PECONIC BAY SYSTEM: AQUACULTURE

Submitted to:

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Table of Contents

List of Figures and Tables

Figure **Page**

Table

PREFACE

This reference document serves as the aquaculture sub-section for Phase II of a four-phase series of economic studies being conducted by Economic Analysis, Inc., for the Peconic Estuary Program. It provides an evaluation of the history, current status, and potential for aquaculture in the Peconic Bay System (PBS).

The major sections include:

- Background of aquaculture production in the world, U.S.A., Northeast U.S.A., New York, and the Peconic Estuary.

  According to the FAO, world aquaculture production has grown 179 percent over the 10 year period (1984-1994) and now accounts for 19 percent of the world's seafood supply. The U.S. produces approximately 3 percent of world production, primarily catfish, and the Northeast U.S. ($162.4 million) accounts for about 15 percent of U.S. production.

- A brief history of aquaculture production in the PBS.

  Shellfish aquaculture production in the estuary began in the 1840s, and, by the late 1800s, much of the Great South Bay was sectioned into parcels and leased to private oyster growers. The industry has experienced turbulent times over the last 150 years. It is currently coming out of a downward production trend, and harvests are expected to increase over the next five years. Private and public aquaculture production in the PBS is valued at approximately $4.1 million (the majority of the production is from transplant/relay operations).

- Opportunities and impediments to aquaculture production in the PBS.

  There is renewed interest in aquaculture throughout the region. Local fishermen are learning a new trade through programs initiated by Greg Rivara of Cornell Cooperative Extension and Suffolk County Marine Environmental Learning Center, scientists are perfecting aquatic reproduction techniques, and entrepreneurs such as Mariculture Technologies are answering the call to increase the edible seafood supply. Opportunities for growth in the PBS potentially exist for oysters, scallops, clams, and several species of finfish. However, as the PBS population continues to grow, a variety of different use conflicts (land, water, waterway rights, etc.) may hinder future growth.

- Recommendations for improving the viability of aquaculture in the region while maintaining environmental integrity.

Further analysis needs to be completed to examine the benefit-cost of aquaculture on the environment, the economy, and enhancement possibilities.

- Appendices:

Appendices A and B describe species that have aquaculture potential in the PBS and provide a classification of culture systems and technologies.

BACKGROUND

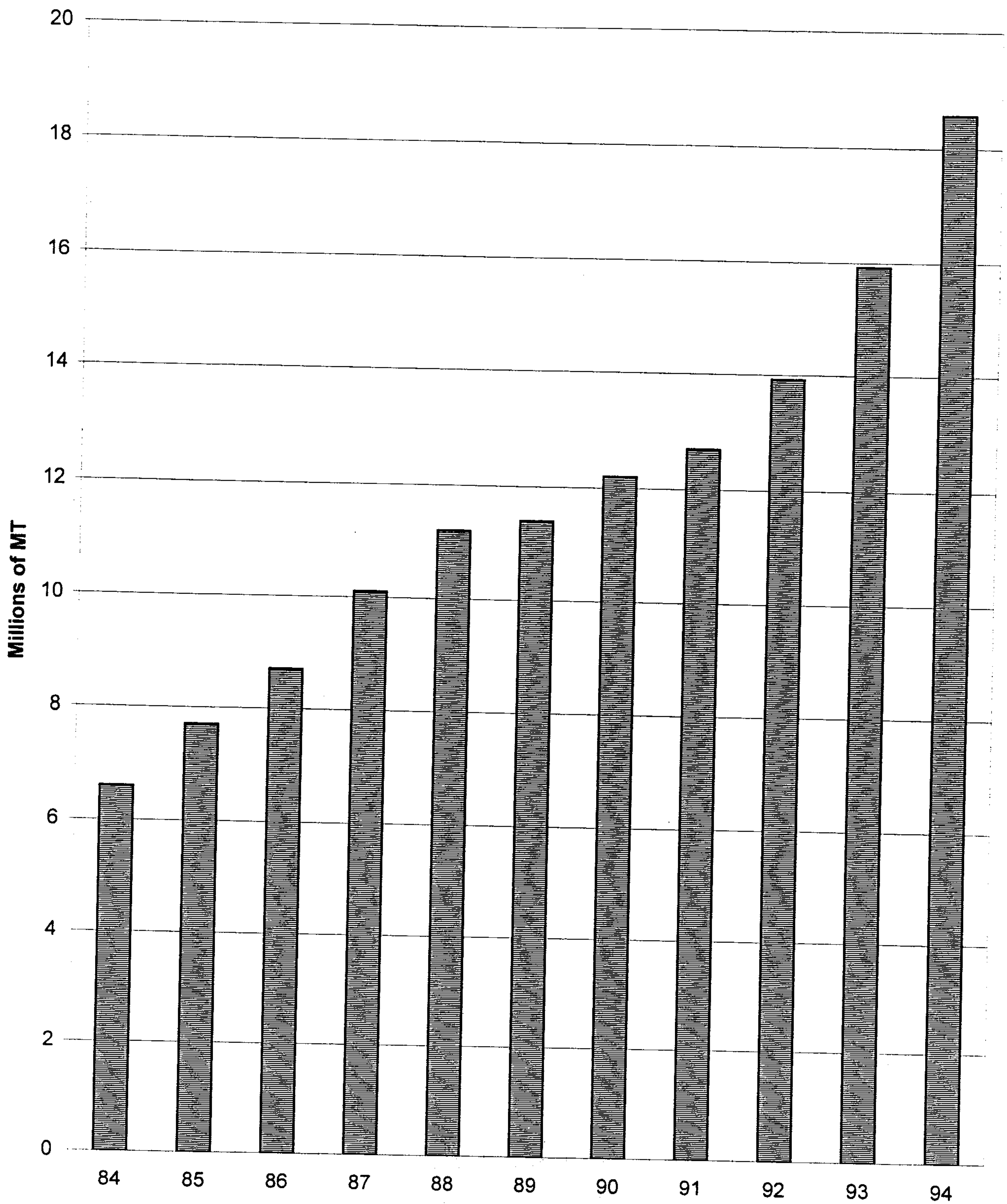
World commercial fishery harvests have been relatively stable since 1988, ranging between 100.3 million metric tons (MT) in 1989 and 101.3 million MT in 1993 (Food and Agriculture Association of the United Nations [FAO], 1995). However, FAO estimates 1994 world catch at a record 109.6 million MT (FAO, 1996).

Global aquaculture production has reached new record highs. Between 1984 and 1994 (the most recent year for which data is available), world aquaculture of fish and shellfish (excluding aquatic plants) increased 179 percent--from 6.66 million MT to 18.56 million MT (Figure 1). With the inclusion of aquatic plants, 1994 aquaculture production was 25.50 million MT, valued at $40.0 billion (*Fish Farming International*, 1996). It is estimated that total production currently accounts for nearly 19 percent of world supply (FAO, 1996). However, this may be an understatement of the total impact of aquaculture, since this figure does not include enhancement of fish stocks, such as hatchery releases from the salmon fishery.

In 1993, finfish (primarily carp, catfish, trout, and salmon) accounted for 49.3 percent of total world aquaculture harvest and 53.0 percent of its value. Crustaceans (primarily shrimp) accounted for only 4.1 percent of harvest, but 16.4 percent of value. Molluscs (primarily oysters, mussels, and clams) accounted for 18.2 percent of harvest and 12.5 percent of value. Finally, aquatic plants accounted for virtually all of the remainder (FAO, 1995).

Aquaculture is particularly significant for many of the high-valued species. For example, in 1980, salmon raised in net pens accounted for less than 1 percent of the world salmon harvest. However, by 1991, farmed, net-pen production exceeded the production of all salmon catch in the U.S. ocean fisheries (including Alaska), and, by 1994, world net-pen salmon production accounted for 36 percent of world salmon supply (Anderson, 1994; FAO, 1996). Currently, more

Figure 1. World Aquaculture Production (excluding aquatic plants)



Source: 1984-1993: FAO
1994: Fish Farming International, 1996

than half of the fresh and frozen salmon consumed in the U.S. comes from farmed production (primarily from Canada and Chile). A similar situation exists for shrimp. In 1985, shrimp aquaculture production accounted for less than 10 percent of global supply. By 1993, it had grown to almost 35 percent of world supply (FAO, 1996). It is estimated that over 50 percent of U.S. shrimp imports are comprised of farmed shrimp grown in Thailand, Ecuador, China, and elsewhere (USDC, 1996). In addition, the bulk of trout, catfish, and oysters are also derived from aquaculture (FAO, 1996).

Although world commercial catch levels have remained relatively stable, many U.S. fish stocks are harvested at levels in excess of maximum sustainable yields. Therefore, many experts expect wild harvest declines. In the Northeastern U.S., Atlantic cod, haddock, yellowtail flounder, winter flounder, summer flounder, American plaice, scup, sea scallops, and Atlantic salmon are some of the fisheries considered to be overexploited (USDC, 1995). Partially because of depleted fish stocks, the U.S. imported over $6.7 billion of edible seafood in 1995 (USDC, 1995), contributing substantially to the nation's seafood trade deficit. Yet, despite a vast coastline and significant water resources, the U.S. accounts for only around 2 percent of world aquaculture production (FAO, 1996).

The dominant aquaculture industry in the U.S. is catfish. Its production has grown from 46.4 million pounds in 1980, to an estimated 470-480 million pounds in 1996, with a farm-gate value of $366 million (USDA, 1996). In 1994, U.S. farmed catfish production was approximately eight times the entire volume of the New York fishery harvest and more than six times the ex-vessel value. In contrast to catfish, farmed, food-sized trout, the nation's oldest finfish aquaculture sector, has experienced a slight decline in production, from 56.8 million pounds in 1990 to 53.6 million pounds in 1996. During the same period, revenue declined more than 13.5 percent, from $64.6 million in 1990 to $56.9 million in 1996 (USDA, 1996). The decline may be due, in part, to competition from salmon, catfish, and tilapia.

Another growing aquaculture sector in the U.S. is ocean net-pen salmon (mostly Atlantic salmon [*Salmon salar*]), grown primarily in Washington and Maine. Production has more than tripled, from about 10 million pounds in 1990, to 33.5 million pounds in 1995, when it was valued at approximately $79.8 million (USDA, 1996; Anderson and Bettencourt, 1992; Spatz *et al.*, 1996; and Churchill, 1996).

In addition to catfish, salmon, and trout, there are emerging operations for many other finfish species. Some of the most promising are hybrid striped bass, tilapia, sturgeon, baitfish (well established in the South, led by Arkansas), ornamentals (well established in Florida), red drum, and carp. Additional experimental and small-scale operations include species such as pacu, mahi mahi, cod, summer flounder, winter flounder, Atlantic halibut, haddock, eel, Arctic char, and several game fish.

Among shellfish and crustaceans, oysters are the dominant aquacultured shellfish, and crawfish the dominant crustacean. In recent years, U.S. farmed crawfish and oyster production has experienced declines.

Production is difficult to measure in the molluscan, shellfish, and crawfish aquaculture industries. One reason is the poor aquaculture data collection system in the U.S. In addition, oysters, clams, mussels, and crawfish are aquacultured using a wide array of technologies, ranging from intensive containment systems to extensive transplant and seed-stocking programs. Despite these measurement problems, in 1993 it was estimated that the West Coast produced 86.0 million pounds (primarily oysters), valued at nearly $46 million (Chew and Toba, 1995), and, in 1995, the Northeast produced over one million bushels (primarily oysters and Northern quahogs), valued at $78.1 million (Spatz, *et al.*, 1996, revised). In Louisiana, 1989 private oyster production was approximately 9.1 million pounds, valued at $20.4 million (Roberts and Keithly, 1993).

The clam, primarily the Northern quahog (*Mercenaria mercenaria),* aquaculture industry is still relatively undeveloped in the U.S. However, clam aquaculture is growing in the Southeast and Pacific Northwest. In Florida, South Carolina, and Virginia, there are substantial hard clam operations. The value of Florida's clam aquaculture grew 358 percent from $1.18 million in 1991 to $5.41 million in 1995, and Virginia's 1993 estimated clam sales were over $11 million (USDA, 1996; *Aquaculture*, 1994). In 1995, Florida Agriculture Statistics Services projected that 142 individuals were actively growing clams. Over the next two years, 65 new growers are expected to begin operation (Florida Department of Agriculture, 1996). The Project *W.A.V.E.* (Withlacooche Aquaculture Vocational Education) program, developed by the Harbor Branch Oceanographic Institution, Ft. Pierce, FL, and funded by The Florida Department of Labor and Employment Security provides clam aquaculture training for 49 displaced net fishermen from five rural Florida counties. Upon completion of the program, each graduate will have grown and harvested a crop of 50,000 clams, initiated nursery operations for a new crop, and received a two-acre lease on which to transfer their equipment and seed clams (HBOI, 1996).

One large South Carolina firm, Atlantic LittleNeck ClamFarms (ALC), has over 3,000 acres of leased growout area and had expected production to be 100 million clams per year with potential value of $20 million by 1995 (Aiken, 1993). However, Atlantic LittleNeck ClamFarms has not yet realized these ambitious goals and is currently experiencing financial difficulty. If they are eventually successful, this level would exceed the entire annual New York harvest of quahogs experienced in recent years.

There is also a significant Manila clam (*Venerupis japonica*) culture industry developing in Washington.

Other molluscs being aquacultured in the U.S. include blue mussels (*Mytilus edulis*) (Maine, Alaska, California, and Washington), bay scallops (*Argopecten irradians*), rock scallops (*Crassadoma gigantea*), abalone, soft shell clams (*Mya arenaria*), Western littlenecks (*Protothaca staminea*), and butter clams (*Saxidomus giganteus*). United States farmed mussel production peaked during 1985-1987 at around 6 million pounds, but in 1992 it declined to 1.4 million pounds--only 2.8 percent of the U.S. mussel harvest (Brooks, 1994).

Crawfish aquaculture is also significant in the U.S. Production is concentrated in Louisiana's Atchalfalaya Basin; however, there are small operations elsewhere, such as in Maryland and New York.

Although there is an enormous farmed shrimp sector abroad, the U.S. has only minimal production of marine shrimp (primarily white shrimp [*Penaeus* sp.]), located in South Carolina, Hawaii, and Texas. Other crustacean culture being attempted is the freshwater shrimp (*Macrobrachium* sp.) and the Australian red claw crawfish (*Cherax quadricarinatus*).

There is a viable alligator farming industry in the South (primarily in Louisiana and Florida). Also, aquatic plants (such as *Spirulina* and *Dunneliella*), aquarium plants, and aquatic plants for wetlands restoration are being cultured, primarily in Hawaii, Alaska, Florida, and California (Chew and Toba, 1993).

THE NORTHEASTERN UNITED STATES

In 1995, the total value of aquaculture in the Northeastern U.S. (from West Virginia and Maryland, north through New England) was estimated to be $164.2 million (Spatz, *et al.*, 1996, revised). The breakdown, by value, is illustrated in Figure 2. The dominant aquacultured species raised in the Northeast are salmon, led by Maine, and oysters, led by Connecticut. Table 1 further illustrates the breakdown by state. In 1995, the top five producing states in the region were Connecticut, Maine, Pennsylvania, Massachusetts, and Maryland. New York's production was the sixth highest in the region at $5.7[1] million. This is a decline from $9.6 million in 1992. This production decline is almost entirely attributed to a drop in oyster production. Production of oysters declined 60 percent between 1992 and 1995 (NYDEC, various years).

[1] Note: New York production does not include transplant/relay hard clams.

Table 1

1992-1995 Estimated Northeast U.S. Private Aquaculture Production by State (1)

State	1992 Farm Gate Value	1994 Farm Gate Value	1995 Farm Gate Value	Dominant Species	Other Major Species
Connecticut (2)	$61,752,000	$55,558,000	$61,881,000	Oyster	1. Northern Quahog
					2. Trout
					3. Baitfish/Other Fish
Delaware (3)	$235,000	$1,085,000	$1,161,000	Northern Quahog	1. Tilapia
					2. Hybrid Striped Bass
					3. Trout
					4. Crayfish
					5. Baitfish/Other fish
Maine (4)	$42,896,000	$37,731,000	$55,207,000	Salmon/Steelhead	1. Oyster
					2. Baitfish/Other Fish
					3. Mussels
					4. Northern Quahog
					5. Aquatic Plants
					6. Trout
Maryland (5) ***	$7,661,000	$8,335,000	$11,032,000	Ornamental Fish	1. Aquatic Plants
					2. Hybrid Striped Bass
					3. Oyster
					4. Trout
					5. Baitfish/Other Fish
					6. Tilapia
					7. Crayfish
Massachusetts (6)	$8,019,000	$7,941,000	$8,622,000	Northern Quahog	1. Oyster
					2. Trout
					3. Hybrid Striped Bass
					4. Scallops
					5. Baitfish/Other Fish
					6. Tilapia
New Hampshire (7)	$756,000	$800,000	$810,000	Trout	1. Baitfish/Other Fish
					2. Salmon Smolt
New Jersey (8)	$2,398,000	$3,997,000	$4,926,000	Northern Quahog	1. Trout
					2. Baitfish/Other Fish
					3. Oyster
					4. Hybrid Striped Bass
New York (9)	$9,637,000	$3,858,000	$5,682,000	Oyster	1. Northern Quahog
					2. Trout
					3. Baitfish/Other Fish
					4. Salmon Smolt
Pennsylvania (10)	$11,926,000	$14,079,000	$13,795,000	Trout	1. Ornamental Fish
					2. Hybrid Striped Bass
					3. Baitfish/Other Fish
Rhode Island	$239,000	$51,000	$83,000	Oyster	1. Northern Quahog
Vermont (11)	$331,000	$300,000	$324,000	Trout	1. Baitfish/Other Fish
West Virginia (12)	$290,000	$518,000	$724,000	Trout	1. Baitfish/Other Fish
					2. Hybrid Striped Bass
Total Northeast**	$146,409,000	$134,252,000	$164,248,000		

* CT Shellfish in 1995 is computed using 1994 production multiplied by the estimated increases in 1995 from survey respondents.

** Totals may not sum due to rounding.

***The Aquaculture office of the Maryland Department of Agriculture reports farm gate value in 1992 of $12.8 million and $16.8 million in 1994. MD Dept. of Ag. farm gate value estimate includes soft shell crabs which are not included here. The use of different farm gate prices may also add to the disparity in estimates.

(1) 1992: Bush & Anderson (1993); Other estimates are based upon surveys unless otherwise noted

(2) CT DEP, 1995

(3) Ewart, 1995

(4) Churchill, 1996; Dietrich and Hastings, 1995

(5) MD Dept. of Ag., 1995

(6) MCZM, 1995; Rask, 1995

(7) Smith, 1995

(8) Canzonier, 1995

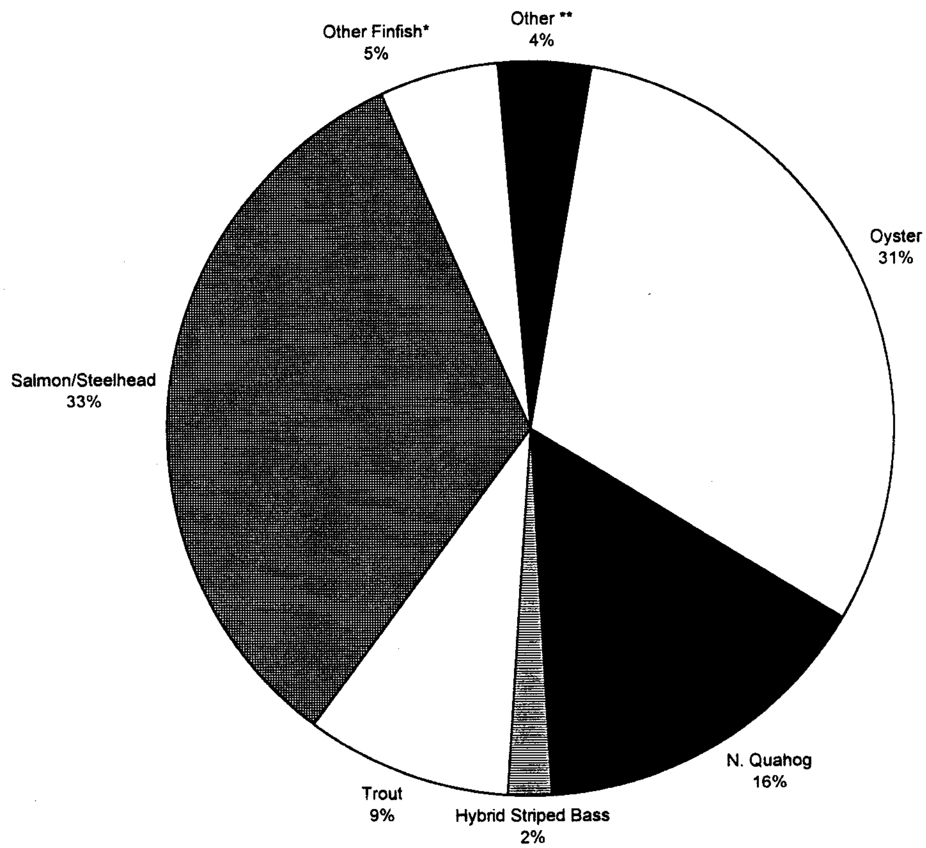
(9) NY DEC, 1996; USDA, 1995; Note: This figure does not include transplant/relay hard clams.

(10) USDA, 1995; Dunne, 1995

(11) Coleman, 1995

(12) WV Dept. of Ag., 1995

Figure 2. 1995 Northeast Aquaculture Production - Farm Gate Value $164,248,000 (est.)



* Other Finfish: Tilapia, Catfish, Ornamental, Baitfish, Bass, Carp, Crappie, Perch, and Other Fish.
** Other: Other Shellfish, Aquatic Plants, Crayfish.

Source: Spatz *et al*., 1996.

AQUACULTURE PRODUCTION IN NEW YORK

New York is a major producer of wild fish and shellfish in the U.S. It has also been a player in aquaculture production for over 100 years. Aquaculture has developed through the work of shellfishermen on Long Island and finfish aquaculturists upstate. Producers in New York grow a variety of species including oysters, hard clams, trout (stocking and foodfish), baitfish (golden shiners, crayfish), yellow perch, walleye, grass carp, bighead carp, triploid carp, largemouth bass, and perch.

Freshwater finfish culture in New York, as in other parts of the U.S., developed in the mid-1800s to supplement wild stocks. In 1859, Stephen H. Ainsworth of West Bloomfield, NY, was one of the first to begin hatching brook trout as a hobby. However, in 1864, Seth Green of Caledonia, NY, realized that trout farming was both practical and profitable, and, by 1868, Green stated his profits to be $10,000 (Benson, 1970). By 1870, over 200 individuals were practicing fish culture for profit or as a hobby, and Seth Green was supplying many of them with the eggs and fry (Benson, 1970). Recreational fishing was also of interest. In 1867, William Nichols of Long Island was operating a fee fishing pond, and it is said to have earned $2,500 in fishing fees (Benson, 1970).

The Long Island oyster industry began thriving in the 1600s when they were harvested for local consumption. However, by the early 1800s, many of the natural beds were completely depleted. In the 1840s, oystermen began experimenting with oyster planting in Great South Bay in an attempt to revive the industry. By 1849, it was a successful project, and the town of Brookhaven began to issue bay bottom leases for oyster planting. By the late 1800s, much of the Great South Bay bottom was sectioned into parcels and leased to private oyster growers. At the turn of the century, Long Island Sound oyster meat production was estimated at over 10,000 MT annually, with approximately 1,000 men utilizing 450 vessels (Koppelman, 1979). In comparison, Connecticut had 88,000 acres of farmed shellfish beds and an oyster crop of about 10,000 MT in 1890 (Volk, 1987). At their pinnacle of production, Rhode Island oyster plots employed up to 1,500 people and produced more than 6,800 MT of product per year (Rice, 1994).

In 1923, two oystermen on Long Island developed a method for algae production, the Wells-Glancy method. This technique helped in the development of captive oyster spawning. A modified version of this technique, the Milford Method, is still used today.

In the 1930s and 1940s, oyster beds in New York, Connecticut, and Rhode Island became unproductive, and there is some uncertainty surrounding the exact cause. A strong possibility is that the 1938 hurricane shifted sediment and silt over prime oyster beds. This, coupled with the spread of pollution and poor spat (young oyster) production in Long Island Sound, quite possibly contributed to the decimation of this once profitable industry.

Mariculture in New York has been stagnant for the past 15 years. Two large companies in western Long Island that have existed for over 100 years dominate the bottom culture clam and oyster industries. Another form of aquaculture, shellfish relaying, is now more prevalent than it was in the past. In 1994, about one-third of New York's hard clam production was from relaying (Barnes, 1996). Relaying involves the transplant of shellfish from uncertified waters into clean waters for depuration. After a standardized time period, the shellfish can be harvested and sold. The relaying program has resulted in the creation of "pre-marketing" jobs and sales. It is also estimated that, in 1989, the transfer program resulted in initial wholesale sales of $10-16 million (Barnes *et al.*, 1991). Most of the relaying takes place between Raritan Bay, off of Staten Island, to sites in the Peconic Bay System (PBS). Barnes (1996) estimates 56,000 bushels of hard clams will be transplanted in 1996. This is a significant increase from 36,000 bushels in 1995. The target transplant will be around 50,000 bushels per year over the next few years. However, this will depend upon natural conditions (Barnes, 1996).

PRODUCTION IN THE PECONIC BAY SYSTEM

The PBS system encompasses 109,416 acres of underwater land bordering the five eastern towns in Suffolk County (Riverhead, Southold, East Hampton, Southampton, and Brookhaven).

Current regional shellfish production is depicted in Figures 3-6. In 1995, shellfish production was valued at approximately \$4.6 million (NYDEC, various years). Of this, hard clams, the majority of which are transplanted, accounted for 94 percent of total landed shellfish value. As seen in Figure 4, 1995 oyster production (mostly aquacultured) was worth about \$18,870. In 1995, it accounted for 2 percent of the total value of harvest in the PBS and about 1 percent of New York State oyster production. This is a tremendous decline from an estimated value of \$1.2 million in 1984 and over \$3 million in 1980 and 1981. Prior to the decimation of scallop stocks due to the occurrence of brown algae blooms in 1985 and 1986, the PBS typically accounted for about one-quarter of the total U.S. bay scallop harvest. In 1995, the PBS accounted for about 33 percent of the value of U.S. bay scallop landings. Bay scallop production was valued at about \$172,000 (21,528 pounds) in 1995 (Figure 5). This is a dramatic increase from no production in 1988. However, in 1994, PBS bay scallop production increased 10 times to 232,004 pounds and was valued at \$1.5 million. This is more in line with the 1966-1986 average annual PBS production of 271,000 pounds (Koppleman, 1979).

Figure 3. Landings of Hard Clams in the Peconic Bay System

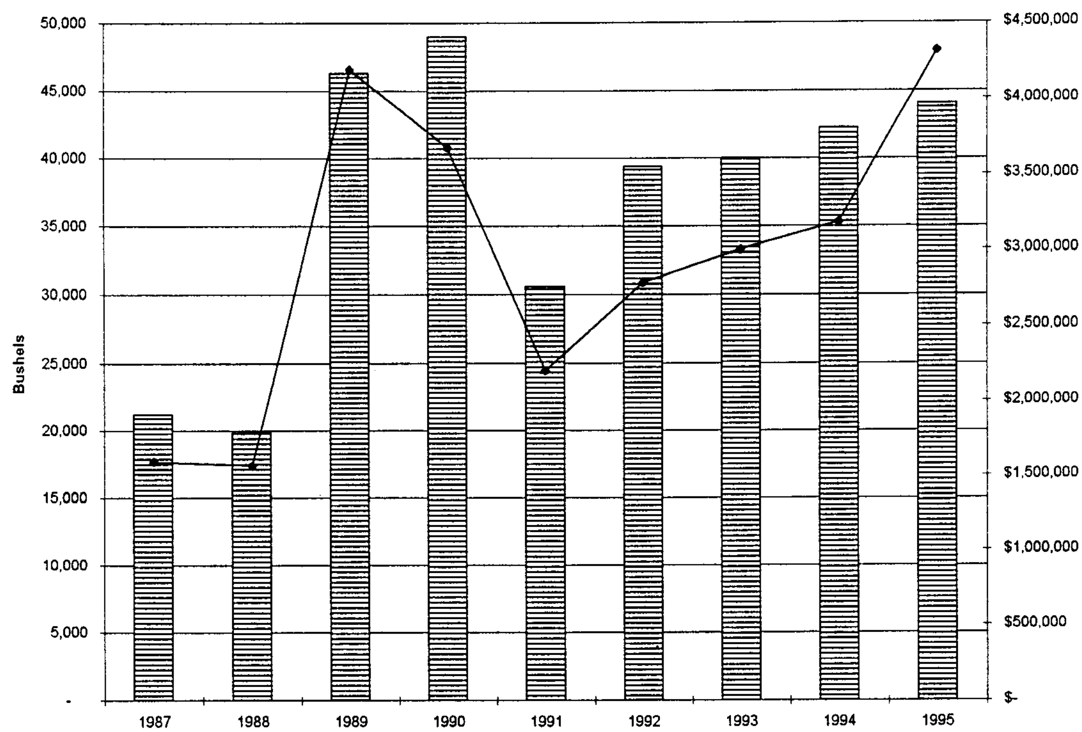
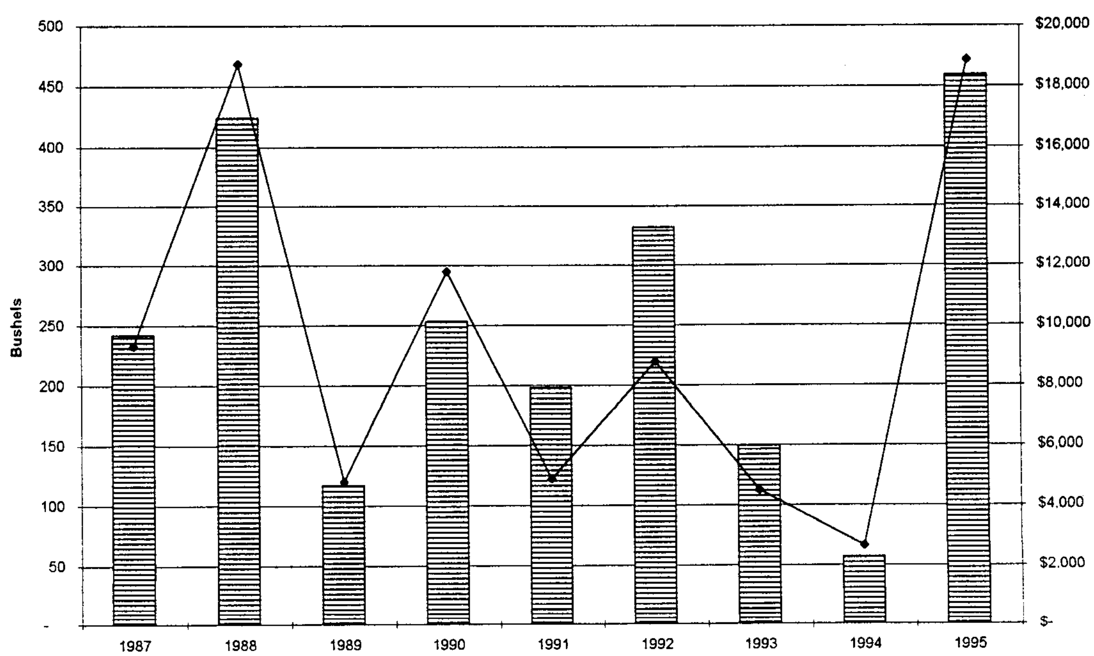


Figure 4. Landings of Oysters in the Peconic Bay System



Source: NYDEC, various years

Figure 5. Landings of Bay Scallops in the Peconic Bay System

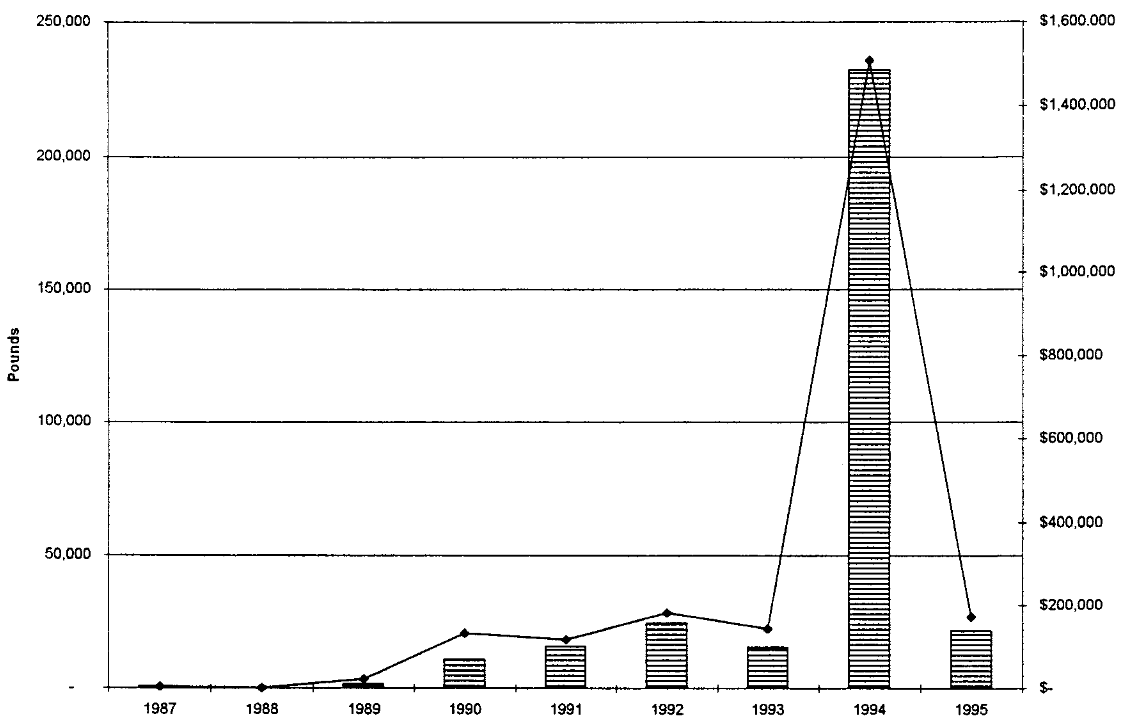
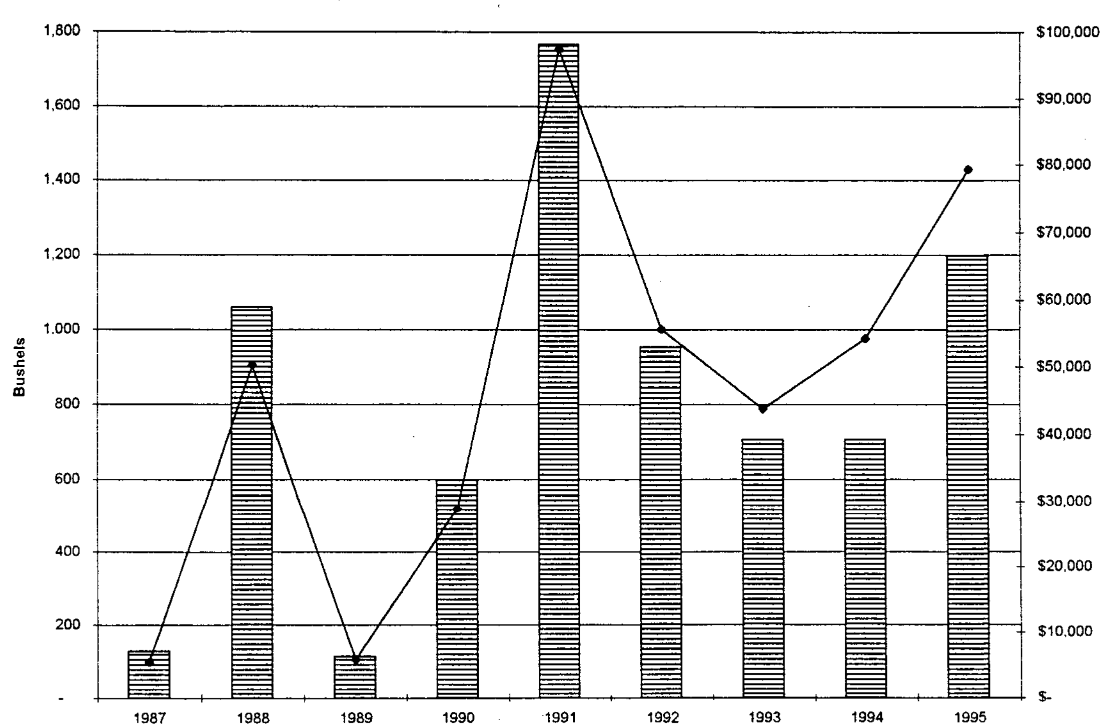


Figure 6. Landings of Soft Clams in the Peconic Bay System



*1994 Bay Scallop Landings are estimates. There is conflicting data between NYDEC and USDC, NMFS, *Fisheries of the U.S., 1994.*

Source: NYDEC, various years.

In 1995, soft-shell clams were valued at $79,394 (Figure 6). This is a decline from 1991, when production valued at $97,387.

HISTORY OF AQUACULTURE IN THE PECONIC BAY SYSTEM

Beginning in the 1890s, seed oysters from Connecticut were planted in Gardiners and Peconic Bays, and, by 1900, these waters gained distinction as a maturing ground for Long Island Sound oysters. However, New York oyster production levels have declined drastically from those of the early 1900s. Beginning in the late 1940s, blooms of a small species of phytoplankton that became known as "small forms" appeared in Long Island bays. Small forms clogged the gills of hard clams and oysters, inhibiting feeding such that the shellfish meats were of poor quality and not acceptable in the market (Gaffney, 1992). Production reached a low in the 1950s and 1960s, and, by 1965, total New York oyster production was valued at less than $500,000 (Koppelman, 1979).

In the late 1960s, New York began to promote aquaculture. This promotion continued throughout the 1970s. In 1979, Dr. Lee Koppelman of the Long Island Regional Planning Board completed the *Assessment of Existing Mariculture Activities in the Long Island Coastal Zone and Potential for Future Growth.* There were four mariculture operations in the PBS in 1979--three shellfish and one finfish. Of them, two are still producing. They are Coastal Clam Farms and Multi-Aquaculture Systems.

Long Island Oyster Farms (LIOF) was, by far, the largest producer in the region, employing approximately 100. In 1979 they opened an oyster hatchery in Maine and started collecting spat in Long Island Sound for growout on the firm's underwater land holdings in the Peconic and Gardiners Bays. In 1979 LIOF had control of an estimated 8,000 acres of underwater land. Much of it has since reverted to the state after LIOF's multiple bankruptcies.

Legal Jurisdiction

Jurisdiction and control of underwater lands of the Peconic Bay System fall under both public and private interests. Approximately 8,700 acres of bay bottom, acquired through county grants for the exclusive purpose of shellfish cultivation, are controlled by private interests (Koppelman, 1979).

The state legislature has ceded the lands under the PBS and its tributaries to Suffolk County for the purpose of the promotion of shellfish cultivation and management.[2] Under the original cession in 1884, the county was authorized to grant submerged lands to private parties for oyster cultivation. The grantee's failure to so use the land resulted in its reversion to the county.[3] Amendments enacted in the 1969 law expanded the original cession to encourage cultivation of all species of shellfish, not just oysters, but limited the interests that the county could transfer to others by changing its authority from the making of "grants" to the making of leases for ten-year periods. Suffolk County was required by the 1969 law to "cause an accurate survey to be made of such lands, and a map or maps to be prepared therefrom," to determine the locations of existing private interests.[4] Suffolk County has not yet met these requirements.

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[2] (Kaplan, 1984) 1969 NY Laws ch 990, preserving provisions of 1884 NY Laws ch 385, as amended by 1906 NY Laws ch 640, and 1923 Laws ch 191, not inconsistent with the 1969 version.

[3] (Kaplan, 1984) 1884 NY Laws ch 385, § 3.

[4] (Kaplan, 1984) 1969 NY Laws ch 990, § 3.

Current Leases in the Peconic Bay System

Historically, most of the PBS has been privately owned or granted for shellfish cultivation. The Peconic Bays are segmented into 550 parcels and owned by the state, county, town, or private interests. Individuals and towns that have the right to operate a hatchery or culture shellfish are listed in Table 2 and Figure 7. Of the fifteen marine hatchery permits in the state, five are located in the PBS. Four of the five permits are for shellfish (oyster, hard clam, bay scallop) cultivation, and one is for a variety of finfish species. There are fourteen private and public bottom culture permits. Of these, six are five-acre, off-bottom permits. There are approximately 1,351 acres that are privately owned (Barnes, 1996).

Oysters and hard clams are the primary species cultured in the region. There is also some bay scallop production; however, brown tide outbreaks have decreased its economical feasibility. Current aquaculture production is valued at about $4.2 million (transplant/relay of hard clams included) or $15,000-25,000 (transplant/relay not included). However, production may be higher (i.e., Blue Points operates a hatchery in the PBS, but grows out the oysters in a different area). Many of the bottom culture permits have recently been granted, and shellfish crops have not yet been harvested.

The use of public funds for shellfish enhancement is accepted. The towns of Southold and East Hampton have their own marine hatchery permits. These towns are currently producing oysters, hard clams, and bay scallops for enhancement purposes. Southampton, East Hampton, and Southold all have culture permits and practice both shellfish transplant and enhancement. For example, in 1996 Southold is planning to enhance the region with 3 million hard clams, 1 million oysters, and about 500,000 bay scallops (McMahon, 1996). Southampton is focusing primarily on transplant to seasonal closed areas with an estimated 1996 budget of $25,000. This

Table 2. Permits for the Peconic Bay System

Source: New York State Department of Environmental Conservation
Division of Marine Resources
** Addresses are mailing, not necessarily production sites.

Marine Hatchery Permits

Permit	Name	Street	City	Zip	Species	Area
2	Bluepoints		Mattituck	11952	Oyster, Hard Clam, Bay Scallop	Upland
7	Multi-Aqua System	P.O. Box 679	Amagansett	11930	Striped Bass, Black Seabass, Lobster, Sm. & Win Flounder	Upland
19	Twn of Easthampton	159 Pantigo Road	East Hampton	11937	Oyster, Hard Clam, Bay Scallop	Upland
22	Twn of Southold	Twn Hall Main Rd	Southold	11971	Oyster, Hard Clam, Bay Scallop	Upland
23	Cornell Coop	3690 Cedar Beach Road	Southold	11971	Oyster, Hard Clam, Bay Scallop	Upland
27	Kaninsky, James	75 Woodcliff Drive	Mattituck	11952	Oyster, Hard Clam, Bay Scallop	Upland

On/Off Bottom - Culture Permits

Permit	Name	Street	City	Zip	Species	On/ Off	Acreage
1	Coastal Farms	P.O. Box 480	Water Mill	11976	Hard Clam	On Bottom	520
3	Twn of Southampton	116 Hampton Road	Southampton	11968	Oyster, Hard Clam, Bay Scallop, Blue Mussel		
10	Twn of Easthampton	159 Pantigo Road	East Hampton	11937	Oyster, Hard Clam, Bay Scallop, Blue Mussel		
11	Twn of Southold	Twn Hall Main Road	Southold	11971	Oyster, Hard Clam, Bay Scallop, Blue Mussel		
14	Great Pec Shl Farm	Box 1168 - Main Road	Cutchhogue	11935	Oyster, Hard Clam, Bay Scallop	On Bottom	346
23	Peconic Mariculture Co.	P.O. Box 1529	Southampton	11969	Oyster, Hard Clam, Bay Scallop, Soft Clam, Surf Clam	Off Bottom	5
29	E. Zeneski	P.O. Box 1647, Main Rd	Southold	11971	Hard Clam	On Bottom	70
34	M. Carrera	193 Riverside Avenue	Flanders	11901	Oyster, Hard Clam, Bay Scallop, Blue Mussel, Soft Clam	Off Bottom	5
35	G. Olsen Sr.	P.O. Box 158	Laurel	11948	Oyster, Hard Clam	Off Bottom	5
36	J. Markow	41 Heathcote Court	Shirley	11967	Oyster, Hard Clam, Bay Scallop	On Bottom	205
37	R. Parrino	5 Jacqueline Drive	Manorville	11949	Oyster, Hard Clam	On Bottom	180
40	Braun Oyster Co.	P.O. Box 971	Cutchhogue	11935	Oyster, Hard Clam, Bay Scallop, Blue Mussel, Soft Clam	Off Bottom	5
41	W. Grothe	P.O. Box 815	East Quogue	11942	Oyster, Hard Clam, Soft Clam	Off Bottom	5
42	H. Pickerell	P.O. Box 598	Water Mill	11976	Oyster, Hard Clam, Bay Scallop	Off Bottom	5

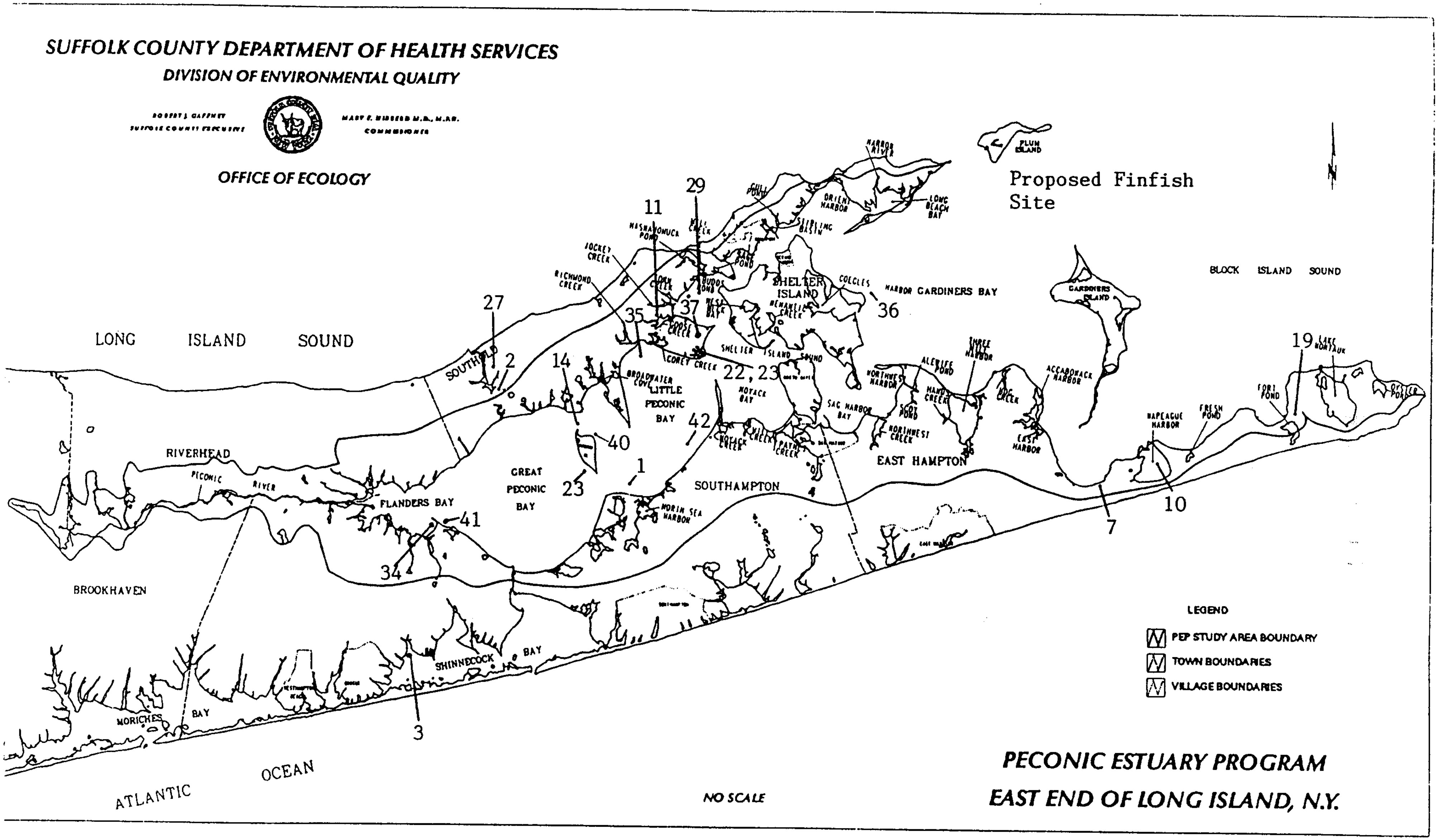


Figure 7. Marine Hatchery Permits and On/Off Bottom Culture Permit Sites in the PBS.

Source: Rivara, G., 1996

will be used to pay baymen to transplant as well as for hatchery stock enhancement (Warner, 1996). The relationship between the commercial and municipal shellfish programs is one of mutual benefit. The towns depend on the businesses for seed and information, while the local and regional for-profit hatcheries rely on town programs for seed sales and seed promotion to prospective culturists. Additionally, hatcheries can provide the public with a valuable educational experience.

Current Developments

Greg Rivara of Cornell Cooperative Extension, Suffolk County Marine Environmental Learning Center in Southold, received a Northeast Fishing Industries Grant (NFIG) of $200,000 to promote aquaculture among displaced regional baymen. They are attempting to culture four million oysters over the three-year project duration. This project involves 40 individuals and ten oyster, hard clam, and bay scallop growout sites. These sites include both on-bottom and off-bottom culture and cover close to 30 acres. The majority of oysters harvested from the sites is sold to local restaurants (Rivara, 1995). It is expected that approximately 12 individuals currently involved in the program will eventually acquire permits and sites on which to culture oysters.

Mariculture Technologies, located in Greenport, is attempting to gather permits for net-pen culture of summer flounder off the coast of Plum Island. To help finance the operation, they received a $458,250 NFIG grant from the National Marine Fisheries Service with which to test the feasibility of net-pen summer flounder growout. They have also completed Environmental Impact Statements and are in the process of acquiring permits from other State and Federal agencies (Link, 1995). The company would like to have a hatchery, net pens, and a fish and feed transfer station. They expect to grow 100,000 fish after operations begin.

Expected Production For 2000

As previously stated, aquaculture production, including transplants, is valued at slightly over $4 million. Table 3 illustrates a breakdown of 1995-1996 estimated production and expected production for 2000. These estimates are based upon 1996 sale prices. A more accurate projection of the industry's output in the near future would require analysis of future demand and market trends, as well as a consideration of future constraints, such as financing and regulation. Exit interviews with participants in Greg Rivara's project could also potentially provide some indication of future shellfish production in the PBS.

Constraints to Aquaculture Development on Long Island

Increased competition, decline in the bay scallop and oyster fisheries, and continued depletion of commercially harvested finfish stocks could significantly affect the economy of the Peconic Bays region. Spatz, *et al.* (1996) conducted a survey of aquaculture producers in the Northeast region in the summer and fall of 1995, resulting in 53 completed surveys from shellfish producers. In the survey, producers were asked to rank a list of constraints affecting the aquaculture industry (financial capital, predation, regulation, marketing, disease, genetic stock, technology, poaching, and nutrition). Figure 8 identifies the four most significant constraints to shellfish aquaculture growth in Long Island and the Northeast U.S. The primary constraints to Long Island shellfish producers, in relative order, are: 1) regulation (n=6); 2) disease (n=6); 3) poaching (n=6); and 4) financial capital (n=6). Regulation and disease both average "very" to "moderately" constraining to aquaculture production.

Table 3. Private Shellfish Production Estimates: 1995-96 and 2000		
1995-96 Private Production Estimates	**Current Production/Value**	**No. of Permits**
Hard Clams (includes transplant/relay)	52,000 bu - 58,000 bu	12
Oysters	440 bu - 460 bu	11
Finfish		1
Bay Scallop		1
Total Value	**$4 million - $4.2 million**	
2000 Private Production Estimates	**Estimated Production/Value**	**No. of Permits**
Hard Clams (includes transplant/relay) (1)	52,000 bu - 58,000 bu	18
Oysters (2)	12,000 bu - 14,000 bu	20
Finfish (3)	500,000 lb - 1 million lb	2
Bay Scallops (4)	5,000 lb - 10,000 lb	15
Total Value	**$4.8 million - $7.8 million**	

Notes:

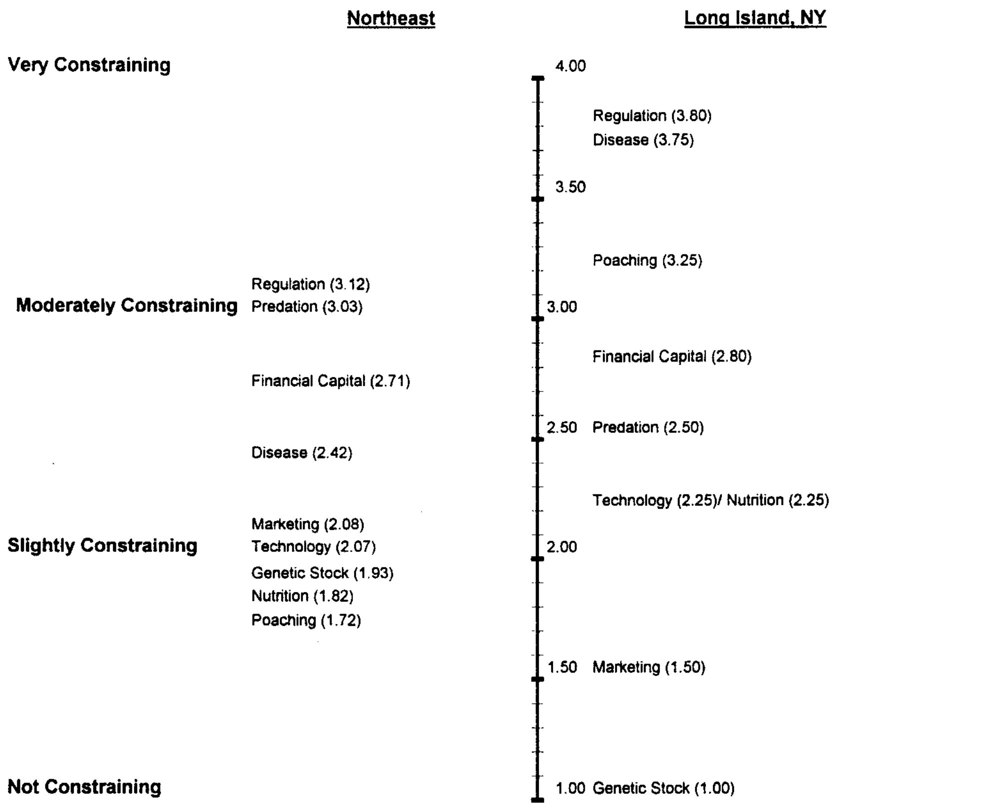
(1) Hard clam production includes transplant/relay production and assumes transplants will continue at the same rate over the next four years. Hard clam aquaculture production increases slightly with additional participants from G. Rivara's project.

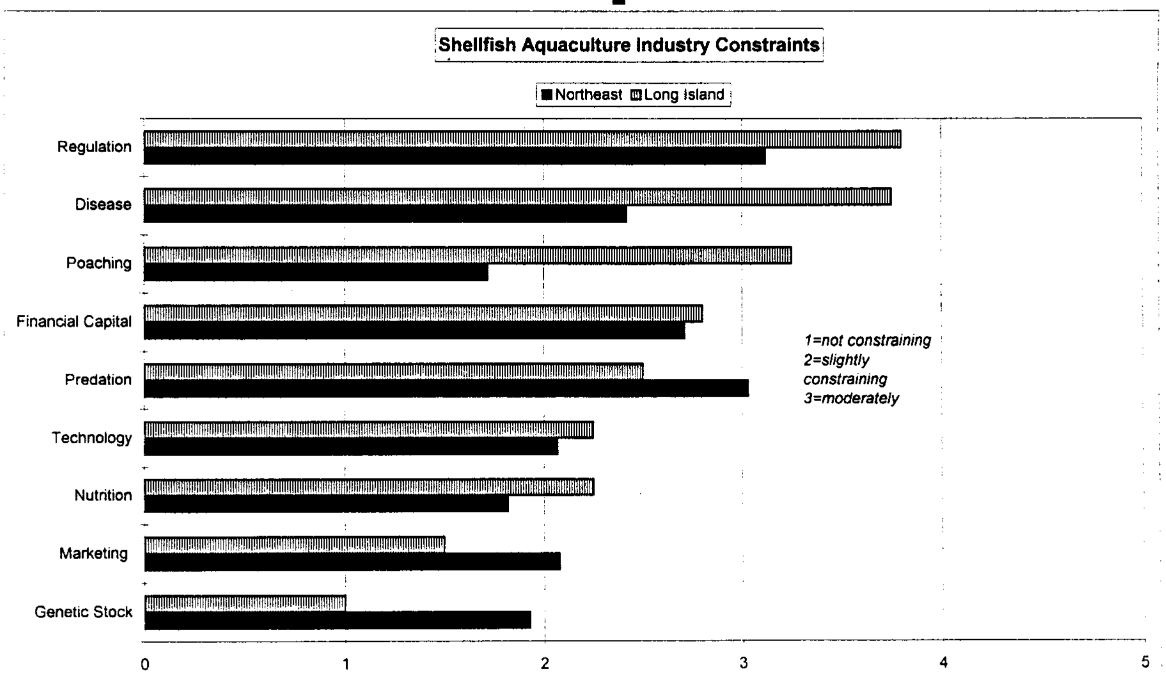
(2) Oyster production will dramatically increase. Production from G. Rivara's project should be about 3-4 million pieces. An additional 8-10 participants should enter.

(3) Finfish production will come primarily from Aquaculture Technologies, Inc. They plan to produce over 500,000 fish and employ 100 people. Multi-Aquaculture Systems is primarily a research firm and will continue to study a variety of species.

(4) Bay scallop production estimates are based upon additional participants entering through G. Rivara's project. Currently, Cornell Cooperative Extension in Southold is conducting experiments to improve the bay scallop survival rate in the PBS.

Figure 8. Northeast U.S. and Long Island Shellfish Aquaculture Constraints
ALL DATA





Source: Spatz *et al*., 1996.

POTENTIAL AQUACULTURE OPPORTUNITIES

Please refer to the Appendices for a description of potential species suitable for aquaculture in the PBS and a classification of culture systems and technologies.

Shallow Water Estuarine Environments (e.g., Oysters, Clams, Mussels, and Scallops)

Although opportunity exists for the expansion of shellfish aquaculture in the coastal near-shore waters of the PBS, the current, intensive use of the coastline may limit development. Benefits of bottom culture of shellfish include its relatively low environmental impact and ecological benefits. Currently, there is a number of small producers in the region. However, a significant increase in the number of producers may create adversity. Possible remedies to some of these potential problems include judicious siting, adoption of practices with low visual impact such as bottom culture which is not exposed at low tide, and transient gear aquaculture. This method involves placing hatchery-reared shellfish in cages resembling lobster pots on the bottom. Since transient gear does not require exclusive use of one area for more than a short period of time, it should not require a controversial exclusive use lease (Rheault and Rice, 1995).

Deep Water Aquaculture (e.g., Flounder, Striped Bass, Turbot, and Shellfish)

Opportunity also exists within the PBS for deep water aquaculture sites. Currently, there is one company in the process of obtaining net pen culture permits for finfish. A significant increase in the number of net pen producers may create conflicts with recreational and commercial marine traffic, commercial fishermen, and abutting land owners. In addition, siting for net-raised finfish is limited by the need for either relatively deep water (generally over 50 feet) or relatively high water exchange. However, a small number of producers may be able to significantly contribute to the local economy with minimal user conflicts.

Land-Based Intensive Systems

Use conflicts, many regulatory constraints, and limited water resource constraints can be reduced by adopting the use of land-based, intensive aquaculture systems. These systems are generally closed or semi-closed systems which use little water and have reduced discharge volumes. Two commercial systems exist is western Massachusetts. One company, AquaFuture, raises hybrid striped bass in 150,000 gallon recirculating tanks in a warehouse in Turners Falls, MA. Current production is about 1,000,000 pounds per year, and product can be shipped within twenty-fours hours (Lindell, 1994). Another operation, Bioshelters, Inc., in Amherst, MA, combines tilapia culture with hydroponic vegetable (basil) production in recirculating systems which minimize water use and discharge. The economic viability of such systems is determined by a complex interaction of technology, species grown, skill of the management and marketing personnel, and other factors. Thus, it is impossible to generalize about the profitability of such systems. However, Long Island has some idle fish processing plants and farm buildings which could perhaps be utilized for this type of aquaculture. In addition, given the relatively close proximity of New York City to the PBS, shipments of live fish to Asian fish markets or upscale restaurants may add to the profitability of land-based systems. Potential species include hybrid striped bass, ornamental fish, tilapia, flounder, cod, and algae, to name a few.

Although it is unlikely that such systems would be an alternative for many traditional fishing industry participants, they have potential as a source of enhancement stocks; new, commercial ventures; tourist appeal; and educational value.

Aquaculture for Enhancement

Aquaculture could potentially be used for the enhancement of shellfish and finfish stocks; particularly oysters, clams, scallops, as well as summer flounder, winter flounder, cod, striped bass, and haddock. Stock enhancement programs utilizing aquaculture can often gain strong support of the community, local schools, and commercial fishermen. On Nantucket, there is an active bay scallop enhancement project, and in, Delaware, shore-front residents who participate in a bay watch program are tending small clam beds for both environmental monitoring and stock enhancement. The success of the Connecticut oyster aquaculture industry is a direct result of a joint effort which combines public enhancement and maintenance of oyster beds under a lease program. An example of private enhancement operations is the successful, private, non-profit salmon enhancement programs managed by Alaskan fishermen.

A successful habitat restoration program is in place in Connecticut. Since 1987, $4.8 million has been raised enabling Connecticut to restore 3,000 acres of seed beds with over four million bushels of clean oyster shell "cultch" (Bush and Anderson, 1993). As a result, oyster harvests there have increased from 30,000 bushels in 1960, to nearly 653,300 bushels in 1994. The 1994 farm-gate harvest value was estimate at approximately $39.2 million, with direct employment exceeding 450 (CTDEP, 1995; Volk, 1994). The state purchases the cultch, but the fishermen provide the labor and equipment for the program at no cost. The state funds most of its $450,000 a year management program and the one million dollar a year cultch program through a tax, as well as through lease and license fees (Connecticut Department of Agriculture, 1994). The tax on shellfishermen is equivalent to 10 percent of the retail value of the shellfish they harvest on state-stocked grounds.[5] Many industry participants feel that the restoration

[5] Laws Relating to Shellfisheries, Sec. 26-237c. Part C, CT Dept. of Ag., 1994.

program is a significant factor contributing to the increase in Connecticut's oyster harvest (Bush and Anderson, 1993). In addition, this type of program utilizes existing fishing industry resources and may create an alternative to current fishing practices.

The Potential Economic Contribution of Aquaculture

Aquaculture in the PBS faces many barriers to development and is currently an industry in its embryonic stage. In 1996, aquaculture production is estimated to be $4-4.2 million. This figure includes the quasi-public practice of transplant/relay of hard clams which accounts for the majority of the production. The transplant/relay program is not expected to significantly increase or decrease during the next three to five years. However, the possibility exists that the PBS will see a two-fold increase in total aquaculture production over the next three to five years.

The following recommendations were generated after review and consideration of state aquaculture plans and their possible effects on aquaculture potential in the PBS. The recommendations address both regulatory and non-regulatory issues.

Recommendations

- Initiate benefit-cost analysis of aquaculture in the PBS, especially in high-use areas. This should be carried out by local towns, in cooperation with the New York Department of Environmental Conservation. The benefit-cost results, together with information regarding the physical/chemical/biological properties of the various water bodies, should be used to help create an aquaculture zoning plan.
- Explore the typical land- and water-based infrastructure needs of the aquaculture industry to determine whether the PBS has an adequate water supply, water treatment/wastewater management and disposal facilities, transportation/storage facilities, and shipping or

processing facilities to support an influx of product.

- Create model ordinances which accommodate aquaculture and then distribute them to the communities.
- Develop a coastal lease fee pricing system which reflects the economic value of the coastal resource. Potentially, this could be done by creating a competitive bid process.
- Initiate a comprehensive review of current public enhancement programs, including their efficiency, cost of operation, and potential for privatization.
- Evaluate and explore the potential of using aquaculture to raise aquatic plants for wetland habitat restoration.
- Collect, analyze, and publish information on the existing seafood marketing structure and market potential for PBS seafood products.
- Broaden educational programs, such as those offered by 4-H and the Suffolk County Marine Environmental Learning Center, to introduce young people to aquaculture-related opportunities.

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APPENDICES

Appendix A

Potential Species for Aquaculture in the PBS

This appendix summarize key characteristics of the culture and marketing of species suitable for aquaculture the PBS. A standardized table accompanies the description of each suggested species, containing information on the geographical location of commercial culture, water characteristics, and production technology.

I. Finfish Species

Atlantic Halibut

Atlantic halibut (*Hippoglossus hippoglossus*) is a large, high-value commercial flatfish. This species has significant market potential in the United States and Europe (Brown *et al.*,1995). Atlantic halibut has been successfully produced and marketed in Norway since 1993 and has been cultured in Maine since 1995.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm
Northeast ✔	Fresh	Cold ✔
PBS	Brackish	

Technology:

- Generally grown in re-circulating systems.

Atlantic Salmon

Atlantic salmon (*Salmo salar*) is an anadromous high-value species that, combined with sea-run rainbow trout (*O. mykiss*), represents the largest segment of the aquaculture industry in the Northeast (Spatz *et al.*,1996). Input prices for smolts and eggs are expected to decline as technology improves and expansion of salmon production continues (Avault, 1996). Although seawater temperature in the PBS may not be appropriate for salmon growout, potential may lie in the culture of smolts, young salmon, in fresh water.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm
Northeast ✔	Fresh ✔	Cold ✔
PBS	Brackish ✔	

Technology:

- Smolts are generally cultured in freshwater tanks and raceways. Growout is usually in floating net-pens in seawater.

Atlantic Sturgeon

The Atlantic sturgeon (*Acipenser Oxyrhynchus*) is an anadromous fish with a wide latitudinal distribution. Problems with its spawning in captivity are being overcome, and farmers are currently culturing sturgeon, primarily in California (Avault, 1996). The market possibilities of this species are potentially significant, as the meat and quality caviar command extremely high prices.

Cultured in:	*Water type:*	*Temperature:*
U.S. ✔	Saltwater ✔	Warm ✔
Northeast	Fresh ✔	Cold ✔
PBS	Brackish ✔	

Technology:

- Cultured in ponds and recirculating systems (Avault, 1996).

Baitfish

Of about 100 species of fish used as sportfishing bait in the United States, at least four are raised commercially in large quantities: golden shiner (*Notemigonus crysoleucas*), fathead minnow (*Pimephala promelas*), white sucker (*Catostomus commersoni*), and goldfish (*Carassius auratus*) (Avault, 1996). These small, freshwater fish can survive in a wide temperature range and are generally raised in ponds (McCormick and McCormick, 1995). Baitfish farming, in general, requires more labor than many other types of aquaculture due to grading and the extra effort required for shipping and delivering product (Avault, 1996). In the Northeast, most culturing of baitfish is done by small operations. Maine has a significant number of baitfish farmers, and it does not permit the import of baitfish from other states (Spatz *et al.*, 1996). An increase in the demand for baitfish is expected to follow the current expansion of recreational fishing (McCormick and McCormick, 1995; Avault, 1996). The demand for baitfish tends to be seasonal (Iversen and Hale, 1992).

Cultured in: U.S. ✔ Northeast ✔ PBS

Water type: Saltwater Fresh ✔ Brackish

Temperature: Warm ✔ Cold ✔

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater	Warm ✔
Northeast ✔	Fresh ✔	Cold ✔
PBS	Brackish	

Technology:

- Pond culture is generally used.

Bluefin Tuna

Bluefin tuna (*Thunnus thynnus*) is a highly migratory, large pelagic fish with great aquaculture potential. This is the result of its high Japanese market value, restrictive fishery regulations and rapid growth rate (Iversen & Hale, 1992). Many commercial aquaculture projects are developing throughout the world, including: Australia, Japan, the Mediterranean Sea, the Caribbean, and (experimentally) off the Virginia coast as part of a project by the N.E. Aquarium.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS	Brackish	

Technology:

- Wild fish are caught by fishing boats and transported to floating pens.

Cod

Atlantic cod (*Gadus morhua*) is a demersal species with both social and economic tradition in the North Atlantic. Although cod are hardy, easy to maintain, grow rapidly, are in strong demand, and command a moderately high market value (Brown *et al.*, 1995), rearing young fish is expensive (Iversen and Hale, 1992). Currently, cod is being experimentally cultured in Maine.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm
Northeast ✔	Fresh	Cold ✔
PBS	Brackish	

Technology:

- Growout is generally in floating net pens. (Brown *et al.,* 1995).

Eel

American eel (*Anguilla rostrata*) is a catadromous fish that spends most of its life in fresh water. The European eel (*Anguilla anguilla*) is another species of the same genus, with characteristics suitable for culture in the PBS. A significant market exists in Europe, Japan, and Taiwan (Avault, 1996; Iversen and Hale, 1992).

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast	Fresh ✔	Cold ✔
PBS	Brackish ✔	

Technology:

- Elvers are collected at river mouths during migration up river. Growout occurs in tanks or earthen ponds (Avault, 1996).

Ornamental Fish

Ornamental fish, also known as hobby or aquarium fish, represent a substantial segment of the Northeast aquaculture industry. Although the domestic industry is growing (Spatz *et al.*, 1996), the United States still imports most of its tropical fish (Avault, 1996). Species from at least seven different families of fish are currently cultured, including: *Poeciliidae* (live-bearers), *Cyprinidae* (carp and minnow), *Cyprinodontidae* (killifishes), *Characidae* (characins), *Cichlidae* (tilapia), *Anabantidae* (gouramies), and *Callichthyidae* (corydoras catfishes) (Avault, 1996). Drawbacks associated with raising most of these fish include temperature sensitivity below 16°C (Avault, 1996) and the threat of intense predation (Spatz *et al.*, 1996). Although the U.S. commercial culture of ornamentals is centered in Florida, there are also significant ornamental fish operations in Maryland and Pennsylvania.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh ✔	Cold ✔
PBS	Brackish ✔	

Technology:

- Cultured in tanks, vats, small earthen ponds, and recirculating systems.

Hybrid Striped Bass, Striped Bass, Black Sea Bass

Striped bass (*Morone saxatilis*) is an anadromous fish originally found from the St. Lawrence River to northern Florida and the Gulf of Mexico (Iversen and Hale, 1992). However, the hybrid striped bass (female *Morone saxatilis* x male white bass *Morone chrysops*) is more appropriate for aquaculture because it grows faster, has a better survival rate, and is more disease-resistant than non-hybrids (Iversen and Hale, 1992). In addition, culture of striped bass is illegal in many states. Northeast producers foresee increasing consumer demand (Spatz *et al.,* 1996). There is a hatchery permit issued in the PBS for black sea bass (*Centropristis striata*).

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh ✔	Cold ✔
PBS ✔	Brackish ✔	

Technology:

- Tanks and ponds. Recirculating systems.
- Grows faster in brackish water (Iversen and Hale, 1992).

Summer Flounder/ Winter Flounder

The summer flounder (*Paralichthys dentatus*) is a flatfish with significant economic value. A facility in New Hampshire is currently raising summer flounder, and one company in the PBS is planning net-pen growout of summer flounder. There is a hatchery permit in the PBS to grow winter flounder (*Pseudopleuronectes americanus*).

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS ✔	Brackish ✔	

Technology:

- Recirculating systems are the most common methods proposed in the Northeast; however, floating net pens are also being considered.

Tilapia

Although tilapia (*Tilapia spp.*) are an African species, their culture has been successfully expanded to other areas of the world, including the U.S. They can survive under a wide range of conditions, making culture in many regions ideal (Avault, 1996). Despite the fact that they can survive in a wide range of salinities, tilapia are commonly cultured in freshwater raceways, ponds, and floating cages (Avault, 1996). This species is currently being produced in several Northeastern states. Colorful strains have been developed, creating a market for ornamental tilapia (Iversen and Hale, 1992).

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh ✔	Cold
PBS	Brackish ✔	

Technology:

- Cultured in tanks, raceways and ponds.
- In Northeastern states, heated water tanks are used during the winter.

Trout

This group of freshwater salmonids includes the rainbow trout (*Oncorhynchus mykiss*), brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and tiger trout (a hybrid of brown trout x brook trout), among others. Rainbow trout grown in freshwater and moved to saltwater during the maturation period are called steelhead trout. Among trout species, rainbow trout dominates freshwater production, due to its considerable capacity to thrive (Dubé and Mason, 1995, Boghen, 1995) in freshwater raceways.

Commercial trout growers in the Northeast expect demand to increase over the next five years (Spatz *et al.,* 1996). In addition, fee-fishing in trout ponds is a potential alternative or complement to commercial production.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm
Northeast ✔	Fresh ✔	Cold ✔
PBS	Brackish	

Technology:

- Freshwater tanks used for culture during early life stages, and raceways for adults.
- Trout require high-quality, oxygen-rich water.

Turbot

Turbot (*Scophthalmus maximus*) is a highly valued flatfish in the European market and appears to be well suited to aquaculture. After 20 years of research in Europe, there is considerable enthusiasm that turbot farming will be a success (Iversen and Hale, 1992).

Cultured in:	***Water type:***	***Temperature:***
U.S.	Saltwater ✔	Warm ✔
Northeast	Fresh	Cold ✔
PBS	Brackish	

Technology:

- Intensive rearing in tanks.

Walleye

Walleye (*Stizostedion vitreum*) is a cold, freshwater fish found in clear water with sandy bottoms. It is a very popular recreational and commercial fish. There is demand for fingerlings to stock natural waters and farm ponds (Iversen and Hale, 1992). Juveniles of this species are successfully cultured in Midwestern and northeastern states, but the high cost of live feed renders the production of large individuals unprofitable (McCormick and McCormick, 1995).

Cultured in:	*Water type:*	*Temperature:*
U.S. ✔	Saltwater	Warm
Northeast ✔	Fresh ✔	Cold ✔
PBS	Brackish	

Technology:

- Raised in earthen ponds fertilized to produce heavy plankton growth (Iversen and Hale, 1992).

Wolffish

Wolffish display impressive growth under culture conditions. Striped wolffish (*Anarchichas lupus*) can reach up to 2 kg in two years, and spotted wolffish (*Anarchichas minor*) can achieve weights of up to 3.5 kg (Brown *et al.*, 1995). Furthermore, the flesh of the wolffish is white and of a quality favored by consumers. Wolffish may be an attractive candidate for cold-water aquaculture (Brown *et al.*, 1995).

Cultured in:	*Water type:*	*Temperature:*
U.S.	Saltwater ✔	Warm
Northeast	Fresh	Cold ✔
PBS	Brackish	

Technology:

- Raised in net-pens.

II. Shellfish and Invertebrates

American Lobster

The American lobster (*Homarus americanus*) is a popular decapod crustacean, whose market is sustained solely by the commercial fishery in the Northeast and Canada. Although hardy and relatively easy to grow, the time required for growth to market size and the high cost of food are significant deterrents to productive farming (Iversen and Hale, 1992). Lobster culture systems are complex land-based facilities with high operating costs (Waddy and Aiken, 1995). Cost-efficient culture of the American lobster is being pursued through intensive research (Waddy and Aiken, 1995). There is currently a hatchery permit issued in the PBS to grow lobster.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS ✔	Brackish	

Technology:

- Communal rearing in deep-tank systems (Waddy and Aiken, 1995).

Blue Mussel

Blue mussel (*Mytilus edulis*) is a widely distributed marine filter feeding bivalve with a tradition of aquaculture in Europe. Culture of this species in North America has taken place in both Canada and the United States, including the states of Maine and Washington (Spatz *et al,*. 1996; Avault, 1996; Mallet and Myrand, 1995; Iversen and Hale, 1992). Although mollusc demand in the U.S. is inclined towards the consumption of clams and oysters, mussel promotion and marketing efforts are proving to be effective in expanding U.S. markets (Avault, 1996).

Cultured in:	*Water type:*	*Temperature:*
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS ✔	Brackish	

Technology:

- Mussels are farmed by one of four basic methods: bottom culture, bouchot method, raft or rope culture, or long-line method (Avault, 1996). In the Northeast, mussels are primarily farmed in Maine by the bottom culture method (Spatz *et al.,* 1996).

Clams

Five species of clams have been identified as candidates for aquaculture in the United States: the quahog (*Mercenaria mercenaria*), surf clam (*Spisula solidissima*), soft-shell clam (*Mya arenaria*), ocean quahog (*Artica islandica*), and Japanese clam (*Tapes japonica*) (Avault, 1996). The quahog is one of the primary species farmed in the Northeast. Soft-shell clams are currently being produced in the intertidal waters of Massachusetts (Spatz *et al.,* 1996). Market prospects for clams, in general, are positive (Avault, 1996).

Cultured in:	*Water type:*	*Temperature:*
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS ✔	Brackish	

Technology:

- Hatchery for larvae and juveniles and bottom culture for adults in open waters.
- Transplant/relay from polluted waters for depuration.

Oysters

The American oyster (*Crassostrea virginica*) and European oyster (*Ostrea edulis*) are sedentary mollusks with excellent suitability for aquaculture. Oysters are in relatively high demand, grow quickly, and do not require commercial feed (Avault, 1996; Iversen and Hale, 1992). Extensive information is available on the culture of this species as a result of a long standing history of culture. Successful production of oysters occurs in many Northeastern states, including several operations in the PBS (Spatz *et al.*, 1996).

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS ✔	Brackish	

Technology:

- Larvae are produced in land-based hatcheries or natural set. Adults grown in bottom or off-bottom culture, although off-bottom rearing techniques yield a greater production of well-shaped oysters. Transient gear may also be used.

Scallops

Of the 360 species of scallops throughout the world only two, the bay scallop (*Argopecten irradians*) and the sea scallop (*Pecten magellanicus*), have been found suitable for aquaculture in North America (Avault, 1996). Scallop culture is currently taking place in Massachusetts and Maine (Spatz *et al.*, 1996). Cornell Cooperative Extension has an experimental scallop project and there are nine on/off bottom culture permits issued in the PBS.

Cultured in:	*Water type:*	*Temperature:*
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS ✔	Brackish	

Technology:

- Bottom culture (Avault, 1996), and suspended lantern nets are two culture methods.

III. Aquatic Plants

Nori

Nori (*Porphyra yeozoensis*) is an intertidal saltwater macroalgae found in the Pacific Ocean. It is a traditional food in Asia, including Japan, where increasing coastal water pollution forces the market to be supplied by foreign production (Iversen and Hale, 1992). A Maine facility is currently culturing this species, which is easy to press, dry, and process into wraps for sushi (Spatz *et al.*, 1996). Difficulty may arise due to the permitting required for farming an exotic species and the space required for culture.

Cultured in:	*Water type:*	*Temperature:*
U.S. ✔	Saltwater ✔	Warm ✔
Northeast ✔	Fresh	Cold ✔
PBS	Brackish	

Technology:

- Net-grown.

Wetland and Ornamental Plants

Plants such as lilies, lotus, ornamental grasses, and estuarine plants could be produced for gardens and/or habitat restoration.

Cultured in:	***Water type:***	***Temperature:***
U.S. ✔	Saltwater	Warm ✔
Northeast ✔	Fresh ✔	Cold ✔
PBS	Brackish	

Technology:

- Tanks, ponds and greenhouses.

IV. Other

Other species that are under consideration for aquaculture in the PBS are the black sea bass (*Centropristis striata*), the tautog (*Tautoga onitis*), and the sea cucumber (*Holothurioidea*).

Appendix B

Classification of Culture Systems/Technologies

The following descriptions follow the classification of Avault (1996).

Pond Culture:

Aquaculture ponds are typically earthen or concrete, and can be natural or artificially lined. Cultured species can be artificially fed or allowed to feed through the natural trophic chain (food chain). Addition of organic and inorganic fertilizers is common in non-fed ponds (Piedrahita and Giovannini, 1991). Circulation and pure oxygen injection are sometimes used to enhance water quality. Paddlewheels or other means of agitation are also used to enhance oxygenation.

Raceways:

Raceways are long, narrow rectangular tracks or trenches through which water is flushed continuously. They can be constructed of various materials, including plastic, fiberglass, concrete or metal. Water flow can be maintained by diverting natural sources (such as a river or stream) or through artificial means (i.e., recirculating systems with oxygen injection).

Tanks (recirculating systems):

Land-based recirculating systems often involve metal, plastic, or fiberglass tanks, normally built above ground. In the Northeast, the systems are generally enclosed in warehouse type structures. Recirculating systems allow greater control of temperature and tend to minimize water use and effluent discharge. Use of these systems requires highly skilled site managers.

Net-Pen Culture:

Net-pen culture involves the culture of species in floating nets that can be secured at the bottom. Net pens used in salmon culture are generally sited in areas with good tidal flow and considerable depth. Salmon net pens are typically 15m x 15m square and 7m in depth. Larger systems are also common.

Sea Ranching:

Sea ranching involves collecting and breeding adult fish. The offspring are raised in a hatchery until release to the wild. Animals are allowed to grow in the wild, and surviving stock is harvested when it returns to the release site (i.e., salmon) or is harvested in the commercial or recreational fisheries. For example, young salmon are generally held in a land-based facility until a minimum size is reached. The fish are then released into the ocean. This method is used to support much of the commercial salmon fishery in the Pacific Northwest.

Bottom Culture:

Bottom culture includes the culture of oysters and other molluscs on ocean or pond bottoms. Markers are used to set boundaries, but public navigation is not generally restricted.

Off-Bottom Culture:

Off-bottom culture of oysters and other molluscs involves techniques employing floating rafts, strings, and sticks.

Transient Gear Culture:

Transient gear aquaculture refers to the use of submerged cages for containment of the animal being raised. These cages are movable and marked by buoys similar to those used by the lobster industry. The cages are raised to the surface for maintenance and harvest. This method is used for oysters, scallops, and other species.

Hydroponics:

Hydroponics is the practice of raising aquatic and terrestrial plants utilizing nutrient rich water and no soil. Fish culture can be integrated with hydroponic systems to grow plants such as tomatoes, bib-lettuce, and basil. Fish waste is utilized as the major nutrient source for the plants.