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Proceedings of the Symposium on the Potential for Development of Aquaculture in Massachusetts

15-17 February 1995

Chatham/Edgartown/Dartmouth, Massachusetts

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NOTE ON SPECIES NAMES

The NMFS Northeast Region's policy on the use of species names in all technical communications is to follow the American Fisheries Society's (AFS) lists of scientific and common names for fishes (Robins *et al.* 1991)[a], mollusks (Turgeon *et al.* 1988)[b], and decapod crustaceans (Williams *et al.* 1989)[c], and to follow the American Society of Mammalogists' list of scientific and common names for marine mammals (Wilson and Reeder 1993)[d]. This policy applies to all issues of the *NOAA Technical Memorandum NMFS-NE* series.

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

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

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[d] *Wilson, D.E.; Reeder, D.M. 1993. Mammal species of the world: a taxonomic and geographic reference. Washington, DC: Smithsonian Institution Press; 1206 p.*

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Acronyms

AFS	=	American Fisheries Society
ARC	=	Aquacultural Research Corporation
CCEDC	=	Cape Cod Economic Development Council
FAC	=	Fishing Family Assistance Corporation
FAO	=	(U.N.) Food and Agriculture Organization
FDA	=	U.S. Food and Drug Administration
FIG	=	Fishing Industry Grant Program
MCZM	=	Massachusetts Coastal Zone Management Office
MDEP	=	Massachusetts Department of Environmental Protection
MVSG	=	Martha's Vineyard Shellfish Group, Inc.
NMFS	=	(NOAA) National Marine Fisheries Service
OTA	=	(U.S. Congress) Office of Technology Assessment
PTD	=	public trust doctrine
SBA	=	U.S. Small Business Administration
SEED	=	South Eastern Economic Development Corporation
SRPEDD	=	Southeastern Regional Planning and Economic Development District
UMD/CMST	=	University of Massachusetts-Dartmouth's Center for Marine Science and Technology
USDA	=	U.S. Department of Agriculture
USDC	=	U.S. Department of Commerce
WHOI/SGP	=	Woods Hole Oceanographic Institution's Sea Grant Program

Scientific Names of Species and Hybrids

Atlantic cod	=	*Gadus morhua*
Atlantic halibut	=	*Hippoglossus hippoglossus*
Atlantic salmon	=	*Salmo salar*
Bay scallop	=	*Argopecten irradians*
Black basses	=	*Micropterus* spp.
Blue mussel	=	*Mytilus edulis*
Channel catfish	=	*Ictalurus punctatus*
Crappies	=	*Pomoxis* spp.
Eastern oyster	=	*Crassotrea virginica*
Haddock	=	*Melanogrammus aeglefinus*
Northern quahog	=	*Mercenaria mercenaria*
Palmetto bass	=	female *Morone saxatilus* x male *M. chrysops*
Rainbow trout	=	*Oncorhynchus mykiss*
Sea scallop	=	*Placopecten magellanicus*
Softshell	=	*Mya arenaria*
Striped bass	=	*Morone saxatilus*
Summer flounder	=	*Paralichthys dentatus*
Tautog	=	*Tautoga onitis*
Tilapias	=	*Orechromis* spp. and *Tilapia* spp.
White bass	=	*M. chrysops*
Yellow perch	=	*Perca flavescens*

PREFACE

The impact of the current fisheries crisis on the fishing industry of coastal New England has inspired numerous recommendations to alleviate the resulting economic stress. Among these recommendations are: 1) retraining of those displaced from the industry, 2) greater exploitation of underutilized species, 3) a government-sponsored fishing vessel buyback program, and 4) development of various forms of aquaculture. It has become apparent that there will be no one solution for the industry's dilemma. Accordingly, although it is not a panacea, aquaculture is one alternative that provides limited employment and a source of high-quality protein.

The primary reasons for organizing these symposia were the needs to educate and inform municipal officials about aquaculture, to encourage development of the emerging aquacultural industry, and to provide a forum for discussion of major constraints affecting the industry. The National Marine Fisheries Service (NMFS) and the Southeastern [Massachusetts] Regional Planning and Economic Development Council (SRPEDD) jointly organized three regional symposia. Over 350 invitations went to state and federal government agencies and to coastal communities throughout southeastern Massachusetts. Because development of Massachusetts' aquacultural industry suffers from a lack of startup capital, the South Eastern Economic Development Corporation sent an additional 300 invitations to lending institutions throughout the commonwealth. Response to the more than 600 invitations was extraordinary. Over 300 people attended the symposia held in Chatham, Edgartown, and Dartmouth on February 15, 16, and 17, 1995, respectively.

This report summarizes the presentations at these symposia. Crucial to success was involvement of the Woods Hole Oceanographic Institution's Sea Grant Program (WHOI/SGP), Martha's Vineyard Shellfish Group, Inc. (MVSG), Cape Cod Economic Development Council (CCEDC), Resource Conservation and Development Council, Center for Marine Science and Technology of the University of Massachusetts-Dartmouth (UMD/CMST), Cape Cod Commission, Martha's Vineyard Commission, and Policy Center for Marine Biosciences and Technology. The symposia were sponsored by NMFS, SRPEDD, WHOI/SGP, CCEDC, MVSG, and UMD/CMST. Special thanks go to Dr. Jean Fraser, Mr. Richard Karney, Dr. Dale Leavitt, and Mr. Dana Morse for their invaluable assistance in organizing these symposia.

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WELCOME AND OPENING REMARKS

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I welcome all participants to this symposium on “The Potential for Development of Aquaculture in Massachusetts.” This event is the result of a cooperative effort by many agencies and organizations that share an interest in development of aquaculture. I gratefully acknowledge the sponsorship of the participating agencies, and particularly recognize the important financial contributions of SRPEDD, CCEDC, WHOI/SGP, and MVSG. Their contributions were fundamental in organizing these symposia. We have set up three similar meetings in order to reach all coastal communities of southeastern Massachusetts: today this one, tomorrow on Martha’s Vineyard, and Friday at the University of Massachusetts-Dartmouth.

These symposia were designed to inform, educate, and address the managerial issues that concern not only local decisionmakers, but the state and federal government, as well. We hope that the information and discussions generated in this forum will help local municipalities and the state to shape their policies on aquaculture. We also certainly hope to create enough interest to stimulate the private sector to make more capital investments. In attendance today are selectmen from most Cape Cod towns, official representatives of conservation commissions, shellfish advisory groups, and state and federal governments, and individual members of the community.

While, throughout most of New England, state government plays a prominent role in the regulatory process, Massachusetts has given local municipalities authority over state waters. This results in a heterogeneity of public laws. These laws generally require applicants to establish local residency before applying for an aquacultural permit.

In the Northeast, the near collapse of groundfish stocks, and the subsequent decline of traditional commercial fisheries, make aquaculture an attractive alternative for many dislocated fishermen. Cape Cod and the Islands seem to be on the brink of an aquacultural revolution. In recent months, the federal government has directed grants to the fishing industry to facilitate development of innovative aquacultural methods. Many people might be skeptical about aquaculture becoming an economically viable activity for this region. Nonetheless, in the last few months, local municipalities have been overwhelmed by applications for aquacultural permits. The aquacultural industry is assuming an entirely new dimension as new and alternate methods are introduced. At the same time, state government is rapidly developing the legislative framework needed to meet the new challenges of the emerging industry.

NMFS promotes marine aquaculture as one of the objectives of the NMFS 1995 Action Plan and as one of the objectives of the Northeast Fisheries Assistance Program. It is important to note that NMFS does not promote aquaculture as the solution to the groundfish fisheries crisis in the Northeast, but rather as an alternative for coastal communities and fishermen interested in exploring a different economic avenue that may help to relieve some pressure on traditional groundfish fisheries. Last year, NMFS distributed over $2 million through the Fishing Industry Grant Program to fund aquacultural projects in the Northeast. This year, $4.5 million will be available for the second round of the program. We anticipate that a significant portion will be directed toward development of marine aquaculture as a new business opportunity.

Although it has one of the longest coastlines in the world, the United States lags most other coastal nations in production of seafood through marine aquaculture. The United States has a tremendous opportunity to develop a high-quality, technologically advanced, aquaculture-based seafood industry capable of satisfying our domestic market. Recent studies show that American consumers strongly prefer seafood that is cultivated under controlled conditions. It is essential for decisionmakers to learn from other nations’ experiences in developing aquacultural industries. Chile, Japan, Norway, and Thailand represent a few of the countries with extraordinary successes in recent years.

During 1993, the United States imported over $5.8 billion worth of seafood products, making seafood trade one of the largest commodities contributing to the trade deficit. According to the U.N. Food and Agriculture Organization (FAO Inland Water Resources and Aquaculture Service 1992), the United States contributes only about 2% of the total world aquacultural production. In the Northeast, Massachusetts lags behind Connecticut, Maine, and Pennsylvania in aquacultural production. According to Bush and Anderson (1993), Connecticut, with estimated sales of $62 million, has the largest aquacultural production in the Northeast. Maine is second largest in aquacultural production with $43 million. Massachusetts modestly contributes only $8 million to the regional economy through aquacultural production.

On Cape Cod, where shellfish farming is the main type of aquaculture, most of the obstacles blocking the development of shellfish aquaculture arise from user-conflict issues and exacting managerial regulations. There are no easy solutions to these problems. However, we should remember that in order to have our communities accept aquaculture for economic development, there must be a common interest in having it. All users and practitioners need to feel involved. Presently, several towns are developing harbor management plans that include aquacultural zones. Local municipalities should coordinate their efforts with state officials, local experts, and economic development officials to elaborate comprehensive plans. I hope that this symposium helps those involved in the regulatory process by providing tools and ideas to deal better with these new challenges.

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AQUACULTURE: A WORLDWIDE GROWTH RESPONSE TO DECLINING FISHERIES STOCKS

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BACKGROUND

Worldwide, farming or husbandry of aquatic organisms, known as aquaculture, has experienced tremendous growth over the last decade. According to the most recently published figures of the FAO, total world aquacultural production in 1992 was in excess of (U.S.) $32.5 billion, almost double the 1986 figure of $16.6 billion (FAO 1994). Growth of aquaculture has been most explosive in Asia where aquatically derived protein is a major portion of many people’s diet. Total value of Asian aquacultural products tripled between 1984 and 1992 from $7 billion to about $21 billion. Significant growth in aquaculture occurred in South America and Europe as well (FAO 1994).

Sadly, in the United States, the rate of growth in aquaculture has been much lower. Between 1986 and 1992, the value of aquacultural products in the United States grew from $471 million to $630 million (FAO 1994), this gain coming mainly from production of channel catfish (*Ictalurus punctatus*) in Mississippi. This state produces about 80% of the national catfish supply (USDA Economic Research Service 1994).

The United States has paid dearly for its lack of interest in fostering aquacultural enterprises in the face of long-predicted declines in natural fishery stocks. During 1983-93, imports of fishery products into the United States grew from $3.6 billion to $5.8 billion (USDA Economic Research Service 1994), with about 40% of these totals representing importation of aquacultured shrimps or prawns. According to the U.S. Department of Commerce and other sources, importation of seafood products is the third leading contributor to the trade deficit, next to petroleum and illegal drugs.

As alarming as the figures are, they should be of most urgent concern in southeastern New England where the economy has relied heavily upon fisheries and seafood since colonial times. For example, the history of New Bedford as a whaling and fishing center is well known throughout the country. As fisheries collapse, secondary industries, such as fish processing houses and fishing gear suppliers and manufacturers that depend on the supply of fisheries products, will falter unless there are suitable alternatives such as aquaculture. As of 1992, total value of aquacultural products in southeastern New England (Massachusetts and Rhode Island) was $8.2 million (Bush and Anderson 1993). This is an astoundingly poor performance for a region with such a proud maritime tradition. But, the existing aquacultural industry cites several “hidden” factors that have hampered development. Governmental attention to changing or modifying inappropriate or excessive regulations, and to promptly resolving multiple-use conflicts, can go a long way toward fostering aquacultural entrepreneurship.

AQUACULTURAL SOURCES OF LOCALLY CONSUMED SEAFOOD

In many ways, it is instructive to examine some of the sources of seafood products in our local supermarkets. Many products that are plentiful, in reliable supply, and of reasonable price to the consumer are often of aquacultural origin.

Channel Catfish

The channel catfish aquacultural industry of the southern United States is often touted as an economic success story. As stated earlier, this industry makes up a major fraction of the entire aquacultural production in this country. Market development was key to success. Catfish is readily available in supermarkets here in the Northeast where catfish was largely unknown up to a few years ago.

The industry originally came about as a secondary means of income for many farmers who had marginal agricultural land. Catfish are generally produced by allowing brooder catfish to spawn in shallow open ponds, then collecting the egg masses and incubating them in indoor hatcheries. Ponds for catfish production generally run from 2 to 10 acres, and a typical farm may have 20-100 or more acres of ponds. Typical pond production of catfish is 25,000-40,000 lb/acre.

Conditions for success in the catfish industry of the southern states rests upon a very workable partnership among industry, state regulatory agencies, state universities, and federal agencies. Once aquaculture became established and track records known, financial institutions were willing to develop financing packages, and secondary industries, such as feed manufacturing, flourished. Auburn University and Mississippi State University have notable academic and extension programs based upon catfish farming. Additionally, the Southern Regional Aquaculture Center of the U.S. Department of Agriculture (USDA) is very active in funding industry-requested research projects.

Atlantic Salmon

Atlantic salmon (*Salmo salar*), a popular fish very commonly found in the fish sections of supermarkets, is often reasonably priced for consumers. Here in the United States, Atlantic salmon are farmed in coastal, floating, fish pens in the states of Maine and Washington (Bettencourt and Anderson 1990).

Domestic production of salmon is dwarfed by production in a number of other countries, including Norway, Scotland, Canada, and Japan. As a result of this massive overseas production, much of the salmon sold in the United States is from foreign sources (Peterson 1994). In the last 2 or 3 yr, Atlantic salmon produced in the fiords of southern Chile have reached U.S. markets, and their production should grow considerably due to fairly low costs.

Tilapia

Orechromis spp. fishes, which are closely related to the well-known *Tilapia* spp., are commonly aquacultured freshwater fishes. (*Orechromis* spp. are hereafter referred to as just “tilapia.”) They are becoming a popular item in many seafood markets in this country. Fresh tilapia have a firm flesh and delicate “non-fishy” flavor that is agreeable to the average North American palate.

Tilapia are mouth-brooding fish, native to Africa. Developing eggs and larvae are incubated by the female parent as a natural defense against predation. Tilapia are grown in many developing nations because they are extremely hardy, easy to breed, and amenable to low-capital culture systems. Being a tropical species, they require a fairly warm environment. They become heavily stressed and die if water temperatures dip much below 15°C (59°F).

In this country, tilapia are mostly cultured indoors in recirculation systems. There are some pond-cultured tilapia in the desert Southwest, particularly in California and Arizona.

Shrimp

Aquacultured shrimp (family Penaeidae) is a very common product in supermarkets and seafood stores. Prior to about 1983, most shrimp on world markets were caught by shrimp trawl fleets. Although there was a considerable industry of shrimp aquaculture in many tropical Asian countries, the industry was limited by availability of juvenile shrimp. These juveniles were caught by small-scale fishermen. Development of commercial shrimp hatcheries in the early 1980s radically changed the face of the shrimp aquacultural industry. The industry in many countries expanded and intensified, with farms often producing 5-6 times more shrimp per unit of pond area than was previously possible. Worldwide, the shrimp aquacultural industry experienced tremendous growth during the middle to late 1980s. Major shrimp-producing countries include Ecuador, Taiwan, Thailand, Philippines, Indonesia, and People’s Republic of China.

Rapid and largely unregulated growth of the shrimp aquacultural industry has created a host of environmental and social problems (Pollnac and Weeks 1992). It is instructive to review them. Key problems include destruction of wetland habitats for pond construction, displacement of fishermen dependent upon community-held resources, and lack of sustainability. Production in the 1990s is declining due to overstocking, stressed stock, and disease (Aiken 1990). For aquaculture to be a sustainable form of economic development, aquaculturists need to be mindful of the socioeconomic and environmental implications of their work. They should not simply follow the pattern set by an overseas shrimp aquacultural operation.

Bivalve Mollusks

Aquaculturing of filter-feeding bivalve mollusks such as oysters, clams, and scallops is often an environmentally sound practice (Newkirk 1992; Rice 1992). Southeastern New England has a long history of shellfishing and shellfish culture. Indeed, the Rhode Island Oyster Act of 1844 was essentially the state’s first aquacultural law. It allowed aquacultural leases in Narragansett Bay (Nixon 1993). On Cape Cod, there is currently a small industry devoted to culture of the northern quahog (*Mercenaria mercenaria*). There are also some small-scale productions of eastern oysters (*Crassostrea virginica*) and bay scallops (*Argopecten irradians*) in southeastern Massachusetts and in Rhode Island.

Although there are a number of excellent examples of successful bivalve culture operations around the world, two of note may provide lessons for southeastern New England. First is the recent development of a multimillion dollar eastern oyster industry in nearby Connecticut. In the late 1980s, Connecticut gave high priority to aquacultural development. One part of their effort streamlined the aquaculture-permitting process. They created a new Division of Aquaculture under their Department of Agriculture, and placed most aquaculture permitting in this new division. The Division of Aquaculture, in one of its first acts, invested $1 million in fossil oyster shells to provide setting materials for native oysters. The investment paid off. A small, oyster seed fishery grew and began to supply commercial leaseholders. Value of Connecticut's aquacultured oyster products by 1992 exceeded $60 million (Bush and Anderson 1993). The Connecticut oyster aquacultural industry is now the single largest segment of the entire New England aquacultural industry. This is largely due to implementation of appropriate governmental structures and strategic seed money (Volk 1994).

Another notable bivalve aquacultural success story is the rapid development of a bay scallop aquacultural industry in China. The Chinese in 1982 introduced 27 New England bay scallops as brood stock for one of their hatcheries (Yarish and Huang 1992). They now culture the scallops in coastal waters using simple "longline" systems and lantern nets. Their state and private hatcheries produce scallop seed and supply their coastal farms. China, by 1992, reported its bay scallop production exceeded 120,000 metric tons (265 million lb), much of which it exported to the United States as frozen scallop meats. We, in Southern New England, clearly have the potential to culture our own bay scallops.

CONCLUSIONS

We could follow many models from around the world for development of an economically and environmentally sustainable aquacultural industry. Additionally, we can learn much by studying the problems that other countries encounter in developing their industry. Our key to success in aquaculture is a workable partnership between governmental regulatory authorities, the educational community, and members of the industry. Talent exists in each of these sectors, but cooperation is the key to successful development.

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NORTHEAST AQUACULTURE INDUSTRY: SITUATION AND OUTLOOK

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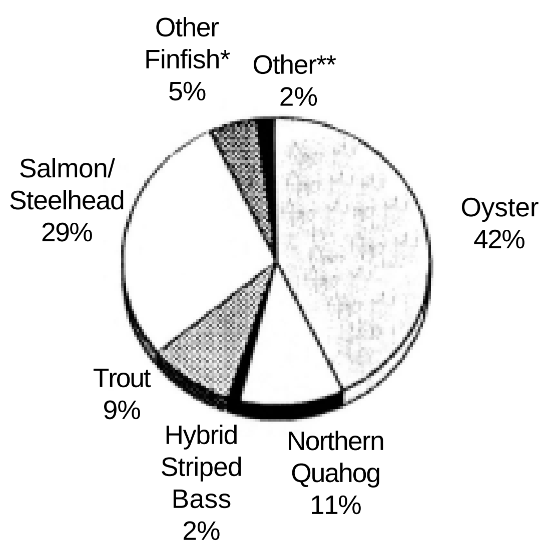
INTRODUCTION

Total 1992 farmgate value of aquacultural products in the Northeast was estimated at $146,409,000. ("Northeast" refers to Maine, New Hampshire, Vermont, New York, Massachusetts, Connecticut, Rhode Island, Delaware, New Jersey, Pennsylvania, Maryland, and West Virginia.) This estimate was based on farmgate prices quoted by those producers interviewed. Based on the strength of its eastern oyster industry, Connecticut had estimated 1992 farmgate sales of $61.7 million, making it the largest aquacultural producing state in the region. The pen-reared salmonid industry propelled Maine's 1992 farmgate sales to $42.9 million, establishing it as the second-largest aquacultural producing state in the region.

Figure 1 breaks down this total by major species category. Eastern oyster production represented the single largest segment of the regional aquacultural industry, accounting for approximately 42% of the total farmgate value. The net-pen culture of Atlantic salmon and sea-run (i.e., steelhead) rainbow trout (*Oncorhynchus mykiss*) was the second largest segment, contributing roughly 29% to the estimated regional value. Northern quahog production was next, followed by freshwater trout production. Two general groups, called "other finfish" and "other," represented a combination of several smaller categories. The category "other finfish" includes tilapia, catfishes, ornamental fishes, baitfishes, black basses (*Micropterus* spp.), sunfishes, crappies (*Pomoxis* spp.), and yellow perch (*Perca flavescens*). The category "other" includes small amounts of other



*Other Finfish = Tilapia, Catfish, Ornamental, Baitfish, Black Bass, Sunfish, Crappie, Perch
**Other = Other Shellfish, Aquatic Plants, Crayfish

Figure 1. Percent composition of aquacultural production in the northeastern United States during 1992. Total farmgate revenue was an estimated $146,409,000. (Refer to text for discussion of species constituting the various categories.)

shellfishes, aquatic plants, and crayfishes. Farmgate sales of "hybrid striped bass" represented approximately 2% of the regional value. [See "Managing Editor's Note" at end of this section.]

SUMMARY OF MAJOR FINDINGS

Based on survey results, the following are preliminary estimates of private aquacultural production and value, future opportunities and current problems facing the aquacultural industry, and priority research directions based on the aquacultural industry's needs in the Northeast.

Eastern Oyster

The eastern oyster industry, with estimated 1992 farmgate sales of $63.4 million, represents the largest segment of the regional aquacultural industry. Approximately 88% of regionally cultured oyster production is harvested from Connecticut waters. Although many oyster producers indicate that it is very difficult to estimate future production levels due to uncertainties associated with disease, weather, growth rates, and predation, producers did expect, on average, to see some growth in regional harvests over the next 5 yr. Based on an average of survey responses, producers also expect demand for oysters to slightly outpace the increase in production, leading to slight increases in real farmgate prices. Oyster growers cite the current regulatory environment, disease, and the unavailability of financial capital as the top three constraints to industry growth.

Pen-Reared Atlantic Salmon and Sea-Run Rainbow Trout

The Maine-based, pen-reared salmonid industry expected limited growth for the 1993 season. However, producers do expect to see substantial production increases over the next 5 yr. Salmon growers expect to see increases in demand for salmon products; however, most producers feel that growth in demand will not keep pace with production increases, leading to stable or slightly declining farmgate prices. Financial capital unavailability, predation, and the current regulatory environment were cited as the most constraining factors on growth of the salmon industry.

Northern Quahog

Regional northern quahog production generated an estimated farmgate value of $15.6 million in 1992. This segment of the industry is centered in Connecticut, Massachusetts, New Jersey, and New York. Survey responses indicated that producers expect to see a steady growth in production over the next 5 yr. As with oyster producers, quahog growers expressed difficulty in accurately forecasting their production levels from year to year due to environmental factors which are beyond their control. Producers also expect to see moderate increases in demand and fairly stable farmgate prices. The top three constraints to growth of the quahog industry, as indicated by growers, are predation, unavailability of financial capital, and the current regulatory environment.

Freshwater Trout

The 1992 regional production of freshwater trout was valued at approximately $12.9 million. Although Pennsylvania accounts for 72% of the volume, making it the dominant producing state, each of the 12 regional states had some commercial trout production. Fifty-seven percent of production is sold for either private stocking or fee fishing. A few large producers dominate the food-fish sector. Although growers, on average, expect production to increase slightly over the next 5 yr, most major producers feel that lack of water resources suitable for large-scale trout production will limit growth. Much of the increase in production will depend on achieving greater stocking densities through use of improved technology for aeration and recirculation. Producers expect demand, especially in the area of private stocking, to remain strong, thereby providing a boost to farmgate prices. Trout producers cite predation, the current regulatory environment, and unavailability of financial capital as the most constraining factors to trout industry growth.

Hybrid Striped Bass

The 1992 regional production of hybrid striped bass was valued at $2.3 million. Maryland and Massachusetts represent the principal producing states; however, active producers also were identified in Pennsylvania, Delaware, West Virginia, and New Jersey. Water recirculating systems were used for about 40% of the 1992 production volume. Their use was expected to increase, affecting roughly 56% of the 1993 volume. Based on producer responses, compared to 1992, the 1993 production of hybrid striped bass was expected to increase by 144% to 2.3 million lb. Producers, on average, expect growth in demand to lag behind production increases, resulting in stable or slightly declining farmgate prices. Growers cited unavailability of financial capital, the regulatory environment, and marketing as the most constraining factors to the hybrid striped bass industry.

Tilapia

Tilapia production in the Northeast remains fairly low, with an estimated farmgate value of $563,000. However, significant growth is projected by several growers in both Maryland and Massachusetts over the next 2 yr. Recirculating systems were used by 100% of the regional tilapia producers identified. Producers also expect to see significant growth in demand for tilapia, leading to some strengthening in farmgate prices. Primary constraints to the tilapia industry, according to producers, include unavailability of financial capital, lack of information on genetic stocks, and the regulatory environment.

Other Finfish

The category of “other finfish” includes ornamental fishes, baitfishes, black basses, sunfishes, and catfishes. Regional production from this group was valued at approximately $6.8 million.

Ornamental fish production is dominated by two major producers, both using open-pond culture techniques. Ornamental fish producers expect production to be fairly stable over the next 5 yr, with demand and farmgate prices stable or slightly increasing. Growers indicated that the current regulatory environment and bird depredation were the most constraining factors to growth of the ornamental fish industry.

Relatively small amounts of catfishes are produced for private stocking and fee fishing markets throughout the region. The only significant regional catfish production for the human consumption market takes place in Maryland. Producers expect to see fairly substantial increases in both production and demand resulting in stable farmgate prices. Although producer rankings of industry constraints were fairly mixed, predation, financial capital, and the regulatory environment received the highest average scores.

With a few exceptions, the baitfish industry is characterized by a large number of small, extensive operations. One operator indicated that he was experimenting with closed systems. Regional production of baitfishes is expected to see only limited growth due to the large volume of relatively inexpensive product which is imported from the southern United States.

Culturists who are also active in the baitfish and catfish sectors produce much of the black basses, sunfishes, crappies, and yellow perch. Major industry constraints, as indicated by this group of producers, are predation, lack of financial capital, and the current regulatory climate.

Other Aquacultural Products

The farmgate value for the aquatic plant and crustacean category was estimated at $2.2 million.

Aquatic plant production consists of ornamental plants, porphyria, and other forms of algae. Production of aquatic plants was identified in Maryland and Maine.

Crayfish production for the human consumption market is centered in Maryland, with additional production coming from Delaware. There are several growers in New York and Pennsylvania that produce crayfish for the baitfish market.

MANAGING EDITOR’S NOTE: The U.S. Food and Drug Administration (FDA), in order to assure the American public of truth-in-labeling in interstate seafood commerce, requires specific labeling of all aquacultural products. The FDA requested and received from the American Fisheries Society (AFS) a list of common names for all hybridized fishes used as seafood. That list (Robins et al. 1991, p. 108) also distinguishes hybrids depending on which parental species is the maternal partner. (In most cases, the maternal partner is the one with the larger eggs, since it is easy for a smaller sperm to enter a larger egg than vice versa.)

In this instance, “hybrid striped bass” refers to a hybridization of the striped bass (Morone saxatilus) and the white bass (M. chrysops). Assuming that the maternal partner is the larger striped bass, then the AFS’s name -- and the FDA’s approved labeling -- for this aquacultural product is “palmetto bass.” Throughout this report, it is assumed that “hybrid striped bass” refers to “palmetto bass.”

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SHELLFISH AQUACULTURE ON MARTHA'S VINEYARD

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INTRODUCTION

First, I should like to thank Carlos and Scott for scheduling this meeting. The timing is perfect to kick off our "Martha's Vineyard Private Aquaculture Initiative," an aquacultural training program funded under the NMFS Fishing Industry Grants Program. The 11 fishermen selected to participate in the training program are in the audience this morning.

I have been in the aquacultural business for over 20 yr and I feel comfortable using the term "explosive" to describe development in the industry over the past couple of years. Increased consumption of seafood in light of its dietary health benefits, combined with a decline in natural stocks, has resulted in price increases attractive to aquacultural development. Of the seafood readily available in local fish markets and supermarkets, much is now farmed. This includes Atlantic salmon, channel catfish, trout, prawns, and shrimp. The bivalve mollusks [northern quahogs, eastern oysters, bay scallops, and blue mussels (*Mytilus edulis*)] increasingly are advertised as "cultured." If anything that grows in water is not yet in commercial culture, it at least is being considered for aquaculture, and methods are being developed for its culture. The list runs the gamut from abalone, alligator, and baitfishes, through crayfishes, geoducks, lobsters, mahi mahi, pearl oysters, and ornamental seahorses, to seaweeds, sponges, scallops, and sturgeons.

INTERNATIONAL CONTEXT

Currently, aquaculture is labor intensive, which has favored its development in the third world. The Chinese have been especially successful adapting scallop culture techniques developed by the Japanese. These techniques include spat collectors, pearl nets, and lantern nets, and have been used to culture scallop species imported from the eastern coast of the United States. Starting with 26 broodstock bay scallop, the Chinese now control the major portion of the world's production of "our" bay scallop! Right here in Edgartown, Massachusetts, a recognized center of the bay scallop fishery, the local A&P supermarket features "Chinese bay scallops" for $3.99/lb retail. The fishermen here receive $7-8/lb for shucked meats of the same species of scallop, and suffer from the competition of the cheap foreign import. I have heard that a "good buck" can be made buying the Chinese product at $3.99 and mixing it with the local catch! But, I am sure that has been just wishful thinking. Clearly, the local product is fresher and superior, but the fact remains that there is local consumption of the cheaper cultured Chinese product.

In Chile, the same Japanese lantern net technology has been employed in a highly successful private venture. In operation less than a decade, this venture employs over 600 people, annually produces over 100 tons of scallop product, and has just been listed on the British stock exchange. Clearly, the third world is beating us at this part of the aquacultural game.

LOCAL OPERATIONS

However, within our region, especially on Cape Cod, some significant private aquaculture has developed. Karl Rask, who has championed the development of the private aquacultural industry on the cape, informs me that presently there are 111 operations, mostly 2- and 3-acre farms (the largest is 33 acres), producing a farmgate value of about $4 million. Northern quahogs are the number-one product, with eastern oysters a close second. There is a little production of softshells (*Mya arenaria*), blue mussels, and bay scallops. Vineyard waters are still essentially devoted to the wild fishery. However, we have been leaders in the development and application of aquacultural technology to the public management of our wild fisheries. For the past 18 yr, the Martha's Vineyard Shellfish Group, in cooperation with local town shellfish departments, has publicly cultured economically important, local species including northern quahogs, bay scallops, and eastern oysters.

Our public stock enhancement program includes the operation of a solar-assisted shellfish hatchery. The hatchery produced over 15 million seed shellfish last year. Hatchery production includes axenic culture of microscopic phytoplankton needed to feed developing shellfish. Small phytoplankton cultures are worked up into larger 18-l and 250-l cultures in the greenhouse at the hatchery. Once adequate algal food stocks are produced, broodstock shellfish are brought into the hatchery and spawned. When ripe, the quahogs, scallops, and oysters are treated to repeated thermal stimuli in the laboratory, mimicking changes in water temperature that elicit spawning in the natural environment. The great fecundity of shellfish (we average over a million eggs per female) makes these species excellent candidates for aquaculture. With adequate care and protection, the culturist can easily produce millions of shellfish. In the big picture of providing protein for a growing global human population, bivalves also score highly. Bivalves are herbivores, low on the food chain, and efficient producers of protein.

Fertilized eggs are counted, then cultured in filtered, heated seawater for the duration of the 2-3 wk swimming larval cycle. During this period, larvae are fed cultured phytoplankton daily. Every other day, culture tanks are drained, cleaned, and refilled with heated, filtered seawater. Shellfish larvae are sieved, culled, and suspended in the tanks. At the end of the larval cycle, shellfish absorb their swimming organs, develop a foot, and become a miniature version of the adult. After this metamorphosis, they are called juveniles. Juveniles are moved to flowing water systems. Our hatchery is located on a rich estuary with dense natural phytoplankton blooms. The plankton-rich water is pumped over the filter-feeding shellfish, so there is little need for additional feeding with costly cultured phytoplankton.

In the hatchery, quahog juveniles are grown on downweller sieves, and, eventually, in upweller silos. We have succeeded in moving seed as small as 1 mm to floating sandbox nursery trays that are suspended in the natural environment. As most predation on small quahogs is from nonswimming crabs, the survival rate is high in the floating nursery trays. The trays are largely inaccessible to the crawling crabs. From June, field culture continues until October when the quahog seed is ½-¾ inch in length. The seed then are broadcast in the natural public shellfish beds.

Very young juvenile scallops are similarly grown on downweller sieves in the hatchery. Larger scallop seed is grown to between 2 and 5 mm in raceways before being moved to floating field nursery cages. After about 2 mo under ideal conditions of temperature and low density, seed scallops attain a size of about ½ inch, and are broadcast into historically productive areas of the saltwater ponds.

Oyster larvae cement themselves to a substrate during metamorphosis. They are cultured using a method known as “remote setting.” Large hatcheries in the Pacific Northwest developed this method. At the end of the swimming stage, oyster larvae develop a distinctive “eyespot.” These “eyed” larvae are screened from culture vessels, wrapped in damp paper towels, and refrigerated overnight. They are then released over bags of oyster shell in tanks of aerated seawater at a site near the growout pond. Within a couple of days, the oyster larvae cement themselves to the shell, and the shellbags are hung from a raft in the saltwater pond. After about a month, the shellbags are emptied and the shell with attached oyster seed is planted on the pond bottom.

Breeding of genetic shell tags into hatchery stock helps to track survival and determine success of the stock enhancement program. After about a dozen years of serious hatchery production and seeding, some town shellfish constables report that 10-20% of the quahog harvest has brown “notata” shell markings. About 80% of our hatchery quahog production is tagged with the “notata” markings. This genetic trait was rare in the local population and harvest before the seeding program. Likewise, shell color variation can be used to mark bay scallops genetically. The Martha’s Vineyard Shellfish Group pioneered the use of shell coloration to tag the bay scallop. In 1979, we produced an “F_2” generation with 95% displaying distinctive orange shells. But when we found that the brightly colored, orange shells increased bird predation, we changed our tag to a striped pattern. Although still distinctive, the striped pattern may provide the shells some camouflage, thus protecting them from predators.

Predator control is a major factor in our ability to succeed. Local shellfish constables have established trapping programs for crabs and starfish. The Town of Edgartown initiated a bounty system and paid fishermen for predators they removed. No matter how successful our public aquacultural program has been, our limitations in manpower and funds prevent us from realizing the maximum yield possible from the island’s waters. Private aquacultural ventures, on the other hand, can do better. Indeed, private culture in Wellfleet, Massachusetts, using only 3% of the total bottom dedicated to shellfish aquaculture, out-produced the wild harvest from the remaining 97%.

It is the policy of the “Martha’s Vineyard Private Aquaculture Initiative” to encourage private aquaculture on the Vineyard. Encouragement consists of a program of education, training, and cooperative extension-like individual assistance. The Vineyard’s long history as a public fishery will be a constraint to private development. By contrast, it is interesting to note that much of the development on Cape Cod is in Wellfleet areas with a long history of private oyster leases. On the Vineyard, interest in aquaculture has heightened within the last year, as evidenced by an increase in the number of applications for shellfish culture leases. Much of the interest is from the fishing community which not that long ago considered aquaculture a threat to the public fishing areas and to marketplace competition. With their natural stocks declining and fishing areas closing, these same fishermen now see aquaculture as their next source of income. Another constraint to the Vineyard’s private aquacultural ventures is our high standard of living, accompanied by high labor cost and outrageously expensive waterfront property. Furthermore, our predominantly tourist economy also competes for use of our waters. Its concerns for aesthetics and for providing recreation pose additional obstacles to local development of aquaculture. On the positive side, the island’s popularity and bustling local restaurants can make any local aquacultural product a marketer’s dream.

Nantucket Island faces similar constraints and opportunities in developing aquaculture. We are encouraged by their innovative, “private-public,” cooperative program. Fishermen are employed in a private venture in public waters. The town provides them with seed and public bottom on which to culture seed. In return, they give the town half of their production. The town uses its half to seed public beds in order to enhance its stock. The Nantucket program may very well serve as a model for the Vineyard. Public stock enhancement efforts here lack the manpower to maximize the size and survival of publicly cultured seed. At the same time, many eager local aquaculturists cannot produce due to a lack of available aquacultural areas. Public-private cooperation could benefit all concerned.

STATUS OF SHELLFISH AQUACULTURE IN SOUTHEASTERN MASSACHUSETTS

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Although eastern oysters, to a degree, are cultured in southeastern Massachusetts, the overwhelming energy devoted to marine aquaculture in Massachusetts and elsewhere on the East Coast is to the culture of northern quahogs, also called littlenecks or hard clams.

BACKGROUND

Two quotes from the eminent treatise on the Massachusetts quahog industry, written in 1910 by Dr. David Belding, a biologist with the Massachusetts Department of Fisheries and Game, lend some perspective to the present discussion:

> *To the popular demand for the LittleNeck, can be attributed the rapid development of the quahog industry during the last ten years. This development has furnished employment for hundreds of men, and has given the quahog an important value as a seafood. What it will lead to is easily seen. The maximum production was passed a few years ago, constant overfishing caused by excessive demand is destroying the natural supply, and there will, in a few years, be practically no commercial fishery, unless measures are undertaken to increase the natural supply. Quahog farming offers the best solution at the present time, and gives the promise of permanent success.*
>
> *In the warm waters of coastal States in the south, where the quahog develops more rapidly, there are large areas which as yet have not suffered from the effects of overfishing, as has been the case with the northern beds in New England and New York, but it will be only a short time before the history of ruthless spoilation will be repeated, as already quahogs from the south are being shipped to the New England markets.*

Although total destruction of the northern quahog industry was given respite by a couple of world wars, a depression, and the eventual implementation of more stringent management regulations, Dr. Belding showed remarkable foresight. However, his anticipation and expectation regarding quahog farming were far in advance of the technology required to produce the quahog seed needed to farm quahogs.

The basic technology underlying controlled culture of marine shellfish was finally worked out at NMFS's Milford (Connecticut) Laboratory during the mid-1950s. From this work at Milford, the Aquacultural Research Corporation (ARC) and other companies along the East Coast were formed in an attempt to put this technology to commercial use. Although many companies succeeded in culturing the quahog, ARC was the first to achieve real commercial success. During the late 1970s and early 1980s, ARC achieved the levels of reliability and quantity needed for widespread quahog aquaculture.

PRESENT STATUS OF THE INDUSTRY

Since its commercial beginnings during the early 1980s, farming of quahogs on Cape Cod and in southeastern Massachusetts has developed from experimental plants into businesses that now form most or all of the incomes for more than 80 individuals and families. In the space of 8 yr, harvests of cultured littlenecks have increased from less then one million in 1986 to more than an estimated 14 million for 1994. The present quahog aquacultural industry is centered in Wellfleet where it began. Lesser segments of industry are in the Towns of Provincetown, Orleans, Yarmouth, Barnstable, Mashpee, Bourne, and Wareham. Other ventures still in the startup phase are beginning or planned for Martha's Vineyard, Brewster, Harwich, Westport, and possibly Chatham. In general, most of the industry continues to take place on intertidal flats on the north side of the cape, but increasingly, work is being done to utilize shallow-water sites on the south side of the cape.

Although increasingly successful, local quahog aquaculture is not a mature industry. In many respects, it is still a startup venture undergoing growing pains. One major problem is the inadequacy of the planted stocks that survive the vagaries of nature. At any particular site, it is often not enough to survive a few years in order to make a success of a quahog aquacultural venture. Many natural cycles of particularly severe weather occur infrequently and may not yet have been experienced, and therefore may not have been adequately guarded against. Natural biological cycles can result in sets of plants or animals that have the potential to smother and kill small quahogs rapidly. Examples are massive sets of potentially smothering macroalgae, such as codium, or large sets of animals, such as mussels, setting on protective netting. Many more subtle problems may not be recognized by a grower until the crop has been damaged. One of the hardest lessons for most aquaculturists to appreciate is that they must not lose a significant portion of a crop. Owing to the lengthy startup time needed to develop a harvestable crop, and the large initial investment in seed, gear, and labor, significant losses of stock can often be financially fatal to the typically undercapitalized aquaculturist.

When dealing with town regulating authorities, there may be conflicts with local shellfishermen, recreational groups, or environmental groups. Even though the industry is nearly 10-yr old and has proven to be totally beneficial and positive, we shellfish leaseholders, in general, and not just ARC, often encounter friction with other users of nearshore areas. I would like to address these problems, in particular, as they are the management issues that will most affect future growth of the industry in Massachusetts.

The industry involves the use of public "lease areas," a practice new to most towns, excepting Wellfleet which has a tradition of shellfish leases dating back hundreds of years. Often, local authorities are at a loss as to how to deal with applications for shellfish culture lease areas. They harbor many misconceptions in this regard. A general misconception is that leaseholders and/or towns need to be protected from large outside entities that somehow may take over the business from locals. This will never happen. Given the nature of the business, especially the fact that leased areas are often remote and totally unsecured, local control of leases by persons knowledgeable with that particular area will always be necessary. There is no evidence that leased areas will be overtaken by large corporations, either here or elsewhere. On the contrary, help from outside sources often can enable a new leaseholder to succeed by the use of joint efforts. Leasing of suitable sea bottom should be viewed as a highly desirable business development project within the towns.

Another misconception is that the success of shellfish aquaculture will be detrimental to the wild shellfishery. This has not proven true. If anything, local success of shellfish aquaculture has resulted in better prices for the wild shellfishery product. It has opened new markets, thereby increasing demand for both the cultured and the wild product. In any event, culture of littlenecks is not just a local phenomenon. Culture practices like those employed in Massachusetts are now widespread along the entire East Coast. Given the nature of the shellfish business, local wild shellfishermen are now in head-to-head competition with aquacultural products from New Jersey, Virginia, North and South Carolina, and Florida, whether they know it or not. This competition for markets will only increase in the future. The only way to retain some control over the local market price is to increase local production.

There has been speculation that, somehow, shellfish aquaculture might degrade the environment, either by physically harming the sea bottom or somehow harming the biological diversity of local ecosystems. I have as much experience as anyone in observing the long-term effects of shellfish aquaculture. For many of the same reasons as anyone else who cares about our environment and ecosystems, and because the natural environment gives me my livelihood, I am more objective about it than one might suppose. If we culturists should harm the overall balance of natural systems, we would tend to put ourselves out of business, for we depend upon these systems to nurture and grow our shellfish.

Shellfish aquaculture strictly benefits the marine environment. Over time, one sees that culture activities actually function in similar ways to those artificial oceanic reefs. The nets and cages actually promote all manner of life in and around them by providing temporary shelters for all kinds of juvenile marine plants and animals. All of our marine waters once held much higher levels of shellfish before man began to harvest them. Shellfish are filter feeders and remove both plankton and particulate matter from the water column. In doing so, they remove nutrients such as nitrogen and phosphorous from the marine system. No doubt, this benefits the modern marine environment which must deal with elevated loadings of nutrients as a result of man's activities upon the land and waters.

POTENTIAL FOR BLUE MUSSEL AQUACULTURE IN MASSACHUSETTS

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Within 50 yr, New Bedford will be the center of a blue mussel industry with annual revenues in excess of $200 million. Regardless of favorable or unfavorable government policies, the fundamental strengths of this region for mussel farming will combine with employment needed to create a vibrant mussel industry. New Bedford has a strong infrastructure for the processing, transportation, and marketing of seafood. The waters between Long Island and Boston can support many farms.

Mussel aquaculture is a billion-dollar industry in Europe, and also thrives in Asia. Our industry will resemble the European mussel industry, except that our mussel farming efforts will be more highly mechanized, and the industry in America will be oriented more towards processed mussel products. To present a view of our future, we take a look at the European industry.

Vigo in Galicia, Spain, is a large fishing and industrial port like New Bedford and Gloucester. The mussel industry of Vigo and neighboring cities annually generates perhaps $400 million. From the hills surrounding the harbor, it appears that the bays are filled with moored ships. These are in fact mussel-growing rafts. The entire Galician mussel industry is based on the very simple method of growing mussels on ropes suspended in the water. Machinery used on the rafts is very simple, as are some of the harvest ships. These farms support many gigantic factories, each larger than any New Bedford plant, and each with hundreds of employees. Vigo prides itself on being "the world capital of mussel farming."

Farther north, in a delightful example of European enthusiasm, there is another "world capital of mussel farming," this one being Charron in northern France. Visitors to Mont St. Michel will remember the extensive sand flats covered with each tide. This region of France supports another prosperous mussel industry. This industry is based on the technique of growing mussels on pilings placed in the flats. While the tide is out, trucks or tractors work the farms. When the tide is in, boats harvest and work the beds. We in New England can appreciate this method by observing how mussels grow on our dock pilings.

Not to be outdone, the Dutch city of Yerseke is another "capital of mussel farming." This industry is as large as that in Spain, and is based on the technique of "bottom farming." Small mussels are transplanted to privately leased areas. They are cultivated so that the meats are full and tender. The area yields abundant crops. There is an active auction for the harvest of each farming vessel. Of the 10 or so large mussel factories, interestingly, only one or two are still locally owned. Multinational corporations have purchased the rest. The harvest vessels are highly automated, as are the factories.

The North American industry is growing rapidly. The Canadian industry is strongly encouraged by government assistance and by the innovative work of many farmers in the Atlantic provinces. Focus has been on producing a uniform grade of fresh mussels which sell at fairly high prices, reflecting high labor inputs at the farm level. Focus of the Southern New England industry will be on producing higher tonnages cheaply from the farm, and utilizing factory labor to produce ready-to-eat products.

Mussel farming is simpler than most other types of aquaculture, which explains why mussels are so abundantly grown throughout the world. Mussels are pre-adapted to be successful in crowded conditions. Other species must be artificially fed and carefully managed to permit growth in dense concentrations. Mussels, however, grow naturally and rapidly in dense concentrations. In fact, that is their strategy for surviving predation and other challenges of their natural environment. Farming mussels has been likened, hypothetically, to farming of dandelions or crabgrass.

The seafood industry is following the path already taken by poultry. If one went to dinner several hundred years ago at a manor, one might be offered a wide range of birds: blackbirds in pies, partridges, sparrows, hens, ducks, geese, etc. These birds were all readily available. As human demand for birds increased, their availability became limited to the few species that were farmed. Similarly, people now eat many different varieties of fish, reflecting the diversity of species available. In the future, people will eat the few major species that are easily farmed, such as shrimp, salmon, and mussels. This pattern is already becoming evident. Regions like New Bedford that are blessed with productive waters, capable people, and the requisite infrastructure will eventually produce seafood tonnages dwarfing the catches we are now trying to recover. In the future, when it finally realizes its peak processing capacity, New Bedford will become a major industrial center of mussel aquaculture.

POTENTIAL FOR FINFISH CULTURE IN MASSACHUSETTS

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The following discussion is an attempt to provide a brief review of the status of the worldwide aquacultural industry, to review constraints to industry growth, and to describe how new controlled-environment aquacultural technology can assist in managing those constraints. Finally, a perspective on the potential for future growth of the Massachusetts aquacultural industry is presented.

AQUACULTURAL INDUSTRY CONTEXT

The decline of many traditional fisheries has been widely documented and has resulted in great hardship for many communities in Massachusetts and throughout the region. Worldwide catch has fallen consecutively for 4 yr, and many experts now believe that the maximum sustainable yield was reached a decade ago. The silver lining which surrounds this dark cloud is the opportunity to hasten development of aquaculture. Aquaculture should be viewed as a complementary partner to traditional capture fisheries as part of a long-term strategy to meet growing consumer demand through sustainable fisheries management.

It is surprising to many of us in the United States that virtually all growth in worldwide fishery production over the past decade has occurred as the result of aquaculture. A recent World Bank report indicates that global aquacultural production nearly doubled in the 9 yr between 1984 and 1993. During this period, fish farming increased from 12 to 22% of the value of the global fish harvest. Worldwide annual aquacultural farmgate value is now estimated to exceed $30 billion. The World Bank report concludes that this dramatic growth "signals the potential for aquaculture to capture half the value of the global fish harvest by 2010."

However, many aquacultural industry observers have speculated about the attainability of this growth and the potential for significant environmental damage. Additionally, given the U.S. protective environmental tradition, it is unclear to what extent the United States will be successful in increasing its share beyond the current 4%. Further development of the aquacultural industry is constrained by three principal factors: 1) environmental restrictions on use of land and water resources;
2) chronic production risks such as pollution, uncontrolled transmission of disease, algal blooms, and storm damage; and 3) market limitations related to high production costs, intermittent availability, variable quality, and lack of product diversity.

Development and recent commercialization of controlled-environment production systems are a landmark for the aquacultural industry. These systems have the potential to address successfully the environmental, social, and economic constraints to further development of the industry within New England. In addition, controlled-environment production has been shown to have a positive impact on growth rate, feed conversion, and mortality compared to traditional methods of production.

AQUAFUTURE, INC.

AquaFuture is an internationally recognized leader in development and commercialization of intensive recirculation systems. The company's development of recirculation technology began in 1982 at Hampshire College (Amherst, Massachusetts) with research on enhanced nitrification. AquaFuture was incorporated in 1987 and began by building a pilot plant for small-scale commercial production of tilapia and hybrid striped bass, integrated with hydroponic herbs and specialty greens. The company has been active in building on its core technology with research on fish genetics, nutrition, fish health, and production management information systems.

AquaFuture's patented water treatment technology brings a high degree of control to the fish farming process, dramatically reducing water consumption and feed requirements while significantly increasing growth rates. In 1992, AquaFuture completed a major expansion of its facilities. These facilities, in a single 1-acre building, today produce 1 million lb (450 metric tons) of fish per year. The company's management believes that this plant is unequaled anywhere in the aquacultural industry.

Faster growth, ability to thrive under intensive culture, efficient food conversion, and high fillet yield are among the desirable characteristics of a culturable species. Hybrid striped bass are relatively easy to produce as juveniles under extensive (pond) conditions, a factor which has facilitated the development of the farmed hybrid striped bass industry. The hybrid striped bass is produced by crossing the striped bass with its freshwater cousin, the white bass. The hybrid grows faster than either parent species, and thrives better under intensive culture.

AquaFuture has recently embarked on a new project to begin demonstration-scale commercial production of summer flounder (*Paralichthys dentatus*). The company is currently completing the permitting for the first vertically integrated facility in the United States dedicated to commercial production of this species. The facility will incorporate hatchery, growout, and processing functions. Summer flounder are a high-value marine fish for which recently imposed fishing quotas have severely limited supply and increased prices. Sales of summer flounder from the Quonset Point aquacultural project will be principally exported to Japan for sushi.

AquaFuture's project has received a $654,000 grant from NMFS to provide partial funding for the project. The project is designed with three principal objectives: 1) establish an entirely new industry in the region with significant potential for growth, export sales, and job creation (i.e., targeting 200 new jobs in 5 yr); 2) retrain displaced commercial fishermen in a sustainable method of fisheries production; and 3) develop a standardized regulatory roadmap for siting and permitting, easing future entry of fishermen and others into aquaculture.

OUTLOOK FOR MASSACHUSETTS

Because of the relatively high production cost of most aquacultural products versus those of traditional harvest, local aquaculture is not likely to be a significant source of raw materials for the state's processing sector in the near future. However, the emerging finfish aquacultural industry in Massachusetts has the potential to create significant numbers of meaningful jobs in coastal communities around the state, to generate significant export revenues, and to become an important new environmentally sustainable industry. Massachusetts aquaculture can benefit from linkages with the existing and undersupplied processing sector in developing new products, as well as with the emerging biotechnological industry. Production must adapt to a series of niche businesses, each targeting high-value domestic and export market opportunities.

Success in aquaculture depends on suitable siting (water quality and quantity, reasonably priced electricity, etc.), operator skill, an acceptable permitting process, and access to appropriately structured (i.e., patient) capital. Investment capital remains a major limitation; the state may need to play a more active role in providing financial assistance for development of this important and highly promising industry.

FINFISH CULTURE IN MASSACHUSETTS: A RESEARCHER'S PERSPECTIVE

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INTRODUCTION

As one considers fish culture in Massachusetts, the first impulse is to divide the topic by environment: freshwater versus saltwater, and -- within the marine environment -- the warmer waters south of Cape Cod versus the colder waters north of the cape. The fact that the cape serves as a boundary between two biogeographic provinces is both good news and bad news. The good news is that there is a wider variety of marine species that can be cultured in waters of two provinces (i.e., both warmwater and coldwater species). The bad news is that culturing species in waters near the limits of their ranges means that the waters may not be optimal for growing fish during some months of the year (i.e., too hot in summer for some, too cold in winter for others).

The culturist, therefore, needs to consider whether culture of particular species in Massachusetts' open waters makes sense from the standpoint of growth of the product (let alone regulatory problems). What are the major species that we need to consider? North of the cape, Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), Atlantic salmon, and Atlantic halibut (*Hippoglossus hippoglossus*) are actual or potential marine fish candidates. South of the cape, summer flounder and tautog (*Tautoga onitis*) are still just potential candidates at this point. In the freshwater environment, trout, hybrid striped bass, and tilapia are presently grown in Massachusetts.

ECONOMIC CONSIDERATIONS

As natural stocks of commercially important species decline, tremendous pressure will build to culture many of those species and to employ out-of-work fishermen in such culture. Several "reality checks" must be put into place in dealing with that pressure.

The first reality check is economics. Fish culture in Massachusetts will be (and is) expensive. Costs of land, labor, and regulatory issues are higher than they are "down south." By "down south," I mean the Delmarva peninsula, the Carolinas, and beyond to Latin America. The farther south one goes, the lower the costs for fish production. The Massachusetts fish culturist who produces a filleted product for the retail market may very well find that the market price for that species is actually determined by the supply from lower-cost southern producers. For example, it is by now well known that the price of Atlantic salmon in the United States is primarily determined by production in Chile. In order to be safe, the culturist should try to produce a product whose price cannot be determined by Latin American competitors. One product that foreign growers cannot economically export to the United States is live fish for the Asian market, so production for that market ought to be high on the list for examination by anyone wishing to enter the Massachusetts finfish culture industry.

The second "reality check" regards the number of jobs created in an aquacultural venture, and, more specifically, how many of those jobs might be filled by unemployed fishermen. I am aware of a few companies in which about one-to-two-dozen people can produce approximately 1 million lb of fish per year. While many of those jobs might be performed by former fishermen, several require specific training or skills not likely to be possessed by fishermen.

TECHNICAL CONSIDERATIONS

Technical issues in finfish culture fall into two basic areas: biological and engineering. Biological issues may be subdivided into hatchery-phase aspects and growout aspects. In the hatchery phase, broodstock fish must be managed in such a way that eggs can be obtained as often as possible, preferably throughout the year. If the goal of the operation is to bring a consistent product to market throughout the year, then a consistent supply of eggs should be going into the production pipeline. For commercially important marine fish species, rearing of larvae into juveniles is often the "bottleneck" because of high mortality associated with that stage (even in natural oceanic populations). Growth of sea bass, sea bream, cod, turbot, and halibut industries in Europe required solution of many problems (e.g., food, nutritional requirements, swim bladder inflation, etc.) in the hatchery phase. Once the fish move to the growout phase (including a "nursery" phase for hatchery-to-growout transition), focus of problems usually shifts to nutrition, disease, and system operation (including effluent management). Growout phase is the most expensive and risky. Feed costs usually account for about one-half of production costs, and the growout period usually takes more than 1 yr.

Engineering issues can also be subdivided; in this case, into those associated with coastal net-pen facilities and those associated with land-based, flow-through or recirculation facilities. Net-pen facilities require mechanical engineering expertise, so that pens can withstand physical stresses of an ocean environment. Recirculation facilities require chemical or process engineering expertise, so that proper water chemistry can be maintained through the production tanks and biological filters.

For reasons mentioned above, especially water temperature and regulatory problems in the coastal environment, I believe that the soundest strategy for finfish culture in Massachusetts is development of land-based recirculation systems. The high-tech, high-(fish)-density, aquacultural system developed at AquaFuture, Inc., in Turners Falls is a model for aquaculture's success. According to the owners, they can produce as much hybrid striped bass in a 45,000-ft^2 facility as is produced in 400 acres of farm ponds "down south." If New England aquaculturists are to succeed, they need to develop appropriate technologies (including development of new hybrids or genetically improved species) for a high land cost, high labor cost, difficult regulatory environment.

Beginning in 1990, the Universities of Rhode Island and Massachusetts collaborated to demonstrate that summer flounder exhibited potential for commercial aquaculture in a land-based recirculation system. This high-value species can be induced to spawn throughout the year with hormonal injections, larvae can be raised using techniques similar to those for turbot in Europe, and fish can grow to about 10 inches within the first year of life and to market size within 2 yr. Although research on this species continues, a Northeast Fishing Industry Grant has assured that a commercial-scale demonstration project will begin this year and will likely create a new industry, since interest from the private sector is high.

CONCLUSIONS

U.S. agriculture owes its success in large part to government-conducted and government-funded research, followed up with technology transfer to the private sector via a strong cooperative extension service. In New England, we are currently in the research phase and entering the technology transfer phase. NMFS is to be lauded for its support of research in culture of commercially important species. The USDA and states must now ensure that the New England cooperative extension network is adequate to the task of serving the fastest-growing, food-producing sector of the U.S. economy -- aquaculture.

DISEASE CONTROL AND ENVIRONMENTAL IMPACTS OF MARINE AQUACULTURE

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INTRODUCTION

The culture of finfishes and shellfishes in U.S. marine and estuarine waters has grown rapidly in the past two decades. Recent declines in major commercial fish stocks have spawned interest in further expanding coastal and offshore aquacultural operations. Culture, maintenance, and movement of finfishes and shellfishes by humans have a history of thousands of years, but only in recent decades has there been much intensive culture of marine species. Intensive marine culture operations now are common in several areas of the world, providing an opportunity to examine the successes and failures of intensive aquacultural development.

The following discussion draws on experience and research conducted primarily in Scandinavia, Britain, Asia, and North America, as a basis for discussing real and potential impacts of marine aquaculture. This is not a comprehensive review of the voluminous literature on environmental impacts of aquaculture, but, rather, an introduction for local decisionmakers to key issues surrounding aquacultural development of coastal areas.

DISEASE AND ITS CONTROL IN AQUACULTURE

Diseases occur in wild as well as in cultured animals, and can be divided into two basic groups: 1) infectious diseases caused by viruses, bacteria, or parasites; and 2) noninfectious diseases caused by toxic substances, improper nutrition, poor water quality, physical damage, or genetics.

Infectious diseases are of major concern in aquaculture because of their effects on production and of their potential impact on wild populations. Outbreaks of disease in finfish culture facilities and shellfish hatcheries typically are caused by opportunistic pathogens that are widely distributed in nature, but have both a low prevalence and low intensity of infections in wild populations. Stress of confinement decreases resistance, and high density of culture situations facilitates transmission of infectious agents; both contribute to onset and progression of disease.

Absolute prevention of disease in aquaculture is possible technically, but rarely achieved in practice, particularly in high-density, commercial culture systems. Recent development of specific, pathogen-free shrimp broodstock, for example, may be substantially ahead of the ability of shrimp farmers to keep their facilities free of all pathogens. Vaccines are an important means of preventing disease, and recent advances in vaccine development have greatly decreased prevalence of bacterial disease in finfish culture.

Since stress of culturing marine organisms at high stocking densities contributes substantially to onset of disease, control of disease becomes important to success of production. Some progress has been made in development of specific disease-resistant strains of cultured species, and in studies on the effect of proper nutrition on disease resistance. For the most part, however, control of disease in aquaculture relies upon good husbandry and drug treatment. Husbandry is the only method of control for adult mollusks (Bower et al. 1994). Drug treatment has been the subject of much attention as a potential source of drug residues in food products and the environment. Drug treatment will be discussed later.

ENVIRONMENTAL IMPACTS OF MARINE AQUACULTURE

There is much published information on effects of aquaculture on the environment. What is presented here is an introduction to some of the concerns surrounding development of aquaculture. It becomes evident when reviewing the literature that intensive culture of finfishes or shellfishes in shallow or poorly flushed coastal areas is a “recipe” for problems.

Physical Impacts

Construction of aquacultural facilities, as with industrial development of other types, can have consequences for the physical environment. In Southeast Asia, construction of shrimp ponds has destroyed thousands of acres of mangrove habitat. U.S. federal and state regulations, however, limit potential adverse effects of coastal and wetlands development, including development for aquaculture.

Changes in the environment may be less obvious when effects are below the water surface. Alteration of water flow has been reported in Europe and Asia where highly intensive culture of mollusks is done on racks or poles. Under these conditions, vertical arrays of mollusks act as a wall, altering natural flows of water. Modifying water flow affects deposition and movement of sediments such that wastes accumulate beneath the racks more rapidly than if the “walls” did not exist; erosional areas develop where previously there were none (Pillay 1992). Adequate spacing of structures vertically arranged in the water column minimizes such effects.

Physical placement of marine culture facilities may conflict with other users of the marine environment, such as commercial and recreational fishermen, boaters, and those seeking aesthetics of the undisturbed beauty of nature.

Impacts from Solid Wastes

In ponds and systems with inadequate flushing, extensive waste accumulates beneath cultured finfishes and shellfishes raised off bottom, and leads to significant physical, chemical, and biological changes to the environment. Solid wastes, consisting of excrement and unconsumed food, alter granularity of sediment, resulting in a fine silty consistency that is less likely to disperse than larger-grained material. This alteration of bottom habitat leads to changes in natural bottom-dwelling organisms. A decrease in diversity and abundance of benthic species has been reported beneath intensive finfish cultures, particularly at sites accumulating more than 20 cm of waste (Weston 1989; Kupka-Hansen et al. 1991). But in well-flushed, less-intensive culture situations, there appears to be a biostimulation of bottom-dwelling species (Churchill, pers. comm.[1]).

Microbial decomposition of organic-rich waste consumes oxygen. If waste accumulation is extensive, the demand for oxygen will be extremely high and can lead to anoxia and to generation of hydrogen sulfide and methane gases. Local anoxia has been reported in Japan in shallow bays where there is intensive mussel and oyster culturing (Nose 1985), and low oxygen levels have been reported beneath intensive net-pen culture of salmonids in Europe (Kupka-Hansen et al. 1991). These conditions are reversible, and crop rotation, bottom harrowing, and leaving areas fallow are some practices utilized to mitigate them.

Turbidity is a measure of solid material suspended in water. Turbidity of local waters may be increased when water is discharged during harvest of pond-raised shrimps and finfishes. Minor changes in harvest practices, such as allowing a waiting period after harvest before discharging water, can greatly reduce the input of sediment-laden water into neighboring waterways.

Impacts from Chemicals

Numerous chemicals have been used in aquaculture to deal with pests, predators, fouling organisms, parasites, and diseases. A chemical used might be considerable in amount, depending on type and intensity of culture, and the extent of impact of the chemical is associated with how it is used (e.g., antibiotics or vitamins as feed additives, antifouling agents in constructional materials, or chemicals broadcast through the water).

Antibiotics are used in finfish and shrimp culture. This has raised considerable concern regarding their persistence in the environment, the development of antibiotic-resistant strains of wild bacteria, and the presence of residues of antibiotics in the cultured food product. Most research has been directed at salmonid net-pen culture where extensive use of antibiotics has resulted in accumulation of drugs in sediments in the vicinity of culture sites. However, studies have shown that after 30 days, oxytetracycline (the most commonly used drug) is bound to sediment in an inactive state (Samuelson et al. 1994). Antibiotic-resistant strains of bacteria have been isolated from sediments near fish culture facilities, but resistance may be as short-lived as 9 days (Austin 1985). With recent development of effective inexpensive vaccines, use of antibiotics in fish culture has declined precipitously, and soon should become a nonissue. Norway has experienced a 73% reduction in use of antibiotics in salmonid culture, and salmon farmers in the United States have had similar experiences. The FDA regulates use of drugs in animals cultured for human consumption. Antibiotics accumulate in tissues of treated animals, and thus may pose a risk to human health. Therefore, FDA requires a period of nontreatment before marketing to allow drugs to dissipate from tissues.

Several chemicals have been approved by the FDA for use in aquaculture to treat external fungal and parasitic infestations. Some of them, like hydrogen peroxide and garlic, are household items. In Europe, treatment of salmonids with organophosphate chemicals to control sea lice infestations showed negative effects on nontarget organisms within 25 m (80 ft) of the net-pens (Egidius and Moster 1987). Use of local, cleaner wrasse fishes and a natural insecticide extracted from a flower are being investigated as alternative control methods. Furthermore, management practices such as maximizing distance between sites, avoiding overlap of generations on farms, and allowing regular fallow periods help alleviate the problem.

Chemicals used as antifouling agents to treat equipment and constructional materials can have substantial effects on cultured or wild marine organisms. Tributyltin, used in antifouling paint, has been implicated as the cause of major reproductive failures and deformities in mollusks in Europe and the United States. As a consequence, its use has been greatly restricted in many countries. Copper-based antifouling agents are used commonly and have shown limited local effects.

Water Quality Impacts

Additions of nutrients, particularly nitrogen and phosphorus, to the environment are a concern because of the potential for these elements to trigger algal blooms. Intensive culture of finfishes and shrimps can contribute substantial amounts of nitrogen to the environment through addition of uneaten feed (only 20% of nitrogen in feed enters the fish) and metabolic waste in the form of ammonia. Algal blooms, however, are more relevant to lake systems rather than to open well-flushed environments where dilution occurs.

Blooms of toxic algae are another issue, as they may affect marine organisms as well as pose a human health risk. Correlations between toxic algal blooms and aquaculture were reported from Japan where mollusks were intensively cultured in poorly flushed embayments (Nose 1985). Such blooms have not been reported in association with finfish farms.

Impacts on Wild Stocks

Threats to wild stocks by aquaculture include disease transferred from cultured to wild stocks, genetic interactions and dilution of the wild gene pool, and competition or predation by escapees. Despite even the best efforts to prevent them, escapes from culture systems still result from accidents and natural disasters. Hatchery-reared or cultured organisms tend toward limited genetic variability and may introduce “weak” genes into the wild gene pool through interbreeding. This is a growing issue as more riverine salmon populations become classified as endangered. Hundreds of thousands of cultured salmonids have escaped from net-pens in Norway over the past decade and no genetic impact has been reported as yet. Reducing the potential for genetic impact could include increasing the number of broodstock to keep genetic variability high, using only sterile finfish in culture, or rearing local finfishes.

Serious problems in aquaculture arise when finfishes or shellfishes and their associated pathogens are introduced to an area inhabited by previously unexposed, susceptible wild populations. This has been the case with transfer of marine mollusks and crustaceans, nationally and internationally, which resulted in wide dissemination of several serious pathogens of oysters and shrimps (Farley 1992; Lightner et al. 1992). The possibility of transferring pathogens from cultured finfishes to wild finfishes has been studied in Britain, and research showed low prevalence of the pathogen studied and no sign of disease in wild stocks (Phillips et al. 1985). However, a recent study in Norway suggests that escapes of infected finfishes, along with transfer and natural movement of finfishes, have contributed to the spread of disease into wild stocks (Johnsen and Jensen 1994). More commonly, though, the impact of disease is on cultured species. Guidelines to minimize disease-based and parasitic interactions between cultured and wild stocks have been established on regional, national, and international levels, and include steps to reduce introduction of diseases when fish are moved to new areas. The only U.S. program requiring disease inspection of imported finfishes deals with freshwater salmonids. Although many states have agreements on interstate movement of finfishes and shellfishes, no federal disease inspection is required for interstate movement of marine organisms.

Environmental Benefits

Most often, discussions about environmental effects of aquaculture are negative, although beneficial effects exist aside from seafood production and economic gain. Mollusk culture makes several positive contributions to the environment. Shell rubble collecting beneath mollusk culture structures helps to stabilize bottom sediments, serves as a surface for spat settlement, and may provide shelter for small invertebrates.

Mollusks, being filter feeders, filter the water of phytoplankton, thus counteracting algal growth. This phenomenon has been exploited in polycultural systems in Israel and other countries, where nutrient-rich wastewater from finfish culture tanks is used to grow algae on which oysters feed. Cultured macroalgae (i.e., large algae such as kelp) and other aquatic plants remove nutrients from the environment, thereby limiting the potential for algal blooms resulting from overenrichment by nitrogen and phosphorus.

Open-water mollusk culture also may enhance natural sets by broadcasting spawn into open water, causing settlements to occur outside the culture site. Finfish culture decreases fishing pressure on wild stocks, and, as mentioned earlier, may increase biodiversity in benthic communities beneath some net-pen systems. Wild finfishes and large crustaceans tend towards densities that are higher around cages than in surrounding areas.

CONCLUSIONS

At present, environmental impacts from marine aquaculture in the United States are few and tend to be localized, although the potential for greater impacts exists. Many potential threats to the environment can be avoided or minimized by thoughtful planning of locations for culture sites, and of culture-carrying capacity of local environments. Some recently developed environmental models are based on the method, species, and biomass of a culture, as well as hydrographical and water quality conditions of proposed culture sites. These models may be useful to planners in considering areas for intensive aquacultural development.

ENDNOTE

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USER CONFLICTS -- CAN AQUACULTURE EXIST WHILE GUARANTEEING PUBLIC RIGHTS?

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BACKGROUND

Public rights which need to be protected when aquaculture is contemplated are known as the public trust doctrine (PTD). The PTD is a common-law concept which has been upheld in varying forms by courts across the country. The PTD gives states title to land under navigable waters and tidally affected land. These lands are held in trust for the public. To protect access for all, the trust restricts, but does not generally prohibit, exclusive use of trust property. Any exclusive use (including aquaculture) of trust lands typically requires a lease from the state. The process of leasing trust lands varies from state to state, as does the cost of leasing.

In Massachusetts, the Massachusetts Department of Environmental Protection (MDEP) is “landlord” for submerged trust lands under regulatory authority of Chapter 91. To date, MDEP has not taken jurisdiction over most aquacultural projects because they are considered temporary moored facilities, and are not generally an exclusive use. A few aquacultural projects have received 10A permits (under Chapter 91) which are issued free by the harbormaster on a year-by-year basis. The 10A permit is only valid for moored facilities. MDEP regulations do not directly address aquaculture, although they may soon be re-evaluating this issue in light of the recent surge in interest in marine aquaculture. Under the present administration of Chapter 91, the only way that an aquaculturist could obtain an exclusive long-term license to an area is to apply for a Chapter 91 license which entails a detailed application, environmental review, and assessment of a license fee. In exchange, the applicant obtains a 30-yr (renewable) license. No aquacultural proponent has applied for a Chapter 91 license to date.

Other states use different systems to handle their submerged lands under the PTD. Some have no leasing structure, relying on taxes from aquaculture (or any other use of trust lands) to meet their obligations under the doctrine. Others have moderate leasing fees to cover attendant costs of environmental monitoring and administration. States like Washington with high leasing fees appraise their submerged lands as a percentage of the value of the adjacent upland. On this basis, they realize a substantial revenue which they use for public education, facilities for public access, removal of derelict shoreline structures, restoration of wild shellfish beds, and marine recreation. Consequently, everyone can see benefits flowing directly from private use of trusted lands, and, therefore, everyone is more likely to accept development of aquaculture. Massachusetts is now assessing its current policy to determine how best to strike a balance among various interests involved in leasing of trusted lands for aquacultural use. The state recognizes that it must temper promotion of aquaculture, a desirable economic endeavor, with various public and private concerns and rights, including environmental protection.

USER CONFLICTS AND SITING ISSUES

User conflicts are one of the major obstacles to development of aquaculture in Massachusetts. These conflicts may vary somewhat from site to site, and from one type of aquaculture to another, but they are common worldwide. The conflicts change somewhat depending on the relative location within the Exclusive Economic Zone, whether it is intertidal or subtidal. In the intertidal area of Massachusetts, most aquaculture today is bottom culture, and, therefore, user conflicts are minimized in some ways. Conflicts are largely aesthetic, and are most apparent at extreme low tide when culture facilities are visible and leaseholders are tending their shellfish. Off-road-vehicle access to leaseholds is another conflict, particularly when access runs over private property, whether upland or tideland. Conflicts with intertidal leaseholders also occur if they involve a loss or restriction of recreational activity.

User conflicts change somewhat as aquacultural activities move offshore to subtidal, state-owned, nearshore waters. Culturing techniques here are more exclusive in nature, generally either water-column culture or pen culture. These types of culture are usually incompatible with other uses of the same site, and user conflicts are more direct. Some conflicts included here are associated with navigation, recreation, fishing gear, and endangered species. When aquaculture is sited in federal waters (i.e., waters beyond the 3-mi limit), conflicts involve navigation (even submarine routes!), commercial shipping, and commercial fisheries. Because the ocean is a limited public resource, there is a need to balance conflicting uses and to reach a consensus on an acceptable mix. Good public policy demands that conflicts involving use of public lands and properties be resolved considering the rights of all interested parties.

Conflicting uses and aquacultural siting issues are not, of course, unique to Massachusetts. Many areas of the world have dealt with these issues. Massachusetts is in a good position to adapt lessons learned elsewhere. Some of these lessons are:

1. **Planning** -- Rather than evaluating a potential aquacultural site only after it appears in a proposal, towns, counties, and states should proactively plan such sites using the "harbor planning" process to map them.

2. **Structure/Gear Design** -- Design the orientation, distance from shore, color, and amount of vertical structures so as to reduce aesthetic conflicts. Use mobile gear, cage culture, or marina culture to reduce exclusive use of an area, and provide flexibility for the culturist to move gear in response to seasonal fisheries, water quality, etc. Placing gear entirely underwater and tending it with remotely operated vehicles are options being considered by a prospective culturist in Chatham. This approach will avoid aesthetic conflicts.

3. **Determination of Priority Uses** -- The State of Washington has a policy that clearly gives preference to aquaculture when there is competition for use of state waters. The policy also says that the state's interest in aquaculture outweighs any local interest.

4. **Education** -- Aquaculture is a new industry in Massachusetts, and most of the citizenry do not understand it. Lack of public knowledge about it and its impacts has resulted in sometimes unnecessary controversy over siting and leasing. Public education of waterfront owners, municipal and state decisionmakers, and school children will go far in familiarizing people with realities of aquaculture. Better understanding should bring greater public acceptance. Use of citizen advisory groups to facilitate siting is an approach that has proven successful at the local level in Nova Scotia. They found that meetings between prospective culturists and community representatives often smoothly resolved otherwise contentious siting issues.

The bottom line for much of the aquacultural siting issue is the realization of priorities for use of limited space. In areas such as Asia and South America, where large-scale aquaculture has been successful, people are voracious seafood consumers who recognize the vital need to allocate space for food production. Recreational use of waters is not a high priority. Another important consideration is the level of government control over decisionmaking. These countries generally have centralized governments with limited municipal-level decisionmaking. In Massachusetts, of course, the situation is just the opposite where aquaculture is concerned. We have strong democratic traditions and do not favor large exclusive uses of our public waters.

MASSACHUSETTS AQUACULTURAL INITIATIVE

The Massachusetts Coastal Zone Management Office (MCZM) has drafted the document, "Marine Aquaculture White Paper," now available for public review. It characterizes the marine aquacultural industry in Massachusetts, and identifies some problems.

The MCZM has formed three working groups, "Environmental Review," "Regulatory Reform," and "Economic Development," to develop state strategies that encourage marine aquaculture while protecting the environment and the rights of public and private property. The MCZM expects that by late spring 1995 it will finalize these strategies, drafting them into another document, "Aquaculture Strategic Plan," for the state.

THE REVOLVING LOAN FUND: ITS APPLICABILITY TO AQUACULTURAL PROJECTS

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The South Eastern Economic Development Corporation (SEED) was established in 1982 as a "Chapter 180" nonprofit corporation to help finance small businesses. Although small businesses create most new jobs in this country, they have a difficult time obtaining financing. This is especially true for small businesses with little collateral and an operating history shorter than 3 yr.

SEED's first step was to obtain a certification from the U.S. Small Business Administration (SBA) to package loans under the "SBA 504 Program." SEED also packages "SBA 7A" guaranteed loans on behalf of local banks and small business clients. In addition to the SBA programs which might be of assistance to some of you, SEED also runs three "Revolving Loan Fund Programs," a "Micro Loan Program," and an "Enterprise Fund Program."

The "Fisheries Adjustment Revolving Loan Fund" was established last year when the U.S. Economic Development Administration made a $500,000 grant that passed to SEED through the Massachusetts Executive Office of Economic Affairs. Purpose of the grant was to alleviate economic distress relating to loss of fishery jobs. SEED covers all of southeastern Massachusetts with this fund, including the Counties of Bristol, Plymouth, Barnstable, Dukes, and Nantucket, but not the City of New Bedford which runs its own program.

The major goal of this fund is to create long-term job opportunities for workers displaced from the fishing industry. Under this fund, SEED provides loans up to $100,000 that can be used as the downpayment on a larger project. The SEED portion of the project is generally 30% or less, although in cases where there is a financing gap, SEED's portion can be larger. The interest rate is generally below prime and fixed for the term. SEED's last loan rates were 8.5% fixed. The loan term is generally 5 yr, although SEED can defer principal payments, amortize over longer periods, or establish seasonal schedules as needed. Loan funds may be used for business real estate, boat construction or repair, equipment and furnishings, or working capital. Aquacultural businesses, lobstermen, and shellfishermen received some of the loans under this fund. SEED can accommodate special needs of the aquacultural industry by making repayment terms very flexible during the first year, and by allowing the client to repay the loan from other sources of income. SEED approves loans on a monthly basis, but can approve small loans more quickly in an emergency.

THE NORTHEAST FISHERIES ASSISTANCE PROGRAM AND FISHING INDUSTRY GRANTS

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BACKGROUND

In March 1994, Ronald Brown, Secretary of the U.S. Department of Commerce, announced the federal appropriation of $30 million to aid the struggling fishing industry in the Northeast. Eighteen million dollars went to the Economic Development Administration for technical assistance purposes and for low-interest loans, and $12 million went to NMFS. Breakdown of the NMFS allocation was as follows: 1) $9 million for the Fishing Industry Grant (FIG) Program, 2) $1 million for fishing vessel obligation guarantees, 3) $1 million for administrative costs, and 4) $1 million for development of six fishing family assistance centers (FACs).

FISHING FAMILY ASSISTANCE CENTERS

The FACs are located in Portland and Rockland, Maine, in Gloucester, Chatham, and New Bedford, Massachusetts, and in Narragansett, Rhode Island. The Rockland and Narragansett offices are mobile and cover large areas. Due to newness of the program and the rapidly changing nature of the industry, duties of the staff are still evolving. Generally, staff have identified tractable problems and have developed remedial programs. For example, to overcome the unfamiliarity with grant proposal writing, all assistance centers have held well-attended, well-received workshops and seminars.

The FACs' services to fishermen and their families at present are largely extensional and educational. These services include: 1) general information; 2) referral to various agencies for loans, education, food and heating assistance, funding for new business startup, etc.; 3) guidance in development of grant proposals; 4) relief and retraining programs conducted with other local entities such as industry cooperatives and Sea Grant offices; and 5) media communication to disseminate information regarding government and other programs.

The FACs utilize existing resources to define, advertise, and implement certain programs and policies, and act as real, face-to-face extensions of the federal government. By offering personal counseling and service, they put the human element back in the relationship between the government and the fishing industry. Recently, there has been a considerable amount of interest, media attention, and criticism surrounding the grants program. Identifying criticisms and offering constructive advice have also been an important FAC activity.

FISHING INDUSTRY GRANT PROGRAM

The FIG Program was delivered under two solicitations, each for $4.5 million. Unlike loans, grants need not be refunded. Typical of other grant programs, this one involves the review of proposals, awarding of funds, project evaluation, and reporting.

There have been many ideas about what the grants program was supposed to achieve, and many misconceptions. Most importantly, the program does not offer instant gratification. There have been requests to draft a program similar to Canada's. In response to closure of its cod fisheries, Canada pays its fishermen, in effect, unemployment compensation. The FIG Program does not provide such immediate financial assistance. It is, however, a means to stimulate ideas for new business opportunities, new processing technology, and fishery development. These ideas should increase diversity of the industry, and help to retain and create jobs.

Today, diversity is an especially important issue in New Bedford. New Bedford has been a “traditional” port, fishing for traditional species, using traditional methods, and selling well-established products in traditional markets. Now, not only is domestic supply obviously changing, but so is the marketplace. Diversity, therefore, is vital to the future of the New Bedford seafood industry. Perceived benefits, in light of the need for diversity, of the FIG Program include: 1) stimulating new businesses and/or processes which would translate to jobs; 2) providing an opportunity to examine propositions which are risky and otherwise might not be tried; 3) stimulating ideas; 4) fostering productive exchanges between science and industry; and 5) familiarizing applicants with development of business plans, a necessary first step in capital formation for companies of any size. Perceived drawbacks include: 1) not providing instant gratification; 2) requiring grant writing, a complicated process foreign to many in the fishing industry; 3) requiring facility with language that is greater than normal for fishermen, compounding the strangeness of the proposal process for them; and 4) requiring reporting, another task that can present writing problems similar to those of the grant proposal.

While FAC staff cannot change the nature of the program, such as the time it takes to process applications, they can help to overcome difficulties encountered concerning writing of proposals and reports. They commonly spend time privately discussing proposals with applicants, performing general reviews of various documents, presenting workshops on proposal development, answering questions, and providing referral to qualified, professional grant writers.

HOW AQUACULTURE FARED IN “ROUND ONE” GRANTS

Twenty-eight projects were funded in the first round of FIG. The nine projects that concerned aquaculture received over $2 million of the funds available, individually ranging from $40,000 to over $650,000.

It is noteworthy that FIG aquacultural projects are still subject to any permits that are required by town, state, or federal agencies. Simply receiving funding does not preclude the need for all appropriate permits. However, since the permitting process is lengthy, use of a “NMFS Experimental Permit” has been suggested. Further, since these permits have limited duration, if towns were to employ an experimental permit as a substitute for “normal” town permits, there would be an opportunity to make detailed assessments of projects at very limited risk. As projects progressed, towns would become better equipped to make educated decisions about any future work, and could develop equitable iterative solutions to problems as encountered.

CONCLUSIONS

The Northeast fishing industry is in great need of alternatives to traditional activities. Current fishing regulations promote attrition of individuals from industry, rather than an “all-or-nothing” effect. Part-time ventures, such as tending an intertidal lease site, could provide some needed employment, with possible transition to full-time nonfishing employment. The FIG Program provides funding for risky ventures in a tight economy.

Exchange and examination of ideas are the most important aspects in the relationship between the aquacultural industry and the grants program. It is imperative that ideas flourish in order for the fishing industry and the region’s economy to survive. This fisheries crisis is inherently one of extreme and rapid change. The Fishing Industry Grant Program provides one door of opportunity to an industry that genuinely requires alternatives.

AQUACULTURAL POLICY: FORMULATION AND IMPLEMENTATION

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INTRODUCTION

The Policy Center for Marine Biosciences and Technology was established in 1992 to address a broad range of problems and opportunities raised by recent developments in marine biosciences. It is concerned that the United States insufficiently applies many recent developments that offer potential economic and social benefit. It is a center "without walls," providing a forum for everyone concerned with marine issues. Its work entails: 1) defining relevant issues; 2) identifying gaps in scientific knowledge; 3) targeting audiences in need of specific information and producing informational packages aimed at their needs; and 4) recommending legislative action to appropriate local, state, and federal policymakers.

The Policy Center stresses effective communication, and provides a credible forum for deriving sound public policy in the growing area of marine regulations. Its offices are at the University of Massachusetts-Dartmouth, the Marine Biological Laboratory in Woods Hole, and the Kennedy School of Government in Cambridge. These institutions are dedicated to both science and public service. By having offices there, the Policy Center has access, free of typical institutional constraints, to a variety of individual talents and organizational strengths. The Policy Center involves scientists, government institutions, environmental experts, and public interest groups as active partners in shaping public policy.

In summer 1993, at the Marine Biological Laboratory, the Policy Center held its first conference, "Aquaculture and the Marine Environment: the Shaping of Public Policy." The purpose was to explore public perceptions about marine aquaculture, assemble relevant facts surrounding these perceptions, and examine resulting impacts. The topic was of interest and concern to the public, and could produce scientific information to assist public policymakers. A number of organizations interested in marine aquaculture sponsored the conference. Participants represented government, academia, industry, research institutes, and public interest organizations. Recommendations that emerged from that conference are relevant to this symposium.

AQUACULTURE'S ROLE IN THE ECONOMICS OF COASTAL COMMUNITIES

Consensus of the conferees was that marine aquaculturists should promise coastal communities no more than what might be accomplished at their current stage of development. However, coastal communities should factor aquaculture into their economic development planning, and bring their needs to the attention of federal and state decisionmakers.

For crafting legislation to provide or create opportunities for economically viable aquaculture, communities need to know about their aquacultural options and how to obtain the mix of sizes and types of aquaculture that will be socioeconomically compatible. Conferees made the following recommendations:

1. State and federal governments should include aquaculture in economic development planning. State aquacultural coordinators might identify existing mechanisms, such as coastal zone management plans or planning councils, to help local governments integrate aquaculture with economic development.

2. The federal government should mandate, by statute, the Joint Subcommittee on Aquaculture's recommendation that participating departments and agencies of the federal government give priority to, and rapidly develop, national aquacultural strategies that the U.S. Congress can assemble into law.

3. Governments should convince lease site applicants of the necessity to address the public trust issue. Applicants should be able to justify clearly and forthrightly why a community should allow them to use public resources for commercial purposes. Governments should assist applicants by compiling descriptions of successful aquacultural projects and ways in which the projects benefitted their communities.

4. The Joint Subcommittee on Aquaculture should determine how aquacultural marine industrial parks could be started. Such parks would foster aquacultural innovation and new businesses. They might receive blanket permits, eliminating the need for new permit applications for every new lease site. The central purpose of such parks would be to reduce startup costs.

STRATEGIES FOR SHAPING PUBLIC POLICY

Strategies to shape public policy in support of marine aquacultural development should be based on a clear understanding of: 1) which key individuals, interest groups, and agencies should receive information and recommendations; 2) kinds of information most appropriate for intended audiences; 3) and the most effective means of communicating relevant information and recommendations to intended recipients. In recommending local, state, regional, and national fostering of marine aquaculture, policy planners should include guidelines for, and examples of, successful planning and development, including marine aquacultural industrial parks.

Governments, industries, and universities, in partnership, should be the pre-eminent planners of marine aquacultural development in coastal states. Coordinators should work closely with their state coastal zone management offices and local communities, encouraging them to include aquaculture in their plans. States should designate a leading agency for aquacultural development. Aquacultural planning should be strongly linked to long-term environmental and economic planning.

Federal Government

The federal government should designate a lead agency that works with the Joint Subcommittee on Aquaculture. This agency should clarify and publish the role of all federal agencies dealing with marine aquaculture.

The federal government should review and modify existing regulations and procedures so that they include aquaculture. Most existing regulations and procedures for protecting the environment preceded the emergence of aquaculture.

The federal government should create a government-industry-university roundtable on aquaculture. This roundtable would advise the Joint Subcommittee on Aquaculture and the leading aquacultural agency on all matters of mutual interest, including research and product development.

Both houses of the U.S. Congress will probably introduce bills governing aquaculture this year. Therefore, it is important that congressional committees be well informed beforehand. The Joint Subcommittee on Aquaculture asked the congressional Office of Technology Assessment (OTA) to make a study of domestic aquaculture. Members of the Policy Center have been involved in a number of OTA's study reports which are currently under review.

The OTA also asked the Policy Center to investigate successes and failures in domestic aquaculture in order to develop options for federal involvement. In its report, "Factors Contributing to Success and Failure in the U.S. Aquaculture Industry," the Policy Center identified the findings and recommendations listed in Table 1.

Table 1. Findings and recommendations of the Policy Center for Marine Biosciences and Technology for federal involvement to help the U.S. aquacultural industry

Factors Limiting Producer Success

1. Outdated and cumbersome regulations
2. Inadequate marketing efforts
3. Disease and lack of approved drugs
4. Lack of capital (i.e., grants, loans, and subsidies)

Desirable Goals for Improvement

1. Firm state and federal support
2. Friendly regulatory environment
3. One-stop permitting
4. Well-defined, consistent public policy
5. More capital for development
6. More research on culture methods and biology

Priority Policy Options for Federal Actions

1. Revise environmental regulations to accommodate aquaculture
2. Streamline permitting process
3. Facilitate siting of aquacultural operations
4. Provide capital for aquacultural operations
5. Expedite review and approval of drugs for disease treatment
6. Educate public about real benefits and risks of aquaculture

Recommendations for Government Assistance

1. Provide general support and information
2. Provide funding for research
3. Develop consistent regulations
4. Provide more capital
5. Streamline permitting process
6. Promote public acceptance and marketing assistance
7. Work for pollution abatement
8. Treat aquaculture like agriculture
9. Educate regulators about aquaculture

Local Government

Local government should be more aware of potential benefits of marine aquaculture, and of the case studies of successes and failures in aquaculture. The case studies will help them to understand the governing regulatory, economic, environmental, and social factors.

Local government should devise a "one-stop" permitting process managed by a facilitator with practical experience, and should study the feasibility of marine parks as initial sites for aquaculture. They should issue one-time permits for the site, rather than subsequently issue permits to every individual entrepreneur.

Scientific Community

The scientific community should encourage and assist scientists to engage in research and technology -- from basic to applied -- relevant to aquaculture. It should also perform additional research in a variety of fields, including population genetics, hybrid fish behavior, and ecosystem dynamics.

AQUACULTURE IN MASSACHUSETTS

That Massachusetts needs to address issues about aquaculture has never been more evident. The local and national press have reported the crisis in our fisheries, the need to create new jobs, the promise of aquaculture, and the state's unique resources in marine biology.

For a sharper focus, the Policy Center made a case study on the use of sea scallops (*Placopecten magellanicus*) for aquaculture in Massachusetts. The study identified opportunities for, and critical deterrents to, development of aquaculture. It addressed regulatory problems, and prepared educational materials for regulators, practitioners, and the general public. Those problems and prosed solutions are summarized in Table 2.

This is an exciting period for Massachusetts. Both federal and state governments are re-examining the role of aquaculture. They are greatly interested in activities that can harm the sensitive marine environment, such as waste treatment, and in policy issues involving environmental protection and economic development. They need a clarification of issues; they need to know about critical gaps in scientific knowledge; and they need to find out what kinds of regulations are appropriate. They also need a consensus among environmentalists, scientists, coastal industries, and coastal community officials concerning the issues. Of critical importance is the communication between the industry, the public, and local, state, and federal officials whose decisions affect aquaculture. The public is best served when policy is based on sound, scientific information and a broad consensus.

Table 2. Problems and proposed solutions for reducing impediments to sea scallop aquaculture in Massachusetts

Problem	Proposed Solutions
Unclear regulatory jurisdiction	Create aquacultural category, develop process for state and federal interagency coordination, and devise coordinated government strategy for development of oceans Take regional approach to federal policy Study approaches in other countries Address and change role of regional fishery management councils over aquaculture, and allow states to coordinate aquacultural zones and management outside of councils Regulate scallop aquaculture through agriculture and farm bureau, not NOAA Create "permitting flow chart" for potential scallop farmers
Need more research and development in all aspects of cultivating and harvesting	Create special state and federal zones, and manage management plans for aquacultural experiments Close some scallop beds and reserve them for aquacultural use
Shortage of capital for entrepreneurs	Provide more start-up capital; broadcast examples of successes, especially of fishermen switching to aquaculture
Very few identified aquacultural sites	Federal government should identify and monitor sites in federal waters Develop policy between federal and state legislative support for siting
Education needs for entrepreneurs, regulators, and investors	Develop extension service for aquaculture (e.g., in Massachusetts Department of Food and Agriculture) Create and distribute education materials
Biological barriers to growing scallops	Consider other species, such as small clams that may be more appropriate due to growth rate Use existing recombinant DNA techniques to mitigate genetic escape from cultured stocks
Wastes from shells and processing	Develop cogeneration of products and waste material
Gear regulations do not make sense	Develop consistency in regulation of gear (e.g., cages accepted for lobsters but not for scallops) Require structural adequacy of aquacultural gear
Little support for new aquacultural opportunities	Develop clear means of evaluating proposals for new aquacultural effort, with criteria for scoring
Conflict between fishing and aquaculture	Develop comanagement between aquaculture and fishing Develop better tracking technology to avoid conflicts with lobstering Separate boat time for aquacultural work from restrictions on boat time for harvesting/fishing

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