
**NOAA Technical Memorandum NMFS-F/NER-4**

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# Aquaculture in the Northeast Region of the National Marine Fisheries Service

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## NOTE ON SPECIES NAMES

The Northeast Regional Operations Office's policy on the use of species names in technical publications and reports is to follow the American Fisheries Society's (AFS) lists of common and scientific names for fishes (Robins *et al.* 1991)[a], mollusks (Turgeon *et al.* 1988)[b], and decapod crustaceans (Williams *et al.* 1989)[c]. This policy applies to all issues of the *NOAA Technical Memorandum NMFS-F/NER* series.

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[a] Robins, C.R. (chair), R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada, 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20. 183 pp.

[b] Turgeon, D.D. (chair), A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompson, and J.D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. *Amer. Fish. Soc. Spec. Publ.* 16. 277 pp.

[c] Williams, A.B. (chair), L.G. Abele, D.L. Felder, H.H. Hobbs, Jr., R.B. Manning, P.A. McLaughlin, and I. Pérez Farfante. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17. 77 pp.

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# EXECUTIVE SUMMARY

## INTRODUCTION

This document summarizes aquaculture-related activities by the Northeast Region (NER) of the National Marine Fisheries Service (NMFS). It describes management responsibilities of the NER Northeast Regional Operations Office (NEROO) in the areas of state/federal cooperative programs, habitat conservation, trade and industry assistance, and fishery resource restoration and enhancement. It also presents an historical perspective of research with aquaculture implications conducted at laboratories of the NER's Northeast Fisheries Science Center (NEFSC). Involvement by other organizations and pertinent legislative authorities are discussed to enable a consolidated perspective of the associated federal roles and mandates.

Most management and research initiatives are directed toward resources and aquaculture operations which occur within the jurisdictional boundaries of state governments. Accordingly, Chapter 3 highlights Maine and Maryland as examples of intensive aquaculture programs in the Northeast. Interstate coordination through the auspices of the Atlantic States Marine Fisheries Commission (ASMFC) is also noted to demonstrate the increasing reliance on cooperation not only among states, but among the state, federal, and private sectors, in addressing issues of interjurisdictional importance.

The report concludes with a discussion of regional concerns which are relevant to the current status and future viability of the aquaculture industry.

## LEGISLATION

The National Aquaculture Act (NAA) in 1980 established national policy to encourage the development of aquaculture in the United States. The National Aquaculture Improvement Act (NAIA) of 1985 designated the U.S. Department of Agriculture (USDA) as the lead federal agency for coordination of federal activities and for dissemination of aquaculture information.

Legislation with particular relevance to NMFS began with the enactment of Public Law 87-183 in 1961 which authorized the construction of a federal shellfish culture laboratory in Milford, Connecticut. Several financial assistance programs established by legislative authorities and administered by NMFS have also been germane to aquaculture research and management. These include the Saltonstall-Kennedy Act (S-KA), the Commercial Fisheries Research and Development Act (CFRDA), the Anadromous Fish Conservation Act (AFCA), and the Interjurisdictional Fisheries Act (IFA) of 1986.

## FEDERAL AGENCY INVOLVEMENT

The USDA, through the establishment of five regional aquaculture centers, provides a focus for the conduct of research, extension, and demonstration projects on prominent issues affecting the commercial industry. The U.S. Fish and Wildlife Service (USFWS), through a national policy, encourages aquaculture development that is compatible with sound public resource stewardship.

Within the U.S. Department of Commerce (USDC), several agencies in addition to NMFS have aquaculture-related programs. For example, the National Sea Grant College Program (NSGCP) in the National Oceanic and Atmospheric Administration's (NOAA) Office of Oceanic and Atmospheric Research (OAR) supports research, extension, and educational projects in cooperation with Sea Grant and Land Grant institutions in coastal and Great Lakes states. Also, NOAA's National Ocean Service (NOS) evaluates changes through the National Shellfish Registry for certification of molluscan shellfishing waters, the results of which are relevant to commercial aquaculture interests in New England and the Mid-Atlantic regions.

## NMFS RESEARCH IN THE NORTHEAST REGION

The genesis of NMFS aquaculture research was prior to Reorganization Plan No. 4 of 1970 at which time the USFWS Bureau of Commercial Fisheries (BCF) was renamed NMFS, and transferred to the USDC. The first permanent assignment of a full-time biologist and plans to establish a laboratory in Milford, Connecticut, occurred in 1931. At that time, a small research program was established to address biological problems facing the shellfish industry.

The development of methods for commercial shellfish cultivation began in 1944. During that decade, federal biologists established procedures for conditioning eastern oysters to ripeness, inducing spawning and fertilization, rearing larvae, determining food requirements, and growing newly-set spat. The status of aquaculture-related research at Milford was bolstered by Congress in 1961 through legislation to construct an expanded research center for shellfisheries production. Activities at this facility have continued on a variety of subjects including natural diets, genetics, disinfection techniques for shellfish hatchery water, and culture methods for eastern oysters, bay scallops, and Atlantic surfclams.

An aquaculture liaison was appointed for the NER at Milford in 1984. In 1992, the NEFSC established the position of a research coordinator/liaison scientist to devise and coordinate the design and development of projects and activities to implement aquaculture goals of the NMFS Strategic Plan (National Marine Fisheries Service 1991) in the Northeast.

## NMFS GRANT PROGRAMS

The involvement of the NEROO's grant programs in aquaculture is as varied as the broad definition of aquaculture allows. In conjunction with state fishery resource agencies, academia, the fishing industry, and other private interests, projects have been conducted covering a range of activities from channel catfish culture to eastern oyster shell planting to hatchery wastewater systems. During the past 25 years, approximately $18 million have been devoted by NMFS-administered programs to aquaculture-related research. These programs include projects funded under the CFRDA, AFCA, IFA, S-KA, and the Oyster Disease Research Program (ODRP).

The CFRDA (Public Law 88-309) has been the major contributor to aquaculture research. During the 23-year period during which funds were apportioned under this legislation, the NEROO administered approximately 80 aquaculture-related projects, conducted or coordinated by state fishery resource agencies in the New England, Mid-Atlantic, and Great Lakes regions. This represented expenditures of about $11.4 million ($7.8-million federal share) under the Public Law 88-309 program. The aquaculture activities were divided among six primary categories: marine fish & shellfish culture (71.8 percent); environmental monitoring (10.7 percent); aquaculture systems (7.8 percent); freshwater fish & invertebrate culture (3.8 percent); restoration/fisheries enhancement (3.2 percent); and processing technology (2.7 percent).

## OTHER REGIONAL INVOLVEMENT

Aquaculture-related activities have also included NMFS participation and responsibilities in the areas of habitat conservation, trade and industry services, and fishery restoration programs. Notably, the NEROO, in collaboration with the U.S. Army Corps of Engineers (USACOE), the U.S. Environmental Protection Agency (EPA), and the state of Maine, have developed and agreed to a joint federal/state permit application for aquaculture projects. The joint application will satisfy requirements for securing USACOE, state, and EPA's National Pollution Discharge Elimination System permits. Federal permits are required for coastal aquaculture operations. Major regulatory concerns associated with these permits include review of site selection, water quality, pollution, disease transmission, and introduction of non-native species.

The NMFS Office of Trade and Industry Services' Technical Services Unit supplies technical support to the Codex Alimentarius Commission. The Codex Committee on Fish and Fishery Products has endorsed a recent proposal by the U.N. Food and Agriculture Organization's (FAO) Fisheries Department for reviewing a Code of Hygienic Practice for the Products of Aquaculture. Also, the NMFS Voluntary Inspection Program is cooperating with private aquaculture operations in the Northeast through a fee-for-service arrangement in the evaluation of product quality and wholesomeness.

The NEROO provides policy and technical representation to several state/federal fishery restoration initiatives in New England and the Mid-Atlantic. These include programs to restore Atlantic salmon to the Connecticut and Merrimack Rivers, and American shad to the Susquehanna and Delaware River watersheds.

In 1970, NMFS initiated an experiment at the Northwest and Alaska Fisheries Center (NWAFC) to determine the feasibility of developing an Atlantic salmon brood stock on the West Coast to provide a source of eggs for restocking New England rivers. The potential for expansion of this study was enhanced in 1972 when the NWAFC, in conjunction with the NEROO, developed a cooperative state/federal proposal entitled Salmon for New England. The proposal provided alternatives for the enhancement of recreational fishing in New England.

In addition to providing an Atlantic salmon egg source, the envisioned initial efforts involved a pilot program to hatch coho salmon in existing state hatcheries, and subsequently, to rear the cultured fish in saltwater pens on Plum Island Sound, Massachusetts. In 1975, the coho salmon component of the proposal was deleted, primarily due to opposition from private Atlantic salmon conservation groups.

The revised proposal was renamed the Atlantic Salmon Brood Stock Program in 1979 when the USFWS requested assistance from NMFS in stabilizing the egg supply for state/federal Atlantic salmon programs in New England. The program continued from 1979 to 1982, and represented NMFS's contribution to a joint state/federal partnership in a proposed long-term effort to restore Atlantic salmon to New England waters. As of 1983, over 9,600 juvenile and 25,000 fry were reared at the NWAFC's Manchester Station for East Coast brood stock purposes. During this period, 176,000 eggs were shipped to New England hatcheries for subsequent stocking. A goal of 3.5-million eggs was anticipated for shipment the following year. In 1984, the program was terminated prematurely due to perceived disease risks and fish health concerns.

## INDUSTRY ISSUES

Throughout the Northeast, the establishment of agency forums and advocate organizations in both the public and private sectors has facilitated the evolution of aquaculture as a growing and integral component of food production. Recent assessments in the Northeast have indicated that commercial watermen are willing and able to learn the "ropes" and technical details necessary for productive aquaculture operations. The availability of information on technology, production costs, and market conditions improves the evaluation of risks and the obtaining of needed financial support. Increasing liaison among government, industry,

and academia is evident in addressing the management and research aspects of aquaculture in the Northeast.

Aquaculture is often seen as separate and distinct from the traditional commercial fisheries. The relationship between aquaculture and the capture fisheries is often assessed from both economic and biological perspectives. A 1988 report by the USDC concluded that dockside prices received by U.S. fishermen are lower than they would be otherwise, in the absence of cultured products. Yet, from another viewpoint, aquaculture is seen by others as a complementary commercial industry with similar interests--e.g., a healthy and unpolluted environment, conservation and productivity of the nation's fishery resources, and profitable seafood marketing channels. The success of present and future aquaculture efforts, as well as the viability of the existing capture fisheries, is contingent upon acceptable water quality. This fact, while recognized by the resource community as a given, will likely become even more pronounced in public view as aquaculture issues receive continued attention. The use of endemic species is often advocated for aquaculture to ensure that operations do not pose a threat to the genetic integrity and health of wild stocks. Otherwise, even stricter standards must be considered to ensure that non-native stocks do not unintentionally escape outside the confines of aquaculture facilities. One major concern facing the industry, the states, and the federal government, are the chemicals employed in fish culture for disease treatment, and the regulatory status pertaining to their use. The U.S. Food and Drug Administration (FDA) has recently established a Work Group on Quality Assurance in Aquaculture to address the proper use of drugs (chemicals), avoidance of illegal residues in food fish, and the drug approval process.

Understandably, the aquaculture industry is concerned that any involvement by public regulatory agencies may cause costly restrictions on its operations. On the other hand, the industry is optimistic about the merits in the potential economic profitability of providing new products for a growing demand, increasing employment opportunities, and establishing a brood stock which could be valuable to fishery resource agencies for restoring historical runs of wild stocks.

## SUMMARY

Given the recent growth of aquaculture operations in the Northeast, it is anticipated that many ongoing aquaculture ventures will expand rapidly and that new ones will develop. This document provides an overview of aquaculture research and management activities in the Northeast in order to facilitate an assertive and proactive response to national efforts in improving opportunities for U.S. aquaculture. It also was written to enhance the NER's ability to respond to public inquiries and internal questions concerning not only "where we've been" but also "where we're going" relative to aquaculture-related involvements. It will also serve as a basis for assessing the future course of NER actions in aquaculture as necessitated by national policy guidance and potential modifications to the NMFS Strategic Plan.

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# LIST OF ACRONYMS

| | |
|---|---|
| AFCA | Anadromous Fish Conservation Act |
| ASMFC | Atlantic States Marine Fisheries Commission |
| BCF | (USFWS) Bureau of Commercial Fisheries |
| CBF | Chesapeake Bay Foundation |
| CFRDA | Commercial Fisheries Research and Development Act |
| DFO | (Canada) Department of Fisheries and Oceans |
| EDA | (USDC) Economic Development Administration |
| EEC | European Economic Community |
| EPA | U.S. Environmental Protection Agency |
| FAO | U.N. Food and Agriculture Organization |
| FDA | (HHS) Food and Drug Administration |
| FMP | fishery management plan |
| GATT | governing agreement on tariffs and trade |
| HHS | U.S. Department of Health and Human Services |
| IFA | Interjurisdictional Fisheries Act |
| IHN | infectious hematopoietic necrosis |
| ISFMP | (NMFS/ASMFC) Interstate Fisheries Management Program |
| LOP | letter of permission |
| MAIC | Maine Aquaculture Innovation Center |
| MDA | Maryland Department of Agriculture |
| MDNR | Maryland Department of Natural Resources |
| NAA | National Aquaculture Act |
| NAIA | National Aquaculture Improvement Act |
| NASCO | North Atlantic Salmon Conservation Organization |
| NCRAC | (USDA) North Central Regional Aquaculture Center |
| NEFSC | (NER) Northeast Fisheries Science Center |
| NER | (NMFS) Northeast Region |
| NEROO | (NER) Northeast Regional Operations Office |
| NESDIS | (NOAA) National Environmental Satellite, Data, and Information Service |
| NMFS | (NOAA) National Marine Fisheries Service |
| NOAA | (USDC) National Oceanic and Atmospheric Administration |
| NOS | (NOAA) National Ocean Service |
| NRAC | (USDA) Northeastern Regional Aquaculture Center |
| NSGCP | (NOAA) National Sea Grant College Program |
| NTIS | (USDC) National Technical Information Service |
| NWAFC | (NMFS) Northwest and Alaska Fisheries Center |
| OAR | (NOAA) Office of Oceanic and Atmospheric Research |
| ODRP | Oyster Disease Research Program |
| S-KA | Saltonstall-Kennedy Act |
| SFCPD | (NEROO) State, Federal, and Constituent Programs Division |
| USACOE | U.S. Army Corps of Engineers |
| USDA | U.S. Department of Agriculture |
| USDC | U.S. Department of Commerce |
| USFWS | U.S. Fish and Wildlife Service |
| VMRC | Virginia Marine Resources Commission |

# FOREWORD

In the November 1990 reorganization of the NER, the NEROO's State, Federal, and Constituent Programs Division (SFCPD) was assigned responsibilities relating to aquaculture/mariculture issues and policy. Concurrent with this reorganization, a mandate to formulate plans and enhance the NER's involvement in aquaculture was articulated in the NMFS Strategic Plan.

This document provides a comprehensive overview of aquaculture activities in the Northeast in order to facilitate an assertive and proactive response to the NMFS Strategic Plan. It was also written to enhance the NER's ability to respond to public inquiries and internal questions concerning not only "where we've been," but also "where we're going," relative to aquaculture-related involvement. We anticipate that this document will also serve as a valuable reference to assist in the development of a coordinated regional framework with respect to current and future operating/regional implementation plans and consequent aquaculture program activities in the NER.

In recognition that aquaculture entails organizational involvement and program interests which "cut across" division lines as well as between research and management, a request to facilitate the input for this document was forwarded to all NER units in March 1991. The material presented in this document is largely based upon review of available documents in the NER's files, of outside information sources such as Sea Grant newsletters, and of personal communications between SFCPD staff, state representatives in Maine and Maryland, and other NMFS personnel in the NER and headquarters.

The NER serves 19 states in three geographical areas: New England, the Mid-Atlantic, and the Great Lakes. This document emphasizes marine aquaculture along the Atlantic coast; however, activities for inland states are briefly summarized, particularly with respect to federally funded research, in Section 2.3.2. Time constraints in the preparation of this document preclude verification of selected data, such as industry economic references. Most details for such accounts have been taken from single sources and not checked against others for verification.

# 1. OVERVIEW

Aquaculture is defined by Meade (1989) as "the practice of rearing, growing or producing products in water or in managed water systems." For federal fishery resource agencies, the term has varied connotations depending upon legislative mandates, articulated program priorities, and/or agency policy (implied or otherwise). This, in turn, influences the public perception of the agency's role in aquaculture issues. Historically, the term as used by state, federal, and private interests includes one or a combination of the following definitions: (1) culture of marine and freshwater organisms in laboratory systems for specific research purposes, such as nutrition and metabolic studies, disease research and life history investigations; (2) hatchery operations encompassing the hatching and rearing of finfish and shellfish for purposes of restoring depleted populations through stocking programs designed to restore species (*e.g.*, Atlantic salmon, American shad, and Atlantic sturgeon) to their historical breeding and nursery grounds, or maintain a "put and take" commercial or recreational fishery for public use and enjoyment; (3) maintenance of commercial fisheries through specific artificial propagation techniques, such as the planting of cultch (shells) for eastern oyster larval attachment and subsequent growth to a size suitable for harvesting; and/or (4) commercial rearing of finfish, shellfish, and aquatic plants for sale, trade, barter, or shipment.

Attention in this document is given to all four facets of aquaculture as outlined above, but emphasis is directed toward a special assessment of the last. It is noteworthy that the FAO has recently changed its definition of aquaculture in an effort to better assist its Fishery Statistics Unit and FAO member countries in compiling more accurate statistics for both cultured and wild-harvested species. The new definition restricts aquaculture to operations which harvest aquatic organisms by an individual or corporate body which has owned them throughout their rearing period. Accordingly, the revised FAO terminology does not include aquatic organisms which are exploitable by the public as a common property resource. Similarly, Nakahara (1992) restricts the definition of aquaculture to "the cultivation of fish in the protected sea area....The most important characteristics [being] (1) that the ownership of fish is quite clear, (2) that human control is possible throughout the whole life of the fish although conditions...are supported by nature, and (3) that the final fruits of the production are countable."

With the passage of the NAIA in 1985, the principal responsibility for the coordination of federal activities relating to the development of aquaculture in the United States became vested with the USDA (Section 2.1). Until recently, other federal agencies have generally not included references in strategic or operating plans concerning aquaculture development, other than through participation in state/federal fishery restoration initiatives (Section 2.6.1) and grants to states and private interests (Section 2.3.2). Within the USFWS, for example, an aquaculture initiative was developed in 1991, with a public policy statement and the designation of a national aquaculture coordinator (Section 2.2).

In the NER, aquaculture research was a prominent and "visible" component of agency task plans and program activities from the establishment of the agency in 1970 until the 1980s. The reasons for a de-emphasis on aquaculture during the past decade are not specific, but they may be attributed to realignment of overall fisheries program priorities accompanying changing administrations, increased devotion of agency resources to administration of the Magnuson Fishery Conservation and Management Act, and the perceived negative implications of aquaculture upon the "capture" (wild stock) fisheries (National Marine Fisheries Service 1988). Nevertheless, it should be noted that the NMFS research laboratory in Milford, Connecticut (Section 2.3.1), has been involved in eastern oyster biology with aquaculture implications since its inception in 1931.

Given the recent growth of aquaculture operations in the Northeast, it is anticipated that many ongoing aquaculture ventures will expand rapidly and that new ones will develop. Accompanying this growth, it is apparent that several key issues must be addressed. These include: (1) how aquaculture should "fit in" with NMFS stewardship responsibilities for the long-term health of living marine resources; and (2) how should the NER interact with other federal, state, academic, and private interests regarding aquaculture research and development issues.

This document presents an overview of previous and current NER involvement in aquaculture, and suggests future directions and options for responding to the aquaculture-related goals as set forth in the NMFS Strategic Plan.

# 2. FEDERAL INVOLVEMENT

The Aquaculture Policy of the American Fisheries Society (1991) indicates that "agencies charged with responsibility of natural resource stewardship owe primary allegiance to the protection of natural resources. Because many proponents believe aquaculture is best served under auspices of agriculture departments, there is a natural tendency to view natural resource agencies and agriculture agencies supporting aquaculture in adversary roles. This must not be allowed to happen because the resource will be the ultimate loser."

This chapter provides an overview of current federal agency involvement in aquaculture. Section 2.1 addresses the primary legislative authorities for this involvement, and Section 2.2 describes the major federal roles and policies in aquaculture, agency by agency. Much of the material for the latter section is taken from the United States Department of Agriculture (1991). Finally, Sections 2.3 - 2.6 provide a comprehensive summary of NER involvement in the areas of inhouse research, state/federal and industry programs, habitat/water quality issues, trade and industry services, and fishery restoration/enhancement initiatives. Aquaculture

research sponsored by the USDA and the NSGCP is also summarized to present a complementary perspective.

## 2.1 LEGISLATION

Three primary and two secondary legislative authorities are highlighted below to reflect the involvement of the federal government in aquaculture. Grant-in-aid legislation for programs administered by NMFS with aquaculture implications is summarized in Section 2.3.2.

### 2.1.1 National Aquaculture Act (Public Law 96-362)

Enacted in September 1980, the NAA states that it is national policy "to encourage the development of aquaculture in the United States." It further cites that "the principal responsibility for the development of aquaculture in the U.S. must rest with the private sector." The purpose of the NAA was to establish a National Aquaculture Plan and encourage aquaculture activities and programs. Although funding was authorized, no appropriation has been made.

The National Aquaculture Development Plan was published in 1983 by the federalwide Joint Subcommittee on Aquaculture. Volume I describes technologies, problems, and opportunities associated with aquaculture in the United States and its territories. Volume II contains an in-depth discussion of important, selected aquacultural species and an extensive bibliography.

### 2.1.2 Agriculture and Food Act of 1980

Title XIV of this legislation established five regional aquaculture centers in Hawaii, Massachusetts, Michigan, Mississippi, and Washington. The centers, jointly administered by USDA's State Research Service and Extension Service, are authorized to conduct research, extension education, and demonstration projects that have national or regional applications. Their primary mission is to enhance viable, profitable commercial aquaculture production in the United States.

### 2.1.3 National Aquaculture Improvement Act of 1985

This legislation amended the NAA and established the USDA as the lead federal agency for coordination of federal activities and for dissemination of aquaculture information. The message sent by Congress in passing the NAIA is that aquaculture is a form of agriculture. Expectations were that the NAIA would help create new jobs, replenish depleted fisheries, and reduce the trade deficit in fishery products. The NAIA also required the Secretary of Commerce to conduct a study on competition between aquaculture products and capture or "wild" fisheries and to recommend measures to ameliorate any such adverse effects. This report was restricted to an assessment of effects by aquaculture in the U.S. seafood market and was published in April 1988 (Section 5.2.7).

### 2.1.4 Magnuson Fishery Conservation and Management Act Amendments of 1990

Of particular relevance to aquaculture is the provision which requires the Secretary of Commerce to submit to Congress a report making recommendations as to the need for the adoption of U.S. import and export restrictions on anadromous fish and anadromous fish products; and identifying, evaluating, and making recommendations regarding any specific statutory or regulatory restrictions that may be necessary for the adoption of such restrictions.

### 2.1.5 Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990

Section 1207 of this act requires a task force to, "in consultation with [s]tate fish and wildlife agencies, [with] other regional, [s]tate and local entities, [with] potentially affected industries[,] and [with] other interested parties, identify and evaluate approaches for reducing the risk of adverse consequences associated with intentional introduction of aquatic organisms."

## 2.2 AGENCY RESPONSIBILITIES AND INVOLVEMENT

### 2.2.1 United States Department of Agriculture

The USDA is the lead federal agency for coordination of federal activities and for dissemination of educational materials to assist aquaculture development. Specifically, the USDA: (1) operates regional aquaculture centers for conduct of aquacultural research, extension, and demonstration projects; (2) provides programs such as workshops for new fish farmers, short courses on management and fish

diseases, and aquaculture demonstration projects; (3) provides a repository for national aquaculture information through the agency's National Agricultural Library [c/o Aquaculture Information Center, U.S. Department of Agriculture, 10301 Baltimore Boulevard, Room 111, Beltsville, Maryland 20705; (301) 344-3704], and participates with NOAA in the collection and distribution of aquaculture information from around the world as part of an international project coordinated by the FAO; (4) conducts research on the market opportunities for aquaculture products; (5) conducts research to determine causes of off-flavor in freshwater catfish, improve productivity and quality in catfish through genetic selection and breeding programs, and develop efficient aquaculture systems for catfish production; (6) provides disease diagnostic and water quality services to fish farmers; (7) makes and guarantees loans to provide facilities and operational resources to produce fish under controlled conditions; (8) prepares and publishes reports from monthly surveys of freshwater catfish processors to monitor prices paid to catfish producers, and prices received by processors by methods of sale; (9) provides leadership for the Joint Subcommittee on Aquaculture; (10) works with state agricultural experiment systems, forestry schools, the Land Grant colleges, and colleges of veterinary medicine in the administration of the Aquaculture Special Research Grant Program; and (11) purchases meat and fish products in order to stabilize market conditions and furnish nutritious food to meet needs of the USDA's domestic feeding programs.

## 2.2.2 United States Department of Commerce

Several programs within USDC are involved in aquaculture research and development. The following subsections highlight this involvement for six departmental agencies. The first four agencies belong to NOAA.

### 2.2.2.1 National Marine Fisheries Service

NMFS directs its efforts toward management and research of living marine resources. The agency cooperates with federal and state agencies, international bodies, foreign governments, and university and private interests. Inhouse research, management, and grant programs by the NER are described in Sections 2.3 - 2.6.

### 2.2.2.2 National Ocean Service

The NOS National Shellfish Register provides an assessment of recorded changes in the pollution-based certification of molluscan shellfishing waters. Implemented in 1966 and published every five years, the register is produced and published in cooperation with the coastal states and the Interagency Task Force on Shellfish Growing Waters, which includes NOAA, FDA, EPA, and USFWS.

### 2.2.2.3 National Environmental Satellite, Data, and Information Service (NESDIS)

Through NESDIS's National Environmental Data Referral Service, the agency maintains a data base across the full spectrum of environmental sciences. This data base includes materials from the physical and life sciences that support marine sciences and aquaculture research programs.

### 2.2.2.4 Office of Oceanic and Atmospheric Research

The OAR's NSGCP conducts research, extension, and educational programs with universities in coastal and Great Lakes states. Sea Grant aquaculture programs, on a state-by-state basis, are briefly addressed in Section 2.3.3.

### 2.2.2.5 Economic Development Administration

Under its Public Works and Development Facilities Program and its Technical Assistance Program, EDA considers funding aquaculture projects that meet EDA regulations, applicant eligibility requirements, and project selection criteria. Recently, EDA has provided funds to the Maine Office of State Planning and the Maine Department of Marine Resources to prepare a report on the economic potential of aquaculture in Maine.

### 2.2.2.6 National Technical Information Service (NTIS)

The NTIS is the central source for the public sale of U.S.-government-sponsored research and development reports on all subjects, including those related to aquaculture.

## 2.2.3 U.S. Fish and Wildlife Service

The new aquaculture initiative within USFWS headquarters has been given further substance by the appointment of a national aquaculture coordinator. The expanding interest in aquaculture by the USFWS is two pronged. First, the agency encourages aquaculture development that is compatible with sound public resource stewardship. Second, to the extent possible, the USFWS makes its expertise available to assist the private sector. Within the USFWS

Northeast Region (*i.e.*, Region 5), a regional aquacultural coordinator has been designated at the USFWS Northeast Fishery Center in Lamar, Pennsylvania.

### 2.2.4 U.S. Army Corps of Engineers

Aquaculture projects that involve discharge of dredged or fill materials into waters of the United States, or construction in the navigable waters of the United States, must have a permit from the USACOE under Section 404 of the Clean Water Act and Section 10 of the 1899 Rivers and Harbors Act, respectively.

### 2.2.5 U.S. Department of Energy

The agency supports aquatic species research as part of the Biofuels and Municipal Waste Technology Research Program. Research is conducted to develop and provide the technology base that leads to the production of liquid fuels from the outdoor mass culture of microalgae.

### 2.2.6 U.S. Department of Health and Human Services (HHS)

Through HHS's FDA, the agency evaluates marketed animal drugs, feed additives, and devices used in aquaculture; and coordinates the veterinary medical aspects of the FDA inspection, surveillance, and compliance programs relating to animal drugs, animal feeds, and other veterinary medical matters. Through the Fishery Research Branch, the HHS conducts inhouse research in aquaculture including processing practices which may contaminate fish products with microbial, chemical, and naturally occurring biotoxins of public health concern.

### 2.2.7 National Science Foundation

This agency's Small Business Innovation Research Program provides funding for aquaculture research. This program annually solicits research proposals from small business firms on important scientific or engineering problems that could lead to significant public benefit. Aquaculture proposals fall under two major topic areas: marine/estuarine or freshwater.

### 2.2.8 U.S. Environmental Protection Agency

The EPA's water quality programs are concerned with setting standards for assuring the protection of the nation's waterways and water supplies. The National Pollutant Discharge Elimination System issues permits for the discharge of waste to surface waters. Permits must be obtained under this program to use pollutants in public waters for aquacultural purposes.

Municipal wastewater treatment in publicly-owned treatment works is amenable to the use of aquaculture systems funded, in part, by EPA's Construction Grant Program. Chemicals and other materials to be used in aquaculture are subject to pesticide registration by EPA.

## 2.3 AQUACULTURE-RELATED RESEARCH AND DEVELOPMENT

NOAA conducts aquaculture research and development through NMFS and the NSGCP. Aquaculture-related research supported by NMFS is conducted by scientific staff at NMFS fisheries science centers and their component laboratories, and through agency funding of projects conducted by state fishery resource agencies, academia, and private industry.

The NSGCP supports research through grants to universities and other entities. The technology gained from this research is utilized by private industry for commercial purposes and by public agencies for augmenting natural stocks through enhancement programs.

The following subsections refer to: (1) aquaculture activities conducted expressly by the NEFSC; (2) research funded by NEROO grant programs; and (3) an overview of activities funded under Sea Grant and USDA programs.

### 2.3.1 NMFS Research -- Northeast Region

#### 2.3.1.1 Historical

The genesis of aquaculture research in the NER conducted by inhouse scientific expertise dates back prior to Reorganization Plan No. 4 of 1970, at which time the BCF (as well as the Marine Game Fish Program) of the USFWS of the U.S. Department of the Interior was transferred to NOAA of the USDC, and was renamed NMFS. The first permanent assignment of a full-time biologist and the plan to establish a laboratory in Milford, Connecticut, occurred in November 1931. At that time, this small program was concerned with biological problems facing the Connecticut shellfish industry. Construction of the original laboratory building was completed in 1940.

The development of methods for commercial shellfish cultivation began in 1944 at the current-day NEFSC's Milford Laboratory. During the mid-1940s, the Milford group established routine and dependable procedures for conditioning eastern oysters to ripeness, inducing spawning and fertilization, rearing larvae to setting, and growing

newly-set spat. Their methods differed primarily from previous culture research in that live algal food, cultured in the laboratory, was provided for larval nutrition. This, plus temperature control of the laboratory seawater, made it possible to conduct hatching operations on a year-round basis and opened the potential for the reliable commercial production of eastern oyster seed (Hanks 1987).

The following is summarized from an article by the late Dr. Victor L. Loosanoff (1971), then Director of the Milford Laboratory:

> During the early 1950s, the cultivation (research) program went through an extremely difficult period when early efforts on shellfish mariculture were considered in some quarters as an undesirable folly. The program was revived subsequently by an inhouse transfer of funds and encouragement from the BCF's Clam Investigations Unit. Due to this support, and continuing success in rearing shellfish larvae at the Milford Laboratory, outside opposition to the mariculture program subsided. In 1954, an article entitled, "New Advances in the Study of Bivalve Larvae," was published in *The American Scientist* and "received general acclaim.

The status of aquaculture-related research at Milford was bolstered by Congress in August 1961 through the enactment of Public Law 87-183. This legislation authorized the construction at Milford of an expanded research center for shellfisheries production. The center was empowered to consist of "research facilities, a pilot hatchery including rearing tanks and ponds, and a training school...for the conduct of basic research on the physiology and ecology of commercial shellfish, the development of hatchery methods for cultivation of mollusks, including the development of principles that can be applied to the utilization of artificial and natural salt water ponds for shellfish culture, and to train persons in the most advanced methods of shellfish culture."

Molluscan research has continued at Milford on a variety of subjects including natural diets (*e.g.*, Ukeles 1971), eastern oyster culture (*e.g.*, Davis 1971), genetics (*e.g.*, Longwell 1976), disinfection techniques for contaminated shellfish hatchery water (*e.g.*, Blogoslawski 1988), and culture methods for bay scallops and Atlantic surfclams (*e.g.*, Goldberg 1980).

### 2.3.1.2 Current

Since the 1970s, aquaculture-related research has continued at Milford and, to a limited extent, at other laboratories of the NEFSC. In 1986, however, fish and shellfish culture work was "reprogrammed" in the NER and elsewhere within NMFS to other program priorities such as environmental pollution research. This was a function of overriding legislative mandates and specific intents of agency appropriations, but was also due to the perceived potential conflicts concerning the effects of aquaculture on traditional commercial fisheries. As summarized by the Joint Subcommittee on Aquaculture (U.S. Department of Agriculture 1991), NMFS in the mid-1980s directed its aquaculture efforts

> toward managing common property resources and contributing to the restoration and protection of endangered species or stocks. It accomplishes this primarily through inhouse research at several NMFS laboratories in the United States. In addition, NMFS disseminates aquaculture-related information and technological advances gained from its fisheries research. NMFS cooperates with [f]ederal and [s]tate agencies, international bodies and foreign governments, and universities and private interests, and promotes the development and expansion of domestic and international markets for products produced by the U.S. aquaculture industry.

Examples of contributions to the aquacultural sciences by the NEFSC during the last four years include: (1) large-scale stocking of broken ocean quahog shell throughout New Jersey's Barnegat Bay to enhance wild northern quahog spat concentrations, a collaborative effort with Rutgers University and New Jersey Sea Grant; (2) commercial testing of Atlantic surfclam rearing methods by private aquaculturists in the Northeast who have received grants from various federal agencies to test the commercial feasibility of rearing Atlantic surfclams using methods established by NEFSC researchers; (3) study of algal nutritional content to promote growth in post-set eastern oysters and northern quahogs; (4) publication of "Rearing of Bivalve Mollusks" by Dr. V. Loosanoff and H. C. Davis; (5) development of mass culture techniques for rearing algae; (6) evaluation of food requirements for larval shellfish; (7) investigations of disease-causing bacteria found on northern quahog planting beds; (8) genetic studies of the eastern oyster; (9) assessment of die-offs and putative bacterial and viral infections of blue crabs held in flow-through and recirculating shedding systems; (10) studies of larval diseases of eastern oysters; (11) evaluation of methods for cleansing bacterial pathogens from the digestive systems of shellfish; (12) study of limiting factors on northern quahog production including assessment of shell-stocking as a means to reduce predation by mud crabs, and investigation of naturally occurring and artificially stocked populations to determine effects of different sites, stocking densities, phytoplankton blooms, and bacterial infections on the quahog's reproduction, growth, and health; (13) publication of a report useful to shellfish aquaculturists on the parasites and predators of shellfish; (14) conduct of annual shellfish biology seminars sponsored by the Milford Laboratory for sharing information about shellfish aquaculture with researchers, extension agents, and industry representatives; and (15) assessment of juvenile eastern oyster mortalities at

a New York commercial shellfish hatchery--a collaborative effort between the hatchery and the NMFS Milford and Oxford Laboratories, Battelle Research Institute, Virginia Institute of Marine Science, Rutgers University, and the USDA's Northeastern Regional Aquaculture Center (NRAC).

In 1984, the NEFSC appointed an aquaculture liaison for the Northeast at Milford. In 1992, the NEFSC converted the position to that of a research coordinator/liaison scientist to devise and coordinate the design and development of projects and activities to implement aquaculture goals of the NMFS Strategic Plan in the Northeast. The responsibilities of this position include advising aquaculture facility managers on the probability that particular facilities will be capable of meeting profit, research, or other objectives. The position develops closer ties with industry through NMFS providing direction for sponsored cooperative research on finfish, bivalve mollusk, and crustacean culture. Also, the position will be involved in determining the feasibility of aquaculture/recruitment replanting of overfished species, especially the demersal marine fisheries of the Northeast. Liaison will be developed with the aquaculture industry to evaluate the environmental risks posed by field plantings of aquacultural species which add to natural recruitment by the wild finfish and shellfish stocks.

## 2.3.2 NMFS-administered State/Federal and Industry Grant Programs

The involvement of the NEROO's grant programs in aquaculture, both past and present, is as varied as the broad definition of aquaculture allows. Each program (*i.e.*, AFCA, IFA, ODRP, S-KA, and CFRDA) has supported projects that run the gamut from those considered traditional aquaculture, such as culturing channel catfish in ponds and cages, to managerial actions, such as eastern oyster shell planting and anadromous fisheries evaluation and enhancement activities.

The number of closed projects pertaining to aquaculture far exceed the number of current projects. This, however, is more an artifact of program length (*e.g.*, CFRDA) and legislative purview than lack of interest in aquacultural research. In general, AFCA and IFA projects pertain to enhancement either through direct stocking of various species or through hatchery support. The projects under the CFRDA cover a wide spectrum from eastern oyster bed restoration in a number of East Coast states to channel catfish culture in the Great Lakes area. The focus of ODRP projects ranges from developing strains of disease-resistant eastern oysters, to understanding the mechanisms of disease transfer, to characterizing the industry. The S-KA, on the other hand, emphasizes the potential for intensive culture of traditional commercial fishery species and aquaculture waste management.

### 2.3.2.1 Saltonstall-Kennedy Act

The S-KA (Public Law 466, 83rd Congress, as amended) is administered by NMFS. The legislation provides that a fund (known as the S-K fund) will be used to provide grants for fisheries research and development projects and to implement a national fisheries research and development program. The *Federal Register* notice of the availability of Fiscal Year 1991 S-K funds included the following funding priorities related to research for domestication and mass culture of regional living freshwater and marine resources: (1) developing methods to differentiate unmanaged cultured species from the same species of wild stock to assist fisheries management and enforcement activities; (2) assessing the genetic effects resulting from the interaction between cultured salmon which escape from net pens and wild fish; (3) determining the effects of net-pen operations on the marine environment, including assessment of the effect of antibiotics utilized in fish feeds on native marine fauna and sediments; (4) improving efficiency and conserving water in closed-cycle systems; (5) improving water quality in the effluent; (6) assessing life cycles, nutritional requirements, growth rates, toxicity levels, and hydrographic processes that lead to blooms of important phytoplankton species such as *Heterosigma akashiwo* which cause mortality in cultured finfish; (7) developing and implementing a comprehensive long-range plan for sponge aquaculture operations in the Federated States of Micronesia, Republic of the Marshall Islands, and Republic of Palau; and (8) aiding the development of the northern quahog industry by addressing genetics, spawning/survival/growth parameters including habitat requirements, and food supply for larvae.

During 1990-91, NMFS has awarded four grants in the Northeast totaling $518,000 (with anticipated obligations of $978,200 through Fiscal Year 1993) to study diverse areas of the aquaculture industry. The following subsections describe these grants.

#### *2.3.2.1.1 Domestication and Mass Culture of Summer Flounder*

Research is being conducted by the University of Massachusetts in cooperation with the University of Rhode Island and NMFS's Beaufort (North Carolina) and Narragansett (Rhode Island) Laboratories on controlled reproduction, larval culture, nursery culture of newly metamorphosed flounder, and grow-out culture to harvestable size. This work involves the collecting and conditioning of spawning stock, determining larval nutritional requirements, developing cost-effective feeds, adapting heated seawater recycle systems to permit rapid growth, and developing production systems for sea cage culture.

This work is being performed on the basis of successful turbot and Japanese flounder commercial enterprises in Europe and Japan. Adaptation and application of aquaculture methods used for those species are hoped to enhance the

probability for success with summer flounder culture in the United States.

#### 2.3.2.1.2 *Waste Treatment and Energy Recovery in Closed-Cycle Aquaculture Systems*

The goal of this project, conducted by Fresh-Culture Systems, Inc., located in Kutztown, Pennsylvania, is to develop an economically feasible, indoor, medium-scale aquaculture system for raising both coldwater and warmwater finfish species year-round in urban and rural regions in the northeastern United States. A demonstration facility, treating fecal wastes from aquaculture operations, will be operated and monitored for the efficacy of the system's design to treat waste and produce methane. The methane will be used to heat the water required in the aquaculture facility.

Successful completion of this project will demonstrate significant cost advantages to medium-scale, year-round, indoor aquaculture for finfish species such as striped bass and rainbow trout.

#### 2.3.2.1.3 *Growth and Metabolism Energy Budget of Lake Sturgeon*

This investigation explores the relationships between food ration and growth for lake sturgeon collected in the Great Lakes region. Standard metabolism will be determined in flow-through respirometers for a wide range of fish sizes at temperatures typical of the sturgeon's natural habitat and hatchery environments. The data will be used to construct a model of energy flux and feeding and growth rates to identify optimal culture practices.

It is anticipated that this project will determine the energy budget for lake sturgeon, classified as rare by the U.S. Department of the Interior and threatened by the state of Michigan, thereby providing essential data for hatchery culture and habitat management practices/policies for propagation of this species. The work is being conducted by the University of Michigan in cooperation with the Michigan and Wisconsin Departments of Natural Resources. The growth energetics aspects of the study are being coordinated with the University of Miami.

#### 2.3.2.1.4 *Development of Benthic-threshold Environmental Impact Model for Net-Pen Atlantic Salmon Culture Mutually Beneficial to Aquaculture and Traditional Fisheries*

This project, conducted by the University of Maine, is assessing the environmental effect of organic enrichment derived from net-pen Atlantic salmon culture production wastes upon the benthic community in Maine's coastal marine waters. The study is being performed at an aquaculture facility located near Swans Island, and will calculate carbon flux to the bottom from sediment trap and core data from samples taken seasonally during various production stages.

### 2.3.2.2 Commercial Fisheries Research and Development Act

The CFRDA (Public Law 88-309) was enacted in 1964 to authorize the Secretary of Interior (Secretary of Commerce subsequent to the Reorganization Plan No. 4 of 1970) to cooperate with the states through their respective state agencies in carrying out projects designed for the research and development of the commercial fisheries resources of the nation. This law was repealed effective October 1, 1987, with the enactment of the IFA of 1986. During the 23-year period during which funds were apportioned under this legislation, the NEROO administered approximately 80 aquaculture-related projects conducted or coordinated by state fishery resource agencies in the New England, Mid-Atlantic, and Great Lakes states. Costs incurred under these aquaculture projects comprised about 16 percent of the total federal funds made available to the 19 states served by the NER. This represented aquaculture-related expenditures of $11,363,100 ($7,800,000 federal share) unadjusted for inflation under the Public Law 88-309 program. The aquaculture activities were divided among six primary categories (Table 1): marine fish & shellfish culture (71.8 percent); environmental monitoring (10.7 percent); aquaculture systems/management analysis (7.8 percent); freshwater fish & invertebrate culture (3.8 percent); restoration/stocking/fisheries enhancement (3.2 percent); and processing technology (2.7 percent).

Shell planting to maintain, restore, and/or perpetuate the eastern oyster commercial fisheries, primarily in the Chesapeake and Delaware Bays, comprised the major component of the marine fish & shellfish culture projects. Approximately 37 percent ($2,891,900) of the federal funds awarded under this category were allocated under the resource disaster provisions (Section 4b) of the act. Funds were awarded under this section when the Secretary of Commerce determined that there was a failure of the eastern oyster commercial fishery due to natural or undetermined causes. The disasters were declared (through a notice in the *Federal Register*) in 1972 resulting from Tropical Storm Agnes and again in 1987 resulting from prolonged drought and warm temperatures in 1985/86 which caused the spread of major eastern oyster diseases. The importance of shell planting to eastern oyster aquaculture is discussed in Section 2.6.2. Other research conducted under this category included northern quahog and bay scallop culture techniques, and a pilot study on the commercial rearing of winter flounder at the University of New Hampshire.

Environmental monitoring projects were conducted by New York and Virginia to monitor water quality on com-

Table 1. Summary of aquaculture research under Public Law 88-309

| Activity (State) | Period Covered | Project Costs | | |
|---|---|---|---|---|
| | | Federal | State | Total |
| **Marine Fish & Shellfish Culture** | | | | |
| Eastern oyster shell planting (DE/MD/NH/NJ/VA) | 1965-88 | $4,024,900 | $1,082,400 | $5,107,300 |
| Eastern oyster culture techniques (DE/MD/NJ/NY/VA) | 1964-81 | $821,200 | $395,000 | $1,216,200 |
| Eastern oyster disease monitoring (MD/NJ) | 1971-88 | $519,000 | $291,200 | $810,200 |
| Northern quahog culture techniques (NY) | 1973-82 | $180,600 | $180,600 | $361,200 |
| Eastern oyster growth & survival studies (DE/NH/VA) | 1968-75 | $123,200 | $88,300 | $211,500 |
| Bay scallop culture techniques (NY/RI) | 1973-82 | $180,600 | $180,600 | $361,200 |
| Winter flounder (NH) | 1977-80 | $69,200 | $23,100 | $92,300 |
| **SUBTOTAL** | | **$5,918,700** | **$2,241,200** | **$8,159,900** |
| **Environmental Monitoring** | | | | |
| Shellfish sanitation (NY) | 1970-87 | $467,200 | $474,500 | $941,700 |
| Eastern oyster habitat survey (VA) | 1976-78 | $140,200 | $140,200 | $280,400 |
| **SUBTOTAL** | | **$607,400** | **$614,700** | **$1,222,100** |
| **Aquaculture Systems/Management Analysis** | | | | |
| Hatchery wastewater treatment (PA) | 1975-85 | $275,600 | $91,900 | $367,500 |
| Rearing of rainbow trout, catfish, walleye, & fathead minnow in vertical silos (PA) | 1970-75 | $121,400 | $40,400 | $161,800 |
| Depuration plants for northern quahogs (NY) | 1965-69 | $77,100 | $25,700 | $102,800 |
| Eastern oyster transplant &northern quahog relay program analysis(NJ) | 1973-79 | $71,400 | $71,400 | $142,800 |
| Hydroponics — channel catfish (IL) | 1976-77 | $48,300 | $16,100 | $64,400 |
| Production ponds — channel catfish (IL) | 1973-74 | $31,300 | $10,400 | $41,700 |
| **SUBTOTAL** | | **$625,100** | **$255,900** | **$881,000** |

Table 1. Continued

| Activity (State) | Period Covered | Project Costs | | |
|---|---|---|---|---|
| | | Federal | State | Total |
| **Freshwater Fish & Invertebrate Culture** | | | | |
| Channel catfish (IL/MN/WV) | 1968-78 | $130,600 | $46,300 | $176,900 |
| Freshwater drum (OH) | 1974-78 | $90,400 | $30,100 | $120,500 |
| Salmonid disease (OH) | 1969-74 | $54,600 | $18,200 | $72,800 |
| Leech-baitfish (MN) | 1979-82 | $30,900 | $30,900 | $61,800 |
| **SUBTOTAL** | | **$306,500** | **$125,500** | **$432,000** |
| **Restoration/Stocking/Fisheries Enhancement** | | | | |
| Lake trout (MI) | 1969-76 | $95,000 | $92,200 | $187,200 |
| American shad/river herring (MA) | 1979-81 | $88,400 | $88,400 | $176,800 |
| **SUBTOTAL** | | **$183,400** | **$180,600** | **$364,000** |
| **Processing Technology** | | | | |
| Eastern oysters (MD) | 1969-73 | $93,200 | $93,200 | $186,400 |
| Freshwater drum (OH) | 1976-78 | $65,700 | $52,000 | $117,700 |
| **SUBTOTAL** | | **$158,900** | **$145,200** | **$304,100** |
| **TOTAL** | | **$7,800,000** | **$3,563,100** | **$11,363,100** |

mercial shellfish grounds and to assess the commercial productivity of eastern oyster habitat, respectively. Several studies were directed toward evaluation of aquaculture systems/management analysis. For example, the Pennsylvania Fish Commission examined the feasibility (*e.g.*, cost benefit analysis, nutritional needs, and fish survival) of rearing channel catfish, rainbow trout, and walleye in vertical silo units. That state also conducted a 10-year investigation on the development of guidelines for economical commercial hatchery wastewater treatment systems. New York in the late 1960s constructed depuration plants to perform various experiments on aspects of northern quahog, softshell, and eastern oyster contamination. Finally, in Illinois, studies addressed the stabilization of environmental conditions in catfish production ponds, and examined the use of hydroponics as a means of preventing waste accumulation in a fish production system.

Freshwater fish & invertebrate projects included culture of channel catfish in West Virginia and the Great Lakes states, effects of whirling disease on the culture of salmonids in Ohio, and the effects of transport on freshwater drum from capture sites to pay-to-fish lakes and commercial hatcheries.

Fishery enhancement studies included assessing the success of lake trout survival and stocking programs in Lake Michigan, and transplanting American shad and alewives to restore depleted populations in Massachusetts. Efforts to improve processing technology for aquaculture products were undertaken by two states, Maryland and Ohio. The

former involved a study on the techniques for cleaning and shucking eastern oysters (for commercial sale) through the use of vibration, ultraviolet light, and thermal shock. The Ohio project investigated the development of processing technology that would allow extended storage and utilization of cultured freshwater drum products.

The above summary presents only a "bird's eye" view of Public Law 88-309 program accomplishments. A more detailed description of the objectives and results of aquaculture projects is available upon request from the NEROO's SFCPD.

### 2.3.2.3 Interjurisdictional Fisheries Act

The IFA of 1986 (Title III of Public Law 99-659) is a formula-based financial assistance program with two overall purposes: (1) to promote and encourage state activities in support of the management of interjurisdictional fisheries resources; and (2) to promote the management of interjurisdictional fisheries resources throughout their range. Any state may, either directly or through its interstate commission, submit a research program which supports management of fishery resources: (1) for which a fishery occurs in waters under the jurisdiction of one or more states and the U.S. Exclusive Economic Zone; (2) for which there exists an interstate fishery management plan; or (3) which migrate between the waters under the jurisdiction of two or more states bordering on the Great Lakes. Aquaculture-related activities which have been conducted by the ASMFC (supported by IFA funds) are summarized in Section 3.3.

During 1987-91, five aquaculture-related projects have been conducted at an estimated total cost of $1.0 million ($15,400 nonfederal match) in the states of Delaware, Maryland, New Jersey, and Vermont. Projects in the Mid-Atlantic states ($916,300) have been funded under the resource disaster provisions of the IFA, which are similar to those previously incorporated under Public Law 88-309 for restoring the viability of commercial fisheries adversely affected by natural or undetermined causes. Specifically, state activities have involved the planting of eastern oyster shell cultch material and an expanded eastern oyster seed distribution program in efforts to alleviate losses to the commercial industry resulting from disease-associated mortalities in the Chesapeake and Delaware Bays.

One goal of the ongoing Atlantic salmon restoration programs in New England is to restore naturally sustained populations of sea-run Atlantic salmon in the Connecticut River system. The present programs are sustained through stocking of hatchery-reared smolts and fry. In Vermont, the Department of Fish and Wildlife, in cooperation with the University of Vermont, is assessing the first-year survival and growth of Atlantic salmon stocked as either feeding or nonfeeding fry at various densities in the White River; additional investigations are evaluating the habitat parameters which affect fry survival. This research is anticipated to provide critical information determining the efficacy of fry stocking in Vermont waters and the data necessary to develop models to allow adjustments of fry stocking levels on a stream-by-stream basis.

### 2.3.2.4 Anadromous Fish Conservation Act

The AFCA (Public Law 89-304) was enacted in 1965 to authorize the Secretary of Interior (and Secretary of Commerce subsequent to the Reorganization Plan No. 4 of 1970) to cooperate with the states in carrying out projects for the conservation, development, and enhancement of the nation's anadromous fish resources and fish in the Great Lakes and Lake Champlain that ascend streams to spawn. During the 25-year period during which funds have been apportioned under this legislation, the NEROO has administered approximately 15 aquaculture-related projects conducted by state fishery resource agencies in the New England, Mid-Atlantic, and Great Lakes states. These projects represent total expenditures of approximately $3.4 million (incorporating a $1.6-million federal cost-sharing level of participation) divided between three primary categories (Table 2): hatchery construction (41 percent); hatchery operation & maintenance (33 percent); and fish culture (26 percent).

The major program expenditure involved the construction, operation, and maintenance of an anadromous fish hatchery in Milford, New Hampshire, by the New Hampshire Fish and Game Department. The objectives of this initiative were to hatch, rear, and release coho and chinook salmon in an effort to generate a marine coastal recreational fishery; and to hatch, rear, and release Atlantic salmon smolts to facilitate meeting the goals of the Merrimack River Anadromous Fish Restoration Program. Construction funds were also allocated to Connecticut and Massachusetts for enhancing Atlantic salmon culture capabilities at the Kensington and Sunderland hatchery facilities, respectively. Also in Massachusetts, a study was funded to investigate the feasibility of raising coho salmon in heated seawater under varying salinity and temperature conditions.

Fish culture projects have been conducted by Michigan, Wisconsin, Maine, and Maryland. The Michigan study investigated the effects of disease on salmonid (brook/brown/rainbow/lake trout and coho/chinook salmon) survival, and systematic control of ectoparasites in hatcheries. Studies in Wisconsin were directed toward assessing the survival and growth of hatchery-reared walleyes stocked as fry and fingerlings in Green Bay. In Maine, striped bass eggs have been obtained from New York, raised to fingerling size at the federal fish hatchery in North Attleboro, Massachusetts, and transported/released in Maine's Kennebec River in efforts to re-establish a spawning population in that watershed. Striped bass investigations in Maryland have assessed the relative viabilities and potential for growth of larvae originating from adult spawning stock in three areas of Chesapeake Bay. Differences in growth/survival were

Table 2. Summary of aquaculture research under Public Law 89-304

| Activity (State) | Period Covered | Project Costs | | |
|---|---|---|---|---|
| | | Federal | State | Total |
| **Hatchery Construction** | | | | |
| Atlantic salmon (CT/MA) | 1973-83 | $86,000 | $86,000 | $172,000 |
| Coho salmon (MA) | 1974-75 | $22,400 | $22,400 | $44,800 |
| Coho/Atlantic salmon (NH/MA) | 1972-81 | $592,900 | $592,900 | $1,185,800 |
| **SUBTOTAL** | | **$701,300** | **$701,300** | **$1,402,600** |
| **Hatchery Operation & Maintenance** | | | | |
| Coho/Atlantic salmon (NH) | 1974-83 | $500,600 | $620,900 | $1,121,500 |
| **Fish Culture** | | | | |
| Great Lakes salmonids (MI) | 1967-76 | $230,200 | $305,100 | $535,300 |
| Walleye (WI) | 1979-87 | $150,400 | $150,400 | $300,800 |
| Striped bass (ME/MD) | 1982-88 | $31,300 | $31,300 | $62,600 |
| **SUBTOTAL** | | **$411,900** | **$486,800** | **$898,700** |
| **TOTAL** | | **$1,613,800** | **$1,809,000** | **$3,422,800** |

Table 3. Summary of fishway construction and fish stocking (anadromous fish restoration) activities under Public Law 89-304

| State (Major Area) | Period Covered | Project Costs | | |
|---|---|---|---|---|
| | | Federal | State | Total |
| MA (Cape Cod; Charles & Taunton Rivers) | 1967-91 | $770,300 | $973,500 | $1,743,800 |
| ME (St. George, E. Machias, & Royal Rivers) | 1969-91 | $801,100 | $801,100 | $1,602,200 |
| RI (Pawcatuck & Hunts Rivers) | 1967-83 | $150,600 | $150,600 | $301,200 |
| NJ (statewide coastal areas) | 1984-89 | $63,400 | $63,400 | $126,800 |
| MD (Big Elk & Tuckahoe Creeks) | 1989-91 | $60,000 | $60,000 | $120,000 |
| PA (Brandywine Creek) | 1967-70 | $19,700 | $64,000 | $83,700 |
| **TOTAL** | | **1,865,100** | **$2,112,600** | **$3,977,700** |

similarly evaluated for strains of striped bass - white bass hybrids and striped bass - white perch hybrids cultured in cages in hatchery ponds.

The construction of fish passage facilities and transplant of wild fish from one watershed to another, for purposes of re-establishing depleted populations of anadromous fish, are not construed as direct aquaculture initiatives in this document. Nevertheless, these restoration activities are related to those aquaculture objectives which involve human intervention to enhance resource productivity and which foster development of the Northeast's commercial and recreational fisheries. Under the AFCA, the NEROO has administered fishway construction and transplant projects in Massachusetts, Maine, Rhode Island, New Jersey, Maryland, and Pennsylvania (Table 3). These projects represent total expenditures of approximately $4.0 million (incorpo-

rating a $1.9-million federal cost-sharing participation). Examples of these activities are fishway construction projects on the East Machias River in Maine, the Herring River in Massachusetts, the Pawcatuck River in Rhode Island, and Big Elk Creek in Maryland. Transplant studies have included the stocking of adult American shad in Maine's Royal River, the planting of rainbow smelt eggs in Mill Creek and the stocking of American shad eggs and spawning adults in the Charles River (both in Massachusetts), as well as stocking American shad eggs in Pennsylvania waters of Delaware River tributaries (Brandywine Creek).

The above summary presents only a synopsis of Public Law 89-304 contributions to aquaculture. A more detailed description of objectives and results is available upon request from the SFCPD.

#### 2.3.2.5 Oyster Disease Research Program

The ODRP administered by the NEROO has incorporated total expenditures of approximately $2.2 million ($1.5-million federal cost-sharing participation) for 1990-91. The ODRP was established to assess research and management issues associated with the effect of shellfish diseases on eastern oyster resources. Projects funded in Virginia, Maryland, New Jersey, Delaware, and South Carolina involve various aspects of laboratory culture and/or hatchery rearing of eastern oysters. The results of these studies are anticipated to not only clarify disease processes affecting resource viability, but also the success of cultural procedures essential to aquaculture-related management practices, particularly in the Chesapeake Bay area. Research projects include investigations on disease diagnostic techniques (34 percent); disease resistance in native and non-native oysters (29 percent); transmission dynamics of oyster pathogens (16 percent); the life cycle of oyster parasites (11 percent); and the success of genetic manipulations in minimizing susceptibility to disease (10 percent).

Funds allocated under this program, in coordination with the Maryland Department of Natural Resources (MDNR) and the NSGCP, also supported an international oyster management workshop in Annapolis during October 1991. The workshop included an overview on the ecological effects of Pacific oyster introductions on the East Coast (Section 5.2.4).

### 2.3.3 Sea Grant Research

The NSGCP is a major contributor to advances in aquaculture research and development in the Northeast. The NSGCP has prepared an Aquaculture Plan through a cooperative effort of involved institutions and has set priorities in line with the National Aquaculture Development Plan of 1983. On average, the NSGCP funds 110-120 aquaculture projects nationwide, worth about $4.0 million each year (University Corporation for Atmospheric Research 1989). Examples of research at academic institutions in northeastern states during the past six years include: (1) **Connecticut** -- shellfish bag relaying systems, effects of neoplasia on softshell survival, competition for settlement sites between eastern oyster spat and other larval shellfish, and biology/cultivation of Atlantic seaweeds; (2) **Delaware** -- development of marine and estuarine halophytes into food and forage crops using seawater irrigation, artificial diets for shellfish, production of algae, chemical ecology of feeding, reproduction, and fright behavior of oyster drills as a means for drill control; (3) **Maine/New Hampshire** -- blue mussel settlement patterns in Maine estuarine systems, research on infectious pancreatic necrosis, establishment of a fish health clinic for aquaculturists at the University of Maine, assessment of effects of fin rot disease on wild and hatchery-reared Atlantic salmon survival, artificial hormonal triggers for fish ovulation, and the effect of eel grass on blue mussel culture; (4) **Maryland** -- eastern oyster seed hatcheries and grow-out facilities, carotenoid enrichment in microalgae for aquaculture, commercial quality of wild-captured and cultured hybrid striped bass, determining the demand for aquacultural products, striped bass demonstration projects in farm ponds, finfish and shellfish genetic engineering, and catfish cage culture; (5) **Minnesota** -- walleye culture and publications on industry financing regulations, fish feed, and aeration equipment; (6) **New Jersey** -- development of record keeping for aquaculture (clam farming), genetic factors associated with disease resistance and growth rates in eastern oysters, physiological factors associated with MSX mortality in hatchery-produced eastern oysters, and predator control nets for aquaculture systems; (7) **Rhode Island** -- determining status of Atlantic salmon aquaculture, bay scallop spawning and rearing, closed-system salmon culture, effects of disease treatment on nitrification in closed system aquaculture, experimental culture-research facility for American lobster, and optimizing the growth and marketing of fish in a controlled environment; (8) **Virginia** -- hybrid striped bass aquaculture and market potential, blue crab habitat preferences, disease resistance in eastern oysters, culture of northern quahog and softshell, hatchery pilot study for development of "eyed" eastern oyster larvae, softshelled blue crab shedding systems, preparing cultch for remote eastern oyster setting systems, containerized northern quahog relaying, and crayfish production; and (9) **Wisconsin** -- provision of advisory services to prospective fish farmers, and technical and marketing assistance in the commercial culture of lake whitefish.

### 2.3.4 USDA Program

The NRAC, one of five regional aquaculture centers established by, is headquartered at the University of Massachusetts - Dartmouth (see Chapter 5). The NRAC is funded by the USDA at an annual level of approximately $700,000.

As of December 1990, the NRAC was supporting nine regional projects involving 11 states, 11 universities, three federal agencies, and over a dozen private companies (Northeastern Regional Aquaculture Center 1990). These projects included: (1) genetic improvement of the eastern oyster for commercial culture in the Northeast; (2) genetic manipulation and sex control in striped bass; (3) analysis of the economics and marketing of farmed finfish in the Northeast; (4) governmental regulation of growth and development of, and improving the legal framework for, aquaculture in the Northeast; (5) a Northeast Regional Aquaculture Extension Program for a more viable, profitable industry; (6) genetic manipulation of eastern oysters through hybridization and polyploidy; (7) a *Northeastern Regional Aquaculture Center Newsletter*; (8) increasing aquaculture production in the Northeast through nutrition; and (9) commercial field trials of MSX-resistant strains of the eastern oyster.

Aquaculture research is a priority under another major USDA program to support agricultural research entitled, "The National Initiative for Research on Agriculture, Food and Environment." This initiative is authorized at $500 million annually by the 1990 farm bill. Congress has appropriated $73 million for the first year of this program. These are new dollars and do not come at the expense of other USDA efforts (Northeast Regional Aquaculture Center 1991). The program has six component areas: (1) natural resources and the environment; (2) nutrition, food quality, or health; (3) processes antecedent to adding value or developing new products; (4) markets, trade, and policy; (5) animal systems; and (6) plant systems.

In addition, the USDA administers a competitive grant program under its Special Research Grants Program. The objective of this program is to enhance the knowledge and technology base necessary for the continued growth of the domestic aquaculture industry. Emphasis is placed on research leading to improved production efficiency and increased competitiveness of private-sector aquaculture in the United States. During Fiscal Year 1991, priority research categories included disease and parasite control, and integrated aquatic animal health management.

## 2.4 HABITAT AND WATER QUALITY

The aquaculture industry, as well as the traditional commercial and recreational fishery user groups, have been and will continue to depend upon good environmental water quality. The quality of the aquatic environment is critical not only to the health and survival of the fishery resources on which the industry depends, but also to public acceptance and consumer confidence in the resultant fishery products. For coastal aquaculture, and perhaps more notably for pond/containment culture operations, their success will require a large volume of high quality, virtually "free" water. Regulating parameters such as ammonia, dissolved oxygen, and water temperature will require the development of reliable techniques to measure and control water quality for optimum production.

Three initiatives have been conducted in the NMFS Northeast Region over the last four years which have effectively facilitated federal/state/private industry coordination and communications in addressing the habitat-related concerns of aquaculture operations. First, the NEROO, the state of Maine, EPA, USFWS, and the USACOE's New England Division have developed application guidelines for net-pen aquaculture projects. The joint application will satisfy requirements for securing USACOE, state, and EPA's National Pollution Discharge Elimination System permits. The guidelines are intended to minimize adverse environmental effects, reduce permit process time, and monitor the environmental effects of net-pen aquaculture.

Second, the NEFSC published a guide for enhancing estuarine molluscan shellfish populations. Habitat deterioration (*e.g.*, shellfish beds silted over so that larval settlement is inhibited) is thought to be a major factor in the resource declines. The guide describes suitable and unsuitable shellfish bed characteristics, survey techniques, and habitat improvement measures. The information contained in this publication directly benefits not only state/federal resource and habitat managers, but also shellfish aquaculture operations along the northeastern Atlantic coast.

Last, in May 1988, the NEROO, in cooperation with the Maine Department of Marine Resources and the USFWS, met with Maine and Canadian fish farming representatives at various field operation sites. These interests represented the Maine Aquaculture Association, fish farm owners, New Brunswick Fisheries and Aquaculture, and Canada's Department of Fisheries and Oceans (DFO) and Environmental Protection Service. During this round of field site reviews, information was exchanged concerning the status and concerns of aquaculture operations in Maine and Canada. Topics discussed included pollution, spread of disease from pen-raised salmon to wild stocks, effects on the wild salmon gene pool, hydrology, the use of antibiotics, and the effects of aquaculture on traditional fisheries.

With regard to salmon farming operations in southern New Brunswick and northeastern Maine, protected areas along the coast have been found to be ideal for the culture of Atlantic salmon. Presently, many sheltered areas are occupied for other purposes, and aquacultural industry expansion appears to be contingent on the development of fish containment systems technology for more exposed or onshore locations.

Federal permits are required for coastal aquaculture operations under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act. In the review of federal permits for aquacultural activities, issues of site selection, water quality, pollution, diseases, and the introduction of non-native species present major regulatory concerns to finfish and shellfish farming ventures. Specifically, some of these concerns include: (1) pollution from residual feeds, feces, and other excreta; (2) altered water

circulation patterns, suspended sediments, and silt deposition; (3) escapement and transmission of disease from cultured to wild stocks; (4) organic solids and effects on benthic organisms; (5) increased phytoplankton growth and its effects on toxicity and dissolved oxygen levels; (6) dispersal of antibiotics and hormones used on farms; (7) use of toxic substances; (8) conflicts with marine birds and mammals; and (9) wastes associated with hatchery and processing operations.

The USACOE has published a public notice requesting comments on a draft Letter of Permission (LOP) for bottom shellfish aquaculture operations in Massachusetts. There have been approximately 150 federally unlicensed shellfish aquaculture operations in the state, predominantly on Cape Cod. These activities have not been covered previously by the USACOE because they were considered to be covered under a nationwide permit program. The NEROO has offered to work with the state and the USACOE to develop a LOP to comply with federal regulations. The issuance of the LOPs will work to the advantage of the aquaculturist in that permit procedures will be shortened considerably and will also limit potential disagreements between state and federal authorities.

The *Shellfish Register of Classified Estuarine Waters* (National Ocean Service 1991) concluded that separate national surveys conducted in 1985 and 1990 confirm that a decline in water quality has led to a decrease in the acreage of approved molluscan shellfishing waters, and to a continuing decline in the nation's shellfish harvest. As recently as 1959, the Mid-Atlantic region harvested the greatest amount of shellfish, especially eastern oysters, in the nation. However, since then, increasing urban pollution has closed many historically productive areas. Overharvesting, eutrophication, and disease have also destroyed many shellfishing areas. Consequently, declines in the overall landings of estuarine shellfish continued between 1985 and 1990, despite increased aquaculture. The survey results indicated an "almost inexorable process which threatens to destroy the harvest of wild or natural shellfish throughout the [n]ation's coastal areas." This decline in the water quality of productive estuaries in combination with problems of overharvesting and disease may place the natural harvest of shellfish at risk of elimination.

In March 1990, a workshop was held in St. Andrews, New Brunswick, for discussion of environmental effects of finfish culture in the Gulf of Maine (Hayden and Choate 1990). Topics discussed included the nature and scale of risks to the environment from cage culture, the role of monitoring in regulation, and research -- both ongoing and needed.

The success of present and future aquaculture efforts, as well as the viability of the existing "capture" fisheries, is contingent upon acceptable water quality. This fact, while recognized by the resource community as a "given," will likely become even more pronounced in the public view as aquaculture issues receive continued attention.

## 2.5 TRADE AND INDUSTRY AUTHORITIES

As with any industry, the need to maintain profitability in aquaculture operations is affiliated with a need to reduce risks and increase returns on investment. Product safety and quality, access to markets, and methods of dealing with trade barriers are being addressed by the Codex Alimentarius Commission, by the governing agreements on tariffs and trade (GATT), and by bilateral negotiations on free trade.

### 2.5.1 Codex Alimentarius Commission

The NMFS Office of Trade and Industry Services' National Technical Services Unit supplies technical support to the U.S. delegation at meetings of the Codex Alimentarius Commission and actively participates as members of the U.S. delegation at meetings of the Codex Committee on Fish and Fishery Products. Codex is a joint commission of the FAO and the U.N. World Health Organization. The Codex Committee's interest concerns the safety, wholesomeness, and trade equities in international trade of fish and fishery products. Codex has adopted a number of Codes for Hygienic Practice dealing with fish and seafood.

At the committee meeting in June 1990, the committee endorsed the FAO Fisheries Department's proposal to hold an expert consultation in late 1990 to review a first draft of a Code of Hygienic Practice for the Products of Aquaculture. The consultation would also provide guidance as to whether an attempt should be made to produce a single code or to divide the subject matter by species or growing technology. The committee noted that a first draft of the code prepared by the FAO Fishery Industries Division would be presented to the committee for consideration at its next session in June 1992. This major undertaking will probably take several meetings to complete.

### 2.5.2 Governing Agreements on Tariffs and Trade

The United States was an active party to the Uruguay Round of GATT; however, the U.S. Trade Representative's attempts, on behalf of NMFS/NOAA, to have fish and fishery products covered under the Agriculture Negotiating Group were unsuccessful. The U.S. position was that fish is food, and it is closely linked to agriculture in the GATT. Furthermore, fish is a rapidly expanding commodity through aquaculture, and in many countries, fish is dealt with in the same government agency as agriculture. The goal was to protect the U.S. fishing industry from adverse trade-offs at the negotiating table when other commodities or goals were the primary concerns. However, the European Economic Community (EEC) wanted fish to be included in the Natural

Resource-Based Products Negotiating Group. Their strategy was to swap access to EEC markets for EEC access to U.S. fishery resources. When the Uruguay Round of GATT ended in November 1990, this issue had not been resolved, and fisheries issues were not addressed.

### 2.5.3 Free Trade Agreements

It has been the Administration's goal to "level the playing field" in foreign trade by negotiating bilateral treaties with the nation's trading partners in order to eliminate government subsidies, tariffs, and trade barriers. Since the U.S. fishing industry enjoys very few subsidies, it is advantageous to eliminate foreign subsidies.

The U.S. recently began an investigation to determine if antidumping regulations have been violated and if countervailing duties should be implemented against the Norwegian salmon aquaculture industry in connection with U.S. industry charges that Norwegian salmon were being sold in the United States at prices below their actual cost due to subsidies and/or to garner market share at the expense of U.S. producers.

Trade barriers take the form of tariffs and nontariff measures. Tariffs are set for several reasons. Some tariffs are created simply to provide revenues to the receiving country's treasury; they may also be set to discourage imports and favor the domestic industry. Examples of nontariff barriers are quotas on imports by species or product type, excessively stringent testing procedures, placing commodities into "quarantine" for excessive periods, or simply banning the import of certain items.

### 2.5.4 Inspection

The Voluntary Inspection Program provides a number of marks on inspected fish and shellfish which denote product quality and wholesomeness. These marks or seals assure consumers that the products have been subjected to tests and are of good quality when packed. This fee-for-service program is funded through user fees borne by the industry. The inspectors are NMFS employees or cross-licensed personnel from other state or federal agencies who have been trained by NMFS.

Some aquaculture operations in the Northeast are or have been recently under Type I product inspection in cooperation with the Voluntary Inspection Program. Blue Ridge Fisheries, an indoor, farm-raised catfish company in Martinsville, Virginia, had been under full-time inspection until a viral infection depleted the stocks and the operation was disbanded. Another facility participating in the inspection program was Ocean Products, Inc., of Eastport, Maine. This is the largest net-pen operation in the Northeast. Recently, the facility was acquired by Conners Bros., a Canadian firm. The company is considering returning to the inspection program.

## 2.6 FISHERY RESTORATION AND ENHANCEMENT PROGRAMS

This section addresses state and federal activities which "fall outside" the customary public perception of aquaculture, but nevertheless represent critical elements in resource management programs which correspond to Meade's definition of the term (Chapter 5). The following discussion summarizes fishery management initiatives involving various aspects of "stocking programs," *i.e.*, release and/or husbandry of marine organisms (and materials) for the purpose of maintaining, enhancing, or restoring the Northeast's commercial and recreational fisheries resources. As such, it is important to note that the public benefits which accrue from these programs would not result without external intervention, *i.e.*, the directed involvement by the respective fishery resource agencies.

### 2.6.1 Fishery Restoration

Restoration has been defined as rebuilding a population of a native species to a level at which the spawning population is of sufficient numbers to ensure optimal utilization of the suitable habitat (U.S. Fish and Wildlife Service 1982). The NEROO provides policy and technical representation to several such initiatives in the New England and Mid-Atlantic states. Notwithstanding the obvious linkage of these state/federal anadromous fish activities to aquaculture, their progress and status relative to the restoration of species to historical spawning and nursery areas have been addressed in great detail under separate documents prepared by the respective programs. For purposes of this overview, the major restoration programs which involve NMFS representation are summarized briefly below with sole reference to the goals and strategies for the respective species and watersheds.

#### 2.6.1.1 Connecticut River Program

The program to restore Atlantic salmon and American shad to the Connecticut River began in 1967. The restoration goal is to provide and maintain a sport fishery in the Connecticut River Basin and restore and maintain a spawning population of Atlantic salmon in selected tributaries. Supporting these goals are four objectives: (1) from natural reproduction, achieve an adult salmon population of 7,470 individuals entering the mouth of the Connecticut River; (2) utilizing cultured smolt and fry releases, establish an adult salmon population of 11,795 individuals entering the mouth of the Connecticut River; (3) provide for a sport harvest of 4,000 salmon; and (4) maintain an effective population of 5,570 Atlantic salmon.

The American shad restoration effort, although not as formally structured as the salmon program, has the following objective: provide an annual run of 1,000,000 adult shad back to the mouth of the Connecticut River by the year 2000 in order to support a sport harvest of 100,000 adults and a commercial harvest of 150,000 adults.

#### 2.6.1.2 Merrimack River Program

The current initiative to restore Atlantic salmon and American shad to the Merrimack River began in 1968 by Massachusetts. The initiative became an interagency (two federal and three state fishery resource agencies) cooperative effort in 1979. The goal of the long-range plan -- to restore the Atlantic salmon resource to a level of optimal utilization of the existing habitat in the Merrimack River for public benefit -- has two supportive objectives. The first is to achieve an annual production of 86,000 wild smolts in the Pemigewasset River system. The second objective is to ensure that 1,000 adults in excess of the spawning population will be available for sport harvest annually within the mainstem of the Merrimack River system.

The planning effort relating to restoring American shad has a single long-term objective -- to provide an annual, self-sustaining run of adult shad of 1,000,000 individuals back to the mouth of the Merrimack River.

#### 2.6.1.3 Delaware River Program

The Delaware Basin Fish and Wildlife Management Cooperative was organized by unanimous consent of the directors of the fish and wildlife resource agencies of Delaware, New Jersey, New York, and Pennsylvania, and the regional offices of NMFS and the USFWS. Its formation particularly reflects recognition of the need for a unified approach to management of the interstate fishery resources of the basin.

The need for this organization is exemplified by the reduced availability of some fishes, the poor suitability of parts of the river for fish, and the recognized potential for damage to the resource through water resource and related development projects. It is the purpose of this organization to review basin matters in order to provide input on behalf of fisheries in the planning process, and to promote a viable fisheries program to protect and, where possible, enhance the resource. Presently, the cooperative devotes most of its efforts on American shad and striped bass restoration.

#### 2.6.1.4 Susquehanna River Program

In 1962, an administrative committee composed of representatives from the states of Maryland, New York, and Pennsylvania, the USFWS's former Bureau of Sport Fisheries & Wildlife, and the BCF was established to study the river and assess the watershed's suitability for spawning of American shad. In 1976, the Susquehanna River Anadromous Fish Restoration Committee was formed to administer programs for the restoration of American shad and other migratory fishes. The ultimate goal is to develop a self-sustaining annual run of two-million shad to the river above dams.

### 2.6.2 Fishery Enhancement

Other programs to improve commercial and recreational fisheries can be grouped under the term "fishery enhancement." The following subsections selectively address examples of such programs, including commercial fish stocking activities, eastern oyster replenishment projects, and a joint NMFS Northwest/Northeast Region initiative to generate enhanced recreational coastal fisheries for coho and Atlantic salmon.

#### 2.6.2.1 Stocking of Commercial Fish Species

Stocking programs have been and are being conducted throughout the country in areas where population growth, watershed development, and increased fishing pressure have decreased the spawning potential and habitat of many fish species. A California program provides a unique example of this type initiative. At the Hubbs Sea-World Research Institute and San Diego State University, researchers have combined resources under the Ocean Resources Enhancement and Hatchery Program to develop the technology for culturing and releasing juvenile marine fish (Sport Fishing Institute 1991). In 1977, experiments began with striped bass as a potential species for enhancement within San Diego Bay. After several successful releases, efforts expanded to a white seabass culture program in 1982, with the collection of juvenile fish donated by local anglers, and the subsequent raising of these fish to spawning size.

In 1983, the California legislature gave life to the program under authority of the California Department of Fish and Game. The bill provides support funds through the sale of $1 (sport) and $10 (commercial) marine enhancement stamps attached to southern California fishing licenses. The California program is being evaluated through marking of hatchery-reared fish (tetracycline) and coded wire tags to track individual release groups. The program is being broadened to include other species such as the California halibut.

In the Northeast, notwithstanding the success of Pacific salmon introductions into the Great Lakes (Tody and Tanner 1966) and ongoing restoration efforts for Atlantic salmon (by all New England states except Rhode Island) and striped bass (by Maryland, Virginia, and Maine), hatchery programs for the express purpose of providing enhanced sport and commercial fisheries have been limited. Notable examples include coho/chinook salmon (in New Hampshire

and Massachusetts) and eastern oyster (in Maryland, Virginia, Delaware, and New Jersey) aquaculture initiatives (described below) to enhance the Northeast's recreational and commercial fisheries, respectively.

### 2.6.2.2 Oyster Replenishment

The status of eastern oyster replenishment/aquaculture activities in Maryland is included in Section 2.2. The following overview of this program in Virginia is paraphrased from Haven *et al.* (1978).

> Active replenishment efforts have been undertaken by Virginia since the 1928 Oyster Repletion Act was passed by the Virginia legislature. Early efforts consisted mainly of spreading or planting cultch in the form of eastern oyster shells on public oyster grounds for the purpose of catching set and, thereby, increasing the supply of eastern oysters. More recently, seed has been transplanted for the same purpose. The effort, the quantity of cultch material planted, and the cost increased significantly from 11,678 bushels ($717) in 1931 to a maximum of 4,148,702 bushels ($494,482) in 1965. Costs have since steadily increased, *e.g.*, to $803,353 for 3,481,727 bushels in 1975.
>
> There are three primary reasons why the Virginia Marine Resources Commission (VMRC) plants shell: (1) to receive a strike of eastern oyster on the shell to provide seed eastern oysters for use by VMRC and the public, *i.e.*, harvest by watermen for sale as seed to growers or for use on their own growing grounds; (2) to receive a strike of sufficient intensity to provide a later catch of market eastern oysters; and (4) political considerations.
>
> The aim of the public repletion efforts in Virginia was stated clearly by VMRC in its report to the governor for Fiscal Year 1968-69: "an intensive rehabilitation program (was begun) in 1963 in an effort to assist the faltering industry." Since its beginning, the repletion program has been a partial state subsidy for the entire eastern oyster industry. It benefits harvesters, commercial watermen, shippers, and private growers.

In a July 1991 letter from the Chesapeake Bay Foundation (CBF) to the Governor of Maryland, the CBF recommended that "efforts to enhance wild stocks of eastern oysters and restore the public fishery should be complemented by a broad-based federal/state partnership to promote aquaculture. The increase in the number of eastern oysters in the water and the off-season marketplace provided by private culture will help both the [b]ay and the public fishery by increasing reproductive potential and filtering capacity and by stabilizing markets."

Federal support has been provided to the states for eastern oyster repletion activities under the Grant-In-Aid Program administered by the NEROO. A summary of this support is presented in Section 2.3.2.

### 2.6.2.3 Salmon for New England

In 1970, NMFS initiated an experiment at the NWAFC to determine the feasibility of developing an Atlantic salmon brood stock on the West Coast to provide a source of eggs for restocking New England rivers. This investigation was conducted on the premise that the moderate saltwater temperatures of Puget Sound were conducive to the rapid growth of marine-reared Atlantic salmon. The potential for expansion of this study was articulated in 1972 when the NWAFC, in conjunction with the NEROO, developed a cooperative state/federal proposal entitled, "Salmon for New England." The proposal was designed as a twofold approach to meeting regional commitments to the increasing number of New England recreational fishermen. The Salmon for New England Program had two major objectives: (1) to develop the technology for large-scale coho salmon releases to generate a coastal marine sport fishery if the states decide this is desirable; and (2) to raise Atlantic salmon brood stock in the Pacific Northwest as an interim means of augmenting East Coast egg production until egg requirements can be satisfied from East Coast sources.

During 1967-73, fishery resource agencies of four coastal New England states experimented with stocking of coho salmon in an attempt to provide improved marine recreational fishing. This species had previously been introduced successfully in Lake Michigan. Massachusetts and New Hampshire were successful in introducing this species, and the sportfishermen's favorable response to this limited effort demonstrated the potential for the development of a coho sport fishery in the coastal waters north of Cape Cod.

In recognizing the potential for introducing certain species of Pacific salmon to the Northeast (Mahnken and Joyner 1973), NMFS held meetings with all New England state fisheries directors in October 1971 to determine their degree of interest in a program involving West Coast species of salmon. They indicated enough interest at that time to justify further action, and in 1972, a group of scientists from the NWAFC spent several weeks in New England studying this possibility. A proposal was subsequently developed which provided several alternatives for the enhancement of recreational fishing in New England. The envisioned initial efforts would have been directed toward a pilot program to: (1) hatch coho salmon in existing state facilities, subsequently rear these fish in saltwater pens in Plum Island Sound, Massachusetts; and (2) develop concurrently a reliable Atlantic salmon egg source at the NMFS Manchester (Washington) facility for augmenting hatchery production contributing to New England Atlantic salmon restoration programs being conducted jointly by the states, USFWS, and NMFS. Should the techniques have proved successful,

it was anticipated that the Salmon for New England Program would be accepted and expanded by the state fishery resource agencies.

In October 1975, the NEROO prepared a draft environmental impact statement concerning the Salmon for New England Program under the provisions of the National Environmental Policy Act. Review of the document, however, received strong opposition from private Atlantic salmon conservation groups. Their contention was that a successful program would, over time, divert public attention and fiscal resources away from the ongoing Atlantic salmon restoration initiatives in New England. Additional concerns were expressed over disease aspects associated with the introduction of nonindigenous species, and potential competition with Atlantic salmon over food and habitat requirements. Although each concern was addressed and alleviated by the NEROO in the context of safeguards and available scientific literature, the coho salmon component of the program received no further serious attention beyond late 1976 due to the associated controversies.

The Atlantic salmon component of the Salmon for New England Proposal was "revisited" in September 1979 when the USFWS Northeast Region requested cooperation from the NEROO in seeking technological assistance from the NWAFC to stabilize the egg supply for state/federal Atlantic salmon programs in New England. This assistance was requested due to the poor return of sea-run Atlantic salmon, a situation which severely restricted the number of eggs available for restoration efforts in the Merrimack and Connecticut Rivers. The immediate goal was to provide 400,000 eggs (fertilized by sperm from Penobscot sea-run stock) from Atlantic salmon captive brood stock maintained in marine net pens at the NWAFC's Aquaculture Experiment Station.

Shortly after receipt of the 1979 request from the USFWS, officials of NMFS and USFWS met to discuss the proposed initiative. As a result of this meeting, the USFWS prepared a position paper, "An Accelerated Atlantic Salmon Brood Stock Development Program," for review by the private sector. This paper stated that the USFWS and state fishery resource agencies viewed the NMFS initiative and its potential implementation as a major positive step in restoring Atlantic salmon to Southern New England rivers. The initiative, thereafter referred to as the Atlantic Salmon Brood Stock Program, was approved and subsequently funded between 1979 and 1982 by the NMFS Washington Office and the NEROO ($75,000 each, annually). The NWAFC also provided $33,000 each year of in-kind funds to the initiative and invested nearly $150,000 for construction of facilities needed to support requirements of the brood stock program. In addition to providing funds, the NEROO served as a liaison among the NWAFC, participating Northeast fishery resource agencies, NMFS Washington Office, and the private sector.

The program had two major long-term objectives: (1) to produce five-million Atlantic salmon eggs annually for 10 years to restore runs in the Merrimack, Connecticut, and Pawcatuck River systems -- an objective similar to one of the two goals in the NWAFC's 1972 Salmon for New England proposal; and (2) to improve marine husbandry techniques for rearing Atlantic salmon brood stock by researching the development of nutritionally adequate brood diets for uniform maturation, maximum fecundity, and gamete viability, the improvement of techniques for detection, prevention, and control of disease, the development of techniques for synchronous ovulation; and the development of spawning strategies.

The associated benefits were: (1) to provide a reliable and continuous supply of high-quality eyed eggs to maintain a stable smolt production program at New England hatcheries based on genetic stocks desirable for restoration; (2) to accelerate Atlantic salmon restoration in Southern New England by making possible an extensive fry stocking program; and (3) to provide a model production-scale system for research on captive marine brood stocks.

The program represented NMFS's contribution to a joint state/federal partnership in a proposed long-term effort to restore Atlantic salmon to New England waters. The restoration program had a first-step objective of providing a sustained recreational harvest of 7,000 fish per year from the Connecticut and Merrimack River systems. Based upon the catch per unit effort and angler expenditure data developed for this fishery in Maine waters, achievement of this objective could have resulted in annual expenditures by recreational fishermen of $2.7 million annually (1983 dollars).

Over 9,600 juvenile and 25,000 Atlantic salmon fry were reared at the NWAFC's Manchester Station for East Coast brood stock purposes as of March 1983. During this period, 176,000 eggs were shipped to New England hatcheries for subsequent stocking. A goal of 3.5-million eggs was anticipated for shipment by 1984.

In July 1984, the Northeast Regions of NMFS and USFWS signed an "Atlantic Salmon Brood Stock Program Disease and Certification Protocol," which governed program procedures to be followed beginning in 1984. At that time, the USFWS Washington Office, however, made it clear that the program was construed as a "variance" to that agency's Fish Health Protection Policy and Salmonid Fish Health Protection Program. Accordingly, there was a strong suggestion that the NMFS Manchester program be considered only as a short-term need, and that the activities be phased out as soon as possible. Also in mid-1984, the USFWS established a state/federal Atlantic Salmon Disease Advisory Committee to prepare a policy for setting forth the essential requirements for restricting the spread of Atlantic salmon diseases and to contain them within their known geographic ranges. The draft policy included a stipulation that "no salmonid gametes, fertilized eggs, or fish from IHN (infectious hematopoietic necrosis virus)-positive geographical areas (defined by the document as the entire western coastal United States) shall be transferred to New England coastal facilities. The NEROO presented a minority opinion that, in lieu of a total prohibition of egg shipments, the Atlantic Salmon Broodstock Program be continued, follow-

ing strict inspection/certification procedures under the terms of risk assessment protocols. However, in November 1984, the Connecticut River Atlantic Salmon Commission voted (5 in favor, 2 in opposition, and 1 abstention) to recommend that the USFWS, on the basis of the Draft Disease Control Policy, not import Atlantic salmon eggs from brood stock being reared by NMFS in Puget Sound.

Accordingly, the anticipated shipment of eggs from Manchester during the spring of 1985 did not occur, thereby terminating the Atlantic Salmon Broodstock Program. In September 1989 (nearly five years later), the New England Atlantic Salmon Committee, a policy-level group representing that region's Atlantic salmon restoration initiatives, voted unanimously to adopt the New England Salmonid Health Guidelines initially drafted in 1984.

## 3. STATE AGENCY INVOLVEMENT

State government involvement in aquaculture issues varies considerably within the Northeast. The extent of this involvement, which has greatly increased over the past decade, largely depends on legislative and organizational authorities, resultant public policies, the availability of educational support to foster communication among the government/academic/private sectors, and the status as well as evolution of aquaculture operations in the respective jurisdictions.

Leasing of subtidal lands from state governments for shellfish and finfish culture occurs in several states, *e.g.*, Connecticut--40,000 acres; Maine--1,050 acres; Maryland--9,500 acres; and Virginia--110,000 acres. Most of these leases are almost exclusively associated with shellfish production. Approximately 48 percent of leases in Maine, however, are devoted to either finfish or combined finfish/shellfish operations. Since 1987, the demand for shellfish leases has diminished, and that for finfish has increased (511 finfish sites as of May 1991), presumably due to industry economics.

Notwithstanding federal involvement as discussed in Chapter 2, it is actually state (*versus* federal) government which exercises the most control over aquaculture due to state jurisdictional authorities (Hildreth 1991). In this chapter, Maine and Maryland are highlighted to demonstrate examples of active aquaculture programs in the Northeast. Interstate activities through the auspices of the ASMFC are also noted to provide an indication of the increasing reliance on coordination, not only between states, but between the state and federal sectors as well, in addressing aquaculture issues of interjurisdictional interest.

### 3.1 MAINE

The major species cultured in Maine are Atlantic salmon, rainbow trout, blue mussels, and eastern oysters. Potential also exists for increased production of trout, clams, scallops, and American lobsters. The aquaculture industry has shown rapid growth in the past decade. Cultivated seafood products in 1979 were valued at approximately $450,000. In 1990, the salmonid net-pen industry became the second most valuable "fishery" in the state valued alone at $25 million (landed product only) *versus* $62 million for the commercial American lobster fishery. For comparative purposes, the commercial groundfish and Atlantic herring fisheries were valued at approximately $21 million and $3 million, respectively. The major species raised in Maine's net-pen industry are Atlantic salmon and sea-run rainbow trout. In 1989, there were 15 firms, 17 sites, 355 pens, and 9 hatcheries. In 1991, the associated production figures were about 10-million pounds for salmon and 280,000 pounds for trout. Approximately 80 percent of salmon aquaculture production is located in Cobscook Bay, Maine, on the southwesterly shores of Passamaquoddy Bay. Currently, these farms vary in size from a single, four-pen operation with a total annual production of 80,000 pounds to farms with over 130 pens.

Most of the existing and proposed salmon aquaculture projects in Maine involve a 4-8 pen operation. Generally, net pens are approximately 12 meters square, 6 meters deep, and consist of two nets, one to hold the fish and the second for protection from predators. Each pen holds approximately 3,000 fish.

In Maine, state aquaculture responsibilities are shared by the Department of Inland Fisheries and Wildlife (salmon eggs and smolts in freshwater jurisdictions), the Department of Marine Resources (primary regulatory authority relative to permit requirements), and the Department of Environmental Protection (water quality certification). Unlike other states, Maine's agricultural agency (the Department of Agriculture, Food and Rural Resources) has no direct involvement in aquaculture regulatory matters.

In 1987, the aquaculture statutes pertaining to the Maine Department of Marine Resources were changed to reflect an increased level of review prior to the approval of an aquacultural lease. This change was due primarily to alleviate conflicts between traditional fishermen and shellfish aquaculturists. In 1988, the Maine State Planning Office and the Maine Department of Marine Resources, with funding support from the EDA, convened an Aquaculture Development Committee that included state agency, university, and industry representation. A report (Maine State Planning Office 1990) resulted which assessed the economic potential of aquaculture in Maine and devised a public policy strategy designed to support the aquaculture industry in meeting research, marketing, environmental, and technological challenges. Identified impediments to the industry included: (1) inaccessibility of information essential to aquaculture development; (2) lack of a lead state agency to coordinate effective action; (3) insufficient state services to aid the industry, such as programs for training, inspection, and grading; (4) lack of coordinating aquaculture research and development among federal, state, and

university research organizations; (5) lack of public understanding that the aquaculture industry, as well as traditional fisheries, depend on good environmental quality in Maine's coastal waters; and (6) lack of an adequate, organized market institution for sale of cultured seafoods.

Subsequent strategies to address these impediments included the encouragement of a positive investment climate for small entrepreneurs, designating a lead state agency to support development of aquaculture, ensuring consistency in the regulatory process, the protection and enhancement of coastal water quality, and development of a comprehensive plan for use of coastal waters. Recently, the state has negotiated a consistent application, assessment, and monitoring protocol with the USACOE and EPA with regard to aquaculture. The application eliminates unnecessary and duplicative requirements on the applicant and on the involved agencies.

In 1989, the Maine Aquaculture Innovation Center (MAIC) was formed through a partnership between the Maine Agricultural Experiment Station's Fisheries and Aquaculture Research Group, the Maine Aquaculture Association, the Maine Department of Marine Resources, and the Maine Science & Technology Commission. The MAIC was established for the purpose of creating industry/academic partnerships to help overcome obstacles to success in aquaculture. The NEROO awarded a $250,000 grant to the MAIC to study the environmental effects of ocean cage rearing of salmon in the state. The MAIC also receives an approximate $250,000 appropriation from the Maine Science & Technology Commission to fund other components of its 1991 research program, such as commercialization of triploid eastern oysters and advanced spawning of Atlantic salmon and Donaldson rainbow trout. The MAIC's board of directors voted in June 1991 to leave its current office quarters at the University of Maine and operate as part of the Maine Aquaculture Association.

A collaborative research effort has been initiated between North Atlantic Aquaculture, Inc., of Eastport, the Washington County Technical College, and the St. Andrews (New Brunswick) Biological Station. Technologies are being developed for the rearing of larval Atlantic halibut and the collection of zooplankton for the halibut's first-feeding stage. A prototype submersible grow-out cage is being constructed for bottom-dwelling flatfish which will be tested at the Eastport lease site. Researchers believe that the halibut has the potential to be a viable aquaculture species due to the low abundance of wild stocks and high market demand.

The MAIC and the college are currently planning to establish a Northeast Finfish Aquaculture Center in Eastport on Cobscook Bay, the watershed from which originates most of Maine's cultivated salmonid production. The proposed components of the center are a diagnostic laboratory for finfish health services, educational facilities for finfish aquaculture training, and a visitor's center.

In July 1991, "An Act Regarding Aquaculture" (Chapter 381 of the Public Laws of 1991) was passed by the Maine legislature which includes provisions for a mandatory leasing program for net-pen and suspended shellfish aquaculture operations, with those under threshold sizes excused from certain elements of the application process (*e.g.*, adjudicatory hearings). The act also calls for a "tax" from suspended-culture operations, the proceeds from which will enhance the capabilities of the Department of Marine Resources in the continued monitoring of approved aquaculture leases. Finally, due to disease transmission concerns, the new legislation provides for a prohibition by 1995 on the import of salmonid (excepting rainbow trout) eggs and smolts into the state from Icelandic or European territorial waters, or from areas west of the North American continental divide.

## 3.2 MARYLAND

The Maryland Department of Agriculture (unlike the state agriculture agency in Maine) is the lead organization for promoting and coordinating aquaculture-related concerns. The MDA employs an aquaculture coordinator, and integrates agency responsibilities with industry participation through the State Aquaculturist Association.

The MDNR is responsible for the enforcement of laws and regulations pertaining to all aquaculture in the state, ensuring that industry operations do not spread disease or parasites, or otherwise adversely affect wild stocks of fish or shellfish. Within the MDNR, the Tidewater Administration's Fisheries Division includes the Hatchery and Aquacultural Programs Unit. This organizational unit, established in 1989, is composed of a staff of three professionals charged with the responsibility for all finfish hatcheries, for restoration programs for (production of) striped bass, yellow perch, and American shad, and for permitting/consultation for commercial aquaculture projects. Additional missions encompass industry issues associated with importation of exotic species, the state's eastern oyster bottom-lease program, eastern oyster cultch plantings, and experimental research located at the MDNR/NMFS Cooperative Laboratory in Oxford. Within the MDNR, the 1992 budget for aquaculture-related programs is approximately $1.7 million.

In Maryland, there are approximately 90 permitted sites for hybrid striped bass culture, and three for channel catfish production. Finfish aquaculture production figures estimated for 1990 were:

| Species | Production (lb) | Average Price ($/lb) | Total Value ($) |
|---|---|---|---|
| Hybrid striped bass | 250,000 | 3.50 | 875,000 |
| Channel catfish | 107,600 | 1.50 | 161,000 |
| Rainbow trout | 48,500 | 5.27 | 256,000 |
| Tilapia | 21,700 | 3.86 | 84,000 |

Grow-outs are the major type of aquaculture operation, but there are a significant number of fingerling and shellfish seed production operations/hatcheries as well. Most operations are small-scale, private ownerships, but some larger operations are owned by partnerships or corporations. More product is sold to the wholesale market than any other outlet, but an important volume is also marketed to retailers, other producers, and/or directly to consumers. Approximately 550 people are employed in the state's production of aquaculture products. Projections indicate that aquaculture in Maryland could become a $100-$200 million industry within a relatively short time if institutional constraints are removed and adequate research and extension efforts were supported. Crayfish aquaculture is one example of the rapidly expanding Maryland aquaculture industry. In 1984, only a few operations for this species existed, whereas today over 40 are in operation on the lower Eastern Shore, an area that has experienced severe economic distress.

The MDNR's Oyster Propagation Program is a prominent component of aquaculture in Maryland. The total projected revenues in Fiscal Year 1990 resulting from this program, under which eastern oyster seed and cultch are planted on public eastern oyster grounds to maintain the state's commercial eastern oyster industry, were $2.7 million, with an annual dockside value of about $7.0 million. The Private Oyster Propagation Program, similarly, is another important component of the MDNR's activities, involving 9,500 acres and 935 leases.

Planned aquaculture research initiatives by the MDNR include a feasibility study of a large net-pen culture facility in tidal waters (tentative location near the Annapolis Bay Bridge). Also proposed is an evaluation of various culture techniques and the success of finfish and shellfish restoration programs which utilize hatchery-produced fingerlings and seed.

The Maryland Aquaculture Bill of 1988 designated the University of Maryland System as the lead agency for aquacultural research and development of educational and extension programs which promote aquaculture as an industry. Research at the Horn Point Environmental Laboratory and other university locations has included studies on hatchery and rearing techniques, genetics and breeding, diseases and their treatment, nutrition, law, economics, marketing, water quality, and product development (University of Maryland System 1991). The university system also provides educational resources for training aquaculturists, scientists, and technical personnel for support of a viable aquaculture industry. Finally, extension activities are tailored to industry needs. Such services include disease diagnostics, water quality testing methods, pond design consultation, technology for remote setting of eastern oysters, and advice on construction and design of net pens or cages for finfish culture. In 1990, Baltimore Gas and Electric agreed to license the Maryland Department of Agriculture to operate its Crane Aquacultural Facility for the next 10 years. Under the terms of this private/public cooperative agreement, the Department of Agriculture contracts with the University of Maryland's Agricultural Experiment Station to operate the facility for aquacultural research, education, and demonstration.

## 3.3 ATLANTIC STATES MARINE FISHERIES COMMISSION

The ASMFC was established in 1942 to represent the interests and needs of the marine fisheries of its member states from Maine to Florida. The purpose of the commission, as set forth by Congress in Article I of the ASMFC compact is "to promote the better utilization of the fisheries, marine, shell, and anadromous, of the Atlantic seaboard by the development of a joint program for the promotion and protection of such fisheries."

A State-Federal Fisheries Management Program, set up in the mid-1970s, was formally modified in the early 1980s and renamed the Interstate Fisheries Management Program (ISFMP). Since then, the ISFMP has been supported through grants and cooperative agreements funded and administered by the NEROO. The goal of this state/federal program is to manage, enhance, restore, and maintain the shared fisheries of the Atlantic coast, with principal emphasis on the conservation and restoration of migratory marine and anadromous fishery resources and their habitat.

Two recent actions under the ISFMP have direct aquaculture implications. The first involves the adoption, in 1990, of the Interstate Fishery Management Plan (FMP) for the Atlantic Sturgeon. As an outgrowth of this FMP, an Aquaculture and Stocking Committee has been organized, composed of state and federal (*i.e.*, NMFS and USFWS) representatives. In 1991, the committee made six recommendations: (1) encouragement of research and development of Atlantic sturgeon aquaculture, taking into account proper genetic and ecological effects; (2) collection of broodstock and release of progeny for restoration programs should be carried out in ways that best maintain genetic integrity of wild stocks; (3) proper care should be taken in translocation of Atlantic sturgeon to protect against inadvertent spread of diseases; (4) introduction of non-native sturgeon species for commercial aquaculture should be permitted only after consideration of spread of diseases, genetics, and ecological effects are addressed; (5) field programs on Atlantic sturgeon should collect material for genetic studies; and (6) effectiveness of restoration programs should be monitored (including collection of any possible baseline population data for receiving waters), stocked fish should be tagged, and research on proper tagging methods should be done.

Secondly, the Shellfish Transport Plan (Atlantic States Marine Fisheries Commission 1989) advocates the training of shellfish biologists from ASMFC member states in the detection and diagnosis of molluscan and crustacean diseases and the establishment of a forum to assess ecological effects stemming from the introduction and/or transfer of shellfish within ASMFC jurisdictions. The plan also calls

for disease certification and quarantine procedures as established by the ICES Code of Practice to Reduce the Risks of Adverse Effects Arising from Introduction of Non-Indigenous Marine Species. In 1990, the plan was amended by the ASMFC to reflect concerns over introductions of the Pacific oyster which is currently being considered as a potential aquaculture initiative on the East Coast.

## 4. AQUACULTURE IN CANADA

Canada offers a unique perspective in the development of the aquaculture industry with government involvement. Within the Gulf of Maine region, the province of New Brunswick has produced 10-times more Atlantic salmon than the state of Maine, despite sharing similar growing conditions and similar start-up dates for industry operations. The industry in New Brunswick benefits from: educational and training programs; coordination of research at the federal and provincial levels; and planning/administrative capacities that include coordinating permitting systems and lending predictive abilities to public policy and industry development (Maine State Planning Office 1990). In 1984, the annual value of aquaculture totaled $7 million; by 1988, the value increased to $109 million (Department of Fisheries and Oceans 1990). In that same year, there were approximately 150 farms and two federally-operated hatcheries capable of producing 1.5-million Atlantic salmon smolts annually. The industry has provided a growing source of employment, particularly in Canada's more remote regions. In 1988, 1,500 jobs were attributed directly to aquaculture operations.

The following overview of shellfish aquaculture in Canada is taken from MacKenzie (1991):

> Following a large decline from 1954 to 1972, production of oysters *(C. virginica)* on Prince Edward Island has since turned upward. Production in 1989, about 60,000 bushels worth $3.8 million Canadian...(ex-island), was four times the total in 1954 and was two-thirds of the total in the best year, 1890. The province produced the increase by transplanting unfished oysters to good market beds and by spreading fossil shells it dredged from deposits on depleted oyster beds to collect spat. In 1989 and 1990, the Province used a new procedure, i.e., cultivating dormant shell beds to remove a deposit of silt. It was successful as the beds (60 acres) received good sets of spat. Such cultivating is perhaps one of the least expensive methods available for producing eastern oysters. New Brunswick has been using cone-shaped spat collectors, about 2/3 meter in diameter and termed Chinese hats, to cultivate eastern oysters successfully. In contrast to Prince Edward Island which has a mixed public and private eastern oyster fishery, New Brunswick's is mainly private. Leaseholders remove the seed collected on the hats, spread them on their leases for growth, and then market them after they reach a length of three inches.
>
> Since the early 1980s, the Maritime Provinces, led by Prince Edward Island and Nova Scotia, have been culturing mussels *(Mytilus edulis)*. Mussel production has been rising rapidly. In 1989 production from Prince Edward Island was about 90,000 bushels worth $4.3 million Canadian....
>
> The Maritime Provinces have achieved their successes in producing shellfish by: (1) using wild seed (it is abundant and inexpensive to collect; little seed has been raised in hatcheries); (2) providing their industries with substantial government financial and technical support; (3) inviting shellfishermen to contribute to development plans; (4) sending biologists and lead fishermen to the U.S. and Europe to observe the best culture methods; and (5) having government personnel aggressively market their shellfish in Canada and the U.S. Thus, sales of oysters and mussels have been good.

The DFO is the lead federal agency for aquaculture in Canada. The DFO has generally defined aquaculture as a fishery, but several provincial governments have given the lead aquaculture role to agricultural agencies. The prevailing Canadian view recognizes the risks in supporting aquaculture development while maintaining conservation of wild fisheries, but also recognizes that risk management implies regulation, not prohibition. Five goals of the DFO in aquaculture are: (1) industry support through scientific and technological leadership and innovation; (2) sound cooperative management for a healthy and productive aquatic environment; (3) an inspection system to support the industry's reputation for high-quality cultured products; (4) provision of market and commercial analysis and advice to assist Canadian aquaculturists to capitalize on market opportunities; and (5) advocacy and dialogue to promote sustained growth and development of the aquaculture industry.

In Canada, recent research has included a plan to maintain genetic integrity between wild and raised salmon, setting standards for both physical and chemical parameters of aquaculture operations and for disease control. Recently, the DFO has announced that three aquaculture research projects at the St. Andrews (New Brunswick) Biological Station have received funding under DFO's Atlantic Fisheries Adjustment Program. The studies involve: phytoplankton monitoring; Atlantic halibut egg and larval rearing; and striped bass salinity tolerance. In 1991, funding was approved to assist in the transfer of aquaculture technology, in development, and in improvement of husbandry in such areas as handling and nutrition.

# 5. AQUACULTURE INDUSTRY IN THE NORTHEAST

## 5.1 INDUSTRY OVERVIEW

Throughout the Northeast, the establishment of agency forums and advocate organizations in both the state and private sectors has clearly facilitated the evolution of aquaculture as a growing and integral component of food production. The NRAC, located at the University of Massachusetts - North Dartmouth, was established as an industry-driven program aimed at solving problems and promoting profitable aquaculture throughout the United States (Section 2.3.4). The NRAC sponsors industry workshops such as larval mortality assessment in commercial shellfish aquaculture, the domestication of striped bass, and alternative marketing options for aquaculture products. The NRAC also administers, under USDA sponsorship, a financial assistance program for aquaculture research. In 1991, the NRAC approved a $50,000 Special Projects Fund to allow expeditious consideration and support of small, emergency, or innovative projects which have regional application and are important to the northeastern aquaculture industry. An initiative to prepare a comprehensive summary of the northeastern aquaculture industry is currently being coordinated with the University of Rhode Island. The objectives of this project are to: (1) compile estimates of private aquaculture production and value; (2) identify future opportunities and constraints facing the industry; and (3) identify principal research directions based on industry need. An overall assessment of the aquaculture industry in New England has been previously conducted by the University of Rhode Island's Sea Grant Program (Gates *et al.* 1974). Among its findings, that report concluded that species appearing to have the greatest potential for commercial culture were the eastern oyster, northern quahog, bay scallop, American lobster, and coho salmon.

The USDA has a second regional aquaculture center in the NMFS Northeast Region, the North Central Regional Aquaculture Center (NCRAC) located at Michigan State University, whose goals are the same as previously mentioned for NRAC. The NCRAC's 1990 research priorities included genetic research, development of feeds and stress management for walleye culture, hybrid striped bass research, yellow perch nutrition, and legal constraints to aquaculture.

In Massachusetts, a lobster hatchery on Martha's Vineyard operated by the Commonwealth's Division of Marine Fisheries has produced approximately 500,000 juvenile lobsters for stocking each summer along the entire coast of the state. On the premise of a 10-percent survival rate to adult size, the program would amount to an immediate value of $130,500 (1986) to the commercial lobster industry (Syslo 1986). This state program has demonstrated that lobsters can be cultured. It is, however, a matter of whether commercial aquaculturists can make a profit. There are two major obstacles to overcome: cannibalism, which necessitates individual compartments for each lobster; and an affordable pelleted lobster diet.

Aquaculture cooperatives have been established in upstate New York. Several culturists have collectively formed Empire State Aquaculture to share information and insight, to reduce feed costs, and to promote marketing. The cooperative will largely target cage culture of bullhead catfish. Aquaculture has also sustained the eastern oyster industry in New York, increasing landings from about 340,000 pounds to about 865,000 pounds between 1985 and 1989. However, the largest New York producer recently reported unexplained massive population mortalities in one of its growing areas. The cause of this setback, as well as the reasons for widespread seasonal losses of cultured juvenile eastern oysters along the Atlantic coast, are currently being investigated by state, federal, and university scientists.

A new program has also begun in Connecticut to revitalize the shellfishing industry. The state legislature has provided significant funding for reef restoration and regulatory program expansion. Under the provisions of this program, the industry is allowed to relay juvenile eastern oysters from public grounds classified as restricted to private leases in approved waters. In addition, there are successful aquaculture operations in production. Eastern oyster landings have, accordingly, increased from less than one-million pounds to two-million pounds between 1985 and 1989.

Aquaculture not only offers some "farmers" (and commercial fishermen) an alternative source of income, but increases the contribution of edible fisheries products to the reduction of the national trade imbalance which now stands at $4.1 billion (American Fisheries Society 1991). Aquaculture, integrated inland with other on-farm production, as well as coastally with other commercial fishing occupations, allows harvesters to diversify and increase total profits. Recent assessments in Maine have indicated that commercial watermen are clearly able and willing to learn the "ropes" and technical details necessary for productive aquaculture operations. The key to this success is oftentimes predicated upon the situation that such ventures tend to be family-oriented, involve low overhead, and utilize existing capabilities and skills in equipment construction, gear configurations, *etc.* Primary impediments, however, include "start-up" or seed money for the necessary initial business investments, attainment of required permits, and what is often perceived to be a burdensome public bureaucracy. For example, a recent survey (Theberge and Neikirk 1987) of Virginia aquaculturists ranked antiquated state laws and regulations as the most serious impediment to the industry. In 1984, the state's general assembly delegated authority to the VMRC to develop fisheries regulations and to prepare management plans. Although this act improved the VMRC's ability to manage traditional fisheries, the commission, in the absence of legislation, is not effectively empowered to

manage aquaculture in Virginia. Most of the respondents to the survey specifically mentioned the prohibition against the use of the escalator dredge as an inappropriate law which is the single most important impediment to aquaculture development in the commonwealth (Neikirk and Theberge 1987).

Understandably, the aquaculture industry is concerned that any involvement by regulatory agencies will delay the "permit process" (see Section 5.2.2) and create costly restrictions on the applicants. Specifically, consultants are often required to provide pre-project baseline data and conduct physical and chemical monitoring studies; further, commercial culturists fear that the government will restrict their use of antibiotics and dictate the size and location of farms. On the other hand, the industry is also understandably excited about the merits in the potential economic profitability of providing new products for a growing demand, increasing employment opportunities, and establishing a brood stock which perhaps could be available to fishery resource agencies for restoring historical runs of wild stocks (See Section 2.6.1).

The following subsections address some of these and other industry-related concerns in further detail.

## 5.2 INDUSTRY ISSUES

### 5.2.1 Economics

Obvious potential ingredients for successful aquaculture ventures are: (1) profits must exceed the "up-front" operational costs and compete with the current value of products from the traditional "capture" fisheries (see Section 5.2.7); and (2) in specific regions, that industry income can be shown to bolster the financial stature of depressed economic areas. With regard to the former ingredient, many aquaculture operations have been shown to be high risk endeavors since market value occasionally may be only 2-3 times the operational culture cost per unit of product. Also, these costs above a threshold amount could create a strong bias against small or individual ownerships, including commercial fishermen who seek to diversify their operations.

With respect to the latter ingredient, crayfish culture on Maryland's lower Eastern Shore, and Atlantic salmon net-pen operations in Maine at Swans Island and Eastport, have demonstrated the positive contributions of aquaculture to the respective state economies. In New Brunswick, Canada, further economic benefits have been identified which extend to other occupational sectors such as cage manufacture, fish processing, boat makers, cement plants, packaging firms, and transportation. It is of interest to note that, in Ireland, a multiplier of "3" has been utilized to generally categorize the "downstream economics" of aquaculture operations.

Two states in the Northeast have estimated it would cost approximately $9-10 million to build a salmon/trout hatchery capable of raising 500,000 smolts per year (National Marine Fisheries Service 1988). For pen-reared salmon, the estimate is $0.25-1.00 million for the construction, placement, and associated costs of 12 pens and a five-acre site. Additional add-on costs may include those for feed, capital, skilled labor, trained managers, water (inland operations), and chemicals. The cost of leasing marine tidal or subtidal acreage from coastal states varies from $5 to $25 per acre annually. Leases are usually for 10 years, but can be renewed for subsequent 10-year periods.

The availability of information for new entrepreneurs on technology, production costs, and market conditions improves the assessment of risks and the securing of financial support considerably. For example, economic models for aquaculture operations have received recent attention. The joint USDA-University of Maryland's Walnut Pond Demonstration Project disseminates information on marketing, growth rates, and production of striped bass hybrids. The profitability of aquaculture, accordingly, will depend on successful application of technology to assure optimum levels of environmental control, mechanization, and system development that are specific to different aquatic environments.

### 5.2.2 Habitat

As indicated in Section 2.4, the viability of aquaculture operations depends on the availability and maintenance of acceptable water quality conditions. With regard to commercial harvest and culture operations for mollusks and crustaceans, recent trends in state agency classification of approved harvest areas, as reported by the National Ocean Service (1991), present a case of special concern. For example, in the Mid-Atlantic region, 5.3-million acres of estuarine waters were classified for suitability of shellfish harvest in 1990. Only 79 percent of these areas were approved, and the remaining 21 percent were denoted as "harvest limited." In the North Atlantic region, 1.1-million acres were also classified; this region experienced the largest decrease in percentage of approved estuarine shellfishing waters nationwide from 88 percent in 1985 to 69 percent in 1990. Loss of habitat due to development and pollution severely limits the subsequent acreage available for aquaculture purposes.

The Northeast aquaculture industry has been affected adversely by public health concerns due to toxic phytoplankton blooms. To address this issue, an international conference on toxic marine phytoplankton was held during October 28 - November 1, 1991, in Newport, Rhode Island. Sponsored by the NRAC and other agencies, the symposium examined toxic blooms with respect to spatial and temporal patterns, ecology, effects on public health and aquaculture, and possible environmental triggers.

### 5.2.3 Disease Control

In September 1989, New England Salmonid Health

Guidelines were developed by the New England Salmonid Health Committee (a subcommittee of, and appointed by, the New England Atlantic Salmon Committee) to address salmonid fish health in New England. The guidelines affirmed that disease control is the responsibility of the natural resource agencies managing the fishery resources. The guidelines set forth the essential requirements for the prevention and control of serious fish diseases. These include the technical procedures to be used for inspecting fish culture facilities.

The guidelines, due to their coverage of salmonid culture issues, have widespread application to aquaculture issues in New England. Covered topics include basic obligations of fishery resource agencies, transportation of fish, release of fish, and fish health inspection. Of special note, Section D(5) stipulates that no live salmonid fish, gametes, fertilized eggs, or fish products may be imported from areas endemic for IHN virus. This guideline effectively set the stage for termination of a NMFS/USFWS memorandum of understanding involving a Connecticut River Atlantic salmon restoration initiative (Section 2.6.2.3).

The effects of disease on aquaculture operations, as well as the overall interactions between cultured and wild stocks, have been largely focused on Atlantic salmon (*e.g.*, Hansen *et al.* 1991). In 1989 and 1990, the Council of the North Atlantic Salmon Conservation Organization (NASCO), which consists of representatives of all North Atlantic countries with Atlantic salmon interests, held special sessions in order to consider the potential effects of salmon aquaculture on wild stocks. At NASCO's eighth annual meeting in Edinburgh, Scotland, in 1991, the council adopted guidelines to minimize the potential threats to wild stocks from disease and parasite interactions. The guidelines also addressed measures to minimize the possible adverse effects from introductions and transfers, as well as the effects of aquaculture on the environment (North Atlantic Salmon Conservation Organization 1991).

One major concern facing the aquaculture industry, the states, and the federal government are the chemicals employed in fish culture for disease treatment, and the regulatory status pertaining to their use. Accordingly, the FDA has established a Work Group on Quality Assurance in Aquaculture to address the proper use of drugs (chemicals), avoidance of illegal residues in food fish, and the drug approval process. One priority of the work group is the acquisition of aquaculture production statistics and drug treatment data from each state. The effort has been coordinated by the Fisheries Administrators Section of the American Fisheries Society. In addition to production figures, data being collected include disease incidence and estimates of resultant annual mortalities by species and life stage, and drugs that might effectively treat the associated epizootics.

Additional aspects of disease-related issues are discussed relative to ASMFC activities (Section 3.3), eastern oyster disease research (Section 2.3.2.5), and in the next section -- exotic species introductions.

## 5.2.4 Exotic Species

For the purposes of this discussion, the term "exotic species" is synonymous with species which are nonindigenous to the aquatic environment(s) of the Northeast. The definition also includes hybrids of species (*e.g.*, splake, a cross between lake trout and brook trout) previously believed as distinct from one another and animals with manipulated (altered) chromosome complements. The introduction of exotic species and frequent local transfer of such stocks create a potential for introduction of diseases, parasites, competitors, and injurious genetic strains. The topic of exotic species introductions is controversial both inside and outside the aquaculture industry. If safe procedures for such transplants can be developed, improvements in cultured products may result (Atlantic States Marine Fisheries Commission 1989). The establishment of procedures has been strongly encouraged for pre-evaluation of all exotic transfers and for quarantine systems/procedures to prevent introduction of disease.

Executive Order 11987 on Exotic Organisms, signed by President Carter in 1977, stipulates that:

> (a) Executive agencies shall, to the extent permitted by law, restrict the introduction of exotic species into the natural ecosystems on lands and waters which they own, lease, or hold for purposes of administration; and, shall encourage the states, local governments, and private citizens to prevent the introduction of exotic species into natural ecosystems of the United States; (b) Executive agencies, to the extent they have been authorized by statute to restrict the importation of exotic species, shall restrict the introduction of exotic species into any natural ecosystem of the United States; (c) Executive agencies shall, to the extent permitted by law, restrict the use of federal funds, programs, or authorities used to export native species for the purpose of introducing such species into ecosystems outside the U.S. where they do not naturally occur.
>
> This Order does not apply to the introduction of exotic species or export of any native species, if the Secretary of Agriculture or the Secretary of Interior finds that such introduction or exportation will not have an adverse effect on natural ecosystems.

A task force established under the provisions of the Nonindigenous Aquatic Nuisance Prevention and Control Act is preparing a comprehensive review addressing approaches (*e.g.*, voluntary guidelines, model state codes, and evaluation protocols) which substantially reduce the risk of adverse consequences associated with intentional introduction of aquatic organisms. The task force anticipates that this review will be incorporated in a report to be submitted to Congress by March 1993.

Proponents of aquaculture retort that "wild strains" of many native species no longer exist (due to hatchery breeding techniques, *etc.*) and that aquaculture, restoration programs, and commercial capture fisheries can peaceably coexist (see Section 5.2.7). A report by Virginia Sea Grant (1990) advocates that "added options" (*e.g.*, hybrids) are more palatable biologically and politically than an introduction of a pure non-native species in that they retain a majority or significant component of the native gene pool. That report further encouraged an informative discussion of this option with ASMFC to encourage support of proposed research efforts involving rejuvenation of the Chesapeake Bay eastern oyster resource.

Exotic species introduced into the Northeast for aquaculture purposes include coho, chinook, and kokanee salmon (Great Lakes, Maine, New Hampshire, and Massachusetts), rainbow and brown trout, edible oyster (Maine), and tilapia. The support for the introduction of the Pacific oyster has increased in recent years due to the demise of the eastern oyster fishery. Although no large-scale introductions have been formally documented, there have been allegations that 8,000 bushels of seed eastern oysters from Washington (state) were introduced in 1988 in the Rappahannock River in Virginia. This has, accordingly, caused concern by state and federal agencies about possible consequences, including: (1) overgrowth and replacement of native eastern oysters by exotic Pacific oysters; and (2) possible introduction of as many as five serious diseases [*i.e., Bonamia ostreae*, nocardiosis (focal necrosis), *Microcytos mackini*, irridovirus disease, and the parasitic copepod *Mytilicola orientalis*] that do not occur in East Coast mollusks.

In October 1991, an international workshop funded under the ODRP was held in Annapolis, Maryland, to address the ecological aspects of proposed Pacific oyster introductions on the Atlantic coast of the United States. The workshop concluded that if a self-sustaining population of this species were introduced in the Mid-Atlantic region, then the introduction could be irreversible and could introduce disease agents not currently present. Identified research needs included studies of physical tolerance, disease susceptibility, gametic competition, and relationships with hard-bottom epibiota. With regard to aquaculture, it was concluded that intertidal bottom and off-bottom culture seems feasible in the Mid-Atlantic region. The workshop report indicated that controlled field experiments were necessary to answer some of the associated research questions. However, the authors recognized that the decision to conduct these field experiments is a management one (Sutherland and Osman 1991).

## 5.2.5 Extension and Education

Increasing liaison among government, industry, and academia is evident in addressing the management and research aspects of aquaculture in the Northeast. Historically, extension activities have focused on the exchange and transfer of information between these sectors to facilitate the awareness of regulatory requirements for commercial aquaculture operations as well as the adoption and use of advances in finfish and shellfish culture techniques.

In Maryland, for example, Baltimore Gas & Electric Co. in 1990 agreed to transfer the license to the Maryland Department of Agriculture (MDA) of its Crane aquaculture facility for the next 10 years. Under the terms of this private/public cooperative agreement, the MDA will contract with the University of Maryland Agricultural Experiment Station to operate the facility for aquacultural research, education, and demonstration. Research will include nutrition, reproduction and disease prevention studies using the facility's flow-through and closed-loop isolation tanks. The facility provides a unique opportunity to conduct research that can lead to the intensive tank-culture production of striped bass in Maryland.

At the University of Maryland, the Sea Grant extension staff, in cooperation with the NRAC, has offered courses for extension professionals on striped bass aquaculture. The university was given, under the Maryland Aquaculture Bill of 1988, a formal research/educational role in aquaculture. This role encompasses educational opportunities available through training and demonstration programs offered to the general public and through curricula in the aquaculture-related sciences leading to the Master of Science and Doctor of Philosophy degrees. Programs at other educational institutions are focusing on aquaculture as well, including a Bachelor of Science curriculum at the University of Maine in Orono. Selected course offerings include resource business management, food and fiber marketing, shellfisheries biology, processing technology, and water supply and waste management. Through this program, graduates receive training and become prepared for technical and supervisory positions in aquaculture, and may choose to pursue advanced degrees in related fields, particularly the pending graduate program in marine bio-resources at Orono. Increased private and public interest in aquaculture has also led to an enhanced emphasis in veterinary school curricula on aquatic animal medicine.

At the high-school level, a national aquaculture curriculum for 11th and 12th grade students was being developed under the provisions of a $485,000 federal grant and tested at several pilot schools in Indiana and Pennsylvania in fall 1991. The program uses an integrated approach with active roles for both agriculture and science teachers.

In the Great Lakes states, a video presentation called "Aquaculture in Illinois" has been developed in the interest of the various public sectors (*i.e.*, governmental and educational) participating in the developing aquaculture industry in Illinois. The basic objective of the video is to improve public understanding of the potential for a strong aquaculture industry in that state. Sponsors include the Illinois State University and the Illinois Department of Commerce and Community Affairs.

In Canada, the New Brunswick Department of Fisheries and Aquaculture has adopted what essentially can be referred to as an extension approach to assure the orderly development of the aquaculture industry. These activities have included institutional changes, fish health monitoring programs, and development of a leasing/licensing policy for the allocation of provincial marine lands for aquaculture. Direct provincial involvement with private industry has addressed the selection of freshwater and marine aquaculture sites, disease diagnostics, and parasite research.

## 5.2.6 Trade and Marketing

In 1989, the United States imported $5.5 billion worth of edible seafood products and exported $2.3 billion, resulting in a differential of $3.2 billion. At the same time, the demand is increasing--*per capita* consumption of seafood in the United States increased approximately 24 percent between 1980 and 1989. The lack of market availability of more desirable wild species (product) acceptable to the consumer, coupled with a concurrent need to decrease the fishery trade deficit, has been responsible for increasing industry interest in commercial aquaculture of finfish and shellfish to accommodate the increased demand for seafood.

In an industry where packaging, package colors, and portion sizes are important concerns, one overriding impediment is the lack of an organized marketing framework for the sale of cultured seafood. One example which demonstrates contrasting differences is how Norway has succeeded in marketing its salmon aquaculture product advertised on American (including New England) restaurant menus as "Norwegian salmon," not Atlantic salmon, which in fact it is. At a recent Boston Seafood Show, the Norwegian Salmon Marketing Council sponsored taste tests and offered prizes (cookbooks) to the American public, providing an opportunity for consumers to see new types of portion-controlled and value-added products from Norwegian-cultured salmon. Along with fresh and frozen whole salmon, the council contended that the new products make Norway the number one supplier of value-added products to the American market. The council also publicized a telephone number to obtain recipes and additional information for Norwegian-cultured salmon: (800) EAT-SALMON (328-7256).

Many foreign salmon-producing countries directly subsidize market initiatives of private companies through brochures and other publicity avenues. Unconfirmed figures estimate that freight costs alone for salmon produced in Chile and shipped to American markets are about $0.90 per pound. Yet the Chilean market is apparently able to offer aquacultured salmon in the United States at $2.90-3.25 per pound.

The NRAC recently hosted a workshop to discuss funding priorities under the heading "Alternative Marketing Options to Improve Profitability of the Northeastern Aquaculture Industry." The highest ranked priorities were marketing strategies, marketing constraints, regional identification of products, and new products with value-added potential. The workshop participants summarized these top priorities into two categories: (1) situation analysis which covers structure, conduct, and performance of the industry, public perceptions, food safety, and consumer education and health awareness, and which, in turn, would provide an assessment for dealing with marketing constraints, domestic and international competition, product distribution, and the financial structure of the industry; and (2) the potential for value-added products, buyer-consumer awareness, niche markets, trade names, and actual product development.

The baitfish and aquarium trade industries are often overlooked by those who intuitively restrict their definition of aquaculture to the production of food commodities. A recent survey discussed in the November 1991 issue of *Catfish and Aquaculture News* indicated that freshwater live bait sales in the United States totaled $609 million in 1985. The industry is controlled especially by seasonal marketing factors, including weather and sales. In addition, the market is affected by government regulations on the use of chemicals used to control the spread of disease during handling and shipping. Irregularities in state inspections and quarantines in the interstate commerce of commercially raised fish have also been identified as prominent concerns affecting the industry.

At a recent Midwest Aquaculture Conference cosponsored by the NSGCP, marketing factors discussed as affecting the aquarium industry (native fish trade) involved optimum size and aesthetic considerations. In Minnesota, aquarium fish wholesalers and pet stores that retail native game fish must be licensed by the Minnesota Department of Natural Resources to preclude sale of other than hatchery-raised fish.

Aquaculture interests in the United States may be affected by a February 1991 directive adopted by the EEC. That directive, which becomes effective January 1993, defines the animal health conditions governing the placing on the market of aquaculture animals and products. An EEC commission has been instructed to create a list of countries whose products are approved for import into the EEC. Products must meet the EEC-approved health conditions and shipments must be accompanied by a certificate drawn up by appropriate authorities.

## 5.2.7 User Conflicts

There is no question that the growth of aquaculture has led to increasing concerns about its effects on the Northeast's historical commercial fisheries. User conflicts are apparent among the Mid-Atlantic states as reported by Virginia Sea Grant (1990):

> In New York, there is a fierce competition for both waterfront and bay bottom use. Access to suitable bottom space is limited by townships who view

water bottom as a public resource for commercial and, more so, public recreational use. Dedication of significant water bottom for use in aquaculture is clearly problematic. In Maryland, there is a continuing opposition even to bottom leasing; the traditional watermen viewing this as a competitor to their lifestyle. In Virginia, there is a much older diversity with both public fisheries and private bottom leases serving an industry; however, there remains staunch opposition to limitation of access of public watermen to previously productive oyster bottom.

The selection of sites for aquaculture operations is a particularly sensitive concern. For example, in Maine, the priority of "rights" assigned to potential sites is vested in the existing commercial fishery and the "nearby" property owner. Prominent environmental and social sensitivities include the effect of aquaculture operations on the endemic flora and fauna, the protection of property owners' access, and the effects upon navigation and commercial fishing activities. Other areas of concern include the effects of aquaculture upon salmonid restoration efforts, and the aesthetics (*i.e.*, size, color, and shape) of aquaculture facilities. The latter issue includes opposition by landowners who maintain they have a right to a view of pristine waters.

The competition for use of public lands for aquaculture purposes is not limited to inshore coastal waters, but also extends into waters under federal jurisdiction. These issues, as well as an overview of state regulatory authorities in Connecticut and New York, are briefly summarized in Terry (1977).

The relationship between aquaculture and the capture (historical) fisheries is often assessed from both economic and biological perspectives. For example, a 1988 report by the USDC evaluated whether existing capture fisheries in the United States are adversely affected by competition from commercial aquaculture enterprises. This report concluded that dockside prices received by U.S. fishermen are lower than they would be otherwise (*i.e.*, in the absence of cultured products) in the U.S. market. However, U.S. consumers enjoy benefits of lower salmon and shrimp prices that are the result of unrestricted foreign imports.

From a biological viewpoint, it has been widely recognized that aquaculture standards must be established to ensure that aquaculture operations do not adversely affect the conservation and enhancement of wild stocks. The use of endemic species only is often advocated for aquaculture (Sections 2.6.2.3 and 5.2.3). Otherwise, even stricter standards must be considered to ensure that non-native stocks do not escape, or are not released, outside the confines of the aquaculture facility (pens, nets, *etc.*). In the case of hybrid striped bass aquaculture, for example, state permit regulations often restrict operations to nontidal lakes, ponds, or compounds, thereby assuring that the non-native strains do not enter tidal waters or "contaminate" the natural stocks. Similarly, concern has been expressed that aquaculture for selected species may encourage market opportunities for fish from depressed stocks illegally captured from the wild population. In this respect, the ASMFC has approved a resolution that whereas aquaculture-raised striped bass produced for market create a potential for the illegal capture of undersized wild striped bass that could undermine management and enforcement goals, all member states should identify hybrid striped bass for market through uniform labeling and tagging procedures.

Clearly, from one perspective, aquaculture is seen as separate and distinct from the traditional commercial fisheries and as a potential threat to their existence. Yet, from another viewpoint, aquaculture is seen by others as a complementary commercial industry which has many of the same attributes and interests, *e.g.*, a healthy and unpolluted aquatic environment, conservation and productivity of the nation's fishery resources, and profitable seafood marketing channels. This relationship becomes even more aligned, considering that aquaculture operations, by their nature, depend upon the existing traditional fishery services, such as wholesalers, processors, packagers, and transportation. In addition, several examples can be used to demonstrate potential commonalities between the two livelihoods. For instance, the commercial harvesting of American lobsters and the cultivation of blue mussels can form a single employment opportunity. Similar equipment and fishing skills could conceivably be utilized to take advantage of peak seasonal variations in the productivity of the respective occupational endeavors (Maine State Planning Office 1990).

In Canada, most jurisdictions recognize the potential for adverse effects of aquaculture on wild fish, but believe that the government should make efforts to reduce unnecessary constraints on the aquaculture industry to support aquaculture through research and development, but not with capital; and to coordinate the involvement of diverse government departments so that aquaculture is not continuously embroiled in red tape. The prevailing Canadian view recognizes the risks in supporting aquaculture development while maintaining conservation of the wild fisheries, but also acknowledges that risk management implies regulation, not prohibition (American Fisheries Society 1991). An ideal scenario would be to treat all interest groups in a fair and equitable manner, as commercial fishermen, aquaculturists, recreationalists, and developers contend for use of the public resources and the aquatic environment they depend upon.

## 6. NMFS POLICY AND STRATEGIES

This document demonstrates that the NER has had an involvement in aquaculture since the inception of the agency. With few exceptions, however, this involvement has been more a result of circumstantial management/research program priorities and events, than a directed, concerted approach toward assessing the NER's role in enhancing the development of the aquaculture industry. From one per-

spective, the articulation of a formal NMFS policy/strategy need not be a prerequisite for demonstrating the organizational contributions to the various facets of aquaculture research and development as defined in Chapter 5. For example, the written consolidation of pertinent NMFS activities, as presented in this document, serves to give visibility both internally and, if subsequently warranted, to external interests (*e.g.*, the public). From another perspective, in view of the expanding aquaculture industry in the Northeast, as well as current and potential future legislative mandates (*e.g.*, to work with USDA as a partner in the development of U.S. aquaculture), it may be advantageous to clearly enunciate the nature of agency involvement. In this regard, the stage has already been set through aquaculture program initiatives included in the NMFS Strategic Plan and complementary actions cited in the Northeast Region Implementation Plan (Roe 1992).

The following subsections address the current status of aquaculture program strategies at both the NMFS Washington Office and Northeast Region levels.

## 6.1 NATIONAL OVERVIEW

The NMFS Strategic Plan recognizes aquaculture as an area of agency program emphasis that is necessary for NMFS to fulfill its mission. That document states that "in some cases American aquaculture has been impeded by concerns that it might adversely affect habitat quality and wild stocks. NMFS has scientific expertise that can help to reduce these and other impediments to U.S. aquaculture development, thus improving opportunities for growth. Expansion of domestic aquaculture production has the potential to narrow the gap between the demand for seafood products and the production of wild stocks. Aquaculture techniques are an option to aid rebuilding of some depleted stocks, as in the case of Columbia River salmon.... Therefore, the eighth goal of NMFS is to improve opportunities for U.S. aquaculture."

The NMFS Strategic Plan identifies the following objectives to achieve this goal: (1) determine the effects of aquaculture on habitat and wild populations, and how to reduce adverse effects; (2) develop means to permit cultured products in the marketplace without jeopardizing conservation of wild stocks; (3) determine the potential for aquaculture to enhance recovery of protected species and depleted fisheries; and (4) re-evaluate NMFS's role in U.S. aquaculture.

The NMFS Strategic Plan also includes the following planned actions to accomplish these objectives: (1) conduct research and provide information on the effects of aquaculture on habitat, and encourage environmentally safe alternatives; (2) evaluate the risks to wild stocks and their habitats from the introduction of cultured species; (3) develop the capability to distinguish cultured stocks from wild populations; (4) develop techniques to use aquaculture to enhance recovery of protected or depleted living marine resources; and (5) develop effective coordination with the USDA and other federal and state agencies involved in marine aquaculture.

In Fiscal Year 1989, the Marine Board of the National Research Council was contracted by NOAA (*i.e.*, NMFS and the NSGCP) and the USDA to produce an assessment of technology and opportunities for marine aquaculture in the United States. Three working groups were established for policy, technology transfer/education, and research/engineering. Policy issues addressed are: (1) identifying issues/lack of national direction/leadership; (2) coastal land and ocean use conflicts; (3) environmental and public health issues; and (4) technology-related policy issues.

## 6.2 NORTHEAST REGIONAL OVERVIEW

In February 1991, the NER adopted objectives and activities for aquaculture in the Northeast Region Implementation Plan, as a complementary action to Goal 8 (*i.e.*, "Improve Opportunities for U.S. Aquaculture") as specified in the NMFS Strategic Plan. The Northeast Region Implementation Plan contained the following initiatives: (1) establish cooperative interagency state/federal approach to protect habitats, fisheries, and marine mammals from placement of salmon pen aquaculture operations; (2) implement joint state/federal application and permit process for siting and monitoring of aquaculture facilities (Fiscal Years 1992-96); (3) in conjunction with Sea Grant institutions, conduct conservation engineering studies for minimizing conflicts between marine mammals, *i.e.*, seals, and maintenance of salmon pens; (4) support grant-based research programs to establish environmental standards for placement of aquaculture pens; (5) establish bilateral U.S./Canadian standards for importation of Atlantic salmon spawn from Europe into Gulf of Maine aquaculture industry; (6) in conjunction with the NMFS Office of Research and Environmental Information, USFWS, and through participation in NASCO, develop and implement national and international regulations for importation of Atlantic salmon spawn into the northeastern United States and southeastern Canada aquaculture industry (Fiscal Years 1992-93); (7) work with the NMFS Office of Research and Environmental Information to maintain current standards for regional importation of disease and predators with mussels and shellfish planned for culturing; and (8) in coordination with Sea Grant and the Chesapeake Basin states, conduct an international workshop on the ecological effect of Pacific oyster introductions (Fiscal Year 1992).

## 6.3 SUMMARY

Clearly, the immediate course of action for continuing NER involvement in aquaculture is articulated within the scope of the NMFS Strategic Plan and the Northeast Region

Implementation Plan. This document has been prepared to give perspective to previous and current NMFS participation in aquacultural activities and development in the Northeast. It should also serve to provide the basis for assessing the future course of NER involvement in aquaculture as necessitated by national policy guidance and potential modifications to the NMFS Strategic Plan.

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