in the harshest offshore conditions.
- Mooring and cage systems can withstand ocean forces when they are the result of innovative engineering combined with rigorous field-testing.
- Remotely controlled operations make the management of offshore farms safer and more efficient.
- Given proper location, species selection, system design, and husbandry practices, the impact of an offshore farm on the surrounding environment is negligible.
- Blue mussels can be successfully grown on submerged longlines in the open ocean.

In a more recent technology development, UNH deployed an innovative, 20-ton automatic fish feeder at their open ocean aquaculture site in the fall of 2007.

In addition to UNH research participation in the open ocean aquaculture program efforts are being made to restore oyster habitat to promote recreational harvesting and potential commercial ventures.

Dr. Raymond Grizzle, of the UNH Jackson Estuarine Laboratory, and his team are experimenting with optimal conditions for reef restoration in the Great Bay estuary. One major research question is whether several small or one large reef will promote abundance, survival and growth of larval oysters.

UNH scientists are also laying the foundation for a sustainable stock enhancement program to bring back New England’s failing winter flounder fishery and work with Massachusetts Institute of Technology Sea Grant’s Aquaculture in the Classroom Program. The program engages teachers in K-12 schools throughout New England and helps them bring fisheries, aquaculture, and animal husbandry to their students in a creative way.

Aquaculture Extension

There are two extension educators who have responsibilities in commercial fisheries, marine aquaculture and seafood safety. Extension has conducted local informational meetings, produced fact sheets, a video, and publications, and met with decision makers and the media on the Open Ocean Aquaculture project. Extension specialists have also presented at National and regional meetings.

Extension specialists identified commercial fishermen interested in mussel culture, helped them acquire permits and are transferring the technology to additional producers at this time.

Aquaculture Education

The University of New Hampshire Marine Docents is a group of volunteers dedicated to the preservation and wise use of our marine resources. One of the areas they provide educational programs on is marine aquaculture. The volunteers conduct programs in public and private schools, parks, on campus, and on the water on passenger vessels.

Aquaculture Resources

Northeastern Regional Aquaculture Center
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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: NEW JERSEY

George E. Flimlin, Rutgers Cooperative Extension
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Industry Trends and Outlook

The northern quahog or hard clam (*Mercenaria mercenaria*) forms the basis for the largest hatchery linked shellfish aquaculture in the state which began in 1976. At present there are about 40 active growers (down from about 60 ten years ago) and four active commercial hatcheries. The largest part of the activity is centered in lower Ocean and Atlantic Counties. The Delaware Bay oyster industry is drastically reduced in size with most of the harvest coming from the seed beds, mainly because of problems with MSX and Dermo disease. New Jersey Department of Environmental Protection (NJDEP) Bureau of Shellfisheries is in the process of establishing Aquaculture Development Zones mainly in Delaware Bay, but this has been an ongoing process for at least five years with no definitive areas specifically designated and permitted as of this date.

There is one long-lived trout hatchery that grows fish mainly for stocking purposes and a small amount for market. There is one medium-sized koi farm and several baitfish and ornamental businesses.

The New Jersey Department of Agriculture (NJDA) currently licenses 183 aquaculture operations, the majority of which are shellfish (164), followed by finfish (15) and aquatic plants and ornamentals (4). These numbers differ from the 2005 Census of Aquaculture, which lists 87 aquaculturists in New Jersey because the U.S. Department of Agriculture's National Agricultural Statistics Service (USDA NASS) only surveys commercial farms of $1,000 annual farm-gate sales or more. The total production from these operations amount to $3.714 million. Of interest is the value of the koi industry. Eight farms earned greater than $13,000 in sales, which is the highest average price per fish ($23.02) in the U.S.

Ed Frankovich planting seed for overwintering. (Photo: Gef Flimlin)

Emerging Issues and Critical Needs

- Market research for cultured shellfish
- Value-added products from cultured species
- Interest by Natural Resource Regulatory Agencies in improving production

"Baymen's Pride" clams displayed at ShopRite. (Photo: Joseph Myers)

Commercial Species List

- Northern quahog (*Mercenaria mercenaria*)
- Eastern oysters (*Crassostrea virginica*)
- Angelfish (*Pterophyllum scalare*)
- Bluegill (*Lepomis macrochirus*)
- Brook trout (*Salvelinus fontinalis*)
- Brown trout (*Salmo trutta*)
- Comet (*Carassius auratus*)
- Discus (*Symphysodon* spp.)
- Fathead minnow (*Pimephales promelas*)
- Hybrid striped bass (*Morone saxatilis x M. chrysops*)
- Koi (*Cyprinus carpio*)
- Largemouth bass (*Micropterus salmoides*)
- Mummichog (*Fundulus heteroclitus*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Tilapia (*Oreocromis* sp. & *Sarotherodon* sp.)
- Triploid grass carp (*Ctenopharyngodon idella*)
- White sucker (*Catostomus commersoni*)
- Yellow perch (*Perca flavescens*)

Addressing Industry Needs

Researchers, extension agents/specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline new initiatives and recent accomplishments in these areas.

Aquaculture Research

Research in New Jersey is mainly conducted through Rutgers School of Environmental and Biological Sciences/New Jersey Agricultural Experiment Station Haskin Shellfish Research Lab in Port Norris. There is a Multi-Species Aquaculture Development facility which is constructed but not presently in operation. There is also some freshwater finfish culture coupled with vegetable aquaponics and ornamental aquatic plant culture at the Rutgers EcoComplex in Columbus.

The New Jersey Agricultural Experiment Station is now working with Quality Koi, Inc. of New Jersey to integrate a research program with koi and plants in the EcoComplex greenhouse. The process will examine the economic benefits of growing koi in recirculation systems instead of ponds in the northeast region.

Other research may be conducted by individuals in other institutions of higher learning, though there is no specific clearing house for the work that is being done in-state. Some research in aquaculture has been funded over the years through the New Jersey Sea Grant Program, and some of those reports can be found at: http://www.njmsc.org/Sea Grant/Publications_Directory.htm#TechnicalReports.

Significant accomplishments of research faculty include:

- Development of tetraploid technology which allows "natural" triploids to be produced.
- Researchers have found that that QPX is in part, stock and latitude dependant.
- Distinguishing oyster species from one-another in China (this has implications on the potential introduction of *Crassostrea ariakensis* in the U.S.).
- Development of a budget for loss of oyster shell in the seed beds.

The New Jersey Department of Agriculture is involved with seafood and aquaculture marketing research. The NJDA, in cooperation with Rutgers University and University of Delaware Sea Grant, is completing a two-year market research study on ethnic live seafood markets in the northeast region. This $56,500 matching funds grant is being completed through the USDA Federal-State Marketing Improvement Program. The project includes a survey of market operators and consumer research of live seafood customers to determine buying habits and preferences of live seafood. The project has also developed a multilingual consumer directory so consumers can be more familiar with retail restaurants and supermarkets that sell live seafood.

In 2006, New Jersey Department of Agriculture, Rutgers Cooperative Extension and Food Innovation Center assisted a group of seven aquaculture producers in the state with marketing hard clams through a $47,100 USDA Value-Added Producer Grant. The seven entrepreneurs formed the New Jersey Seafood Marketing Group and developed unique retail

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packaging and marketing campaign under the Baymen's Pride trademark. The group has partnered with Wakefern Corporation, and this item continues to be sold in major supermarket chains including ShopRite stores across New Jersey, New York and Pennsylvania.

Aquaculture Extension

There is presently one extension agent working in commercial aquaculture, based at Rutgers University. Extension programming focuses on shellfish aquaculture, specifically the nursery and growout phases of the hard clam, but has recently included ornamental aquatic plant production. At present, Rutgers Cooperative Extension is leading the Barnegat Bay Shellfish Restoration Program: http://ocean.rcre.rutgers.edu/marine/bbsrp1.html

There are not any extension centers in the state, however, the Multi-Species Aquaculture Development Center in Cape May will likely have an outreach component when it is completed. Part of a research greenhouse in the Rutgers Eco-Complex in Columbus has a recirculating tilapia system linked with hydroponics for vegetables and aquatic plants, as well as a demonstration project using aquaculture as the model to teach high school math and science in the classroom.

Aquaculture Education

There is an aquaculture education program at Cumberland County College which has a large tilapia production facility in it. There are also about five high schools which have aquaculture course work or formal aquaculture curricula.

Aquaculture Resources

New Jersey Aquaculture Information: http://www.jerseyseafood.nj.gov/aquaculture.html

ReClam the Bay http://www.reclamthebay.org

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: NEW YORK

Gregg Rivara, Cornell Cooperative Extension
Michael Timmons, Cornell University

Industry Trends and Outlook

New York State is diverse both geographically and in terms of aquaculture species and systems. The industry ranges from flow through raceways to bottom culture of shellfish to intensive water reuse systems. Reliable production statistics are difficult to come by, but it is estimated that the State's aquaculture industry annually generates $20 million in farm-gate sales. These figures do not include state, county and municipal finfish and shellfish production for resource enhancement purposes. The predominant cultured species in New York are trout, baitfish (e.g. golden shiners), oysters, hard clams, large and smallmouth bass, bluegills and tilapia. Other products include bay scallops, koi, crawfish, winter flounder and aquatic plants (e.g. water lilies, hyacinths, arrowheads).

Commercial Species List

- Bay scallop, *Argopecten irradians irradians*
- Eastern oyster, *Crassostrea virginica*
- Northern quahog, *Mercenaria mercenaria*
- Brook trout, *Salvelinus fontinalis*
- Brown trout, *Salmo trutta*
- Rainbow trout, *Oncorhynchus mykiss*
- Tilapia (*Oreochromis niloticus*)

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

Bill Pell of Southampton Oyster Company (Photo: Gregg Rivara)

Aquaculture Research

Facilities conducting aquaculture research in the State include Cornell University, Stony Brook University, Long Island University, Brooklyn College, Dowling College, Morrisville State College and various field stations including the Suffolk County Marine Environmental Learning Center operated by Cornell Cooperative Extension of Suffolk County.

Much of the funded research in the State is for shellfish restoration and closed system engineering. Some of the first salmonid and shellfish hatcheries in

Emerging Issues and Critical Needs

- Lower cost electrical power would benefit all land-based farms, especially water reuse systems and shellfish hatcheries/nurseries.
- There is a need for better marketing of cultured product. While there is a generic campaign for New York seafood, some growers would like to see a program tailored to their industry. The danger is alienating the fishing industry (by comparing farmed to wild) to which a number of growers belong.
- With the growth of cottage-scale shellfish farms comes the need for more underwater land. While there are a number of ways to access these lands, it has become a constraint for growth. A solution on the horizon is the leasing of underwater land owned by the State by the County of Suffolk (the eastern-most county in New York State). While the county has had this capability since 1969, nothing was done due to the onerous requirements of the enabling legislation and baymen opposition. Since the brown tides of the 1980's and 1990's and greater restrictions on finfish landings, baymen have looked at shellfish farming as another tool to maintain their lifestyle and remain on the bay. In 2004, with support from the baymen, a revamped lease law was put into effect. This law made it easier for the county to lease lands for shellfish cultivation. The county has devoted staff and approximately $600,000 to develop a leasing program which must be in place by the end of 2010 when the law sunsets.
- Shellfish farmers that culture on bottom need to quantifying the ecological effects on the benthos during harvest.

Juvenile winter flounder raised for stock enhancement program. (Photo: Mark Abramson)

Commercial fisher Steve Gauger with oyster cages in Peconic Bay (Photo: Gregg Rivara)

the nation started in New York. Some of the State's "breakthroughs" in aquaculture include innovative water reuse systems for finfish culture, an axial-flow floating upweller nursery system for shellfish, lipid enrichment of oyster broodstock for increased production, innovative mechanical harvesting and sorting devices for northern quahogs and oysters, and hormonal manipulation of fish to increase production.

Aquaculture Extension

There are two full-time extension specialists in the state and a number of personnel that have part-time aquaculture extension responsibilities. The primary extension program is shellfish aquaculture which includes both private and government-operated shellfish farms. Assistance is given to established culturists (diseases, marketing, technology) as well as new start-ups (permit assistance, business planning). A major extension program accomplished with state and federal funds and in cooperation with a town shellfish hatchery was retraining commercial fishers (mainly inshore fishers or "baymen") to culture oysters. The program became the nucleus for the still expanding, cottage-scale shellfish aquaculture industry on eastern Long Island.

Aquaculture Education

There are two "aquaculture education centers" in New York. One is at the Suffolk County Marine Environmental Learning Center (SCMELC), operated by Cornell Cooperative Extension (CCE) of Suffolk County and focuses on shellfish aquaculture; the other is at CCE-New York City in the Bronx, and deals largely with water reuse systems and aquaponics.

Both programs send representatives to schools as well as have students come in to learn the basics of

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Stephen Tettelbach	Department of Biology- Long Island University (516) 299-3509 Stephen.Tettelbach@liu.edu	shellfish biology
Michael Timmons	Department of Biological and Environmental Engineering- Cornell University (607) 255-1630 mbt3@cornell.edu	recirculating system design
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Gregg Rivara	Cornell Cooperative Extension (631) 852-8660 gjr3@cornell.edu	shellfish/commercial production
Christopher Smith	Cornell Cooperative Extension (631) 727-7850 cfs3@cornell.edu	program director/scallop restoration
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Philson Warner	Cornell Cooperative Extension (212) 340-2960 paw14@cornell.edu	aquaponics
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Karen Rivara	East End Marine Farmers Association (631) 765-1808 keeno@juno.com	
Testing Laboratories		
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Bassem Allam	Marine Disease Pathology and Research Consortium (631) 632-8745 bassem.allam@stonybrook.edu	shellfish

aquaculture. The Suffolk County program operates summer day camps that expose children to an intensive program that includes information on growing shellfish from egg to market size.

In 2000, a shellfish gardening program SPAT (Southold Project in Aquaculture Training) was initiated by CCE-Suffolk. Incorporating monthly classes, thrice weekly volunteer workshops, a community shellfish garden and social events, the program has grown to 200 member families. SPAT volunteers work closely with the resource enhancement hatchery and nursery at the SCMELC and run their own hatchery on the site.

Aquaculture Resources

Cornell University Cooperative Extension http://www.cce.cornell.edu/~suffolk/Programs/MARhome.htm

Northeastern Regional Aquaculture Center The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: PENNSYLVANIA

Ann Faulds, Pennsylvania Sea Grant
Charles Conklin, Pennsylvania Department of Agriculture

Industry Trends and Outlook

The USDA National Agricultural Statistic Service Aquaculture Census of the Pennsylvania agricultural industry reports aquaculture sales of $10.9 million in the 2004. Sales of food fish comprised 68% of total sales with the remainder of the sales composed of sport and game fish, baitfish, crustaceans, molluscs, ornamental fish and water garden plants, and other animal aquaculture (tadpoles, frogs, trout eggs, and others). While trout comprises most of the fish food sales, tilapia and hybrid striped bass are also produced.

Recreational fishing activities associated with the release of hatchery fish also contributes a substantial amount to Pennsylvania's economy. For example, the Pennsylvania Fish and Boat Commission and Penn State University released a 2004 report entitled, "Creel Analysis and Economic Impact of Pennsylvania's Lake Erie Tributary Fisheries in Erie County, Pennsylvania, with Special Emphasis on Landlocked Steelhead Trout *(Oncorhynchus mykiss)*". This report concluded that in 2003, steelhead anglers spent $9.5 million on trip-related expenditures. The report goes on to conclude that this activity accounts for 219 jobs through direct and indirect efforts. The Pennsylvania Fish and Boat Commission annually stocks over one million steelhead smolts into Lake Erie to support this important fishery.

Up until 1998, the Pennsylvania aquaculture industry was regulated primarily by the Pennsylvania Fish and Boat Commission as an activity related to fish and fishing in Pennsylvania waters. Act 1998-94 recognized aquaculture as a farming activity and transferred registration and regulation of aquaculture activities to the Pennsylvania Department of Agriculture (PA DAG), which remains the lead agency promoting and regulating the aquaculture industry). The PA DAG Aquaculture Production Development Program is located within the Bureau of Market Development. The program is designed to help current and prospective aquaculture farmers to access information easily to help them achieve success. The program provides:

Pond aquaculture in Pennsylvania (Photo: Charlie Conklin)

- Links to information regarding regulations affecting aquaculture, species production research sales and marketing
- Guidance on business development
- Access to local sources for food fish, ornamental fish, sports fish and baitfish

Emerging Issues and Critical Needs

- Development of more effective and uniform regional policies and management techniques dealing with interstate regulations on fish health and biosecurity.
- Help bring the industry into compliance with the National Pollution Discharge Elimination System permits with a minimal financial effect on the farmer.
- Provide clear messages and balanced public awareness of the risks and benefits of consuming farmed fish.
- Develop of practical bird predation deterrent methods to reduce the economic loses to the aquaculture industry.

- Marketing initiatives designed to help fish farmers penetrate new markets and expand sales
- Educational opportunities for aquaculturalists

Commercial Fish List

- Bluntnose minnow (*Pimephales notatus*)
- Brook trout (*Salvelinus fontinalis*)
- Brown trout (*Salmo trutta*)
- Coho salmon (*Oncorhynchus kisutch*)
- Comets (*Carassius auratus*)
- Common carp (*Cyprinus carpio*)
- Creek chub (*Semotilus atromaculatus*)
- Emerald shiner (*Notropis atherinoides*)
- Fathead minnow (*Pimephales promelas*)
- Golden rainbow trout (*Oncorhynchus mykiss*)
- Golden shiner (*Notemigonus chrysoleucas*)
- Goldfish (*Carassius auratus*)
- Koi (*Cyprinus carpio*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Tiger trout (*Salvelinus fontinalis* x *Salmo trutta*)

Addressing Industry Needs

Researchers, extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

Aquaculture Research

As Pennsylvania's aquaculture industry continues to develop, the need for research is being addressed through private, governmental, feed manufacturing, and university-based research programs. This research provides a broad base of support for Pennsylvania, and for the aquaculture industry throughout the Northeast. The strength of the State's research, as with its industry, lies in salmonid aquaculture, but significant resources are also devoted to other species including tilapia, striped and hybrid striped bass, ornamentals, and freshwater shellfish. The organizations mentioned below provide an essential research core for the State and have access to other individuals and resources.

There are two strictly commercial research groups in the state who have had long tenures and significant success. Aquamarine Fish Farms, Inc., under the leadership of Dr. Steven Van Gorder, specializes in research on recirculating system and urban aquaculture. Van Gorder has partnered with several other organizations to provided support to commercial aquaculturists in Pennsylvania for over 20 years, and much of his work with salmonids, tilapia, and striped bass has been groundbreaking. In a similar fashion, the staff of Emperor Aquatics have been leaders in water treatment research since the early 1990's. In particular, their expertise in both UV sterilization and in foam fractionation has supported superior fish health in venues from ornamental backyard ponds to full scale commercial growout facilities and municipal aquariums.

The State has two federal facilities devoted to aquaculture. The Northeast Fishery Center Complex of the U.S. Fish and Wildlife Service, which is based in Lamar, specializes in culture and management techniques for threatened and endangered species as well as providing fish health services and research for both natural and aquacultured populations. Their expertise in research on the culture of river herrings, Atlantic sturgeon, striped bass, Atlantic salmon and rainbow trout has made their staff a critical resource to many aquaculturists in the region and their latest initiative to create an Aquaculture Research Consortium within the State could lead to significant collaborations among private and public groups within Pennsylvania's aquaculture community. Likewise the U.S. Geological Survey's Northern Appalachian Research Laboratory in Wellsboro has significant resources and expertise invested in all aspects of salmonid culture. In addition, research conducted at this facility has led to the development of culture methodologies for American eels (*Anguilla rostrata*) and various freshwater mussels. The central location of this facility has greatly facilitated the ability of its researchers to provide outreach to all regions of the state from the Great Lakes to the Delaware River Basin.

Research Contact Information		
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Ann Faulds	Pennsylvania Sea Grant (215) 806-0894 afaulds@psu.edu	risk communications and fish consumption issues
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Steven Hughes	Cheyney University of Pennsylvania (610) 399-2275 or 1-800-CHEYNEY	
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Gary Reddinger	Pennsylvania Trout Farmers Association (570) 992-4429	
Testing Laboratories		
Corinne Sweeney	University of Pennsylvania School of Veterinary Medicine - New Bolton Center http://www.vet.upenn.edu/nbc/	
Michael Millard	U.S. Fish and Wildlife Service, Lamar Fish Health Center (570) 726-6611	
John I. Enck, Jr.	Penn State University, Animal Diagnostic Laboratory (814) 863-0837	

Trout aquaculture raceway (Photo: Charlie Conklin)

Pennsylvania is the only state in the northeast with two aquaculture feed producers and both are family owned and operated. Melick Aquafeeds in Catawissa has served the region under several different names during the past three decades and produces a wide variety of aquatic animal feeds. Zeigler Brothers in Gardners is in the second generation of ownership and not only produces aquatic animal feeds, but also produces pet and zoo animal feeds. Along with its feed production, Zeigler also provides equipment and consulting services to the aquaculture industry. Both firms are committed to collaborative research and export products outside of the United States.

Five universities in the State have significant investments in aquaculture research and education. The University Park campus of Penn State and the New Bolton Center Campus of the University of Pennsylvania both provide aquatic animal health research and diagnostic support to the state's industry as component laboratories in the Pennsylvania Animal Diagnostic Laboratory System (PADLS). There is also some fish culture research carried out at the New Bolton Center which has mostly been centered around fish nutrition research. Drexel University has begun in the past few years to develop a program for the culture of freshwater mussels native to the region. Proposed collaborations with several federal and state agencies promise to expand this program significantly in the future. Mansfield University has had a strong program in aquaculture education and research for over 20 years. The students trained in this program are from throughout the U.S. and their continued research in the culture of native and endangered species has been well received by both government agencies and professional organizations. In 2004, Cheyney University began an aquaculture program whose main educational and research focus is on urban aquaculture, aquaponics, fish nutrition, and aquarium fish culture.

Aquaculture Extension

The Pennsylvania State Department of Agriculture hosts a statewide aquaculture workshop, *PennAqua*, biennially that serves as the main training opportunity for the aquaculture industry. The Pennsylvania Aquaculture Coordinator leads this effort, and works with the industry to solve emerging problems. Pennsylvania Sea Grant and New Bolton Center have also been active in helping the industry prepare for and respond to biosecurity issues such as Integrated Pest Management and Viral Hemorrhagic Septicemia.

Aquaculture Education

Mansfield University and Cheyney University both offer coursework in aquaculture. See the Aquaculture Research section above for more information about their programs, and the Contact section for Web sites.

Aquaculture Resources

Northeastern Regional Aquaculture Center The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: RHODE ISLAND

Michael A. Rice, Rhode Island Cooperative Extension, University of Rhode Island
Dale Leavitt, Roger Williams University
David Alves, Rhode Island Coastal Resource Management Council

Industry Trends and Outlook

Rhode Island is a producer of farm-raised shellfish, including eastern oysters *Crassostrea virginica* and northern quahogs *Mercenaria mercenaria*, valued at greater than $1,348,525 (farm gate value) in 2006. The eastern oyster is the number one product in terms of production and value with 2.4 million pieces sold, representing 97% of the farm gate value total. There are 28 companies cultivating shellfish in Rhode Island (2006) with 99 acres under lease. The majority of the shellfish industry relies on purchase of hatchery seedstock, but there is some spat collection. The State Department of Environmental Management (DEM) operates three trout hatcheries and a warm water hatchery for stocking of species such as largemouth bass. Other species of interest include: blue mussels, bay scallops and ornamental fish species. There is an annual Rhode Island aquaculture report produced since 1995 with detailed information about Rhode Island's Aquaculture Production available from the State Aquaculture Coordinator.

Workboat of Saltwater Farms, on the East Passage of Narragansett Bay, off Middletown. (Photo: Saltwater Farms)

Cultured Species List

- Bay scallops (*Argopecten irradians*)
- Eastern oyster (*Crassostrea virginica*)
- European oyster (*Ostrea edulis*)
- Northern quahog (*Mercenaria mercenaria*)
- Brook trout (*Salvelinus fontinalis*)
- Brown trout (*Salmo trutta*)
- Koi carp (*Cyprinus carpio*)
- Rainbow trout (*Oncorhyncus mykiss*)
- Tilapia (*Oreochromis aureus*)
- Clownfish (*Amphiprion* spp.)
- Atlantic Cod (*Gadus morhua*)
- Black sea bass (*Centropristis striata*)
- Haddock (*Melanogrammus aeglefinus*)
- Summer flounder (*Paralichthys dentatus*)
- Winter flounder (*Pseudopleuronectes americanus*
- Eelgrass (*Zostera marina*)

Addressing Industry Needs

Researchers, Extension specialists, resource managers, industry associations and concerned

Emerging Issues and Critical Needs

- Environmental impacts of aquaculture
- Disease management & quarantine issues
- Commercialization of non-traditional species
- Business management issues (i.e. costs, risk management, profitability)
- Permitting & policy issues related to multiple-use conflicts in public trust waters

stakeholders all play a role in addressing industry needs. The following sections outline new initiatives and recent accomplishments in these areas.

Aquaculture Research

The University of Rhode Island (URI) conducts aquaculture-related work at two campuses (Kingston and Narragansett Bay), and within five academic Colleges and several departments at the University. An overview of research topics is as follows:

- **Aquaculture Biotechnology** Faculty in the Department of Cell and Molecular Biology (CMB) in collaboration with Fisheries, Animal and Veterinary Sciences (FAVS) researchers have isolated protective heat shock proteins in salmon smolts, elucidated the molecular biology of growth in salmonids, and the physiology and molecular biology of several *Vibrio* species that are pathogens of a multitude of cultured species. Work is also underway to develop vaccines for the protection against bacterial infections in fish. Researchers in the Department of Biomedical Sciences in the College of Pharmacy are studying the pharmaceutical properties of biochemicals extracted from cultured algae.
- **Aquaculture Pathology** Aquaculture pathology has a long history in FAVS (one of the first fish disease laboratories in the region was established by departmental faculty.) Researchers have described a new type of Vibrio infection in summer flounder, characterized a Rickettsia-like infection of scallops, and described a retro-virus that induces neoplasia in soft-shell clams. Annually, URI cooperates with the Rhode Island Department of Environmental Management to survey bivalve diseases throughout the state. URI also serves the local aquaculture industry by providing diagnostic services using state-of-the-art tools in molecular biology and genomics. For example, these tools are being used to investigate the molecular mechanisms of bivalves to parasitic infection. In collaboration with Roger Williams University (RWU), URI scientists are developing and selecting disease resistant strains of oysters for use by the local shellfish farmers.
- **Aquaculture Systems** Aquaculture in Rhode Island and the Northeast is hampered by user conflicts in the coastal zone and relatively high land and utility costs. As a result, research into aquaculture systems at URI has included improvements in water reuse and recirculation tank systems, development of transient-gear shellfish aquaculture systems, methods for nursery culturing of shellfish in small boat marinas, and the refinement and optimization of the design of floating upweller systems (FLUPSYs).
- **Bivalve Molluscan Aquaculture** URI research has focused on methods to improve shellfish production. This includes means to improve the overwintering survival of oysters and quahogs and optimizing the harvest yields of shellfish by managing stocking densities. Research has been undertaken to model shellfish growth in relation to food availability and water currents.
- **Coastal Policy and Aquaculture** URI's Coastal Resources Center (CRC) has a long-standing program to assist governments in developing countries to adopt policies to promote and manage sustainable forms of aquaculture in the coastal zone. CRC projects have included working with

Graham Brawley tending oysters on the Moonstone Oyster farm, Point Judith Pond, Rhode Island. (Photo: Moonstone Oyster Company)

local and national governments abroad to restrict the rates of mangrove deforestation for fishpond construction and to manage pond effluents. Additionally, faculty from the Department of Marine Affairs (MAF) have conducted several studies on fisheries and coastal property rights as they relate to aquaculture industry development.

- **Culture of Novel or Non-traditional Species** Faculty in FAVS and the Graduate School of Oceanography are working on culture methods for novel fish species including tautog, winter flounder, summer flounder, haddock, cod, and black sea bass. FAVS and Biological Sciences researchers have studied the culture of lobsters in an effort to remediate environmental accidents (e.g., oil spills).

- **Economics and Business of Aquaculture** Faculty in the Department of Environmental and Natural Resource Economics (ENRE) have interests in the economics of salmon and shrimp production, economics of aquaculture production systems, eco-labeling of aquaculture and other seafood products, the economics of global trade of aquaculture-based products, and the relative valuation of multiple uses of aquatic environments. URI's College of Business Administration (CBA) has been active in assisting aquaculture businesses in Rhode Island, nationally and internationally through workshops and face-to-face assistance in business planning. Recently, CBA has undertaken a project to characterize the financial structuring of aquaculture businesses throughout the Northeast.

- **Environmental Impacts of Aquaculture** Environmental science is one of the most notable institutional strengths at URI. A number of aquaculture and extension projects are involved with assessing the environmental impacts of aquaculture. Internationally, the CRC has analyzed the impacts of shrimp farming in Ecuador and Indonesia, and advised on the management of seaweed and pearl farming for greater environmental sustainability in Indonesia and Tanzania. Other projects undertaken by URI faculty include improvements in methods to minimize the environmental impacts of cage culture of groupers and finfish in the Philippines and improvement of integrated tilapia culture systems in Africa.

- **Nutrition and Feeds for Marine Species** From the 1980's to the present, Drs. David Bengtson, Terry Bradley, Jennifer Specker and, in recent years, Chong Lee have conducted research on development of the larval fish digestive tract and processing of ingested feeds; protein sparing with lipids in diets for juvenile summer flounder and black sea bass; substitution of plant proteins for fish meal in diets for juvenile summer flounder; and use of squid hydrolysate in diets for larval and juvenile fish.

Bob Rheault, Shellfish grower and East Coast Shellfish Growers Association President, demonstrates his floating upwellers system. (Photo: Mike Rice)

- **Salmonid Aquaculture** Research on the culture of salmonids has a long history at URI. Recent research projects involving salmonids have focused on the characterization of the physiology of smoltification or the changes that occur to the anadromous fish as they adapt to salt water. Much of this research has been dedicated to characterizing various indicators of the timing of the onset of smoltification and the characterization of control systems involved in the smoltification process.

- **Sociology and Anthropology of Fisheries and Aquaculture** The sociology and anthropology of aquaculture communities is another internationally recognized research area at URI. Projects have involved the study of the social factors leading to success of international development projects, including aquaculture, and the study of social factors in communities in transition from a predominantly capture fishery economy to an aquaculture-based economy.

The National Marine Fisheries Service (NMFS) Narragansett Facility focuses on reproductive biology and artificial propagation of marine finfish species of the North Atlantic. Currently, scientists at the Narragansett Laboratory are developing methods for the intensive culture of cod and haddock and conducting research to fill critical voids in our knowledge of their early life history. Both Atlantic cod and haddock broodstock are maintained at the Narragansett Laboratory. Methods are under

Dr. Dale Leavitt and student Eric Payne of Roger Williams University placing oysters in Jenny's Creek Estuary, Prudence Island (Photo: Karin Tammi)

investigation to produce high quality embryos, larvae and juveniles through out the year. Swimming behavior, activity, feeding, digestion and metabolism (oxygen consumption) are examined as they relate to development, growth, and prey availability. The effects of the physical environment (temperature and turbulence) are considered. Results will be integrated into individual-based, bioenergetic models of growth and survival. This facility, with its two large seawater tanks and extensive seawater systems, has allowed the scientists at Narragansett to spawn and rear over a dozen different species of marine fish, many for the first time in captivity.

Roger Williams University supports academic research, technology transfer and outreach that promote the aquaculture industry within Rhode Island and the northeast region. The university accomplishes this by providing: 1) release time for full-time faculty to permit research, 2) institutional funds to allow faculty and students to travel and network with other aquaculture researchers at national and international meetings, 3) facilities for workshops, courses and meetings for local and regional aquaculture outreach, and 4) administrative support and grants management from the university. The range of projects is broad, with species diversity from fresh to salt water and from local to tropical in nature. The current RWU aquaculture permits allow the culture of 35 shellfish species and 60 fish species, and production systems include both flow-through and recirculating on scales ranging from tanks to ponds. RWU maintains a number of field sites that include floating upwellers for shellfish culture at local marinas, and several experimental aquaculture lease sites throughout Narragansett Bay. A brief description of the major research projects currently underway or recently concluded are:

- **Public Benefit Aquaculture** In collaboration with local commercial shellfishermen, the ongoing research program rears clam and oyster seed at RWU and releases seed into the bay for subsequent harvest. Over 15 million seed have been planted since the inception of this project, and RWU staff are assessing the economic viability of this form of shellfish enhancement. Should this concept work in Narragansett Bay, the intent is to develop it as a resource management tool to enhance the recreational and commercial harvest of shellfish.

- **Culture of alternative species** Shellfish farms in Rhode Island grow two species commercially, the oyster (*Crassostrea virginica*) and the quahog (*Mercenaria mercenaria*). To expand the opportunities for shellfish growers, RWU faculty and staff are developing methods for farming alternate shellfish species. RWU is investigating the potential of the razor clam, the surf clam and the bay scallop as additional species for local cultivation.

- **Converting non-profitable cranberry bogs to fish production** Cranberry farming in the region has faltered because of competition and overproduction. RWU is working with local farmers to incorporate fish farming as an alternate cash crop for the cranberry grower. This involves modifying an existing cranberry bog into a fish farm to demonstrate crop diversification. The fish farm is entering into its third year of operation and is transitioning to a commercial enterprise.

- **Generating native strains of disease resistant oysters and oyster restoration in Narragansett Bay** Oyster farming is the largest aquaculture business in Rhode Island, and oyster diseases are a significant risk for local oyster farmers as well as wild harvesters. RWU staff are working with

Roger Williams University Student Maura Flynn holding bay scallop seed. (Photo: Karin Tammi)

disease specialists at URI and Rutgers University to breed selected disease resistant lines of oysters using native oyster stocks. Disease resistant Rhode Island oysters have been produced by the RWU Shellfish Hatchery for restoration in the bay and for use by commercial oyster farmers.

- **Hydroponics** Effluent management is an important component of fish farming. An effective strategy to manage effluent is to use fish waste effluent as a nutrient source for growing commercially important plants. RWU maintains several active recirculating hydroponic systems to test the effectiveness of this concept.
- **Developing a tropical fish hatchery for the ornamental aquarium trade** The market for ornamental marine fish in the Northeast is large, however a major bottleneck to supplying this market is the cost and risk of shipping tropical fish from farms in the south. RWU is testing the economic feasibility of operating a commercial ornamental fish hatchery in Rhode Island. Current efforts are focused on rearing the clownfish, sea horse and ornamental shrimp.

Aquaculture Extension

In the traditions of both Land Grant and Sea Grant, the University of Rhode Island manages extension program in aquaculture that has maintained strong ties with the Northeastern Regional Aquaculture Center since the Center's inception. Through the Rhode Island Aquaculture Initiative (RIAI), a federally funded program jointly administered by Roger Williams University, Rhode Island Sea Grant and the Rhode Island Coastal Resources Management Council (CRMC), URI has joined with RWU to expand aquaculture extension programming to Rhode Island's East Bay. Aquaculture extension programming at URI over the years has included assisting the aquaculture industry to organize into the Ocean State Aquaculture Association (OSAA), providing topical aquaculture classes for fishers, offering gear workshops, business workshops, and instituting and hosting Rhode Island's Annual Aquaculture Conferences and in cooperation with the Northeastern Aquaculture Extension Community assisting in the organization and implementation of the biennial Northeastern Aquaculture Conference and Exposition (NACE).

Aquaculture Education

Rhode Island has a rather modest involvement in aquaculture education in the secondary schools. In the past 10 years, individual teachers on their own initiative have taken on aquaculture as part of marine

The Blount Aquaculture Research Laboratory opened in 2005 at the University of Rhode Island Narragansett Bay Campus. (Photo: Michael Rice)

studies curricula. Two notable cases include the inclusion of aquaculture of shellfish as part of the Marine Technology curriculum at South Kingstown High School, and for several years in the late 1980s to early 2000s, an aquaculture curriculum at the Davies Technical High School and Career Center in Lincoln, RI offered instruction in methods of tank culture of freshwater finfish. Both of these programs have been discontinued due to lack sustained instructor interest.

At the post-secondary education level, Rhode Island has two Universities involved in aquaculture education, the University of Rhode Island (URI) and Roger Williams University (RWU). The aquaculture program at the University of Rhode Island, begun in 1969 and administered by the Department of Fisheries, Animal and Veterinary Sciences (FAVS), is one of the oldest aquaculture programs in the northeastern United States. The Aquaculture Program offers a degree program at the undergraduate level (B.S. in Aquaculture and Fisheries Technology) as well as opportunities to study at the graduate level in or M.S. in Fisheries and Aquaculture program or our Ph.D. program in Environmental Sciences with an aquaculture emphasis. Students in the programs at URI have come from throughout the United States and from many foreign countries. Faculty in the department have research interests in culture of salmonids, culture of marine finfish and marine finfish larviculture, DNA vaccines, culture of bivalve mollusks, recirculation aquaculture systems, development of new aquaculture species, and environmental impacts of aquaculture among many others. The educational program in aquaculture at RWU is part of their bachelor's degree program in Marine Biology. Excellent experiential learning opportunities in aquaculture at RWU are

Research Contact Information

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Terence Bradley	University of Rhode Island (401) 874-5404 tbradley@uri.edu	physiology of salmonids; marine finfish aquaculture
Lawrence Buckley	National Marine Fisheries Service, Narragansett Lab (401) 782-3200 Larry.Buckley@noaa.gov	aquaculture of cod, haddock and other marine finfish species
Kathleen M. Castro	University of Rhode Island, Rhode Island Sea Grant (401) 874-5063 kcastro@uri.edu	lobster propagation & stock restoration
Robert A. Comerford	University of Rhode Island (401) 874-4315 bobcom@uri.edu	aquaculture business structuring; aquaculture business planning
Barry A. Costa-Pierce	University of Rhode Island, Rhode Island Sea Grant (401) 874-6800 bcp@gso.uri.edu	sustainable aquaculture systems; tilapia aquaculture; mussel aquaculture
Joseph T. DeAlteris	University of Rhode Island, Kingston (401) 874-5333 jdealteris@uri.edu	oyster reef structures; aquaculture gear design & performance
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Aquaculture Industry Association		
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enhanced its seaside location and its state-of-the-art aquaculture teaching laboratories housed in the Marine and Natural Sciences (MNS) building that was opened in 1997 and a recently acquired oyster farm site at Jenny's Creek on Prudence Island. Student research projects at RWU have included culture of oysters and other bivalves, as well as spawning and culturing of valuable marine aquarium species.

Aquaculture Resources

State of Rhode Island Annual Aquaculture Report
http://www.crmc.ri.gov/pubs/index.html

Coastal Resources Management Council
Aquaculture permitting and policy information
http://www.crmc.ri.gov/

Northeastern Regional Aquaculture Center
The NRAC is one of five Regional Aquaculture Centers established by the U. S. Congress which supports research and outreach efforts to promote the development of the aquaculture industry. http://www.nrac.umd.edu

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A copy of this report may be downloaded from: http://www.nrac.umd.edu

NRAC Publication No. 111-2007

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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: VERMONT

Jurij Homziak, Lake Champlain Sea Grant Program, University of Vermont Extension

Industry Trends and Outlook

Vermont has six permitted trout producers. All produce rainbow, brown and/or brook trout. Most fish are used to stock public and private ponds, often through Conservation District pond stocking programs. The producers also supply trout fingerlings. A small amount of trout is produced on farms for sale to local markets. The number of trout producers has declined from 15 producing farms, including two food fish producers, in the last 15 years.

There are two permits for tilapia production. While these are currently limited to production for research or education only, these producers are using the permits to determine economic feasibility. If successful, the State expects the holders to apply for commercial production permits.

Currently, there are not any commercial baitfish producers in the State, although several have produced small quantities on an off and on basis in previous years.

Commercial Species List

- Rainbow trout (*Oncorhynchus mykiss*)
- Brown trout (*Salmo trutta*)
- Brook trout (*Salvelinus fontinalis*)
- Tilapia (*Oreochromis* spp.)

Addressing Industry Needs

Researchers, Extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline new initiatives and recent accomplishments in these areas.

Most fish are used to stock public and private ponds. (Photo: Lucas James Williams Memorial Youth Fund http://www.lucasjameswilliamsyouthfund.org/)

Aquaculture Research

Aquaculture research is not underway in the State of Vermont at this time.

Aquaculture Extension

The University of Vermont (UVM) Extension and local Conservation Districts have periodically partnered to bring in Aquaculture Specialists from neighboring states to lead pond owner workshops on recreational and small-scale food fish production, and pond management. Currently, there is not an Aquaculture Extension Specialist in the State.

Emerging Issues and Critical Needs

- Circumstances have recently changed that will strongly encourage the development of local baitfish production. Baitfish are an important commodity that supports an economically important recreational fishing industry (both open water and ice fishing). Vermont state baitfish regulations changed in 2007 to reduce the risk of introducing exotic invasive fish species into the state and the Lake Champlain Basin. Regulations limit the types of baitfish permitted (golden shiner, emerald shiner, and white sucker only) and phase out imports of baitfish from outside the basin. New regulations will further restrict baitfish movement within the state. On the other side of the Lake Champlain Basin, New York is also restricting baitfish movement to prevent the eastward spread of Viral Hemorrhagic Septicemia (VHS). Cutting off external supply and limiting in-state movement of baitfish provide multiple opportunities for in-state bait fish production.

- In response to new State restrictions on baitfish import and movement, Lake Champlain Sea Grant, the Vermont Agency of Natural Resources and University of Vermont Extension are actively seeking support to develop projects to demonstrate baitfish production techniques and document financial aspects of small-scale, low tech baitfish production. We are also collaborating with New York Department of Environmental Conservation to expand the demonstrations to New York in support of their VHS prevention effort.

We provide regionally appropriate aquaculture information on request to the public. UVM Extension has also presented state information at limited national and regional meetings.

Aquaculture Education

The University of Vermont does not have any formal undergraduate or graduate programs in aquaculture education, however, UVM Extension does host informal education seminars and workshops in pond management and small-scale aquaculture. Post-educational surveys have documented both improved knowledge and changes in pond management practices among participants in workshops hosted by University of Vermont Extension.

Aquaculture Resources

Vermont Aquaculture Association
http://www.vermontagriculture.com/vaa/index.htm

Northeastern Regional Aquaculture Center
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AQUACULTURE SITUATION AND OUTLOOK REPORT 2007: WEST VIRGINIA

Ken Semmens, West Virginia University
Daniel J. Miller, West Virginia University
Rodney Kiser, West Virginia University
Steven Summerfelt, The Freshwater Institute

Buckhorn Trout Farm, Pendleton County. Photo: Ken Semmens

Industry Trends and Outlook

Trout is the fish most commonly grown by West Virginia producers. According to the USDA National Agricultural Statistics Service data, West Virginia reported 21 operations in 2005-06 with sales valued at $1,145,000. At this time nearly all the trout grown are distributed to the recreational market, including nearly 30 fee fishing locations.

The West Virginia Division of Natural Resources is the largest single producer of fish in the state. It operates two warm-water and seven cold-water hatcheries. The warm water hatcheries produce muskellunge, walleye, channel catfish, hybrid striped bass, paddlefish, black bass, sauger, blue catfish, and shovelnose sturgeon fingerlings. The cold-water hatcheries produced 744,057 pounds of trout (brook, brown, rainbow, and golden rainbow) in 2005-06. Federal facilities important to the aquaculture industry include the USDA-ARS National Center for Cool and Cold Water Aquaculture, the Leetown Science Center, and the White Sulphur Springs National Fish Hatchery.

WV Aqua grows arctic charr as a food fish and is the largest private producer in the state. The fingerlings are grown indoors and utilize recirculated mine water. Fish are processed at WV Aqua's processing plant and distributed fresh nationwide. Custom smoking is done by a business in Kentucky. Estimated annual live weight production is between 300,000 and 400,000 pounds.

Three resident businesses offer a variety of fish, plants, and other products for warm water ponds and distribute throughout the state. They compete with businesses in Arkansas which send trucks to local farm supply stores. These vendors sell catfish, bass, sunfish, baitfish, koi, carp, and other species.

Often, fee fishing businesses do not grow the fish they need, rather they are purchased from a distributor who obtains the fish from a variety of sources and delivers them as needed. Trout are the fish of choice during the cool months and catfish are the fish of choice during the warm months. Catfish are purchased from growers south of West Virginia where the growing season is longer.

The West Virginia Aquaculture Association (WVAA) is the only state-wide producer organization.

Emerging Issues and Critical Needs

Utilization of mine water for production of salmonids:

- "Impaired" water has value to aquaculture industry. It could be a significant resource to development of the West Virginia Aquaculture industry.
- Development of a profitable, processor-based trout enterprise has not yet been successful in the long term.

Recreational use of farm raised fish:

- Increasingly, private water is managed to support recreational activities. West Virginia vendors are increasing their market share for stocking warm water ponds.
- Private recreational enterprises which focus on fishing are being developed. Landowners are creating habitat, lodging, and seek to market the fishing experience.
- Fishing events are developed which utilize both public and private water.
- There is an effort to create a program which will use lottery funds to purchase live fish from private producers to stock public water to increase tourism.
- The stocking of streams by private individuals for recreational opportunities is growing faster than the traditional pay-pond format. Individuals utilize the stocking of large trout (1.5 pounds+) into a pay-to-fish format in streams which flow across their property. Issues of stream ownership and access have surfaced since the inception of this new pay fishing technique
- Viral Hemorrhagic Septicemia issues in adjacent states create incentive to utilize water sources in West Virginia.

WV Aqua in Mingo County. (Photo: Ken Semmens)

Cultured Species List

- Black crappie (*Pomoxis nigromaculatus*)
- Black sandshell mussel (*Ligumia recta*)
- Blue catfish (*Ictalurus furcatus*)
- Bluegill (*Lepomis macrochirus*)
- Brook trout (*Salvelinus fontinalis*)
- Brown trout (*Salmo trutta*)
- Bullfrog (*Rana catesbeiana*)
- Channel catfish (*Ictalurus punctatus*)
- Common carp (*Cyprinus carpio*)
- Fathead minnow (*Pimephales promelas*)
- Golden rainbow trout (*Oncorhynchus mykiss*)
- Goldfish (*Carassius auratus*)
- Grass carp (*Ctenopharyngodon idella*)
- Hybrid bluegill (*Lepomis macrochrius* x *L. cyanellus*)
- Hybrid striped bass (*Morone chrysops* x *M. saxatilis*)
- Koi (*Cyprinus carpio*)
- Largemouth bass (*Micropterus salmoides*)
- Mucket (*Actinonaias ligamentina*)
- Muskellunge (*Esox masquinongy*)
- Northern riffleshell (*Epioblasma* t. *rangiana*)
- Notched rainbow mussel (*Villosa constricta*)
- Paddlefish (*Polyodon spathula*)
- Pistol grip mussel (*Tritogonia verrucosa*)
- Plain pocketbook mussel (*Lampsilis cardium*)
- Pocketbook mussel (*Lampsilis ovata*)
- Purple wartyback mussel (*Cylonaias tuberculata*)
- Rainbow mussel (*Villosa iris*)
- Rainbow trout (*Oncorhynchus mykiss*)
- Sauger (*Sander canadensis*)
- Shovelnose sturgeon (*Scaphirhynchus platorynchus*)
- Smallmouth bass (*Micropterus dolomieu*)
- Striped bass (*Morone saxatilis*)
- Three ridge mussel (*Amblema plicata*)
- Tilapia (*Oreochromis niloticus*)
- Walleye (*Sander vitreus*)
- Wavy-rayed lamp mussel (*Lampsilis fasciola*)
- White bass (*Morone chrysops*)
- White crappie (*Pomoxis annularis*)
- Yellow perch (*Perca flavescens*)

Addressing Industry Needs

Researchers, Extension specialists, resource managers, industry associations and concerned stakeholders all play a role in addressing industry needs. The following sections outline the new initiatives and recent accomplishments in these areas.

Aquaculture Research

The following research is being conducted at West Virginia University:

- **Rainbow Trout Genome Project** The focus of the rainbow trout genome project is to develop genetic/ genomic resources (e.g. microsatellite markers, linkage maps, ESTs, BAC libraries and microarrays) and utilize them to identify genetic elements that control economically important production traits such as fillet quality, embryogenesis, growth rate, feed efficiency and disease resistance. The ultimate goal is to use this knowledge in selective breeding programs to develop more desirable strains of rainbow trout for efficient production. This project is in collaboration with the USDA-ARS National Center for Cool and Coldwater Aquaculture.

- **Aquaculture Product and Marketing Development Project** (APMDP) at West Virginia University is a market-oriented, multidisciplinary effort that is administered through the Davis College of Agriculture, Forestry and Consumer Sciences. Individual objectives of the project focus on the following disciplines: Marketing, Agricultural Economics, Animal Science, Food Science, Engineering, Recreation and Parks, Horticulture, and Extension. The project seeks to focus on two economic development opportunities associated with aquaculture development in West Virginia - flowing water systems, and niche markets.

- **Marketing** Marketing studies have been conducted to identify and assess market opportunities for aquaculture products in both recreational and food fish markets. Surveys of the fee-fishing industry have focused on four areas -- the general fishing population, people who patronize fee-fishing establishments, visitors to West Virginia where fee-fishing is not the primary purpose of the visit, and managers of fee-fishing businesses. Surveys have also focused on businesses (restaurants, supermarkets, institutions) that purchase fish as part of the food fish market industry. The second phase of this objective initiated a market-driven network for providing Appalachian aquaculture products to the recreational fee-fishing market. The third phase is focusing on development of targeted, fishing-based recreational travel packages for visitors to West Virginia. The travel packages would include lodging, meals and recreational activities where fee-fishing would represent one of the activities. Efforts also will be made to implement a cooperative approach to marketing among small producers and to assess the market potential for recreational fee-fishing in rivers and streams.

West Virginia University at Dogwood Lake in Monogalia County. (Photo: Ken Semmens)

- **Recreation and Parks** This work focuses on use of fish for recreation in the private rather than public sector. Investigators seek to identify and quantify the impact of management variables on costs, revenues and profitability of food and recreational fishing enterprises and to assess demand and develop marketing strategies for recreational fee fishing packages as complementary recreational activities. Investigators are also working to determine standards of quality for fishing programs that stock hybrid striped bass and hybrid bluegill sunfish, and determine the stability of demand behavior for a changing fee fishing market.

- **Agricultural & Resource Economics** Economic feasibility is a key piece of the puzzle. Project investigators started with trout and have since looked at other species suitable for hill land such as hybrid bluegill. In addition to profitability, we estimated economic risk using a combination of tools such as enterprise (or cost and return) budgets, capital investment techniques and economic models. To date, the economics of both production and processing assuming different operational sizes (small, medium and large) have been analyzed. In addition, firm-level analyses, as well as aggregate, economic development impacts for both the food fish and fee fishing sub-sectors have been examined. The economics of mine water aquaculture in flow-through systems from the producers' perspective, have been studied, and, in collaboration with other investigators, profitability-risk characteristics of alternative

combinations of species and sizes, and marketing alliances for various market segments (i.e., processing, stocking and fee fishing) will be studied. In the process, researchers will identify economically optimal feeding and harvesting rates, given alternative product price/feed cost ratios, feed conversion rates and stocking rates. On the recreation side, researchers plan to evaluate the relationship among anglers, various attributes of recreational fishing (in both private and public settings) and statewide economic development. The goal is to provide information that can be used by the industry, policy makers and other clientele groups to build a sustainable aquaculture industry in hill country.

- **Food Science and Technology** Investigators in this objective are focusing on product quality and product development. The effect of water quality and stress on the consistency and quality of fresh trout fillets and value added smoked trout products have been examined. The effect of culture conditions, post-harvest handling and antioxidant feeding on product quality has been investigated. Investigators have also characterized the impact of varying CO_2 and O_2 levels on growth efficiency, nutrient utilization and fillet attributes of rainbow trout and arctic charr. This work was in collaboration with Cornell University and The Conservation Fund's Freshwater Institute. Potential new products may be obtained with "cold set" technologies for production of value-added trout products. Researchers seek to develop value-added food based on proteins and lipids recovered from trout processing by-products and to evaluate the feasibility of fortifying rainbow trout fillets with heart friendly omega-3 fatty acids.

- **Animal Science** Animal science researchers work with a diversity of species to answer both basic and applied questions. Investigators seek to characterize the impact of varying CO_2 and O_2 levels on growth efficiency, nutrient utilization and fillet attributes of rainbow trout and arctic charr. They are also examining the metabolic aspects of growth and efficiency of nutrient use in different strains of rainbow trout. In order to produce fish for the recreational market, investigators have conducted production and nutrition experiments to evaluate hybrid bluegill sunfish as an alternative species for fee-fishing businesses, and are examining genetic diversity in green sunfish to assist development of superior hybrids. Another experiment is evaluating the production of all-female triploid brook trout to produce large fish for recreational markets.

- **Civil Engineering** New materials provide new opportunities. Researchers have designed and constructed three systems using a honeycomb fiber-reinforced polymer (HFRP). This material is relatively light and stiff and is being tested as an alternative to concrete. Two pilot scale modular raceway systems have been installed for production of trout, one using treated mine water and another using spring water. In collaboration with a NRAC project, a floating raceway using HFRP material was constructed and installed. We seek to optimize performance and minimize costs of HFRP raceway systems to enhance profitability of trout production and to develop HFRP tanks for field assembly from flat panels.

- **Engineering – Simulation Tool Development** The objective is to provide a flexible and user-friendly software tool to help fish growers to plan, simulate and analyze raceway systems. The software is named "Raceway Design and Simulation System" (RDSS). The approach has been to develop RDSS so that the user has as much flexibility as possible in configuring the raceway and determining the economic impact of any given scenario in that raceway. The software tool has been developed in an Excelä programming environment using the VBA programming language. A generalized raceway system, consisting of any number of tanks in series with multiple parallel raceways may be modeled. The software allows the user the capability to simulate scenarios in which fish cohorts (of different species) may be placed in different tanks at different times. The program then simulates the growth, optimal feed rate, oxygen consumption, nitrogen production, oxygen replenishment via

Mountain State Trout Hatchery in Pendleton County. (Photo: Ken Semmens.)

weirs and/or other reoxygenation technologies, and a variety of other factors crucial to the successful operation of a commercial raceway. The program output documents all fish movement, feed requirements and other parameters relating to the fish growing process. Basic economic information on the cost of feed, cost of fingerlings, and revenue from sales as a function of time is also included in the output. The current version of the software and an extensive users' manual are available at the project's website: http://www.caf.wvu.edu/afmdp/disciplines/engineering/chemengineer.shtml

- **Environmental Engineering** Determining the feasibility of growing trout in water from acid mine drainage treatment plants will be an ongoing focus of aquaculture research at WVU. Following a technical assessment of impaired water resources near the WVU campus in Morgantown, a pilot scale flowing water system was designed and installed. We continue to evaluate production of rainbow trout in a modular raceway system using water from an acid mine drainage treatment plant. In collaboration with other investigators, we have conducted feeding trials, examined trout fillet quality analyzed the flesh of trout grown in treated mine water for accumulation of heavy metals and PCB in excess of recommended amounts. A secondary focus of this objective has been effluent management. We collected baseline water quality data from select trout production facilities in West Virginia and characterized the resulting effluent. We seek to develop designs for increasing the efficiency for removal of solid wastes from the quiescent zone in raceway systems producing trout.

- **Horticulture** The project objective is to determine the efficacy of plants for removal of soluble nutrients in a flowing water system for producing trout. In collaboration with environmental engineers, watercress will be evaluated as a tool to recover dissolved nutrients like nitrogen and phosphorous from water leaving the experimental raceway system at the Reymann Memorial Farm. Operational conditions which affect nutrient removal and watercress growth will be determined.

Annual grants for the APMDP are awarded by USDA/CSREES to the WVU Agricultural and Forestry Experiment Station. The Principal Investigator is Kenneth J. Semmens, P.O. Box 6108, Morgantown, WV 26506-6108, (304) 293-6131 Ext. 4211, Ken.Semmens@mail.wvu.edu .

The mission of the National Center for Cool and Cold Water Aquaculture (NCCCWA) is to support and

Guyses Run in Marion County. (Photo: Ken Semmens)

enhance the nation's cool and cold water aquaculture production through research and technology transfer. The goals of the program are to improve production efficiency, aquatic animal health, and product quality through the development of economically and environmentally sustainable commercial systems and practices. Research emphases include applied genetics and breeding, integrated aquatic animal health, aquaculture engineering, nutrition, physiology, culture and management, and product quality. The focus of the research programs is cool and cold water aquaculture species including, but not necessarily limited to rainbow trout, Arctic char, and striped bass.

The following research is being conducted at the NCCCWA:

- Application of remote sensing techniques to address impacts of agriculture on water quality and fish habitat within the Chesapeake Bay watershed
- Host, pathogen and environmental interactions in cool and cold water aquaculture
- Identification and characterization of genes affecting cool and cold water aquaculture production
- Utilizing genetics for enhancing cool and cold water aquaculture production
- Development of sustainable land-based aquaculture systems
- Genome sequencing and identification of virulence factors in *Flavobacterium psychrophilum*
- Transcriptome analyses in salmonids
- Genetic and diet effects on growth rate and reproduction in the rainbow trout strains of Troutlodge, Inc.
- Production of An Integrated Physical and Genetic Map for Rainbow Trout

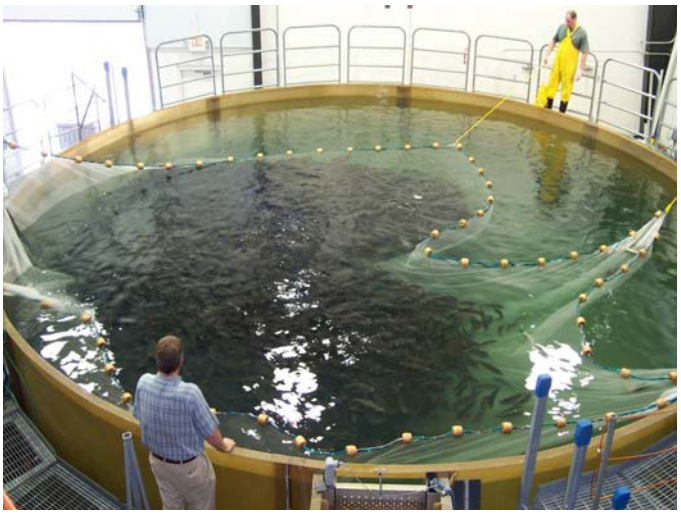
- Evaluation of Genotype by Environment interactions in rainbow trout
- Evaluation of selected rainbow trout lines fed grain-based diets under farm scale conditions
- Functional genomics research for rainbow trout aquaculture production
- Production for superior rainbow trout broodstock by genetic manipulation
- Production of a physical map for the rainbow trout genome using high throughput DNA fingerprinting

Learn about additional research conducted by the National Center for Cool and Cold Water Aquaculture at: http://www.ars.usda.gov/Research/Research.htm?modecode=19-30-00-00

The Freshwater Institute http://www.freshwaterinstitute.org is a nationally recognized program of the non-profit Conservation Fund http://www.conservationfund.org, a 501(c)(3) organization based in Arlington. Recognizing the value of clean water resources, the Freshwater Institute works with government, industry, nonprofits and individuals to shape sustainable, environmentally responsible solutions to water resource management. Over two decades, The Conservation Fund's Freshwater Institute has become one of the nation's premier research and development facilities dedicated to the sustainable use of water. From its campus in Shepherdstown, West Virginia, the Institute's staff combines applied research, engineering, and economic development skills to show the critical role fresh water resources play in the achievement of economic and environmental goals. Freshwater Institute projects provide demonstration of practices or development of technology that meet concern for environmental protection and the recognized need for fair return on investment. The Freshwater Institute has four primary focus areas:

- **Pioneering Aquaculture Research and Technology Development** Under a Cooperative Agreement funded by the U.S. Department of Agriculture, Agricultural Research Service, the Freshwater Institute is working to develop more cost effective and environmentally compatible land-based finfish production systems that utilize intensification and water recycling technology consistent with biological, environmental and food security objectives. Water recirculating systems are highly valuable because they conserve water and concentrate effluent into smaller and more treatable discharges. However, these systems need improvement to become more economically viable to compete with traditional salmonid culture systems. For these reasons, research is conducted to develop and evaluate functional, operational, and economic efficiencies through close integration of engineering, biological assessment, and water quality maintenance within large-scale recirculating systems. Waste management technologies are also evaluated, and an integrated approach has been conceptualized and developed to improve aquaculture waste management by linking waste reduction to culture system design and management. Concurrent animal health studies explore common and emerging infectious and non-infectious diseases and potential management strategies. All together, this ARS-funded project has produced significant advances in numerous aspects of recirculating aquaculture system technology. To demonstrate a practical and environmentally compatible alternative to current fish farming practices, the Freshwater Institute operates a commercially relevant recirculating fish farm system that produces approximately 30 tons of market-sized rainbow trout or Arctic char annually. This research has been used to improve the production efficiency of rainbow trout and Arctic char, as well as Atlantic salmon smolt, tilapia, cobia, and barramundi, sturgeon, and hybrid striped bass that are cultured within large-scale recirculating aquaculture systems at public and private fish culture facilities in North America and around the world.

- **Fish Health and Aquatic Veterinary Consulting** The Aquaculture Veterinarian at the Freshwater Institute provides the following services: fish health management and welfare consulting; disease prevention and control programs; biosecurity plans; assistance with fish health certification for



The Freshwater Institute, Jefferson County. (Photo: The Conservation Fund)

interstate and international fish transport; disease diagnosis and treatment; and producer education through industry extension. As well, the Aquaculture Veterinarian oversees the health and humane treatment of on-site fish populations, and is actively involved with in-house research to further the understanding of health and disease in recirculating aquaculture systems, and to improve the welfare of production animals in these settings.

- **Technology Transfer and Engineering Services** Technology developed at the Institute has been implemented by stakeholders in West Virginia and across the country. From Arctic Char production in Mingo County, WV to Atlantic salmon restoration in the Northeast to Pacific salmon restoration in the Northwest, solutions developed by the Institute are providing far-reaching benefits. Technology transfer is provided in informal communications throughout the year and in a classroom setting twice per year reaching over 50 stakeholders. Detailed engineering assistance is also provided to enable technology implementation for individual clients on a contract basis. Engineering services focuses on design of intensive fish culture systems, but also includes feasibility studies, influent and effluent water treatment systems, environmental permitting, construction management, and full facility delivery.

- **Watershed Assessment and Planning** The solutions to today's water pollution challenges lie in the development of a broad understanding of aquatic impacts at the watershed scale and the willingness to work across the boundaries of discipline and jurisdiction to bring innovative ideas and approaches to bear. The Freshwater Institute uses geospatial technologies to assess watersheds and develop plans for their restoration and management. These technologies allow us to place community needs in a geographic and economic context in order to provide the most benefit possible to the citizens of West Virginia and their aquatic resources. Watershed assessment is used to identify watersheds with the most critical water quality problems, restoration opportunities, and barriers to economic development. Planning efforts include development of watershed restoration strategies from local to regional scales; the Institute is currently involved in water quality trading and Chesapeake Bay restoration efforts. Water quality trading provides opportunities for point sources, such as aquaculture to maintain environmental performance with minimal cost.

In West Virginia, the Freshwater Institute has completed several projects in support of aquaculture, including:

John Davidson with dual drain tank / partial reuse system.. Photo: The Conservation Fund

- Fish culture systems design and construction management at the Mingo County Redevelopment Authority's Arctic Char Hatchery (Delbarton, WV);
- Design and construction of an integrated tilapia and basil/vegetable producing greenhouse to demonstrate the feasibility of using natural gas from shut-in wells in an alternative to traditional agriculture (Tallmansville, WV);
- Hatchery evaluation and planning at the White Sulphur Springs National Fish Hatchery (White Sulphur Springs, WV)
- Hatchery effluent treatment conceptual design at the Spring Run State Fish Hatchery (Dorcas, WV)
- Spring water development design for Mountain Meadows Trout Farm (Scherr, WV)
- "Freshwater aquaculture in Appalachia: Infrastructure development for an emerging industry"
- "An economic feasibility study of trout production using a flow through tank system: An alternative enterprise for the Appalachian region"
- "Economic analysis of non-traditional water resources for aquaculture in West Virginia"
- "West Virginia mine water inventory site summary"
- "Water quality criteria, uptake, bioaccumulation, and public health considerations for chemicals of possible concern in West Virginia mine waters used for culture of rainbow trout"

- "Arctic char: Development of production technologies suited to water resources in Appalachia"

The Natural Capital Investment Fund (NCIF) was established by The Conservation Fund in 2000 to provide financing to natural resource-based businesses that will advance sustainable economic development http://www.ncifund.org. NCIF focuses its activities on the following sectors: sustainable/value-added agriculture; sustainable forestry & value-added forest products; renewable energy & energy efficiency; heritage & eco-tourism; green building; and recycling. NCIF provides subordinated debt and equity financing to new and expanding businesses in these sectors, especially those that are unable to obtain sufficient financing from conventional sources. As an affiliate of the Freshwater Institute, NCIF is interested in working with and has supported aquaculture business in West Virginia.

Investigators at West Virginia State University, Department of Biology/Biotechnology are conducting research on the molecular and genetic/genomic basis of feed efficiency. The objective is to combine classical nutrition with modern molecular techniques to understand the differences in feed efficiency within the same and/or among different stains/families of channel catfish and rainbow trout. To explore this possibility investigators will study the interface between dietary manipulations and mitochondrial functions in feed efficiency and possibly determine the potential role of nutrients and non-dietary factors (genetics) in the molecular modulation of mitochondrial functions (protein and gene expression levels) relating to feed efficiency.

Other research activities include the determination of the nutritive value of recovered protein from treated poultry wastes from thermophilic anaerobic digester as dietary supplement for aquaculture. By-products recovered from biological treatment of poultry wastes may provide a cheap alternative protein source for cultured fish.

Investigators have collaborated with WVU on trout yield verification trial, and National Center for Cool and Cold Water Aquaculture, National Warm Water Aquaculture Center at Mississippi State University, and USDA-ARS Catfish Genetic Research Unit on understanding the molecular mechanism for differences in feed efficiency.

Bethany College, in collaboration with West Virginia University, investigators are studying the genetics of green sunfish.

White Sulphur Springs National Fish Hatchery is a disease-free broodstock hatchery that maintains two strains of rainbow trout as part of the National Broodstock Program. Broodfish are grown, spawned and each year approximately 7.5 million eggs are shipped all over the United States. Shipments are made to tribal, state, and other national fish hatcheries. These production hatcheries rear the eggs and grow the fish to a stockable size.

Investigators are also developing a freshwater mussel propagation program aimed at restoring imperiled species in the mid-Atlantic and southeastern states of the U.S. Ongoing research with Virginia Tech seeks to improve aquaculture technology for the restoration of threatened and endangered freshwater mussel species in West Virginia and southern Appalachia

Aquaculture Extension

West Virginia University is the primary aquaculture extension program in the state. Many different methods are used to reach a diverse group of stakeholders. The year begins with a state wide meeting known as the Aquaculture Forum. WVU grows fish at two locations with flowing water systems. These facilities are utilized for research and demonstration and are made available to classes, visitors, and for workshops. A web site is maintained for extension and for communicating research results. A quarterly newsletter is distributed and articles are submitted to popular publications. Responses to requests for literature and information are made via email, and telephone. When these methods are not sufficient, site visits are scheduled to meet directly with the stakeholder. Research results are presented at regional and national meetings and published in scientific journals. Specific activities include:

The Lincoln County High School aquaculture lab (Photo: Dan Miller)

- Coordinating with local groups to develop recreational fishing opportunities and formats for fairs and festivals, etc. Examples include the Pendleton County Trophy Trout Rodeo, and the Mountain State Arts and Crafts Festival Kids Fishing Derby.
- Demonstrations and presentations about trout production to youth organizations and schools.
- Educate county agents, farm supply stores, and the general public about where and how to purchase fish from local producers.
- Conversion of an acid mine discharge water treatment plant into a county fishing park in Marion County.
- Encourage use of mine water as an aquaculture resource. As a result of one request, a mining company was granted the nation's first aquaculture site as a post-mining land use permit, saving reclamation costs of $450,000.
- Work closely with producers interested in finding and evaluating water sources
- Work closely with producers to develop plans for managing solid waste and effluents.

The program directly serves current and future West Virginia producers of fish for food and recreational purposes and processors of food fish and has conducted activities in more than 15 counties. Over 100 individuals annually attend the Aquaculture Forum and other aquaculture presentations and approximately 400 requests for information are received annually. Over 100 visits to specific sites are conducted annually. Technical assistance has assisted with development of five new production facilities in and near West Virginia. Aquaculture extension also provides services such as water quality testing, testing for contaminants, disease diagnosis, etc. and develops tools which will positively impact the aquaculture industry in West Virginia.

Aquaculture Education

Students statewide are presently receiving exposure to career development opportunities in aquaculture through the secondary agricultural education program. In many cases, aquaculture instruction is infused in the advanced agriscience curriculum. Students are afforded some excellent opportunities for "hands-on" instruction through agricultural education aquaculture labs. These labs have been made possible by local partnerships, private foundation monies and special appropriations by the West Virginia Legislature. In some cases aquaculture is delivered via specialty courses - semester or year-long.

New River Community and Technical College, an accredited two year college, with campuses in Bluefield, Beckley, Greenbrier Valley and Nicholas County, WV offers an Associate Degree in Aquaculture. The course Includes instruction in the basic principles of aquatic and marine biology; health and nutrition of aquatic and marine life; design and operation of fish farms, breeding facilities, culture beds, and related enterprises; and related issues of safety, applicable regulations, logistics, and supply.

The Morgantown campus of West Virginia University offers undergraduate and graduate level courses that include Aquaculture Management and Recreational Pond Management. They are offered annually through the Division of Resource Economics.

West Virginia State University at Institute, West Virginia offers undergraduate and graduate courses in aquaculture that include Principles of Aquaculture, Aquatic Animal Nutrition, and Biology of Fishes. There are Masters Degree in Biotechnology and aquaculture is offered within the curriculum track called organismal/environmental biotechnology. There is also an MA degree in Biotechnology suitable for education students who do not need research based degree.

Aquaculture Resources

The National Aquaculture Association, and the US Trout Farmers Association and the Striped Bass Growers Association have their national office in West Virginia:

11 West Washington Street, Suite One
Charlestown, WV 25414-1529
Telephone (304) 728-2189

Hill ponds are not often drained so cages are handy for small operations that harvest as needed (Photo: Ken Semmens)

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