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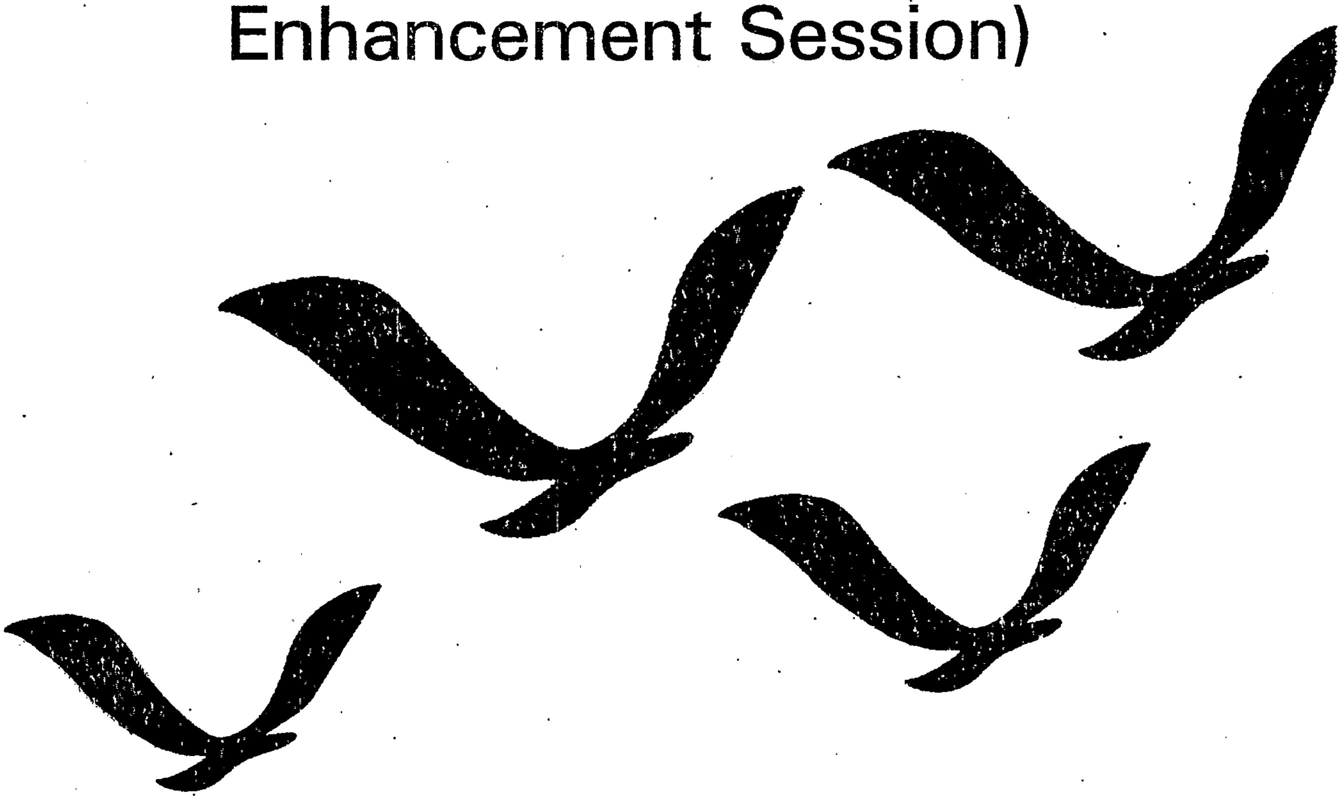

Sea Grant
New Jersey

OFFICE OF WATER PROCEEDING

1994 ANNUAL MEETING OF THE NATIONAL SHELLFISHERIES ASSOCIATION (SHELLFISH STOCK ENHANCEMENT SESSION)

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PREFACE

Each year the National Shellfisheries Association holds an annual meeting at which time scientist, government officials, and resource managers participate in discussions about shellfish. The participants come from around the nation. In 1994, the meeting was held in Charleston, South Carolina.

This proceedings document contains articles from the presentations of the Shellfish Stock Enhancement Session. It was compiled from submissions from each author. The final compilation and editing was done by James Woodley of EPA and Gef Flimlin of NJ Sea Grant. Additional copies can be obtained by from James Woodley, Oceans and Coastal Protection Division, USEPA 4504F, 401 M St., SW, Washington, DC 20460.

CHAPTER 1

HISTORY AND CURRENT STATUS OF NEW YORK STATE SHELLFISH ENHANCEMENT

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Abstract:

As early as 1825 shellfish seed were transplanted into New York City waters from Chesapeake Bay. From these early efforts Long Island Municipalities have utilized techniques to increase the population of harvestable shellfish. Seed planting, spawner sanctuaries, agreements with private mariculture firms, public and private relays, predator control and management areas are used towards this end. Although many of these methods are not critically evaluated they remain politically and publicly popular in most towns. Resource enhancement strategies used in the marine district of New York State will be summarized and quantified. In addition, a new method for evenly dispersing hard clam seed using a modified agricultural seed planter will be described.

Introduction:

Five types of shellfish enhancement methods are or have been used on Long Island. These are: seed planting/shell planting, relays/depuration, spawner sanctuaries/spawner relays, predator control and a special case, the Green Seal bay scallop restoration. All twelve towns in Nassau and Suffolk Counties have attempted at least one of these strategies in order to increase the number of shellfish available to residents.

Although most of these programs are politically and socially popular, their cost effectiveness is largely unknown. Only two towns perform annual hard clam surveys in part to determine how much of a contribution cultured shellfish make to the fishery. Without at least qualitative proof that these programs are worthy of continued funding by municipalities their future is in doubt, especially in light of taxpayer unrest and the desire to downsize government.

Seed Planting/Shell Planting:

As early as 1825 private transplants of oyster seed to New York were common. Seed was purchased from the Chesapeake Bay area and moved to New York City waters or Great South Bay. By the middle of the 19th century oystermen wanted more control over cultivated beds and

Brookhaven Town in Suffolk County granted the first lease in New York State. In 1881, probably due to pressure from wild oyster harvesters, Brookhaven seeded oysters on public bottom. This was New York's first public aquaculture project. During the latter half of the 1800's the rift between the fishermen and cultivators became known as "The Oyster Wars". This period saw private concerns take over almost all the underwater lands on the South Shore and East End of Long Island. Some of today's baymen are still hostile to private mariculture firms due largely to how their predecessors were nearly forced off the bays by monopolistic practices of a few large firms in the late 1800's.

In 1909 the first recorded private transplant of 50,000 bushels of Massachusetts hard clam seed resulted in a 4:1 return. The first quarter of the twentieth century saw experimentation with artificial propagation of oysters and hard clams. Wells and Glancy, two oystermen, were the first to artificially spawn oysters in 1923. By 1926 Wells was spawning and setting both oysters and clams in his Oyster Bay hatchery; by the early thirties Glancy was able to grow hard clams from egg to 25 millimeters at the Bluepoints Company in West Sayville.

During 1955-56 New York State planted about 5,000 clams, a small number by today's standards although the first public hard clam seeding project in New York. The late '50's and '60's were a time of great strides in hatchery technology. In 1958 the Bluepoints Company started an experimental hatchery in West Sayville (South Shore) followed in 1962 by F.M. Flower and Sons in Bayville (North Shore). In 1968 the notata shell marker was first used to identify hatchery-reared clams. In 1970 Long Island Oyster Farms opened a state-of-the-art oyster hatchery on the discharge lagoon of a large oil-fired power plant on Long Island Sound. The heated effluent of the lagoon was used to increase growth rates of clams and oysters prior to planting until 1991; the hatchery was closed in 1982.

Public seed programs became more sophisticated in the 1970's and '80's. Islip Town was the first to undertake a truly modern clam seed program in 1975. In 1986 Islip built the first municipal hatchery/nursery, primarily for hard clam production. East Hampton built their public hatchery/nursery at Montauk with partial funding from New York State in 1989. This came at a time when the bay scallop population was at very a low level due to brown tide and commercial fishermen were banned from selling striped bass due to high PCB levels. The hatchery raises hard clams, oysters and bay scallops and is the largest in square footage of any town hatchery/nursery. Southold Town contracted with Cornell Cooperative Extension in 1991 to operate a hatchery/nursery at the Cornell-operated marine lab located in Southold. Note that all three of these facilities were not purpose-built but were modified from other uses.

During the mid 1980's research on planting strategies versus predation was undertaken. It was clear that evenly-dispersed clam seed had a better chance of surviving predation by foraging crabs (New York's most voracious shellfish predator) than seed that was planted in clumps. In 1989, with funding from New York State, a hard clam seed planter was developed from a modified corn planter. The planter was shown to evenly disperse clam seed onto the bottom with little damage to the seed. It has been used by Towns in Suffolk County to plant millions of clam seed over many acres. This strategy should result in more clams surviving to be recruited into the fishery while preventing "bonanza" harvests of high density plants by harvesters.

Summary of Long Island Town Modern Seed Planting Activities- 1993

Town	Date Program Started	1993 Total Planted (thousands)
Babylon	1978	1,000
Brookhaven	1978	2,000
East Hampton	1981	10,000
Huntington	1981	------
Islip	1975	40,000
Oyster Bay	1982	600
Riverhead	1984	1,000
Shelter Island	1981	250
Smithtown	1980	200
Southampton	1979	100
Southold	1982	800

Table 1

Relays/Depuration:

An obvious method of enhancing the number of shellfish that are marketable in a given area is to enable fishers to harvest shellfish from areas that have been closed to shellfishing. This is allowed in three ways: relaying, depuration and conditional/seasonal harvest areas. Under supervision, many bushels of hard clams, oysters and soft clams have been harvested from closed areas in New York State since the 1920's.

Due to outbreaks of diseases related to eating raw shellfish, New York State started sanitary inspections in 1913. Most of the suspect areas were around New York City, where raw sewage was being dumped into the rivers surrounding Manhattan. The first chlorination plants were opened in the early 1920's. These were outfitted with tanks so that harvesters might store products without it becoming contaminated as was the case with "floating", where bushels of shellfish were simply hung over the side of a boat or dock. Floating is still illegal in New York. In order to coordinate sampling programs in producer states, the National Shellfish Sanitation Program (NSSP) was founded in 1925. The last chlorination plant was shut down in 1932, probably due to lack of efficiency of such plants.

True depuration, an intensive method of microbiologically cleansing, started on a pilot scale in 1941. Chlorine was used as the cleansing agent. In 1964 the State used ultraviolet light in depuration studies and a demonstration plant was built on Long Island in 1971. The required period for depuration is 48 hours, and there are guidelines in the NSSP with respect to tank size, numbers of shellfish per gallon, temperature, flow rate and other parameters to ensure depuration takes place. The first commercial plant was opened on Staten Island in 1979 but closed four years later due to management problems and lack of a steady clam supply. In 1993 a small plant on Long Island was operating at test capacity, but was closed in early 1994.

Relaying is an extensive process which in New York requires the relayer or transplanter to place shellfish on approved lots (on the bottom or off-bottom in cages) for a minimum of 21 days. Unlike depuration, which can be conducted year-round, relaying is limited to warmer months (generally April through October) and relaying cannot start until the receiving (clean) waters have reached 10 C for one week. In 1938 the first 1,500 bushels of clams were relayed from Staten Island to Brookhaven Town. Intra-town relays were popular during the 1960's and 70's until Baymen pressure in the late 70's ended most of these. The problem, say some fishermen, was that when the clams are removed, there is no broodstock left to create set. They also felt that relaying and depuration (especially with clams from Long Island rather than New York City) took the pressure off politicians and regulators to clean up waters.

In 1964 the transplants from western Long Island Sound were harvested by mechanical (hydraulic dredges) means and all the clams went to public lands for the benefit of all permit holders. By 1993 70% of the 58,000 bushels of transplanted clams were hand-harvested and 97% went to private relayers. Relayed clams in the early 1990's represented between 25 and 33% of total hard clam landings in New York, and this by a very small portion of licensed commercial diggers.

Seasonal and conditional openings allow baymen to gain access to shellfish resources during certain periods. In the case of seasonal openings, where water quality improves during the fall and winter months, harvesting is allowed during this time. Conditional areas open only when there is no rainfall of a certain amount, depending on the hydrography of the site. After a rain event exceeding this minimum, the area is closed for a set period, again depending on what past bacteriological samples have shown. Both seasonal and conditional openings may be limited not only by the State Department of Environmental Conservation, but also by each town's shellfish management authority.

Spawner Sanctuaries/Spawner Relays:

These two techniques attempt to increase the number of larvae in the water and hence the number of juveniles that will be recruited into the fishery. Sanctuaries, which were started in 1938 are simply areas where large numbers of broodstock shellfish are placed. In New York, most work has been done with the hard clam. Chowder clams are used due to their low cost and high fecundity. They are also low in value so are inexpensive (on a per piece basis) and do not attract poachers. The theory is that a high fertilization rate will occur due to males and females in close proximity. Beginning in 1963 relays were performed for the same reason, but spawners from cooler waters were brought in so that they would spawn out of sync with local populations. It is thought that this stretches out the spawning season, increasing the chances of a successful set. Despite years of trying, including hydrodynamic models to place broodstock in areas to target their larvae to productive areas, sanctuaries are still unproven due to negative or non-existent evaluations. Reasons for failure include the fact that even a sanctuary with hundreds of bushels of spawners has a minuscule egg output compared to the native broodstock. Despite this seemingly ineffective management method, it is still popular, probably because it is inexpensive and appears to be making a positive impact. The special case of a total lack of broodstock, such as the bay scallop recruitment failure in the mid 1980's in the Peconic Bays is where spawner sanctuaries have been shown to work.

Predator Control:

Predation on bivalve shellfish is thought to be the primary limiting factor with respect to recruitment. Most techniques to control predation were developed by commercial firms, some have been attempted by municipal enhancement programs. In 1912, New York State made the destruction of shellfish predators mandatory by law. While the law does not cover some crusteacea (e.g. lobster, blue crab), it is still a part of the environmental conservation law, though not strictly enforced.

Starfish mops were first used during the 1930's. This control method entangles the stars in mop-like drags. The animals are removed by dipping the mop in either a brine solution or hot water contained in a tank on an oyster boat's deck. Smaller vessels have been used, especially in reseeding efforts. In these cases the stars are hand-picked off the mop. Even with a large oyster boat hauling two dredges, the work of clearing a large area of stars is time-consuming. In the late 1930's Butler Flower of F.M. Flower and Sons Company in Oyster Bay used quicklime to control starfish. This innovation is still used today by some commercial firms when an outbreak of stars is found.

During the 1940's Butler Flower developed his suction dredge. Working like a huge vacuum, the dredge head removes a layer of bottom. The resultant slurry is pumped on board and the predators are picked out while water, sediment and shell goes overboard. This device requires a large vessel with a large pump and is used primarily for prepping grounds for planting.

In 1960 poisons were used to control crabs. Fish heads soaked in pesticides were strung along the shellfish lot. Thankfully the technique was short-lived due to its high cost and the potential for toxin accumulation in shellfish. Another, more passive approach that was successful in Virginia was attempted in New York in 1983. The placement of aggregate (e.g. bluestone) over seed clams was shown in Virginia to protect small clams from crab predation. A similar trial in New York failed to protect seed clams. It was thought that while the most abundant crab in Virginia is the blue crab, smaller mud crabs do the most damage on small seed clams in New York. The stone was actually providing the mud crabs a refuge from their predators along with a free lunch nearby.

During the early 1980's work was progressing in Virginia and later in New York on biological control methods. One animal found to protect clam seed was the oyster toadfish, *Opanus tau*. A 1986 study in Smithtown Bay using tethered and fenced-in toadfish was inconclusive. During the same period, a project examined differences in hard clam survival due to subsurface versus surface planting, and high versus low density plants. While planting clams under the substrate had no effect on survival, low density plants had better survival after two weeks than high density plants. Foraging crabs will eat more clams in a given time period if they are close in proximity to each other. It is not just density, but how evenly-dispersed they are.

This information was used in designing a hard clam seed planter. Modified from a corn planter, the clam planter was tested in 1989 as a better way to plant clams. Hand-broadcasting seed clams results in "clumpy" distribution. Results of the planter trials showed even dispersal of the seed with little damage. It was tested in both municipal settings, where a low density plant is desirable (large acreage to cover, little or no predation control) as well as a commercial planting which was much higher in density (smaller acreage, predation control). No long term trials have been performed, where the actual survival over years is monitored and compared with hand-planted clams.

Green Seal Bay Scallop Restoration:

This is a special case of shellfish enhancement, made necessary by the appearance and perseverance of the "brown tide", a bloom of algae that is poor food for bivalve shellfish, especially larvae. First seen in 1985, the blooms caused recruitment failure of bay scallops in most of the Flanders-Peconic-Gardiners Bay system. Beginning the next year, a group of commercial fishermen along with university and extension personnel with a combination of state, county and local funding restocked areas with hatchery-reared stock. Many of the plantings either died from predation or subsequent brown tide events and by 1988, the commercial fishery had crashed, going from a $2 million pre-bloom value to only $2,000.

In 1989, genetic work on juvenile scallops showed 25% of these were genetically similar to the 1988 hatchery stock that was planted. By 1990, recruitment was up and there was some signs of recovery. A *Polydora* (mud-blister worm) infestation along with another summer of brown tide caused mortalities in 1991. During 1992 and 1993 (non-brown tide years) a slowly-improving commercial fishery was seen from east to west. Over six million bay scallops were planted over the life of this project; much was learned about planting these shellfish. It was the first time in New York State that hatchery-reared broodstock was used to assist in revitalizing a shellfishery.

Recommendations for New York's shellfish enhancement programs:

There is a need to critically evaluate present programs, both town and state-funded. Although once universally politically popular, some programs are under fire for being inefficient, ineffective or both. Only two out of twelve towns have an annual shellfish census, which provides critical information to evaluate such programs as seed planting and spawner sanctuaries. Funds must be targeted to what works best in a given area, rather than the "shotgun" approach of many present programs.

A facility exists on north-central Long Island where heated effluent is available for shellfish culture during the late fall through late spring period. The Northport Power Station is a large, four unit oil/gas fired plant that was designed with a shellfish farming component. Unfortunately, a fire in 1991 destroyed the entire environmental center where shellfish nursery culture was taking place. A coalition of Long Island Towns have approached the plant's owner, the Long Island Lighting Company about utilizing the site. Negotiations are ongoing. The effluent lagoon would complement municipal hatchery production by allowing late (fall) spawns and "runts" to grow to a large planting size by summer.

Relay sites in western Long Island Sound and around New York City are under heavy harvest pressure. The New York State Department of Environmental Conservation recently completed a Generic Environmental Impact Statement for the relay program. Mention is made there of "sustainable harvests", and the old theory of reducing shellfish populations as much as possible in closed areas is no longer espoused. Along those lines, public depuration should be explored. While private depuration in New York has experienced failure, a public plant with a larger supply base and some government support could work.

The clam seed planter needs to be evaluated and fine-tuned so that its use may be increased, especially among Long Island Towns growing millions of hard clams each year. In addition, the need is still strong to educate the general public, commercial and recreational shellfishers, regulators and policy makers through one-on-one meetings, baymen/advisory committee meetings, fishermen's forums, newsletters and mass media. Only in this way can the science and art of shellfish enhancement evolve in New York.

CHAPTER 2

SETTLEMENT AND RECRUITMENT OF BAY SCALLOPS, *ARGOPECTEN IRRADIANS* (LAMARCK 1819), TO ARTIFICIAL SPAT COLLECTORS IN THE WESTPORT RIVER ESTUARY, WESTPORT, MASSACHUSETTS

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Abstract

In January 1993, The Waterworks Group initiated the Bay Scallop Restoration Project as an attempt to restore the once prolific bay scallop population within the Westport River Estuary in Massachusetts. This project is a multi-phased endeavor aimed at better understanding recruitment failures of both natural stocks and introduced seed of *Argopecten irradians*. The main objective of this project is to assess juvenile recruitment (survival to > 4 mm) to artificial spat collectors placed in historically productive scallop beds and within close proximity to adult spawner rafts. Spat collectors (2 to 4 mm plastic-mesh bags) containing monofilament were suspended on 28 to 35-meter floating long lines at 9 locations in the Westport River. A total of 1400 spat collectors were sequentially deployed on 89 long lines from June to August 1993 to determine the timing of peak settlement and recruitment at each study site. The 1993 harvest yielded 4000 scallops of varying shell heights ranging from 4 to 60 mm, with an overall mean of 36.9 mm. The variability in shell height was related to the soaking time of the spat collectors which ranged from 68 to 152 days. The most productive long lines were located in the vicinity of Corey's Island, Horseneck Channel and Canoe Rock. The greatest recruitment was observed at Corey's Island which yielded 1882 scallops averaging 6.1 scallops per collector, with individual long lines harvesting 18.2 scallops per collector. This study indicates that *A. irradians* will settle on artificial spat collectors containing monofilament, which may offer an alternative tool for resource management and stock enhancement.

Introduction

The bay scallop, *Argopecten irradians* is an economically important bivalve harvested

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commercially and for recreation in coastal communities along the Atlantic and Gulf coasts of the United States. The total supply of bay scallop meat for the United States between 1983 and 1992 showed a gradual decrease in the annual harvest. In 1983, 2,338,000 lbs of meat were landed compared to 356,000 lbs in 1992. Comparing recent landing records with 1991, the 1992 season decreased by 82,000 lbs (O'Bannon and Holliday, 1993). These nationwide landings indicate a notable decrease in bay scallop stocks within the last decade which needs to be addressed. Historically, Massachusetts has been the leading producer of bay scallops for New England and the nation. Belding (1910) reported that commercial scalloping began in 1872 in Massachusetts. The most abundant scallop beds were found along the south shore of Cape Cod, Buzzards Bay, Martha's Vineyard and Nantucket. Matthiessen (1992) reported that between 1951- 1960 Massachusetts landed an impressive on average 915,000 lbs of bay scallops annually. However, between 1981- 1990, Massachusetts landed 23% fewer scallops from the earlier decade. Since Matthiessen's (1992) review, bay scallop harvests have declined further in the 1990's.

Recruitment Failures

Sporadic recruitment failures have always been reported along the Atlantic coast, with stocks constantly wavering from year to year (Belding, 1910). A precise cause for the recruitment failure is not known, but evidence suggests that a number of factors are to blame such as nuisance algal blooms (Bricelj et al., 1987; Summerson and Peterson., 1990; Tettelbach and Wenczel, 1991), poor water quality (Stewart et al., 1981), industrial waste (Beaumont et al., 1987), fishing pressure (MacFarlane, 1991), environmental conditions (Gaines and Ross,1983; Tettelbach and Auster, 1985), habitat loss (Stauffer, 1937; Cottam and Addy, 1947; Marshall, 1960; Fay et al., 1983) and predation (Peterson et al.,1989; Prescott ,1990; Pohle et al., 1991)

In general, it is believed that sporadic recruitment and declining stocks are related to the bay scallop's life span of 20 to 26 months in New England (Belding, 1910; Gutsell, 1931; Roberts, 1978) and 12 to 16 months in the mid-Atlantic (Castagna, 1975). This short life span coupled with the previously mentioned factors are responsible for the decline in scallop harvests. After consecutive years of poor recruitment, spawning stocks are reduced, thereby adversely affecting the fishery over time. Most coastal communities are unable to rebound without some type of management intervention. As a result, many communities implement reseeding or transplanting programs to enhance the natural stocks (Burns, 1990;Tettelbach and Wenczel,1991). The most common practice is to purchase aquaculture seed from hatcheries. Yet, hatchery reared seed may not survive well when transplanted or reseeded into the estuary prior to the winter season. Consequently, seed purchased to rebuild stocks may not live to spawn (Tettlebach et al.,1990). Furthermore, the availability of seed at affordable prices is often a limiting factor in implementing a reseeding program in some small coastal communities (Sherman, pers. com.)(***Figure 1***.).

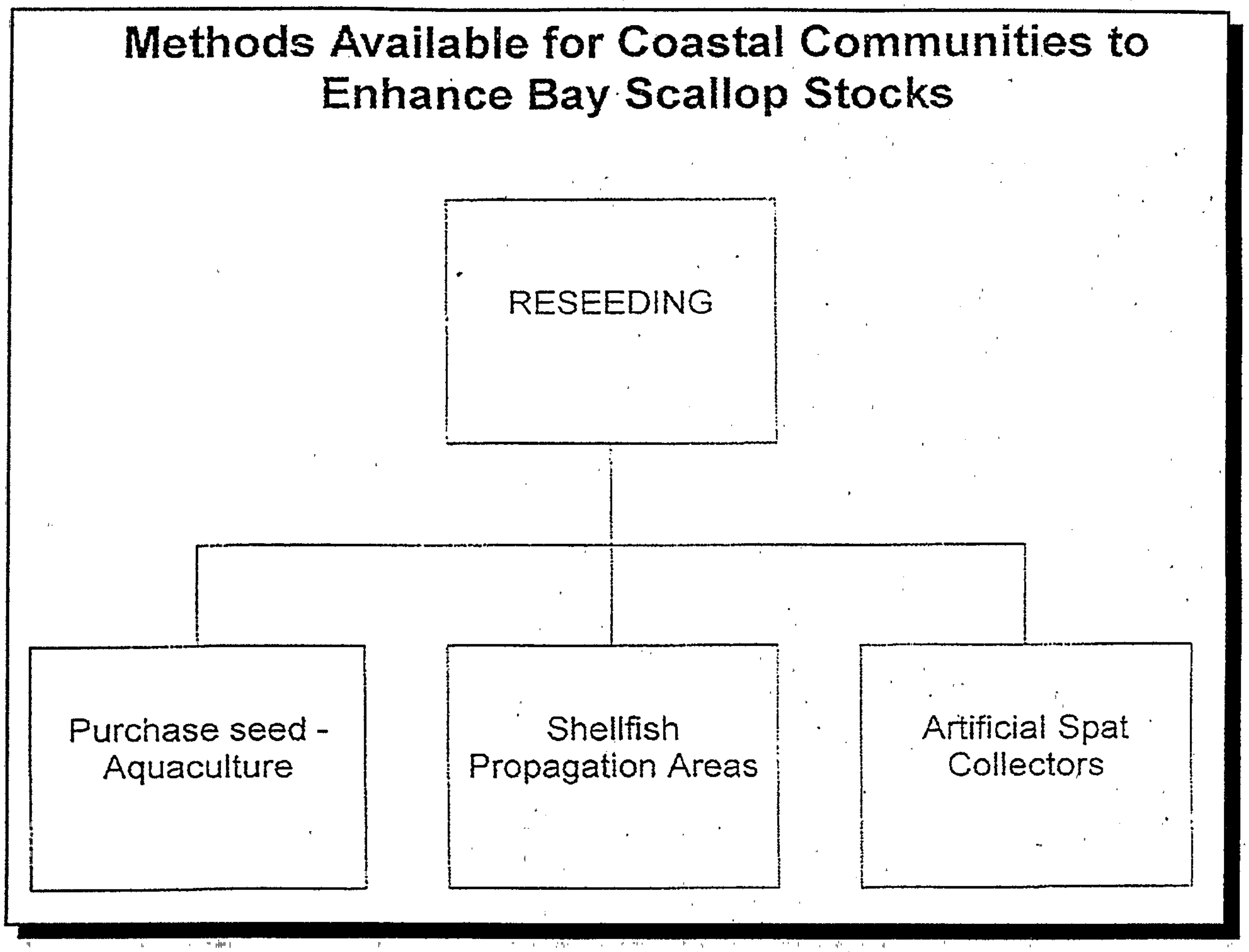


Figure 1.

Stock Enhancement: Artificial Spat Collection

As a consequence of fluctuating scallop stocks, many countries such as Japan, Tasmania, New Zealand and Canada have devised various schemes to enhance natural stock. Methods such as reseeding, artificial propagation and artificial spat collectors have been incorporated into management plans. The collection of natural seed with artificial spat collectors, in addition to reseeding, has effectively resulted in stabilizing the scallop fishery. The artificial spat collectors have not been commercially utilized in the United States, but are widely used in Japan (Ito and Byakuno, 1989), Tasmania, New Zealand (Bull, 1989), and Canada (Cropp, 1989) as part of their overall scallop management program . In addition, countries such as Mexico (Verdugo and

Caceres-Martinez, 1991), Scotland (Fraser, 1991), Yugoslavia (Margus, 1991) and Ireland (Burnell, 1991) are utilizing artificial spat collectors to study scallop populations and to assess the potential for establishing a commercial fishery. With the advent of the artificial spat collector, Japan has maintained a commercial scallop fishery by collecting scallop seed in areas which had lost eelgrass beds (Ito and Byakuno,1989; Ito, 1991).

Artificial spat collectors of similar designs have only been used for experimental purposes in the United States. In North Carolina, Ambrose et al. (1992) used artificial spat collectors of various colors and different surface size to determine factors influencing scallop recruitment to the artificial collector. Researchers on Nantucket Island, Massachusetts collected over 40,000 scallop spat from 90 collectors placed in early July. After reaching 10 to 20mm, the scallops were transferred to larger floating cages. Once the scallops reached 40 to 50mm in shell height, scallops were redistributed onto the shellfish beds (Kelly and Sisson, 1983).

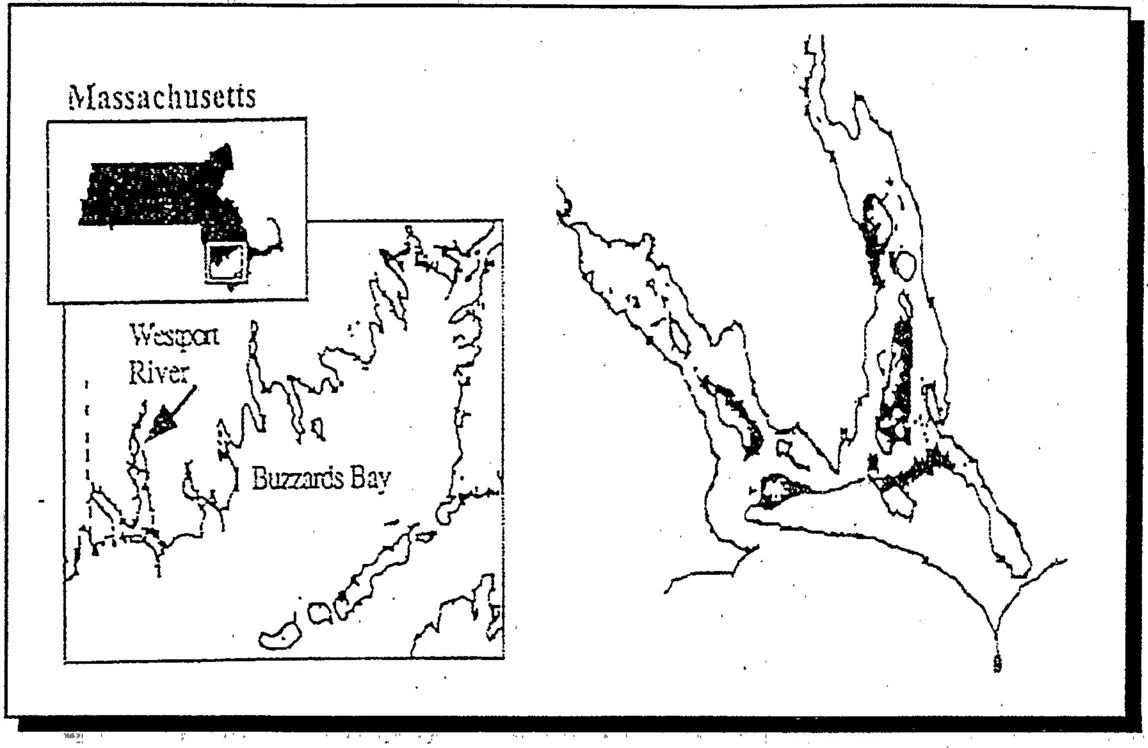
Nevertheless, very few New England coastal communities have attempted to utilize artificial spat collectors to investigate the settlement and recruitment of bay scallops to artificial substrate or as part of a management strategy for long-term stock assessment and enhancement.

Westport Estuary

The Westport River estuary harbors one of the most productive shellfisheries in Massachusetts (Fiske et al, 1968). Historically, Westport has always enjoyed successful bay scallop harvests, rarely experiencing large fluctuations in scallop stock (***Figures 2 and 3***). In 1985, Westport harvested a record 66,000 bushels of scallops which produced $ 2.5 million for the local economy (Westport Annual Town Report, 1985). However, since the 1985 harvest, only meager amounts of scallops have been harvested. The recent decline in this once prolific resource questions the feasibility of future commercial scalloping in Westport. Furthermore, the harvesting of clams, quahogs and oysters have been drastically reduced due to shellfish bed closures from fecal pollution. The lack of a successful bay scallop set coupled with shellfish closures have hurt the local and regional economy in southern New England. Faced with the decline in scallop stocks, other methods of stock enhancement are needed to maintain bay scalloping.

The purpose of this research is to investigate settlement and recruitment of bay scallops to artificial spat collectors at various study sites throughout the Westport River estuary. The goal of the Bay Scallop Restoration Project is to collect sufficient numbers of juvenile spat to be placed in protective grow-out rafts at propagation areas in the estuary. The juvenile spat collected from artificial collectors will be used as spawning stock. This preliminary research provides insight into the feasibility of implementing artificial spat collectors and spawner rafts as long-term enhancement tools that could help restore bay scallop stocks in the Westport estuary.

Figure 2



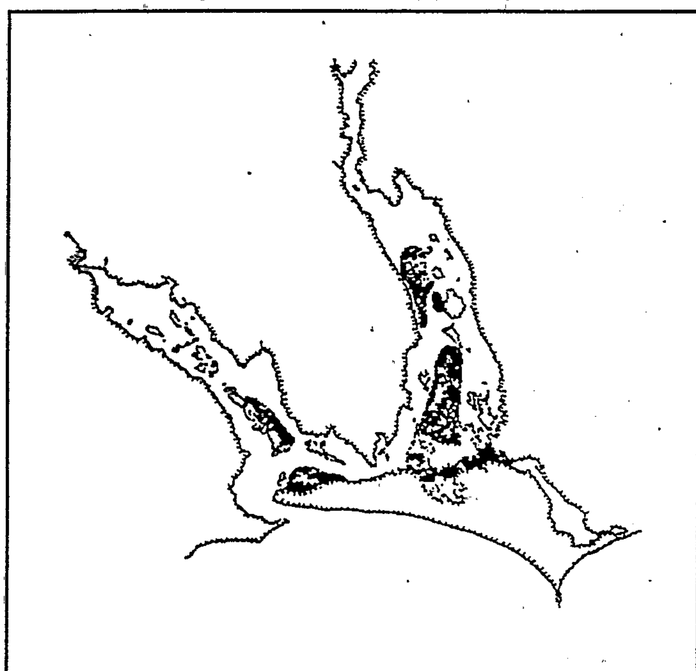


Figure 3

Shaded Areas Represent Historic Bay Scallop Beds in the Westport River Estuary (Fiske et al., 1968)

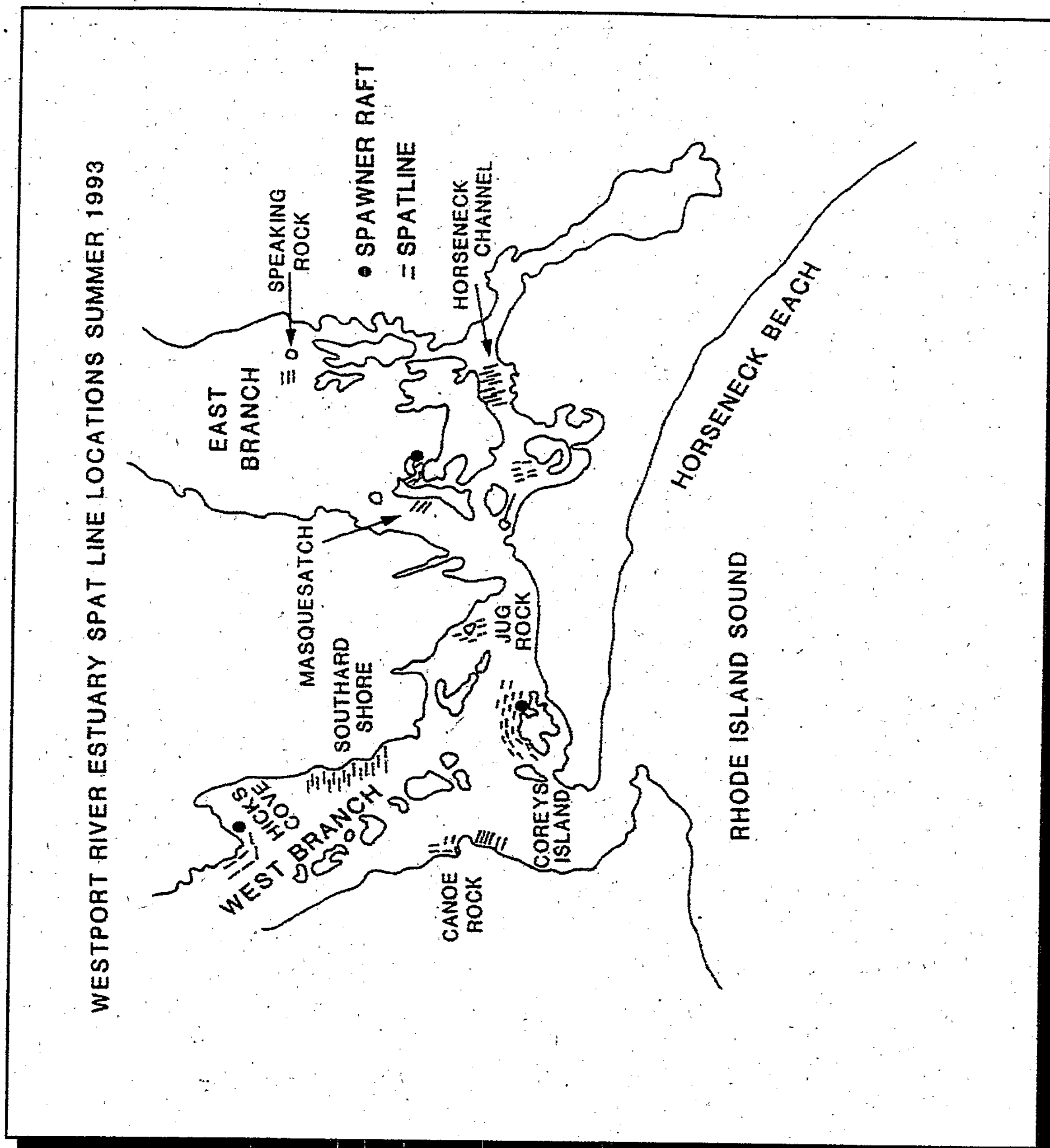


Figure 4

Material and Methods

During the summer of 1993, spatlines containing 20 to 25 individual spat collectors were deployed at 9 study sites within the Westport Estuary (***Figure 4***). Artificial spat collectors consisted of (2mm - 4mm) 50 lb. plastic mesh onion bags filled with monofilament (***Figure 5***). Spat collectors were weighted in order to maintain a vertical soaking position. Horizontal spatlines 28 - 35 meters long were sequentially deployed between June and August 1993. Each spatline was color coded by date to aid in the determination of soaking time. A total of 89 spatlines and 1,400 spat collectors were deployed into both branches of the Westport River. Spatlines were strategically located within close proximity to adult scallops held in spawner rafts and in the vicinity of historic scallop beds seen in Figure 2. Each raft contained approximately 300 sexually mature adult scallops. Spatlines and collectors were retrieved in September and October 1993. Spat collectors were opened and several quantitative and qualitative variables were analyzed from each collector, noting the location and time. Juvenile scallops were counted and shell height (mm) was measured with hand held calipers (0.05 mm) precision. Fouling and predatory organisms were also identified.

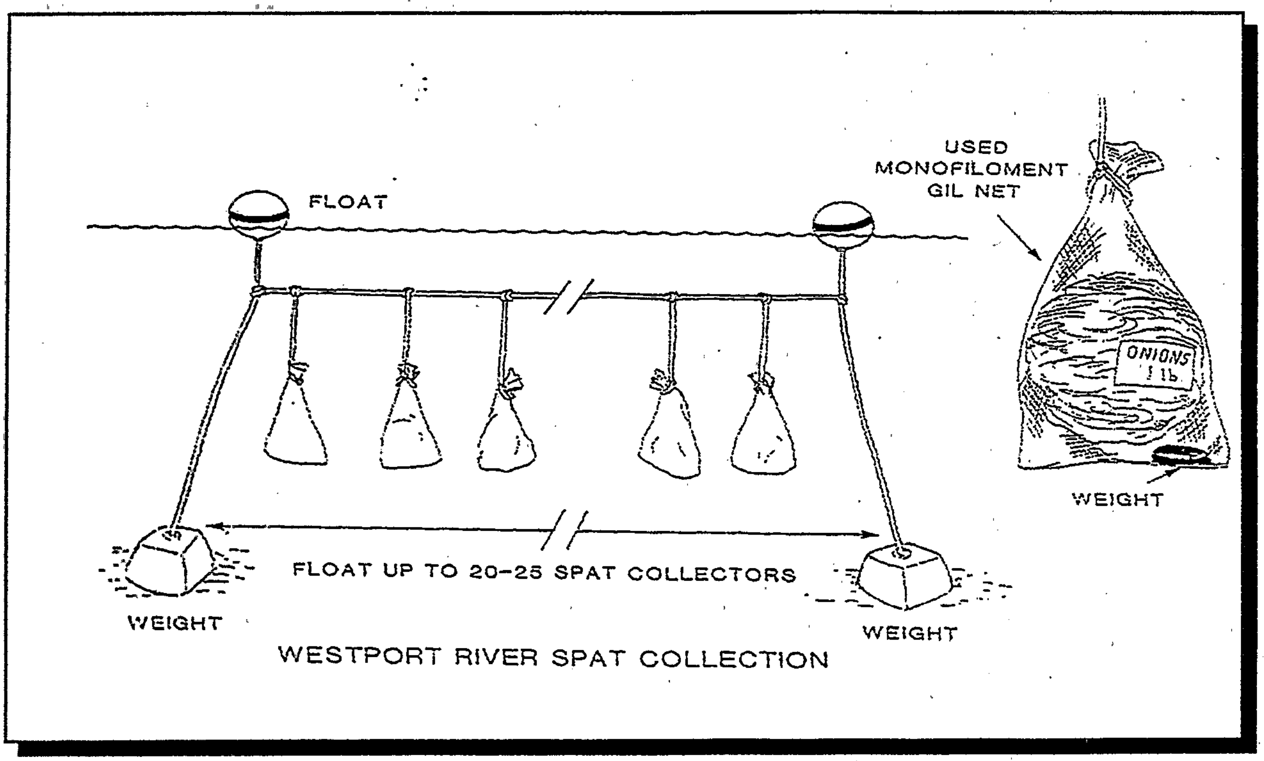


Figure 5

Results and Discussion

Spat Settlement

Settlement of scallops to artificial spat collectors was successful in the summer of 1993. A summary of each site is shown in ***Table 1***. Of the 4,002 scallops collected, Corey's Island displayed the highest recruitment of any study site, harvesting a total of 1,882 in 19 spatlines. The average number of scallops/collector for this location was 6.1 (***Figure 6***). Individual spat collectors deployed in July averaged 18.1 scallops/collector with the greatest overall recruitment of 32 scallops in one collector. The second best collection site was Horseneck Channel which harvested a total of 621 scallops, averaging 2.16 scallops/collector. Canoe Rock also displayed favorable recruitment harvesting 491 scallops/collector and averaging 2.58 scallops/collector. In general, the highest recruitment values were observed at Corey's Island, Canoe Rock, Hick's Cove and Horseneck Channel spatlines deployed on July 4th and July 18th (***Figure 7***). The analysis of the individual spatlines deployed at Corey's Island showed that July 4th had greater recruitment than July 18th (***Figure 8***).

In summary, during the summer of 1993, bay scallop spawning in the Westport Estuary may have occurred during late June and mid-July. Maximum recruitment estimates were observed for those spatlines deployed the week of July 4th and July 18th with Corey's Island representing the best study site, having the highest total recruitment value of 1882 scallops.

Summary of Westport River Research

Results of Summer 1993

LOCATIONS	# SPATLINES DEPLOYED	TOTAL SCALLOPS HARVESTED	MEAN SCALLOPS PER COLLECTOR	MEAN SHELL HEIGHT (mm)	RANGE OF SOAKIN G TIME
CANOE ROCK	12	491	2.58	37.1	108 - 152
COREYS ISLAND	19	1882	6.1	25	75 - 114
HICK'S COVE	6	341	3.04	32.2	93 - 100
HORSENECK CH.	19	621	2.16	29.8	89 - 118
JUG ROCK	6	131	1.51	26.9	68
MASQUESATCH	3	32	0.65	30.7	122
RAM ISLAND	5	183	3.21	31.5	88
SOUTHARD SHORE	16	158	0.62	30.4	93 - 100
SPEAKING ROCK	3	163	3.01	29.1	80
TOTALS	89	4002	NA	36.9 mm	68 - 152

Table 1

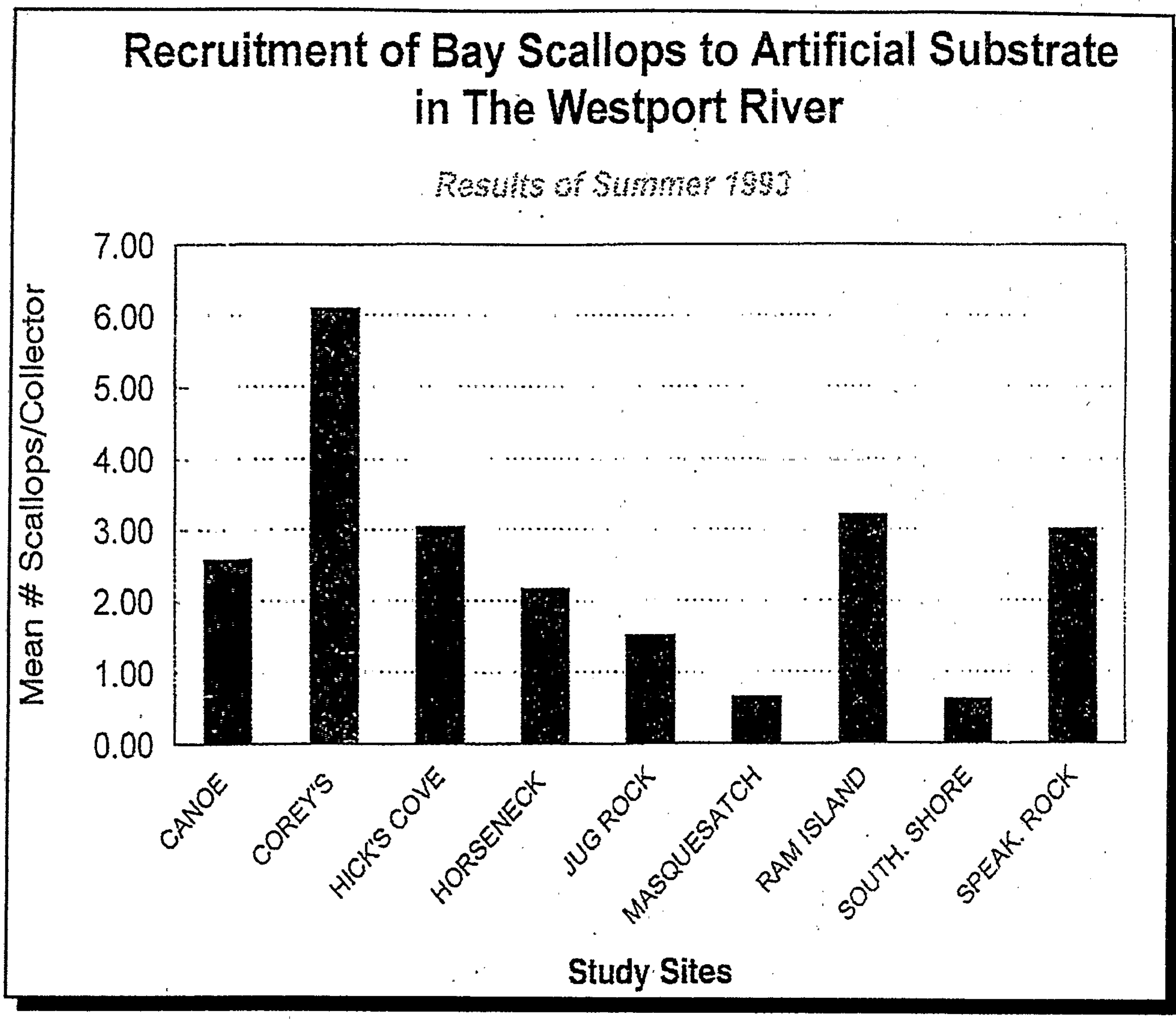

Recruitment of Bay Scallops to Artificial Substrate in The Westport River
Results of Summer 1993
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Mean # Scallops/Collector
CANOE
COREY'S
HICK'S COVE
HORSENECK
JUG ROCK
MASQUESATCH
RAM ISLAND
SOUTH. SHORE
SPEAK. ROCK
Study Sites

Figure 6

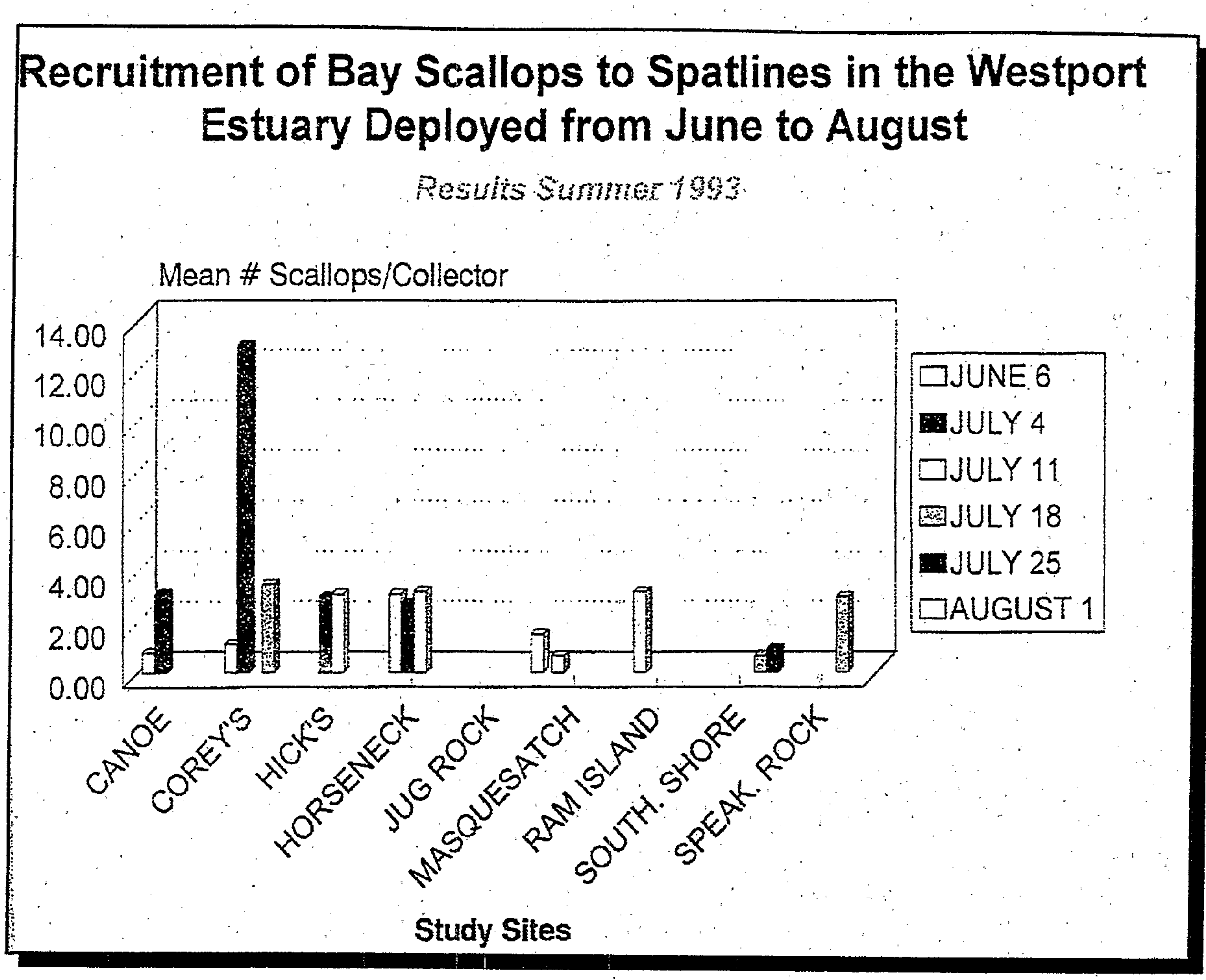

Recruitment of Bay Scallops to Spatlines in the Westport Estuary Deployed from June to August
Results Summer 1993
Mean # Scallops/Collector
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JUNE 6
JULY 4
JULY 11
JULY 18
JULY 25
AUGUST 1
CANOE
COREY'S
HICK'S
HORSENECK
JUG ROCK
MASQUESATCH
RAM ISLAND
SOUTH. SHORE
SPEAK. ROCK
Study Sites

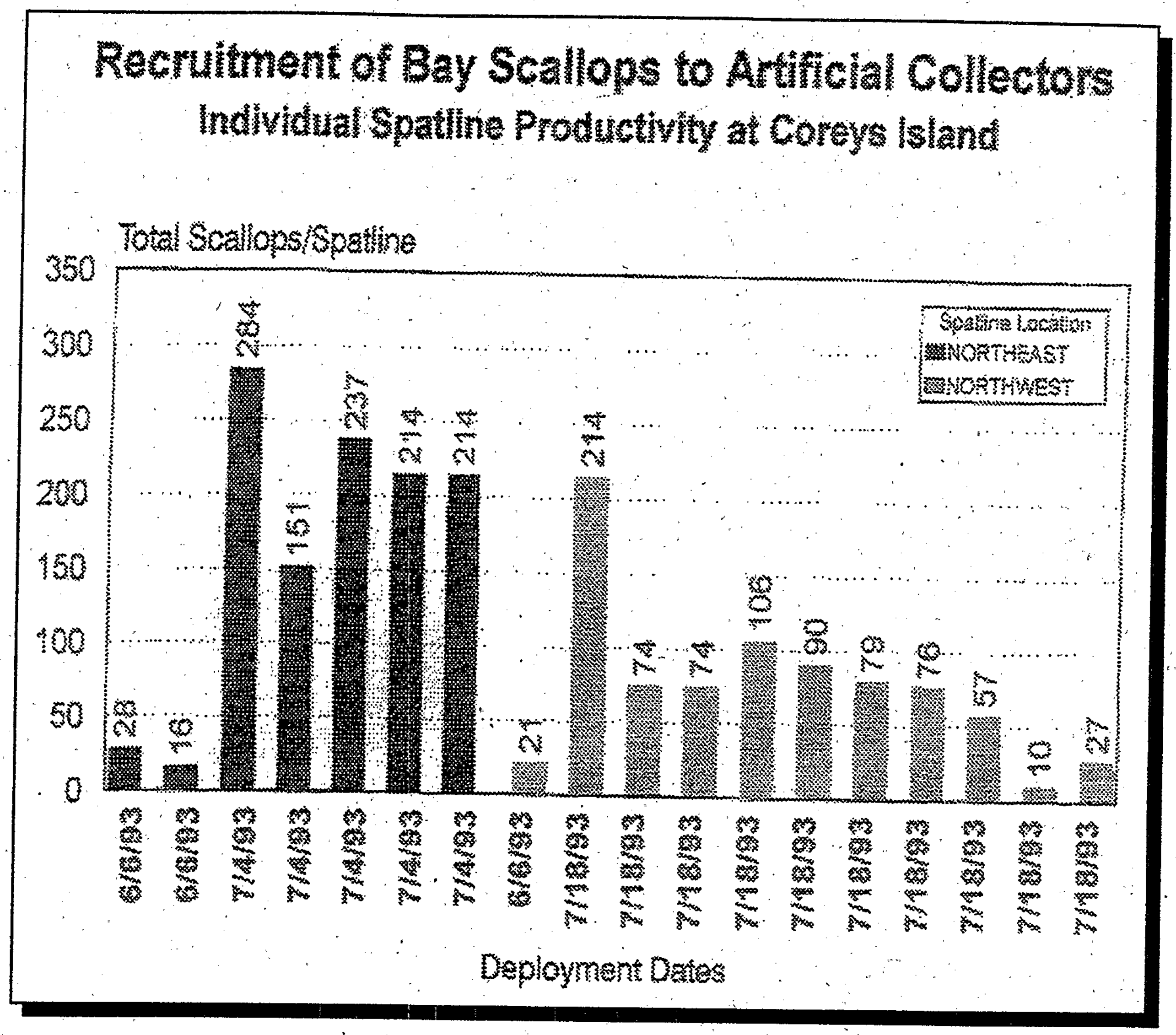
Figure 7

Growth Measurements

The juvenile scallops harvested from the collectors ranged from 4 to 60 mm in shell height, with an overall average of 36.9 mm. The difference in shell heights related to the soaking time of the long lines which ranged from 68 to 152 days. Canoe Rock displayed the largest shell height averaging 37.1 mm with the longest soaking time of 152 days, whereas Corey's Island averaged 25 mm scallops with a maximum soaking time of 114 days (***Table 1.***). A frequency distribution of spatlines deployed at Corey's Island exhibited a difference with respect to the size classes observed. Spatlines deployed on the northwest side of Corey's Island were smaller than the scallops collected from the northeast spatlines. However, northwest spatlines were deployed on July 18th, one week shorter than the northeast spatlines which may explain for the difference in shell height ***(Figure 8)***.

Lastly, normalization of the shell height measurements was conducted in order make a comparison of possible scallop growth at each study site. Scallop heights were normalized to a soaking time of 89 days. The 89 period represented the modal soaking time observed for all spatlines. As a result, the mean shell height for all locations using the 89 days was approximately 30.2 mm (***Figure 9.***). Jug Rock displayed the largest scallop height approximately 34 mm. The Masquesatch study area displayed a lower value which may relate to having 3 spatlines and harvesting only 32 scallops with great variation in size.

Normalizing of growth measurements only suggests possible growth potential and not an actual growth rate of scallops within at the study sites. Since individual growth rates and settlement times vary in estuary systems, determining these factors becomes difficult without larval sampling and marking individual spats for growth monitoring.


Recruitment of Bay Scallops to Artificial Collectors
Individual Spatline Productivity at Coreys Island
Total Scallops/Spatline
350
300
250
200
150
100
50
0
Spatline Location
NORTHEAST
NORTHWEST
28
16
284
151
237
214
214
21
214
74
74
106
90
79
76
57
10
27
6/6/93
6/6/93
7/4/93
7/4/93
7/4/93
7/4/93
7/4/93
6/6/93
7/18/93
7/18/93
7/18/93
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7/18/93
Deployment Dates

Figure 8

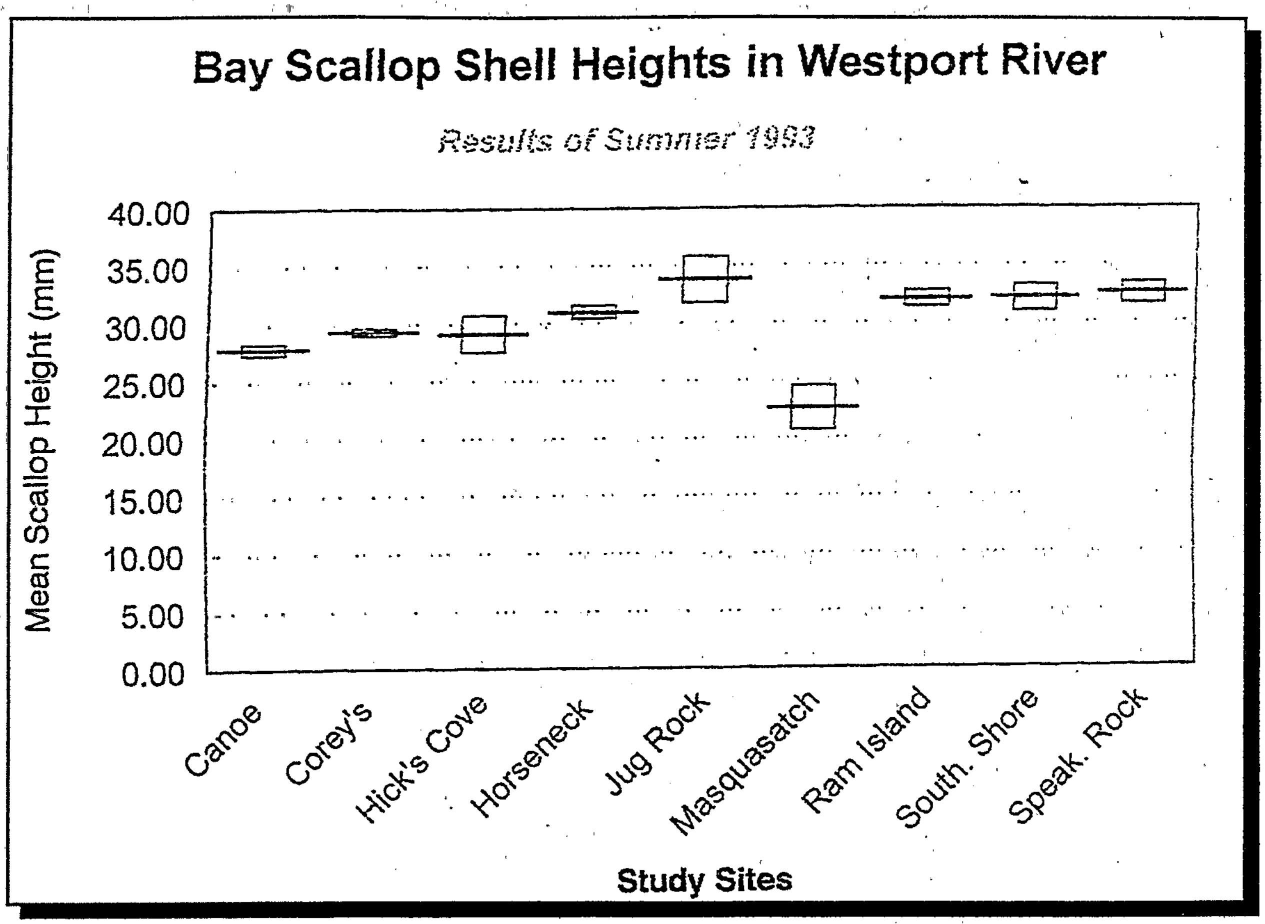

Figure 9

Fouling Index

A fouling index was created to access the "cleanliness" of the artificial spat collector. Collectors were rated on a scale of 1 to 5, with 1 representing a clean bag and 5 a heavily fouled bag. Collectors were closely examined with respect to this index. Spatlines and collectors with longer soaking time were heavily fouled and given a rating of 5. A majority of the spat collectors from Canoe Rock, Corey's Island and Horseneck Channel had soaking times over 100 days. As a result, these collectors were given ratings ranging from 3 to 5. The remaining locations displayed a variety of ratings from 1 to 5. The Jug Rock study site had the cleanest collectors averaging 2.5 relating to the shortest soaking time of only 68 days.

Fouling and Predatory Organisms

A variety of fouling and predatory organisms were collected outside and inside the spat collectors. A summary of these organisms can be seen in ***Table 2***. Organisms defined as fouling in nature were mostly marine invertebrates and algae. *Mogula spp*., *Ciona spp*., *Styela partita*, *Microciona prolifer*, *Didemnum spp*., *Botryllus schlosseri*, *Crisia* and *Enteromorpha spp*. were among the fouling organisms that settled on the exterior of the collector bag and inside on the monofilament.

Predatory organisms such as *Carcinus maenas*, *Libinia dubia*, *Panopeaus spp*., *Tautog onitis* and *Opsanus tau* were found inside the spat collectors feeding on *Panopeus spp*., mud crabs. It could not be determined whether these predators had also fed on the juvenile scallops within the collectors.

Artificial Spat Collector Contents

Common Names	Scientific Names
Green Crab	*Carcinus maenas*
Spider Crab	*Libinia dubia*
Mud Crab	*Panopeus spp.*
Sea Grapes	*Molgula spp.*
Sea Vase	*Ciona intestinalis*
Sea Squirts	*Styela partita*
Red Beard Sponge	*Microciona prolifera*
White Crust	*Didemnum spp.*
Golden Star Tunicate	*Botryllus schlosseri*
Red Crust	*Cryptosula spp.*
Jointed Tube Bryozoans	*Crisia spp.*
Hollow Green Weeds	*Enteromorpha spp.*
Tautog	*Tautog onitis*
Cunner	*Tautogolabrus adspersus*
Blennies	*Ophioblennies atlanticus*
Oyster Toad Fish	*Opsanus tau*

Table 2

Conclusion

This study determined that *A. irradians* will settle on artificial spat collectors containing monofilament in the Westport Estuary. Our results indicated that the maximum settlement time occurred during mid-July, similar to other research in New England (Belding, 1910; Gutsell, 1931; Kelley and Sisson, 1983). In addition, we determined that Corey's Island, Horseneck Channel and Canoe Rock were the most productive study sites and therefore, the best areas to deploy spat collectors in the future. The greatest overall recruitment was observed at Corey's Island yielding 1882 scallops. Historically, Corey's Island has been the most productive scallop bed for the estuary known by researchers and local fisherman (Fiske et al, 1968; Sherman pers. com., 1993). Lastly, fouling and predation may influence scallop settlement and actual recruitment estimates for all study sites.

This preliminary research displayed a high degree of variability with respect to the number of spat collectors and spatlines deployed at each of the study sites. Along with the biotic and physical factors, this variability greatly influenced the actual assessment of productivity, settlement and recruitment values, and growth rate estimates determined for the 9 study areas. Research conducted in the future will focus on improving the methods from this 1993 experimental study. In addition, larval sampling and monthly spat settlement will be monitored thoroughly as will water chemistry, current and food availability. Applying these techniques will further advance the accuracy of determining the optimal settlement and recruitment times of scallops to artificial spat collectors.

This research indicates that spat collectors may be a means to predict recruitment into the bay scallop fishery. Secondly, juvenile scallops harvested from spat collectors could be utilized for other grow-out applications to enhance natural stocks. Consequently, the implementation of spat collectors into an overall management plan could be a method employed by coastal communities to improve, stabilize and restore bay scallops in Southern New England.

Acknowledgements

This is publication # 3117 of the Rhode Island Agricultural Experiment Station. This project has been supported by the Westport Water Works Group and project H - 870 of the Rhode Island Agricultural Experimental Station.

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Personal Communications

Gary Sherman, Westport Shellfish Constable, Fall 1993

CHAPTER 3

SHELLFISH STOCK ENHANCEMENT ON MARTHA'S VINEYARD

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Introduction

The Martha's Vineyard Shellfish Group, Inc. is a nonprofit consortium of the shellfish departments of five Island towns attempting to manage the economically important public stocks of quahogs (Mercenaria mercenaria), bay scallops (Argopecten irradians), and oysters (Crassostrea virginica). Over the past 15 years, the shellfish management program has included efforts to augment natural recruitment through the application of aquaculture techniques. Foremost in this stock enhancemnent effort has been the local production of seed shellfish from native broodstock in a solar assisted shellfish hatchery. Cost effective nursery methods have been developed to grow quantities of seed shellfish of sufficient size to positively impact local natural stocks.

The community shellfish resource development program is funded primarily with local tax dollars appropriated at the town meetings of the five participating communities. The Shellfish Group receives no financial assistance from the state. This grass roots program has of necessity addressed the immediate concerns of the local populace. Cost effective production of seed shellfish to improve local harvests has been the primary focus. The voters are reluctant to fund "yet another study" of why shellfish stocks are in decline. The production of seed shellfish to plant on public beds has been a more tangible and acceptable use of their tax dollars. With the livlihoods of the local citizens at stake, a "shotgun approach" of trying any and all methods at once has been used rather than more scientifically designed single variable experiments. Consequently, a degree of uncertainty is inherent in the observations. Investigators whose funding is further removed from the local level are invited to take these preliminary observations to a higher degree of scientific certainty.

Hatchery Culture

Seed shellfish used in the stock enhancement efforts are spawned and cultured in a solar assisted shellfish hatchery. Within the 1,000 sq ft building, about 15 million seed shellfish (quahogs, scallops and oysters) are produced annually. For a detailed description of the solar hatchery operation see Karney, 1991.

Phytoplankton fed to the larvae are batched cultured using the Milford method. The Tahitian strain of Isochrisis galbana and Chaetoceros gracilis provide the bulk of the larval food. The larger Thalassiosira weissflogii is fed to post set, especially scallops, which require phytoplankton of larger cell size. Batch cultured Tetraselmis maculata (TTM strain) is used for conditioning broodstock. Also, a variation of the Wells-Glancy method is used to grow wild cultures of phytoplankton which are used primarily for ripening broodstock. Except for stock cultures which are grown in a hood under artificial light, all algae are cultured in natural light in a passive solar greenhouse.

Broodstock, conditioned in the hatchery or collected naturally ripe in the field, are spawned in pyrex dishes using thermal stimuli. The resulting larvae are grown in 400 liter conicals in seawater filtered to five microns, heated to about 23 C and supplemented with cultured phytoplankton. Throughout the two to three week larval period, the larvae are fed daily. Every other day the larvae are drained, sized, culled and resuspended in new sea water. With the onset of metamorphosis, quahog and scallop pediveligers are held on sieves in the larval conicals with a downflow of water recirculated with an air lift. (Eyed oyster larvae are remote set on shellbags at a site about five miles from the hatchery.)

Completely set quahogs and scallops are eventually moved to sieves with a trickle flow of seawater bag filtered to five microns ***(Figures 2 and 3)***. As the juveniles grow, they are moved to larger mesh sieves with stronger seawater flows filtered through 10, 25 and finally 50 micron bag filters. At about 0.5 mm the seed are given a flow of unfiltered raw seawater. The quahogs are grown in upweller silos and the scallops in raceways. In these culture modes the seed is rinsed daily and sized weekly.

Field Culture of Quahogs

In recent years, hatchery seed production has been increased with the use of field nursery systems capable of handling smaller seed. Quahog seed is now routinely moved at 1 mm from upweller silos to field nurseries. The quahog seed is planted in sand in both floating sandboxes and wooden bottom boxes ***(Figures 4 and 5)***. These nurseries are designed to protect the seed from crawling predatory crabs. Green crabs and mud crabs are major predators of the small quahogs. The floating sandboxes suspend the seed off the bottom and away from the crabs. In the bottom boxes window screen covers exclude the crabs. If the 1 mm seed is planted in the nurseries in early July, it will reach about 20 mm by October. The seed is usually free planted in public beds with a 60-70% survival. Protection for another growing season in bottom boxes results in increased survival but is labor intensive as the larger seed must be thinned and many more culture units constructed. Short wire fencing has proved effective in reducing predation by whelks (Busycon carica) which can be significant predators on larger seed.

Hatchery stocks have been selected for fast growth and genetically tagged for monitoring. Annual shell growth rings may be used to estimate a quahog's age. Wild stock may take five to seven years to attain legal littleneck size. The cultured stocks are selected for fast growth and are legal for harvest at three to four years of age. About 80% of the quahogs cultured in the hatchery are tagged with the brown genetic shell markings referred to as notata. Notata markings are rare in indigenous Island stocks. Cross breeding of notata with native broodstocks have given the hatchery stocks the genetic shell tag. One indication of the effectiveness of the quahog stock enhancement efforts is the fact that some town shellfish constables now report 20% of the harvest with notata markings. Natural sets of notata quahogs have also recently been observed.

Field Culture of Scallops

At about 2 mm, seed scallops are moved from the hatchery raceways to field cages anchored in the bay outside the hatchery. The cage nurseries are 6 feet long, 2.5 feet wide and 1 foot deep (15 cu ft); and constructed of 2X3 lumber frames with various size plastic netting on the sides ***(Figures 6-8)***. The 2 mm seed from the hatchery raceways are transferred to cages with fiberglass window screen mesh at a density of about 100,000 scallops per cage. The window screen fouls quickly and must be brushed clean daily. After about a week in the field, the seed have grown enough that they may be transferred to a larger 3 mm vexar mesh cage at about half the original density. Ideally, the scallops are eventually reduced to a density of 15,000 in 10 mm mesh cages. Under these conditions the scallops reach about 20 mm at 2 months of age and are broadcast into public beds known to be good natural scallop grounds.

Because of limited man power and rafting capacity, not all the scallops set in the hatchery can be cultured in the cage nurseries. A portion of the set scallops are moved to the field in biodegradable burlap bags. Post set scallops on hatchery sieves are presented with swatches of burlap to which they readily attach. The scallop coated swatches are moved into burlap bags suspended over eel grass beds from longlines and floats. The scallops quickly spread themselves over the burlap bags which provide a source of attachment in warm surface waters away from bottom dwelling predators. As they become crowded, the scallops drop off and seed themselves in the eel grass. This slow seeding over time may prevent the drawing of predators sometimes associated with mass seeding events. In time, the self destructing burlap nurseries decompose and deposit the remaining seed scallops in the underlying eel grass beds. The use of the burlap nurseries is new to the program and its effectiveness is yet to be determined.

The mobility of the scallop has made it more difficult to assess the survival of the seed and effectiveness of the seeding techniques. Exploiting the naturally occuring variation in shell color, strains of scallops genetically tagged for shell color have been produced and used to monitor survival. Orange shell scallops, rare at only 1.5% of a natural population sample, were used as a hatchery tag for several years resulting in a noticeable increase in orange shelled scallops in the local harvest. Orange shell color has been determined to be a dominant trait (Adamkewicz and Castagna, 1988), so that the increase in frequency in the population was probably not due only to the release of orange shelled seed but to the resultant increase in the dominant gene in the population. It is believed that the anomoly of the rare occurence of the dominant orange shell gene may result from increased predation pressure on brightly colored shellfish by diving waterfowl (Elek, 1985). Presently, hatchery seed is tagged with striped shells which may offer some camouflage advantage in eelgrass habitats.

Seed scallops often react to disturbances with a growth check on their shells. The increased handling of the scallops in the hatchery and nursery systems "tag" the cultured stock with numerous check marks. These, along with the shell color tags, have aided in the recognition of hatchery stock collected from the wild population. Further, the cultured scallops produce a distinctive deeper cupped, more convex shell form which is easily recognized. Perhaps this more ovoid scallop results from crowding the juveniles and should be further investigated. Although the cupping may result in decreased shell height, adductor muscles are comparable to natural stocks and thus do not affect the market product.

From these recognizable tags, cultured scallops have been recovered from the natural population; sometimes in good quanities, other times not. In some cases predation has been a clear reason for the mortality. At least two of the more successful recoveries appear to be associated with small seed released late in the season. Perhaps the small size of the seed late in the season is out of sync with the predators. Further investigation is warranted.

In addition to the seeding of hatchery cultured stock, some efforts have been made to manipulate the spawning of field populations. Spawning sanctuaries have been employed on a number of occasions and at least once has coincided with a heavy "natural" set. A spawning sanctuary is a surface floated shallow cage filled with several hundred scallops. In theory the scallops in the sanctuary are held in close proximity and subjected to repeated warming and cooling stimuli in the surface water. One shellfish constable has taken this method a step further by actually inducing spawning on his boat, mixing eggs and sperm, and releasing embryos directly into the environment.

Remote Set Oysters

Annually about two million hatchery produced eyed larvae are remote set using methods described by Jones and Jones, 1983. The eyed larvae are drained on to nitex netting, wrapped in damp paper towel and refrigerated for at least 12 hours before introduction into the remote set system. This treatment appears to expedite setting. The oysters are set on bags of oyster shell cultch in aerated tanks with daily partial exchanges of sea water and daily feedings of cultured phytoplankton. After about 5 days, the shell bags are removed from the tanks and hung from a float in the pond. After about a month, the bags are emptied and the spat covered shell planted on the pond bottom.

Predator Control

As in any aquaculture venture, predation has been identified as a major obstical to the success of the stock enhancement program. In response, the town shellfish constables have initiated vigorous trapping programs for predatory crabs and starfish. The town of Edgartown pays a bounty to fishermen for the crabs they remove from the shellfish beds.

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Diagram of the Martha's Vineyard Shellfish Group Floating Sandbox Quahog Nursery

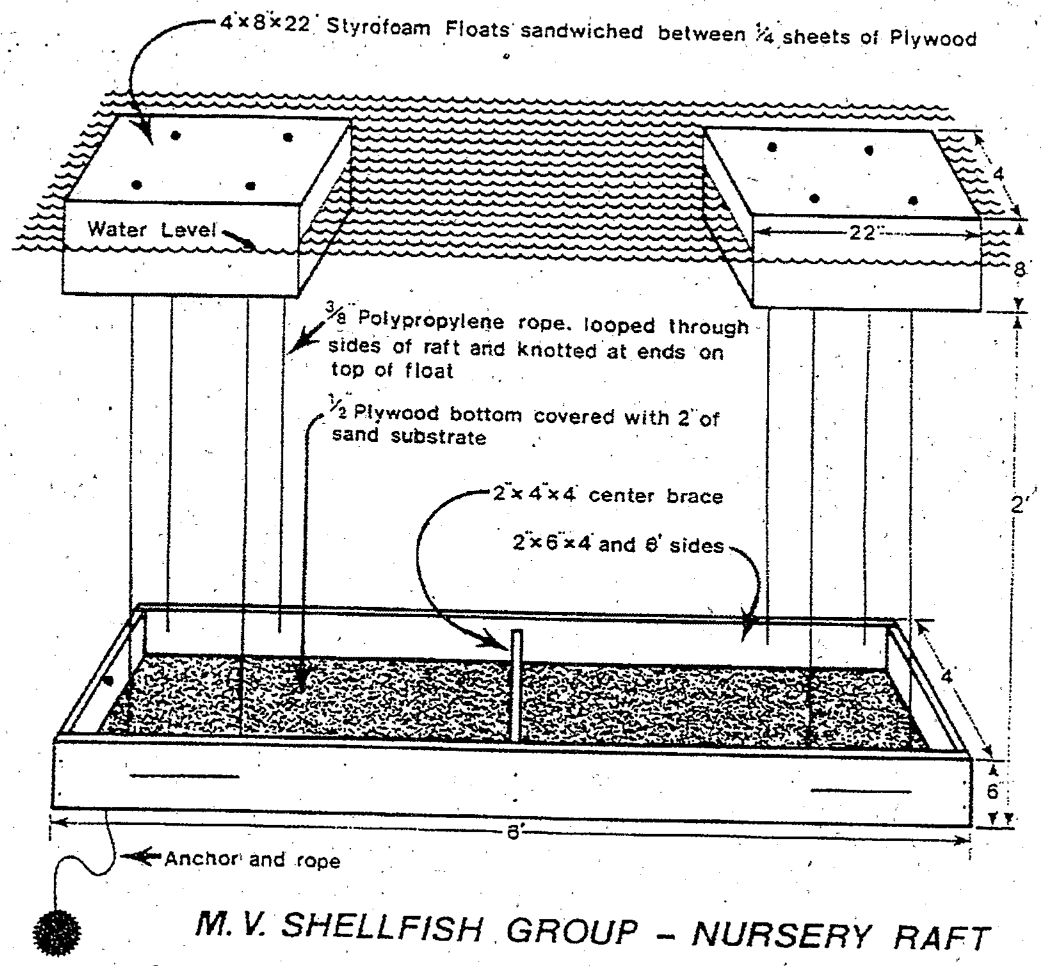


Figure *1*

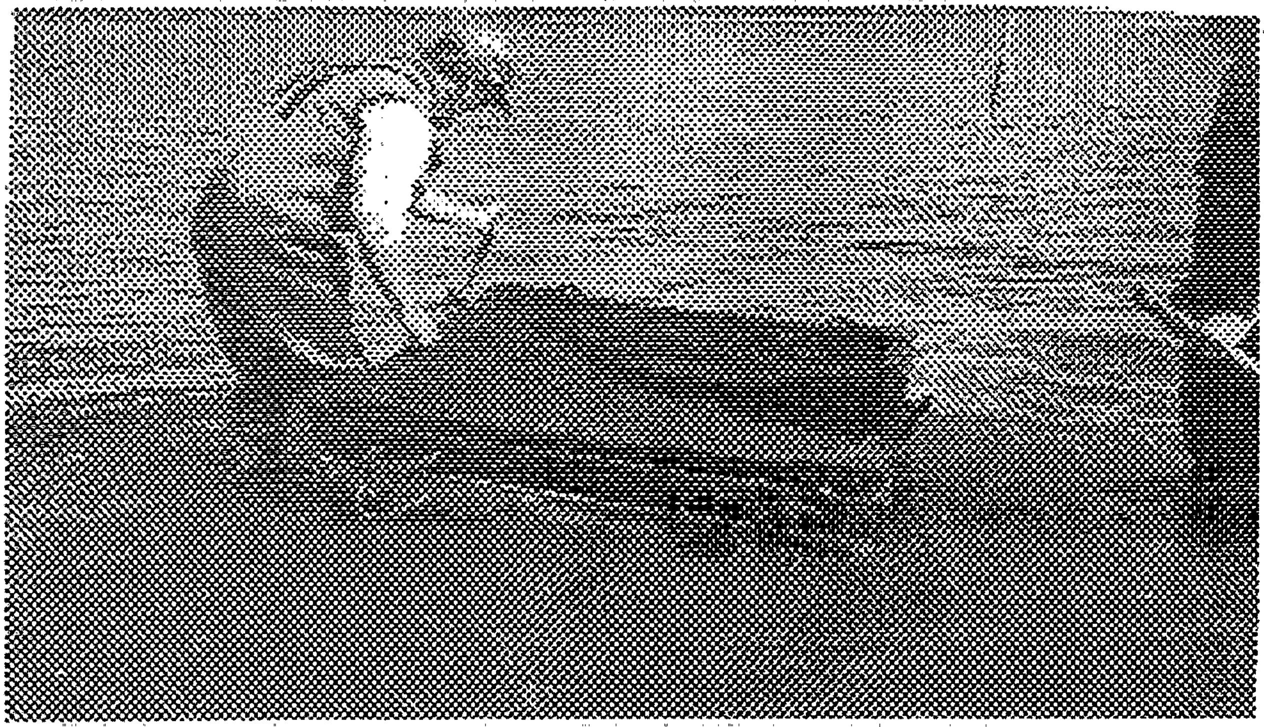


Figure 2

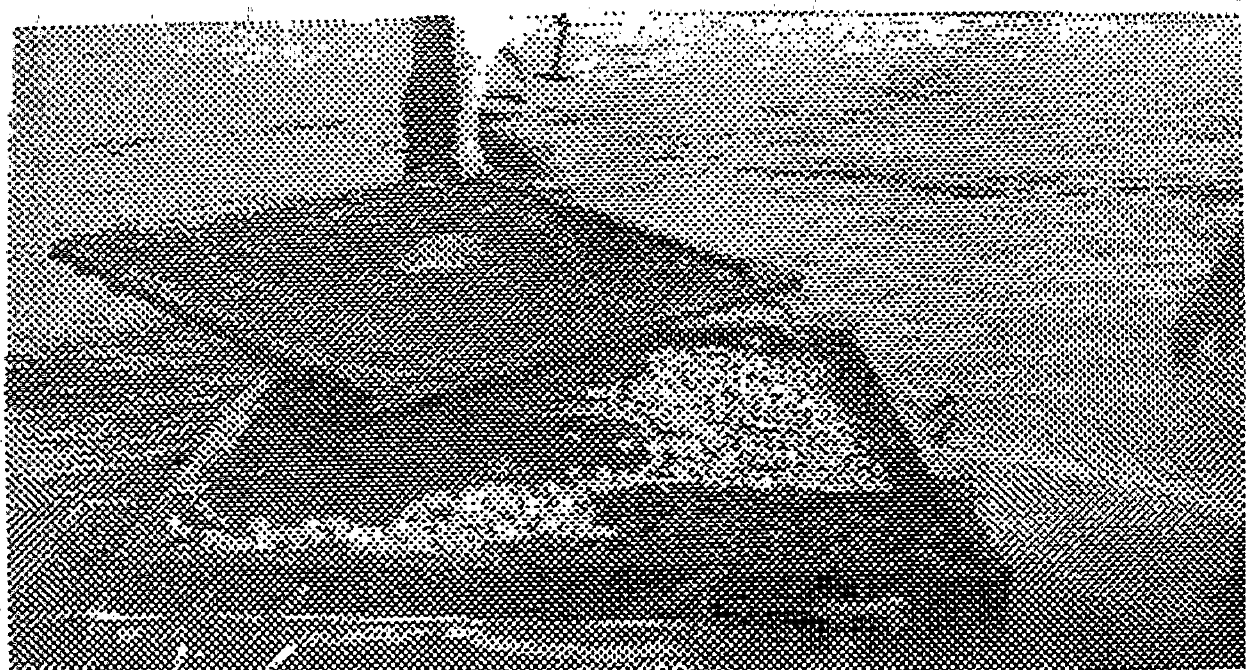


Figure 3

· Quahog seed from floating sandbox nursery after one growing season

Figure 4

Two year old quahogs from bottom box nursery

Figure 5

Cultured scallop seed in nursery cage and collected in fish box prior to field planting

Figure 6

Figure 7

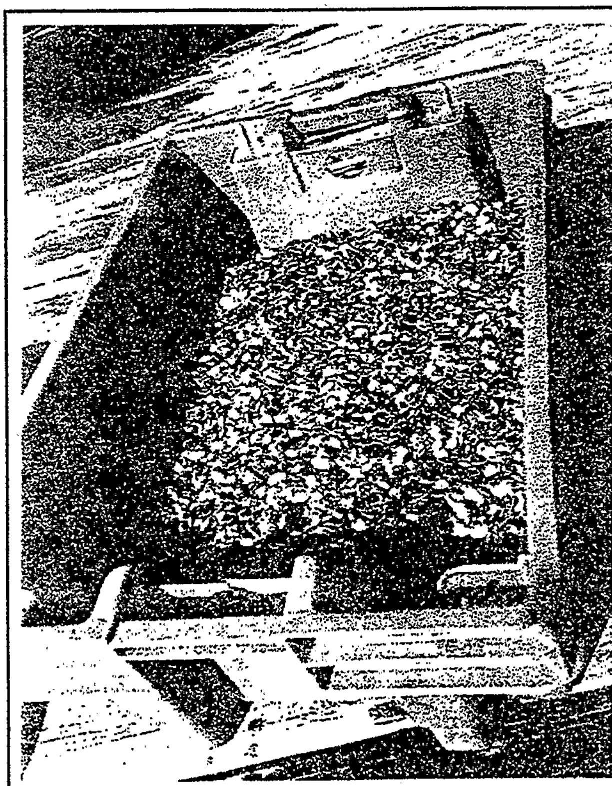
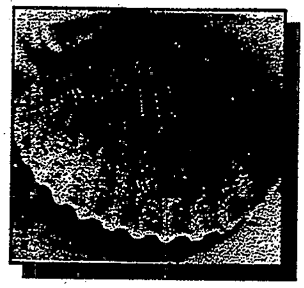


Figure 8

CHAPTER 4

THE BAY SCALLOP RESTORATION PROJECT IN THE WESTPORT RIVER



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Abstract

The time has come to reverse the trend of the deteriorating water quality in the Westport River. To this end, it has become increasingly evident that a positive way to mitigate the effects of pollution is to make it economically advantageous to do so. In an effort to focus public attention on the problems facing communities like Westport, states like Massachusetts and Rhode Island, and the economic well-being of the entire coast of the United States, The Water Works Group has spawned the Bay Scallop Restoration Project.

This undertaking was launched in January of 1993 with the aim of increasing public awareness about the plight and potential of the Westport River. By virtue of its economic value and universal appeal, the bay scallop was selected as the vehicle through which resources could be mobilized and public support and local commitment garnered. From its inception, the Project has rallied an unprecedented outpouring of community and regional involvement centered around the effort to return the bay scallop resource to the Westport River.

Faculty, graduate, and undergraduate students from the University of Rhode Island, Massachusetts Institute of Technology, University of Massachusetts-Dartmouth, and Marine Biological Laboratory at Woods Hole have been brought aboard to address technical aspects of bay scallop propagation and pollution remediation. In support of these initiatives, local town boards and agencies, including the Shellfish Department and the Board of Health, the Massachusetts Division of Marine Fisheries, a substantial number of local businesses and volunteers from the Westport Fishermen's Association, Westport River Watershed Alliance, and

the general public as well as students and teachers from schools of five surrounding communities have provided necessary building materials and equipment while investing more than 10,000 volunteer hours in the effort during its first year.

The Water Works Group is a nonprofit organizanon working to restore, maintain, and improve the economic, recreational, and aesthenc values oSwatersheds for the benefit of the public: present andfuture.

Introduction

Historically, the Westport River ***(Figure 1)*** has supported a significant shellfishery for bay scallops, Argopecten irradians ***(Figure 2)***; oysters, Crassostrea virginica; quahogs, Mercenaria mercenaria; and soft shell clams, Mya arenaria, providing employment and enjoyment for many residents of Westport (Town of Westport, Annual Reports 1949-1993). In fact, the Massachusetts Division of Marine Fisheries, in 1968, recognized the Westport River as one of the most productive commercial shellfishing areas on the south coast of Massachusetts (Fiske et al, 1968). Since those prosperous days, Westport shellfish harvests have declined siznificantlv and the town's commercial shellfish industry has suffered accordingly.

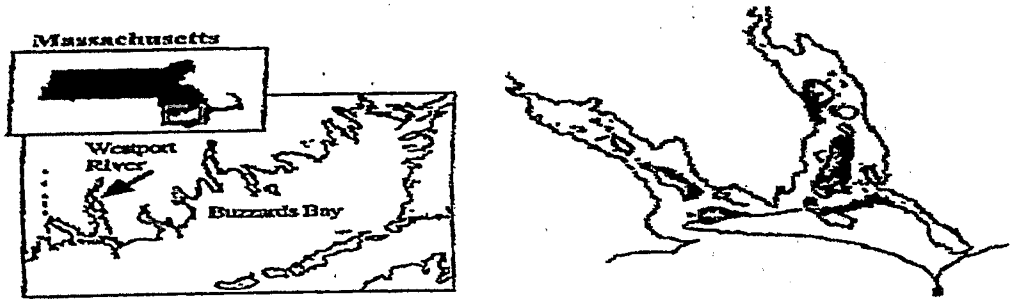

Figure 1. ***Historic Bay Scallop Beds of the Westport River (shaded).***

Though prodigious quantities of oysters, quahogs, and soft shell clams are still found throughout the estuary, the largest percentages of these remain unharvestable as a consequence of permanent and conditional shellfish closures. Westport saw its first shellfish closure in 1978 when the Massachusetts Depallllllent of Environmental Quality Engineering imposed a temporary closure in a portion of the East Branch of the Westport River by virtue of bacterial contamination. More extensive closures followed during the 1980s culminating in the closure of 1,300 acres of the West Branch and 1,776 acres of the East Branch by a combination of permanent and conditional closures.

In the years following 1978, the town of Westport has made several efforts to identify the sources of its closure-causing pollution. These in depth studies documented the nature and origins of the bacterial pollution: stormwater run-off; obsolete septic systems; and agricultural practices (Pivetz et al, 1986, Department of Health and Human Services Public Health Service, FDA Shellfish Sanitation Branch, 1987; Hoagland et al, 1988; Metcalf et al, 1989). In spite of the Town's best efforts over the past fifteen years, it has become increasingly evident that a positive way to mitigate the effects of bacterial pollution is to make it economically advantageous to do so.

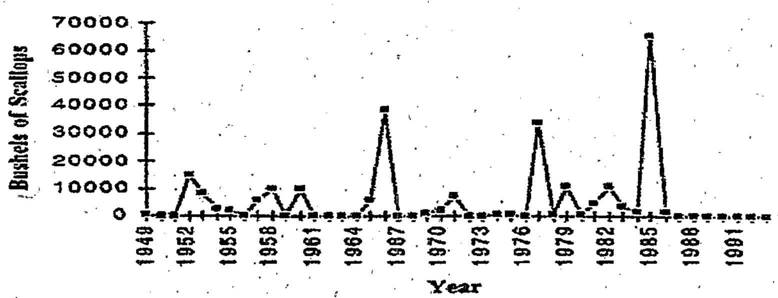

Figure 2. ***Estimated Scallop Harvest in the Westport River 1949-1993.***

Discussion

In January 1993, under the auspices of the Westport Shellfish Department, the Bay Scallop Restoration Project, further referred to as the Project, was launched with the goal of focusing public attention on the continuing decline of water quality in the Westport River with an eye toward reversing the trend. The bay scallop, by virtue of its economic value and universal appeal, was selected as the vehicle through which resources could be mobilized.

The ability to harvest bay scallops from waters deemed bacterially contaminated sets the bay scallop apart from other shellfish species. This distinction arises because the marketable portion of the bay scallop is the adductor muscle (the "eye"), whereas the marketable portion of the other local shellfish species (oyster, quahog, soft-shell clam, and blue mussel) include the viscera, where the water-borne pathogens associated with bacterial contamination accumulate. Because of the risk to public health from the pathogens, these other shellfish have been declared unfit for human consumption by the Division of Marine Fisheries. It was, however, this distinction that allowed Westport scallopers in 1985, amidst shellfish closures, to harvest 66,000 bushels of bay scallops with a value exceeding two million dollars (Town of Westport, Annual Report, 1985).

According to historical data, the Westport River has supported a substantial commercial bay scallop population (Town of Westport, Annual Reports, 1951-1985). However, as is the case throughout the species range, extreme fluctuations in population raise a question regarding the commercial dependability of the species. In an attempt to narrow the range over which bay scallop populations fluctuate, various municipalities have initiated shellfish propagation programs to manage their shellfish resources. These enhancement programs include the broadcasting of hatchery reared and natural caught seed, bottom and hanging culture, as well as the relocation of indigenous stocks (Kelly, 1981 and 1985; Manzi, 1988; Aoyama, 1989; Grochowski, personal communication, 1993; Karney, personal communication 1993; Sherman, personal communication, 1993).

In Westport, Massachusetts, oneSsuch endeavor, the Bay Scallop Restoration Project, has aimed its efforts at increasing the recruitment of bay scallop larvae and enhancing survival of scallop seed to harvestable size and age. Recruitment and survival is enhanced through the use of simple and innovative equipment such as: spawning rafts; spat bags; and nursery rafts at various stages throughout the life of the bay scallop. These methods serve to reduce mortality rates at the most susceptible phases of the bay scallop's brief two year life.

With increased recruitment and improved survivability, Westport's bay scallop fishery may once again flourish. The presence of a healthy bay scallop fishery would lend credence to me economic significance of a clean and productive river. Furthermore, the presence of a profitable bay scallop fishery may ignite interest in taking action to resolve the pollution problems hindering the harvest of other shellfish species including the ever abundant yet long unharvested oyster.

Methods

Increasing bay scallop larval recruitment suggests maximizing the success of the summer spawn. To realize this, spawning scallops must first be in close enough proximity so as to engage in mass spawning (Belding, 1910; Karney, personal communication, 1993). The importance of this mass spawning event is the generation of a high, localized concentration of eggs and sperm which increases the chance of fertilization.

To encourage mass spawning, brood stock scallops were housed in wood framed rafts covered with 1/4" hole extruded plastic mesh ***(Figure 3)***, built from donated materials by students in the Westport High School wood shop class and other volunteers. Extensive scallop dragging in both branches of the Westport River during the month of May 1993 (under the direction of the Westport Shellfish Department and Massachusetts Division of Marine Fisheries) turned up 213 brood stock bay scallops in which to stock the rafts. To bolster this brood stock, an additional 174 bay scallops were harvested in the waters of nearby Marion, MA (courtesy of the Marion Shellfish/Harbor Master Department).

Figure 3. ***Spawning Raft.***

These 387 brood stock bay scallops (ranging from nine to eighteen months old; 38.5% first year scallops and 61.5% in their second year) were divided amongst three spawning rafts and moored in three areas within the Westport River. Spawning sites were selected using information about historic bay scallop beds in the Westport River and data collected by various investigations of: the Massachusetts Division of Marine Fisheries; the Westport River Watershed Alliance's Citizen's Monitoring Project; University of Massachusetts-Dartmouth; and the Massachusetts State Climatologist; as well as the work of other bay scallop researchers (Belding, 1910; Gutsell, 1931; Marshall, 1960-61; Duggan, 1975; Tettelbach, et al, 1981). The data discerned information regarding: annual precipitation; salinity; dissolved oxygen; turbidity; and temperature for the Westport River and the watershed from which it originates during the past two to forty years (depending on the parameter) and parameters conducive to bay scallop growth.

With the warming waters of late spring and early summer, investigators on the Project observed the ripening of the bay scallop gonad as it increased in size, altered its shape, and changed color from black to bright orange. The transformation of the gonad precedes the spawn which is marked by the release of eggs and sperm when the water temperature rises to 20°C -24°C (Belding, 1910; Sastry, 1963; Hardy, 1991). In addition to gonad observations, weekly measurements of water temperature, salinity, and dissolved oxygen were collected at various locations in the Westport River (data courtesy of the Westport River Watershed Alliance's Citizen's Monitoring Project). Between April and September 1993 investigations of bay scallop larval abundance/identification and food availability (seston analysis) were conducted by the University of Rhode Island (data presently under analysis).

With observations indicating the advent of the spawn, (i.e., gonad development, rise in water temperature, appearance of larvae) the work of Belding (1910) and others have suggested that larval settlement should occur within two to three weeks from the spawn. Typically, bay scallops set on eel grass, Zostera marina, however various studies have shown that bay scallop larvae will attach to artificial substrate (Kelly, 1981 and 1985; Aoyama, 1989; Manzi, 1988; Coutier, 1990). Accordingly, the Project utilized artificial substrate called spat bags (named for the post larval, pre-seed scallops) to enhance the amount of available setting surface area. This technique served to index settlement and post settlement recruitment in areas where the spat bags were deployed.

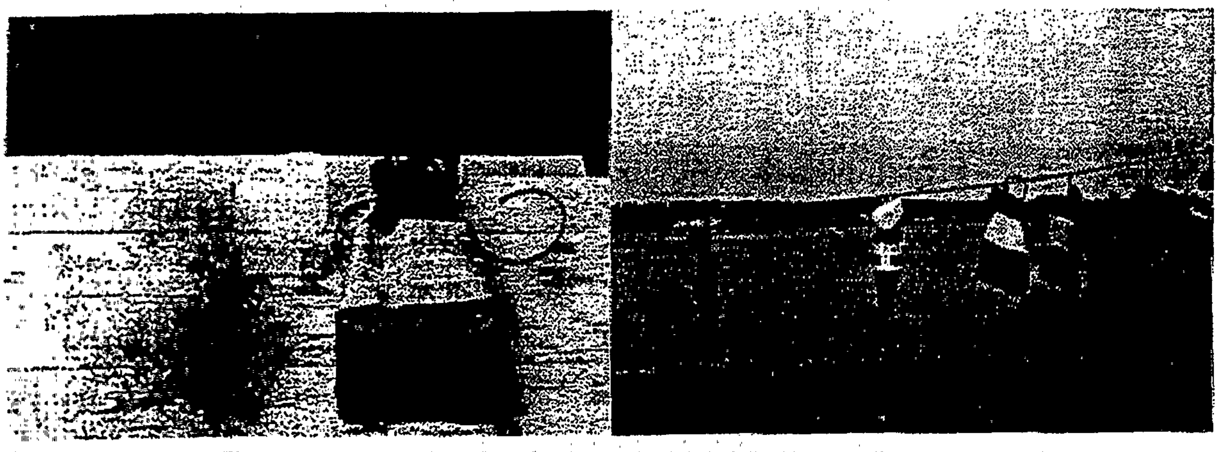

Figure 4. ***Spat Bag Components and Longline Configuration.***

With the assistance of numerous volunteers, 1,400 spat bags were constructed using donated 50 pound capacity onion bags, used gillnet monofilament, polypropylene rope, and small stones (for weight) ***(Figure 4)***. These spat bags were rigged with floats on 89 longlines, 28-35 meters in length, which were deployed and moored in nine historically significant scallop harvesting areas ***(Figure 5)***. Lines were sequentially deployed over a six week period (the weeks of June 6 and July 4 through August 1) which provided "fresh" substrate throughout the spawning and settlement season. This deployment scheme also provided information indicating which times and locations within the Westport River the best sets occurred for the 1993 spawning.

Within the last week of spat line deployment, periodic "spat checks" were added to the testing regime and on August 17, 1993 the first spat was discovered (approximately 4mm in height). As the weeks progressed spat checks revealed bay scallops in each area that spat bags were positioned. Reports from local shellfishermen also confirmed the distribution of bay scallop seed throughout the estuary (Earle, personal communication, 1993; Sherman, personal communication, 1993).

The rapidly approaching 1993/94 bay scalloping season, opening October 15, mandated the retrieval of the 89 spat lines which were positioned above historically popular scalloping beds. Accordingly, spat line collection began on the second week of September. Participation of Westport and Dartmouth High Schools facilitated the laborious task of bringing in the lines and the cataloging, recording, and subsequent analysis of all the scallops, the fouling organisms, and volumes of other related information gleaned from each spat bag. This information was recorded by the students on sheets that provided information for the quantitative and qualitative analysis of each spat line. Additional analysis conducted by the University of Rhode Island (URI) revealed the total yield to be 4,002 scallops ranging from 4-60mm in shell height with an overall mean of 36.9 mm. The U1tI study also identified Cory's Island as the area displaying the greatest recruitment (Tammi et al, 1994).

The bay scallop seed, collected in the spat bags and measured by the high school students, was placed in rafts identical to the rafts used to hold the brood stock scallops (Figure 4). These rafts, called nursery rafts at this stage, were moored in three areas selected so that periodic observations made throughout the winter would not be inhibited by ice ***(Figure 5)***. From the 4,002 scallops collected, 1,100 were transported to URI for over winter monitoring and further studies on spawning and development. Additionally, 12 liters of the seed (approximately 70 scallops/liter) were divided between two different raft types and placed in the three areas shown in (Figure 5). URI is using these rafts: I) to compare raft design; and 2) to determine growth differences between scallops living on the bottom and scallops floating just below the surface (report pending)

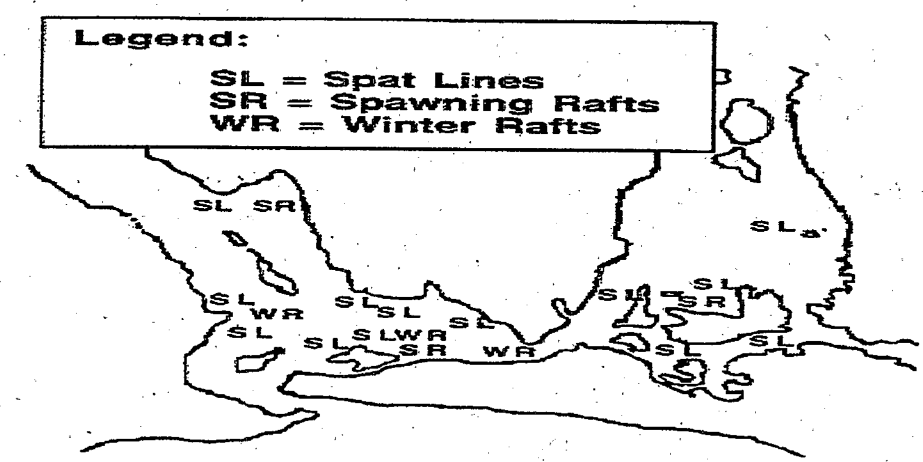

Figure 5. ***Study Locations in the Westport River.***

Conclusion

A year's worth of work on the Project has shown that bay scallops will settle on artificial eel grass ("spat bags"). More importantly, the methods employed by the Project serve to demonstrate the potential of unified community action. In combating the problem of poor water quality in Westport, the Project has produced a plan that encourages economic incentive, public education, and hands-on community involvement all aimed at economically advantageous pollution remediation.

With community involvement, enthusiasm, and energy at an unprecedented high, the opportunity to capitalize on the public interest has presented itself. The awareness and attention focused on the economic significance of the Westport River, shown by the presence of the Project, has spurred interest in rejuvenating Westport's long dead oyster fishery which was closed due to widespread bacterial pollution in 1978. To address the issue of Westport's bacterial pollution problem, the Project has spawned two united undertakings: the Living Laboratory and the One Watershed-at-a-Time Campaign.

Along the way, the three arms of the endeavor to reclaim the Westport River, have captured the spirit, imagination, and involvement of a diverse congregation of people. These people, to the tune of thousands of volunteer hours, have connected with some aspect of the Project, whether it be on the bay scallop end, the education front, or the tributary watershed effort. The work being done in the Westport River watershed represents a model for designing economically advantageous ways to remedy non-point source pollution and holds boundless opportunities for other communities suffering from similar problems.

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CHAPTER 5

ENHANCING NEW YORK'S GREAT SOUTH BAY HARD CLAM (MERCENARIA MERCENARIA) RESOURCE: DETERMINING WHICH STRATEGY TO USE

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Abstract

Over the past two decades, spawner relays, sanctuaries, and transplants and seed hard clam plantings have been undertaken in attempts to enhance the hard clam (*Mercenaria mercenaria*) resource in New York's Great South Bay. Enhancement enjoys considerable popular support but determining which strategy or strategies will yield the greatest return on investment is fraught with uncertainties and difficulties: it must e assumed that the shellfish population is not at its environmental carrying capacity and that the cause(s) can be corrected; the life history stage(s) and environmental condition(s) limiting hard clam abundance may not be known; the existing management regime may be a contributing factor; and assessing the contribution of enhancement strategies is technically difficult and expensive. The choice of strategy is critical because whatever funds are expended on an enhancement strategy are no longer available for other enhancement strategies or management options.

Introduction

Enhancing the abundance of commercially important molluscan shellfish stocks is a historical and integral component of the management of many coastal shellfish resources. Beginning the middle of the 19th century, for example, oystermen transplanted seed oysters to growout beds and planted cultch to catch sets of oysters (Kochiss, 1974). In the early years of this century, Belding (1909) concluded that one way to stop the decline of the quahaug [hard clam] from the waters of Massachusetts was to seed the public waters and tidal flats with small shellfish. With the development of shellfish mariculture technology over the past several decades, the use of hatchery raised seed in the management of clam fisheries has been either suggested or tested in a number of locations (Malouf, 1989). The concept of enhancing public shellfish resources in coastal waters is generally viewed positively. Politically, measures to improve the supply of shellfish have long enjoyed support because they are seen as an active solution rather than a passive response to the problem of low stock abundance (Kassner, 1988A). Shellfish harvesters favor augmenting the natural abundance of shellfish as an alternative to restricting harvest levels (Kassner, 1988B). There is thus a strong underlying predilection towards undertaking a resource enhancement activity of some kind.

There are a variety of resource enhancement strategies that have at least a theoretical potential to increase the abundance of shellfish in public waters. Determining which resource enhancement strategy to use, however, is not an easy task but one of great importance because funds spent to implement one strategy are not available to undertake another. In this paper, I will first present a general background for enhancing public shellfish resources and then describe the various projects being used to enhance the hard clam (*Mercenaria mercenaria*) resource of New York's Great South Bay.

Enhancing Shellfish Populations --Theory

It must be recognized at the outset that the decision to undertake resource enhancement is often motivated by falling shellfish abundance and landings and is thus driven by politics. As a result, there is a prevailing sense of urgency which means that there is neither the time nor the interest to undertake extensive studies or research as to the causes of the condition of the stock. It also means that the enhancement must begin immediately.

The underlying assumption of shellfish resource enhancement is that a shellfish population is not at its environmental carrying capacity and that if whatever conditions are preventing the shellfish population from attaining its carrying capacity are eliminated or counteracted, the size of the shellfish population will then increase to the carrying capacity. Determining the carrying capacity and the conditions limiting shellfish abundance for a particular shellfish population is not a simple technical task and one that is made more difficult because both the carrying capacity and the limiting condition probably vary both temporally and spatially. The necessary studies are also likely to be costly and time consuming.

An additional complication in undertaking shellfish resource enhancement stems from the fact that shellfish populations fluctuate from year to year (Caddy, 1989). The implication is that the strength of the condition limiting abundance varies as well which could, in turn, mean that enhancement will succeed in adding individuals to a shellfish population only when conditions are favorable for the existing population to produce recruits and that enhancement will make a minimal contribution when conditions re not favorable for the existing population to produce recruits. Thus, resource enhancement rather than increasing abundance when population size is depressed and therefore most needed, may only succeed when production is naturally high and not as needed.

For convenience, the conditions limiting the size of a shellfish population can be divided into life history based, environmental based, and management based. For shellfish, the life history based conditions can be further subdivided into three stages: (1) larval supply including gametogenesis and fertilization; (2) settlement success together with initial post-settlement growth and survival; and, (3) juvenile growth and survival. Environmental based conditions that may be limiting population size include deterioration of water quality, habitat loss or alteration, and unusual biological or climatic events. Management based conditions include the harvest of undersized shellfish and overfishing. Assuming that management is not a limiting condition or can be addressed independently, if a resource enhancement strategy is to increase shellfish abundance, it must therefore either bypass the limiting life history stage or mitigate the limiting environmental condition.

Unfortunately, the limiting life history stage or limiting environmental condition at a particular time and location is often not known and may not be easily identified within the time frame available. The choice of enhancement strategy must therefore often rely upon the best available information from limited field data as well as the scientific literature. For each of the life history stages and environmental conditions that may be limiting population abundance, there are number of alternative resource enhancement strategies that could be implemented. For each strategy, however, there are numerous technical and theoretical reasons why it should and shouldn't succeed in increasing the abundance of shellfish. The different enhancement strategies also vary with respect to cost, length of time required to achieve results, and ease of implementation. Acceptability to shellfish harvesters may also be a significant factor as shell fishermen are often politically active and can use this to block the implementation of an enhancement strategy that they do not support.

The Practice, The Location

The Great South Bay is the largest in a chain of bays created by a series of barrier islands that extend nearly the entire length of the south shore of Long Island, New York. The bay is 50 km long, varies in width from 2.5 to 8.0 km and has an area of approximately .16 million hectares (Kassner,1988B). During the 19th century, the Great South Bay was a major producer of the east coast oyster (Crassostrea virginica) and was world famous for its "Blue Point" oyster (Mattiessen, 1992). The oyster fishery began to decline shortly after the turn of century due to a variety of social and economic actors as well as a shift in the bay's ecology that greatly reduced the abundance of oysters. The abundance of hard clams rose, however, and a fishery for hard clams replaced the oyster fishery. Over the past half century, the hard clam fishery has undergone two periods of expansion and contraction (Kassner, 1988B). Following a peak in hard clam production in the mid 1940s, hard clam abundance and landings fell through the early 1950s. Beginning in the early 1960s, hard clam abundance and landings rose, reaching a peak of over 600,000 bushels in the early 1970s. After 1976, abundance and landings fell dramatically.

The distribution and abundance of the hard clam is weather, bottom type, harvesting effort, and predator abundance (Stanley and DeWitt, 1983). In the Great South Bay, hard clams are widely distributed with distinct and stable areas of high and low hard clam abundance (Kassner, Cerrato, and Carrano, 1991). Hard clam abundance also varies from year-to-year and appears to be limited by either a low level of hard clam setting or poor survival to age 1.

The Strategies

Four strategies have recently been or are now being used to enhance the public hard clam resource in the Great South Bay: spawner relays, spawner transplants, spawner sanctuaries, and the planting of hatchery raised seed hard clams. The first three strategies address abundance limiting conditions due to problems with larval supply and the fourth strategy addresses abundance limiting conditions due to problems with post settlement survival.

Spawner relays entail increasing the abundance of spawning individuals by transplanting adult hard clams from other coastal waters into the Great South Bay. It is an appropriate enhancement strategy when there is an inadquate supply of larvae or when the proximity of breeding individuals to each other is too great to ensure fertilization success. Spawner relays are a traditional enhancement strategy that enjoy the support of the shell fishermen.

Typically, several hundred bushels (approximately 150 large, chowder size hard clams) of "spawners" are purchased at a cost of $15 to $20 per bushel for planting in the Great South Bay in the spring and early summer. The spawners are typically spread out in several areas of the bay from slow moving boats. A spawner sanctuary is defined as a site that is stocked with large, fecund adult hard clams and located such that the setting of larvae from the site will be maximized in a previously selected area which has been identified as good hard clam habitat. It is an appropriate enhancement strategy when breeding subpopulations are positioned so that hard clam larvae are not being transported to desired areas.

Fortunately, computer modeling of the circulation in the Great South Bay was done in the 1980s and has provided guidance in the selection of spawner sanctuary locations (Carter, Wong, and Malouf, 1984). The use of spawner sanctuaries has been gaining increased acceptance over the past several years. To increase larval production, adult hard clams are initially transplanted into a sanctuary and to protect the spawning population, harvesting within a spawner sanctuary may be prohibited. One advantage of a spawner sanctuary is that once established, it should continue to supply hard clam larvae indefinitely. A major problem with the implementation of spawner sanctuaries is the high abundance of shellfish which is attractive to poachers so that the success of a spawner sanctuary may depend highly upon enforcement.

Determining the contribution of spawner relays and spawner sanctuaries to the hard clam population is very difficult. Monitoring spawning and tracking larval abundance and distribution is time consuming and methods for differentiating the larvae of the natural population from the those arising from the relay or sanctuary are not readily available. It is also probable that spawner relays and spawner sanctuaries are not successful every year and must therefore be viewed as long-term enhancement strategies.

Spawner transplants are a variation of the spawner relays. This strategy involves harvesting adult clams during early spring from waters cooler than the Great South Bay and then transplanting them into the expectation that they will spawn, because of their presumed delayed gametogensis (Loosanoff, 1937), after the native hard clam population has spawned. The rational is that reproductive success is dependent upon the chance co-occurrence of hard clam larvae and suitable environmental conditions so that the longer larvae are present in the bay, the greater the chances at least some will encounter favorable conditions for survival and setting. Timing is therefore critical but problematical (Kassner and Malouf, 1982). Although highly popular with shell fishermen, spawner transplants are no longer undertaken primarily because of difficulties in obtaining bloodstock.

The planting of hatchery produced seed hard clams having shell lengths of 5 to 25 mm has been practiced in the Great South Bay since the late 1970s and several million seed hard clams are currently being planted annually. The planting of seed hard clams is the appropriate enhancement strategy if larvae are reaching an area but are not setting or do not have high survival to some minimum size. Seed clams thus bypass the larval period and initial high mortality sizes. This strategy is relatively popular among most baymen and elected officials because it is tangible, offers increased control and lets the shellfish be placed into a particular area. The survival rate of seed hard clams planted to increase natural production is, however, largely uncertain. Survival is likely to increase with increasing seed size but because the cost per seed hard clam increases with seed size, there is a tradeoff between number of seed planted and the expected return. At its present scale, seed planting does not contribute a significant number of hard clams to the total harvest, although it does increase abundance in discrete areas.

Discussion

While enhancement offers the potential of increased abundance, the cost-effectiveness of the various resource enhancement strategies to increase stock size is not known. It is difficult to differentiate natural production and natural population fluctuations from production arising from enhancement activities and for various technical reasons, tracking the subsequent survival and contribution to the shellfish population has proven to be very difficult. In addition, trying to assess the contribution of an enhancement project can be costly and enjoys little support because the money spent on evaluation is not available for enhancement. Small pilot projects may not yield the type of information needed because scale may be influence the results. There has been relatively little attention given to mitigating environmental conditions that may be limiting the abundance of hard clams in the Great South Bay. This may be, in part, because the benefits of environmental based strategies do not seem as tangible as putting more hard clams into the bay, either as bloodstock or seed hard clams. It is also probably reflects a lack of knowledge as to what conditions are causing low hard clam abundance (or are conducive to high abundance) and the inability to mitigate many of the environmental conditions that can limit abundance.

Increasing the amount of favorable hard clam habitat in the Great South Bay is one environmental enhancement strategy that may hold considerable long term potential. Hard clam abundance in the Great South Bay has been found to be generally higher in course sediments containing shell and many areas of high hard clam abundance are associated with relic oyster reefs (Kassner, Cerrato, and Carrano, 1991). The planting of shell to create to this type of habitat could increase the amount of productive bay bottom. A pilot scale planting using surf clam (*Spisula solidissima*) shells was undertaken in 1989 (Kassner, Cerrato, and Carrano, 1991) but the project has been subsequently deemed unsuccessful because the volume of shell used was too small and it was placed on a muddy bottom where it sank into the sediment.

One aspect of shellfish resource enhancement that is often neglected is the matter of scale. The logistics and expense of producing enough hard clams to significantly increase production is considerable. The problem is that according to McHugh (1981), enhancement tends to consider that "millions are sufficient when billions may be required". Population enhancement can be an important component of a shellfish management program, although enhancement should not be seen as a justification not to limit harvesting or institute other regulatory controls. The absence of scientific certainty should not preclude trying to enhance population abundance such that the only realistic option may be to simply do what makes sense and to then hope for the best.

Acknowledgements

The continuing support of Brookhaven Town Supervisor John LaMura and members of the Brookhaven Town Board for improving the shellfish resources of the Town of Brookhaven is recognized and appreciated. The commercial shellfish harvesters have provided many hours of stimulating discussion and considerable assistance and are the reason why shellfish resources must be enhanced whenever possible.

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CHAPTER 6

SHELLFISH ENHANCEMENT PROGRAMS: ARE THEY ENOUGH TO MAINTAIN A FISHERY RESOURCE?

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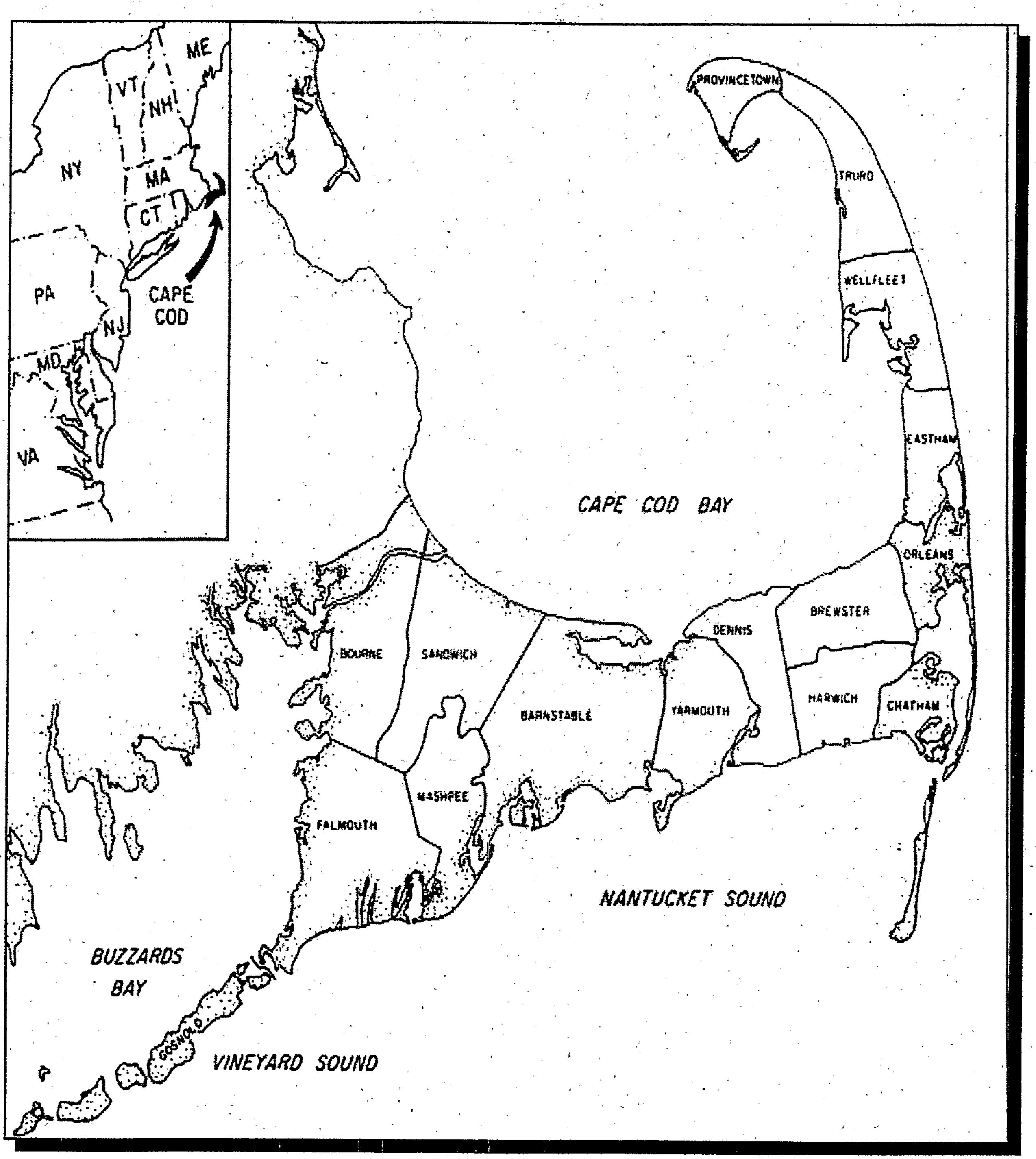
Introduction

The landmass of Cape Cod, Massachusetts resembles an arm when viewed from a satellite image. But this peninsula is not much more than a large sandbar sticking out into the Atlantic. And like a sandbar, it is a fragile piece of land that is part of a geologic evolutionary chain of events with a finite lifespan. The people who live there as residents and those who visit as tourists enjoy the multitude of natural resources that Cape Cod offers, but protecting those resources tomorrow is an increasingly difficult challenge for the 15 towns that delineate the municipal boundaries of Cape Cod.

Shellfishing has been an important activity, both economically and culturally, for hundreds of years as indicated by the number and location of shell middens found along our coasts, but it is mostly within the last century that shellfish resources have been "managed". Shellfish management in the Town of Orleans, a small community located in the "elbow" of Cape Cod, takes place primarily at the local level where each individual town controls its own shellfish resources under broad guidelines by the state. Size limits of shellfish, duties of shellfish officers, and contaminated shellfish are all regulated by the state hut harvesting areas, catch limits, methods, and licenses are all managed on the local level[1].

The Town of Orleans (it may be referred to as Orleans in this document) is fortunate to have three separate estuaries within its jurisdictional boundary: Cape Cod Bay, Pleasant Bay and Nauset/Town Cove. Each of the embayments are very productive estuaries,) that provide habitat for four major species of commercially important shellfish: soft shell clams (Mya arenaria), hard clams or quahaugs (Mercenaria mercenaria), mussels (Mytilus edulis) and bay scallops (Argopecten irradians irradians).

[1] Roman, C.T. and K.W. Able ct. al. 1989.


ME
VT
NH
NY
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CT
PA
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NJ
MD
VA
PROVINCETOWN
TRURO
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EASTHAM
CAPE COD BAY
ORLEANS
BREWSTER
DENNIS
BOURNE
SANDWICH
BARNSTABLE
YARMOUTH
HARWICH
CHATHAM
MASHPEE
FALMOUTH
NANTUCKET SOUND
BUZZARDS
BAY
GOSNOLD
VINEYARD SOUND

Figure 1

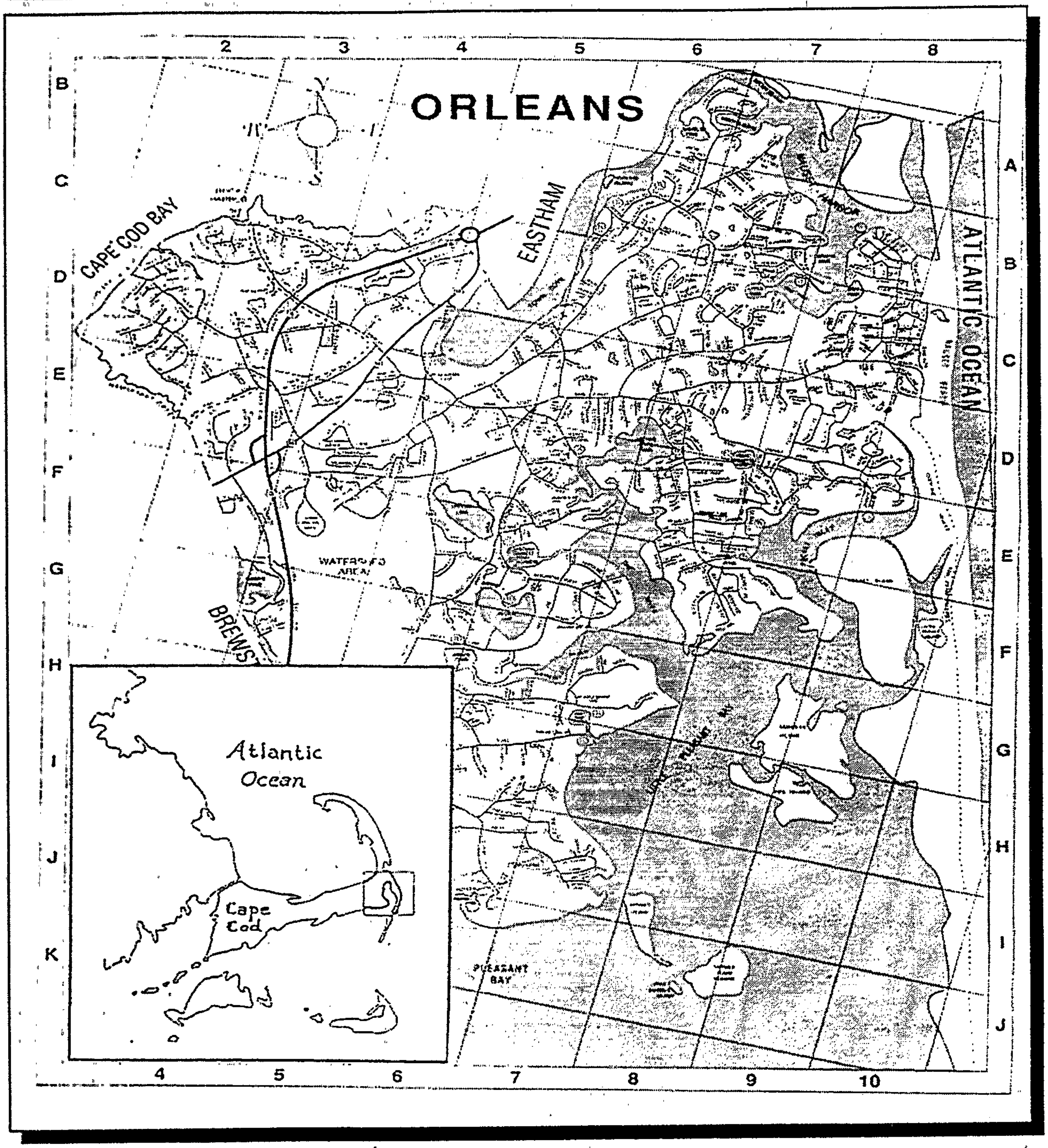
ORLEANS
CAPE COD BAY
EASTHAM
ATLANTIC OCEAN
BREWS
WATERSHED AREA
PLEASANT BAY
Atlantic Ocean
Cape Cod
2
3
4
5
6
7
8
B
C
D
E
F
G
H
I
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Figure 2

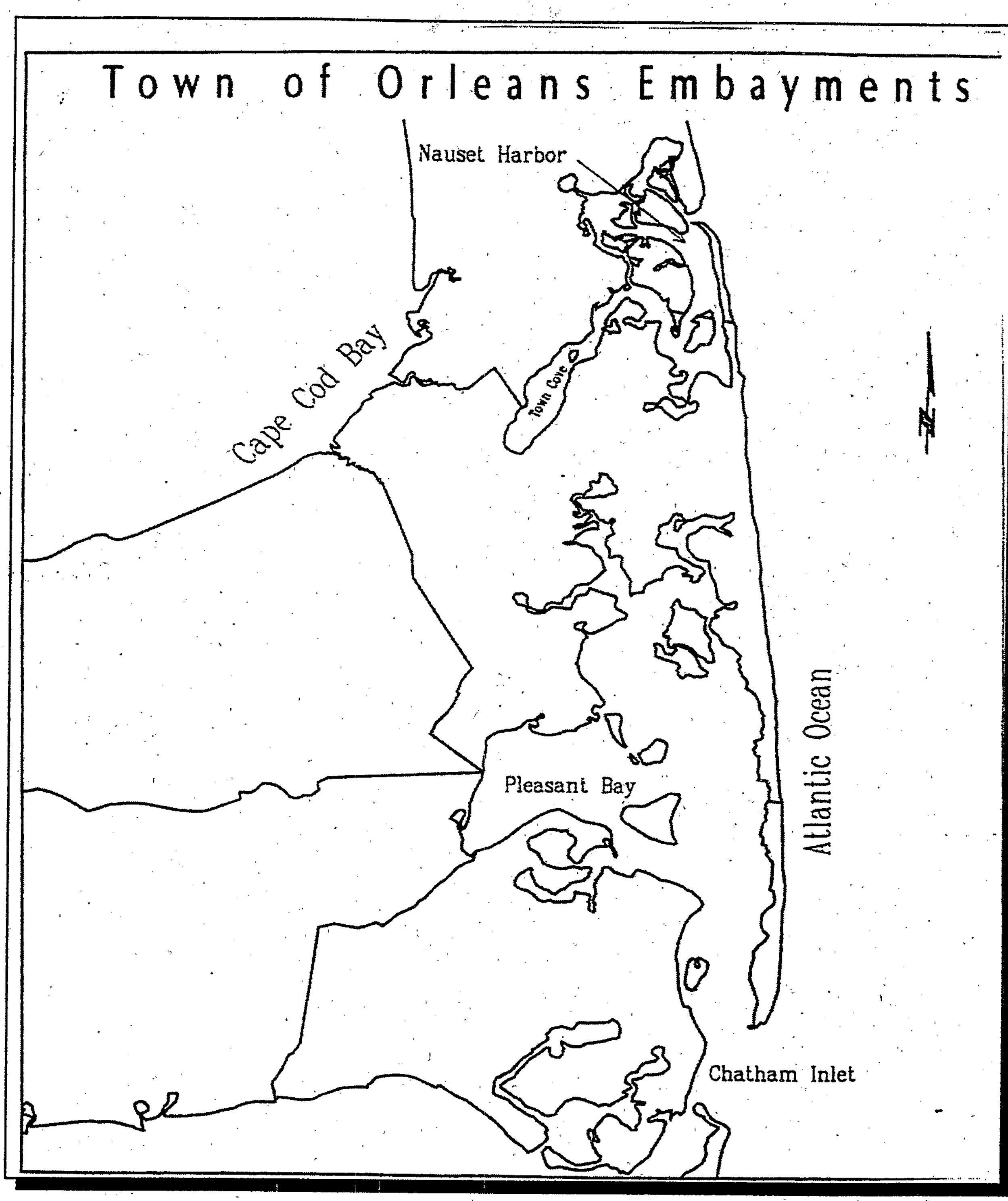
Town of Orleans Embayments
Nauset Harbor
Cape Cod Bay
Town Cove
Pleasant Bay
Atlantic Ocean
Chatham Inlet

Figure 3

Most of the shellfish harvest statistics have shown a decline over the years with the exception of scallops that show typical peaks and valleys of abundance. Although over-fishing is a problem and may be one of the causes of decline, other factors such as land use patterns over the last twenty years, and their effect on shellfish resources and habitat may play a more important role. Attempts to counteract the decline in abundance of shellfish involve various management tools including, but not limited to, enhancement programs.

Management Options

Enhancement projects have been conducted by the town for all species of shellfish over the years but the primary programs have concentrated on clams and quahaugs. Propagation techniques included re-seeding programs using hatchery reared seed, transplants of seed shellfish from abundant areas to less prolific areas, and transplants of spawner stocks to the natural environment.

In addition to enhancement or propagation projects, the primary tools used for shellfish management in Orleans have been seasonal opening or closing of specific areas to allow for either harvest or natural re-seeding (harvest area rotations), catch limits, gear restrictions and enforcement of established regulations.

Commercial and recreational permit holders may fish in any open area, but commercial harvesters are prohibited from fishing in areas reserved for recreational permit holders in accordance with state mandate. Areas may also be restricted according to the season of the year or by harvest methods. Some are open during the summer setting (and tourist) season while others are closed during that time to allow for natural propagation.

Established harvest limits are dependent on the type of permit issued and may change according to abundance. Generally, recreational permit holders are allowed 1 ten quart bucket of clams or quahaugs per week, 0.5 bushel of mussels per week and 1 bushel of scallops per day during scallop season (October 1-April 30). Scallops are the most valuable species of shellfish within the town, and when abundance is high, the economic boon to the local economy is substantial.

Soft Shell Clam Projects

Orleans has experimented with transplanting seed clams (Mya arenaria) from Lonnie's River in the Pleasant Bay system to Town Cove and Cape Cod Bay flats with excellent results. For several years, 1977-1980, a portion of Lonnie's River yielded seed clams in excess of 400/square foot (1/3 square meter). When the clams were approximately 0.5 -1 inch (15-25mm), the town transplanted some of them to less productive areas. The clams were harvested from the river by using a pump to loosen the substrate in which they had become embedded. The clams and sand were then vacuumed into a hardware cloth basket where the sand was pumped through the mesh and the clean clams were captured. Damage to the clams was minimal using this method. The clams were transferred to onion bags and usually held overnight in the water.

On the following day, the intertidal flats scheduled to receive the seed clams were harrowed with a mechanized plow. The clams were broadcast in the loosened furrows on an incoming tide. The majority of clams burrowed in quickly (within an hour) and transplant mortality, usually caused by avian predation, was limited to damaged clams. By the next season, those clams that survived the initial transplant and the following winter had become both sexually mature and of legal size for harvesting.

The Cape Cod Bay flats, which extend approximately 1.5 miles from shore are considered to be a hostile environment for shellfish because of wind and wave action in the 9-foot tidal range and ice scour in the winter. The town conducted experiments on these intertidal flats where netting was added to the experimental plots the following year after transplant to contain the clams. The clams had attained sexual maturity and the town attempted to produce a new set of seed clams in the same area from these adult clams. Wooden frames covered with netting were placed over the transplanted clams in late spring. The transplanted clams produced a new set of seed. Covering large areas with netting was prohibitively expensive; yet without the netting; successful setting of new seed clams was inefficient. therefore, the town opted to transplant clams to areas where natural production gained from the transplant was more assured instead of continuing with a "put and take" approach.

Quahaugs

The major propagation program from 1975-1989 utilized by the Town of Orleans was the nursery culture of hatchery-reared quahaugs (Mercenaria mercenaria). Orleans used bottom and raft cultures; (?) extensively utilizing the natural environment for both methods. In addition, the town transplanted thousands of bushels of spawner-size quahaugs from the deep waters of Cape Cod Bay to the Town Cove and Pleasant Bay. Orleans also developed a small hatchery using pumped seawater which evolved into an upweller facility.

The program began with bottom cultures in which hatchery-raised seed was embedded in plots that were covered with netting attached to wooden frames (3 feet X 6 feet) at 10 experimental sites throughout the estuaries. The success in the first year, based mostly on survival, led to an expansion of the program. The contained areas, outlined by the wooden frames, were increased (6 feet X 10 feet) and embedded with more seed. These larger boxes were dug into the substrate at locations that had shown promise the previous year. Since the winter of 1976-77 was more harsh than the previous winter, the survival of the seed was substantially less than the previous year.

Based on a design by George Souza, shellfish constable of the neighboring Falmouth, the town constructed floating sand-filled rafts in 1976. The rafts were set a float in two protected ponds, one in the Pleasant Bay area (Lonnie's Pond) and one in the Nauset system (Mill Pond). The rafts proved very successful with very little mortality and excellent growth. As a bonus, the seed was large enough by the end of the growing season to be transplanted to the wild without having to worry about over wintering. However, a planting density of about 500 per sq. ft. inhibited the expansion of the program further because of the number of rafts that would be required and the labor necessary to manage the rafts.

When waterfront property became available, a small (16 feet X 24 feet) building was moved to a site on Town Cove where a small low-tech, low-cost hatchery was established. The rafts were used while the hatchery was being developed. The hatchery used plastic trash cans for larval tanks and free plastic buckets for sieves; typical hatchery algal species (T-Isochrisis, Monochrisis, and Dunaliella) were grown on site to feed the larvae and juveniles. Spawning stock was harvested from different areas in town and spawning took place in June and July using the animal's natural spawning time.

The hatchery was successful in spawning quahogs but using the animal's natural rhythm and spawning them in the summer did not allow enough time for them to grow to a size where they would survive the winter and therefore the seed had to be over wintered, which proved to be a difficult task. Fortunately, while methodologies for over wintering seed were being developed, the upweller technology became available.

The building was modified as an upweller facility rather than a hatchery by adding tanks and silos. Upwellers are designed with a container (silo) of seed inserted in a tank with flowing seawater. Water flows into the tank, up through netting on the bottom of the silo and exits the silo from an outfall pipe near its top. The flow of water allows some fecal particles to be washed away but daily cleaning of the silos is generally required especially when the seed is very small. The silos were made of free 5-gallon plastic buckets with tight fitting lids that contain holes and netting. If the volume of water being pumped is sufficient, each silo can handle tens of thousands of seed. As the seed grew, they were thinned and transferred to more silos. At the completion of this process, 1.0 million seed were raised from 1.0 mm. to 12-15mm in 46 silos. Growth appeared to be directionally proportional to the density, volume of water and the number of silos available.

Algae, the animals' daily source of food, was grown on site. It was observed that quahogs generally stop feeding in late July and early August because of the high water temperature, lack of oxygen, and the type of phytoplankton in the water. This phytoplankton was predominantly dinoflagellates. To overcome this, the water was aerated; the animals were given a dose of food and their environment was kept clean. These techniques were apparently successful. During the four year period, between 1986 and 1989, 1 million seed was raised per year, with a greater than 95% survival prior to transplant.

By utilizing upwellers, the facility was operated only in the summer; therefore it was not necessary to expend funds on heating seawater during the winter which would have been necessary to condition and spawn quahogs in the hatchery. From 1975-1989, the Town of Orleans raised approximately 6 million seed quahogs which were transplanted throughout the estuaries bordering the town. To prevent predation during transplant, the seed was transplanted in November when the water temperature had cooled to approximately 8-10° C. It was observed that transplanting earlier, in September or October, especially if the seed was less than 1 inch, was futile because of predation, primarily from baitfish which ate either the foot or siphon of the seed. It was also noted that quahogs stop feeding entirely when the water temperature falls to 38° F and start feeding again at 42° F. By planting them at around 45° F, the seed had enough energy to burrow and their predators had slowed their own feeding activity; thereby creating a favorable environment for the seed to survive the initial transplant and generally the winter as well. The land-based facility was abandoned in 1990 in favor of lower cost (less labor and no seawater system to maintain) bottom boxes and floating trays. Orleans currently raises 300,000 seed per year.

Although the propagation program was successful, the impact of pollution became a concern. Meetinghouse Pond in Pleasant Bay was closed to harvest by the Mass. Division of Marine Fisheries because of higher than acceptable levels of fecal coliform bacteria (14/100 ml.). In 1988 and 1989, large areas of the estuaries bordering Orleans were being closed. At one point, the entire Nauset estuary, the marsh creeks on Cape Cod Bay (5), and several ponds in Pleasant Bay were closed. All of the areas closed were productive habitat for shellfish with the exception of the upper marsh creeks on Cape Cod Bay.

[See ***Figures 4 - 7*** for shellfish harvest information.]

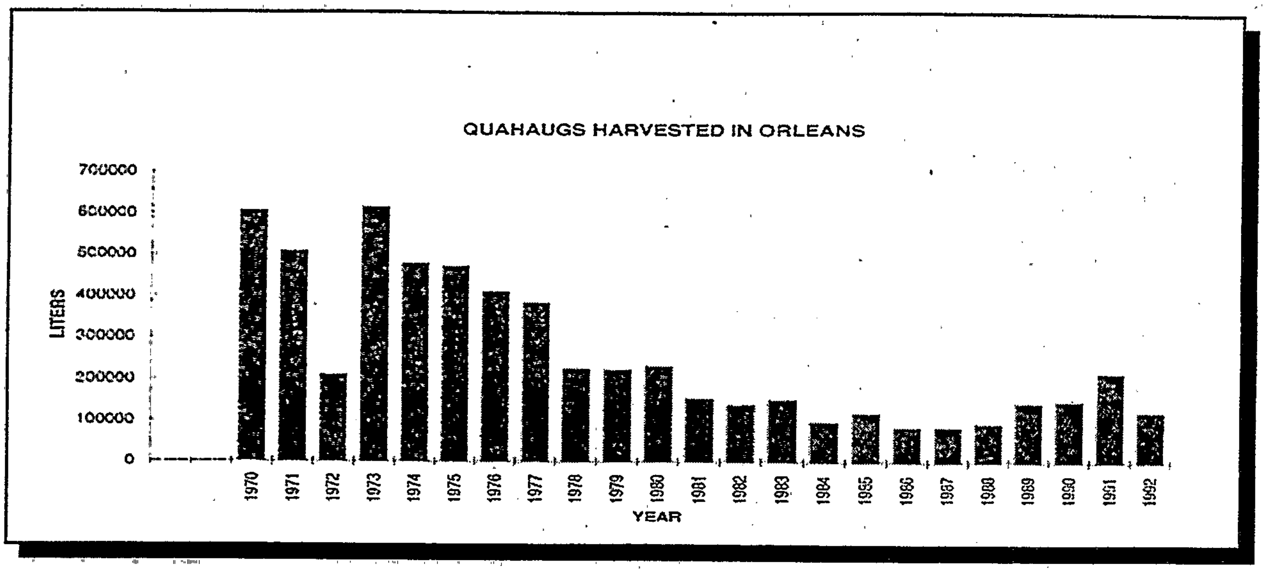

Figure 4

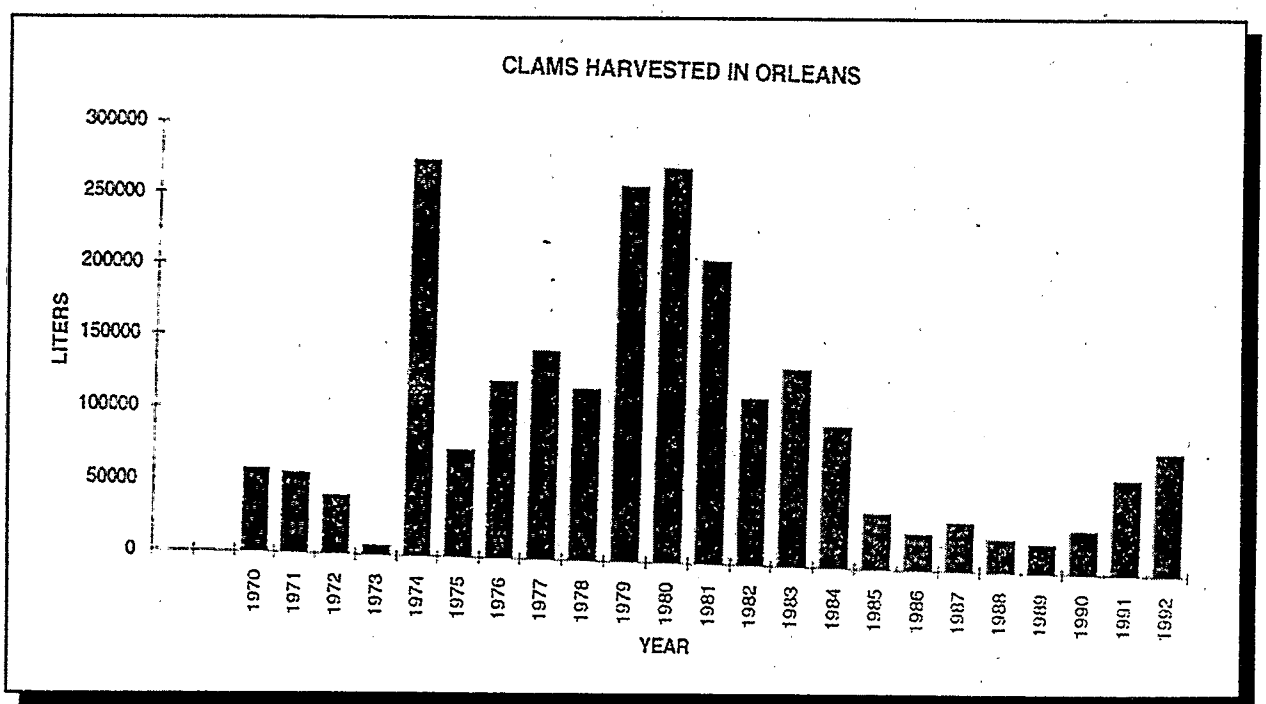

Figure 5

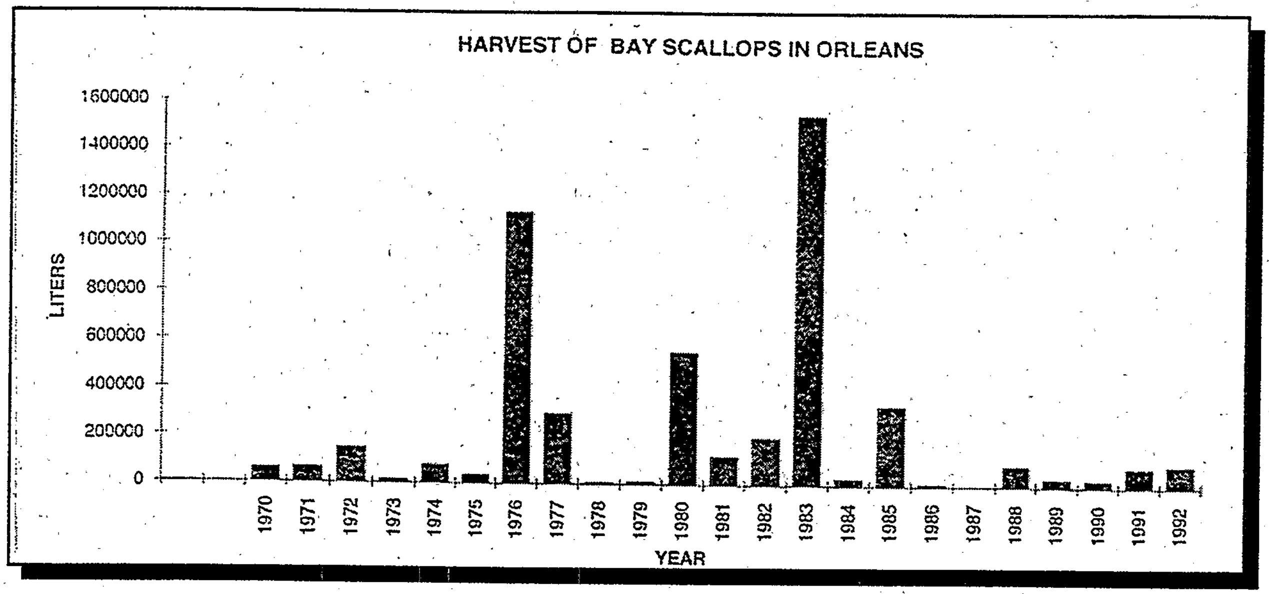

Figure 6

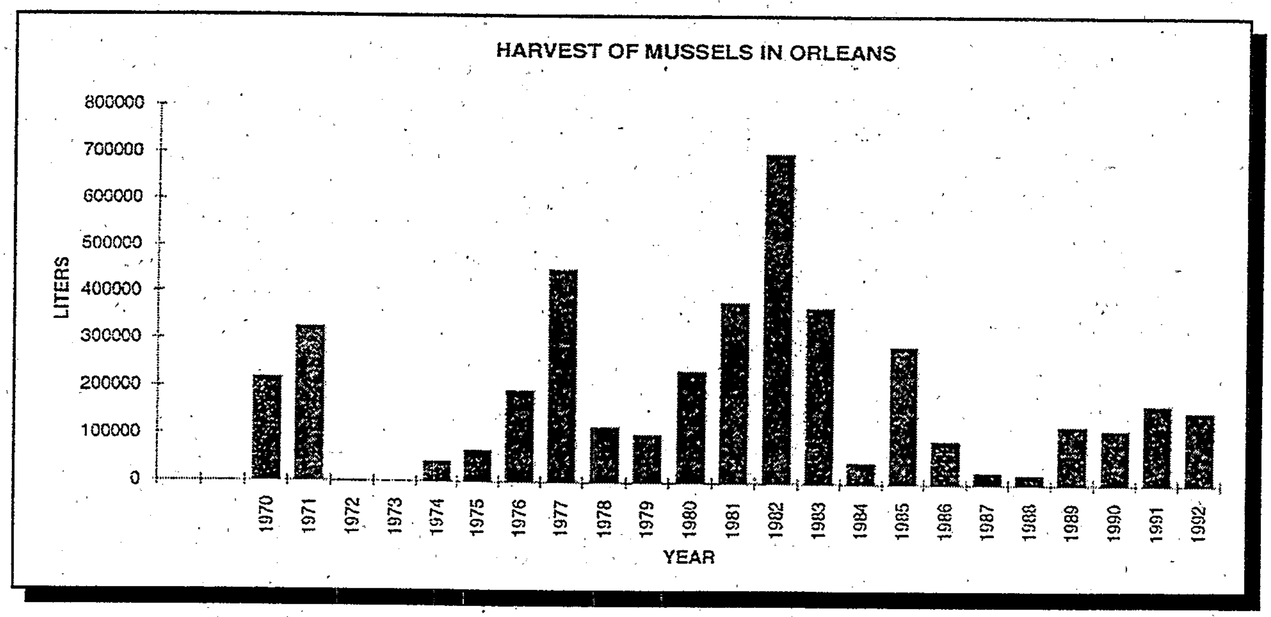

Figure 7

Demographics

Orleans was considered a rural fishing/farming community until the middle of this century but the economy has shifted more toward tourism. As a tourist area, Orleans-- located adjacent to the Cape Cod National Seashore-- is known for its sandy beaches and as a haven for water-dependent activities such as boating and fishing. It is accessible to millions of people who live within a day's drive and because of its location at the confluence of three major roads, Routes 6, 6A and 28, it is the business hub of the Lower Cape. Visitors, especially retirees, stayed and made Orleans their home. A building boom in the 70's and 80's[2] took place to accommodate the influx of new residents who were attracted to the town ***(Figure 8)***.

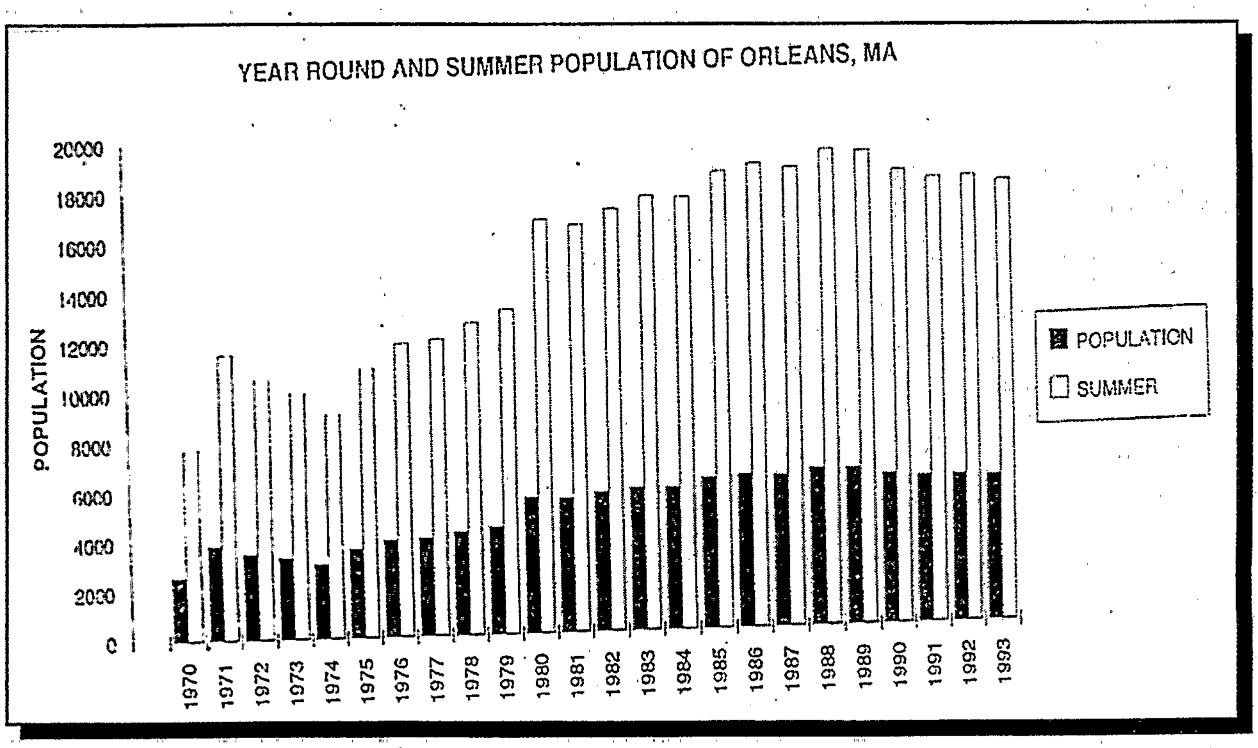

Figure 8

[2]Cape Cod Marine Quality Task Force, 1988.

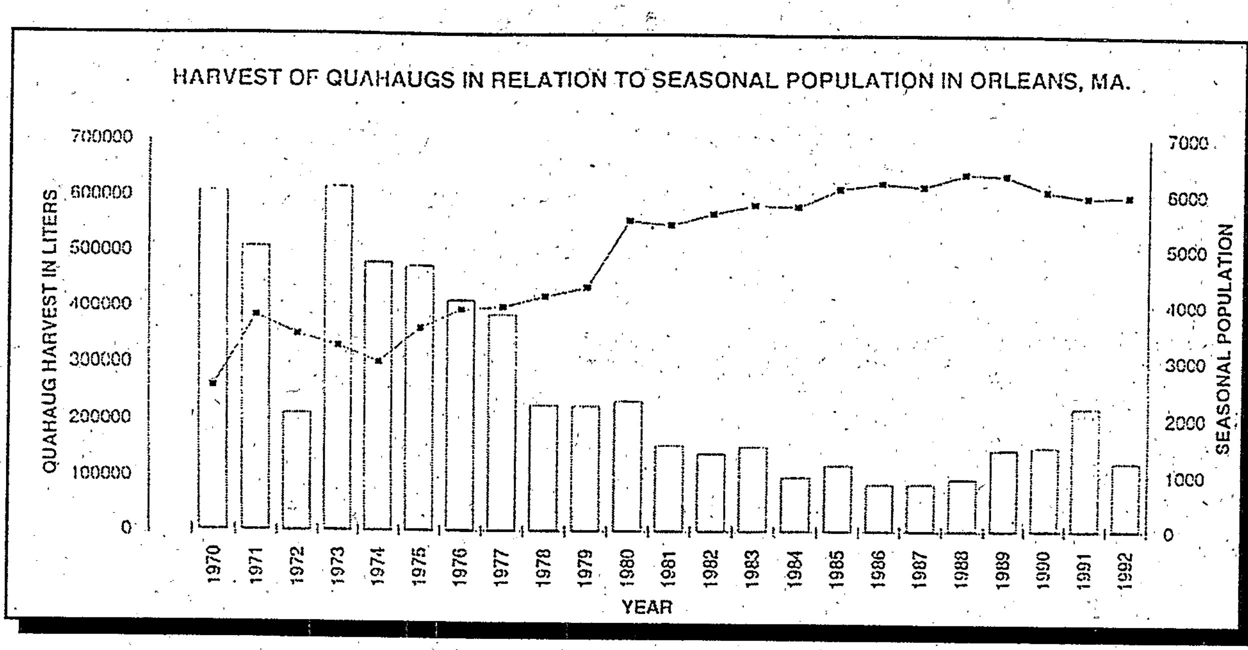

Figure 9

The population in Orleans in 1970 was 2700; by 1988 it had increased to 6000 permanent residents. Although the population triples during the summer tourist season[3], it was estimated that in 1980 sixty-nine percent of all homes in the town were occupied year round (or at least one half of the year[4].

The development of single family homes on 40,000 square feet of land per lot has resulted in the construction of 2378 new housing units from 1970 to 1990[5]. Individual septic systems are the method of waste removal and although they are efficient at removing bacteria, they are inefficient at removing nutrients, especially nitrogen compounds, that can cause nutrient enrichment in the estuaries. However, this development also resulted in an increase in impervious surfaces, especially roads. Storm water runoff from impervious surfaces has been documented as a source of nonpoint pollution including bacteria, nutrients and toxic chemicals. These pollutants have been implicated in water quality degradation. Therefore, the impact of pollution from development, specifically nonpoint source pollution, is a growing concern.

[3] Marilyn Fifield, Statistics Office, Cape cod Commission, personal communication

[4] Town of Orleans, 1994.

[5] ibid

Shellfish harvest is directly related to abundance and effort, and effort is directly related to economic factors such as price and abundance of off-shore fin and lobster fisheries and/or the availability of shore side construction related jobs [6]. Abundance, however, may be related to such factors of as over-fishing; however, it could also be associated with the effects of land use patterns in the watershed of the estuary ***(Figure 9)***. These factors may play a more important role than harvesting. Since 1980, most species have shown a decline in harvest. Scallops, which are notorious for peaks and valleys of abundance [7], [8], [9], have been abundant sporadically but high quantity is generally the exception, not the rule. Because of the economic factors, harvest statistics do not necessarily reflect the amount of stock present; they can indicate the condition of the stock but they can also indicate problems within the embayments.

In 1974, most of the Nauset estuary was closed to shellfishing because of "red tide" or paralytic shellfish poisoning found primarily in two semi-enclosed ponds within the estuary. The "red tide" are algal blooms consisting of motile cells in ideal conditions and produce resting cysts during unfavorable conditions. These cysts often bloom again into a planktonic stage when conditions are favorable. The Environmental Protection Agency ocean survey vessel, the Peter W. Anderson[10] while monitoring conditions in Orleans, found a correlation between temperature, salinity and possibly nutrient levels as triggers for an algal bloom.

In 1982, Meetinghouse Pond (Pleasant Bay) was closed to shellfishing by the State because of fecal coliform levels that exceeded the established limit ***(Figure 10)***. In 1988, portions of the Pleasant Bay estuary were closed as were the marsh creeks on Cape Cod Bay and the entire Nauset/Town Cove estuary was again closed during the summer and in 1989, and portions of the Nauset system have been closed for extensive periods of time. Since fecal coliform bacteria originates from warm blooded animals, including but not limited to humans, finding the source of contamination became an important aspect of shellfish management.

[6] Macfarlane, S.L., personal observation

[7] Belding, D.L. 1910.

[8] Macfarlane, S.L., 1991.

[9] Capuzzo, J.M. and R.E. Taylor, Jr. 1980

[10] Anderson, D.M., 1979

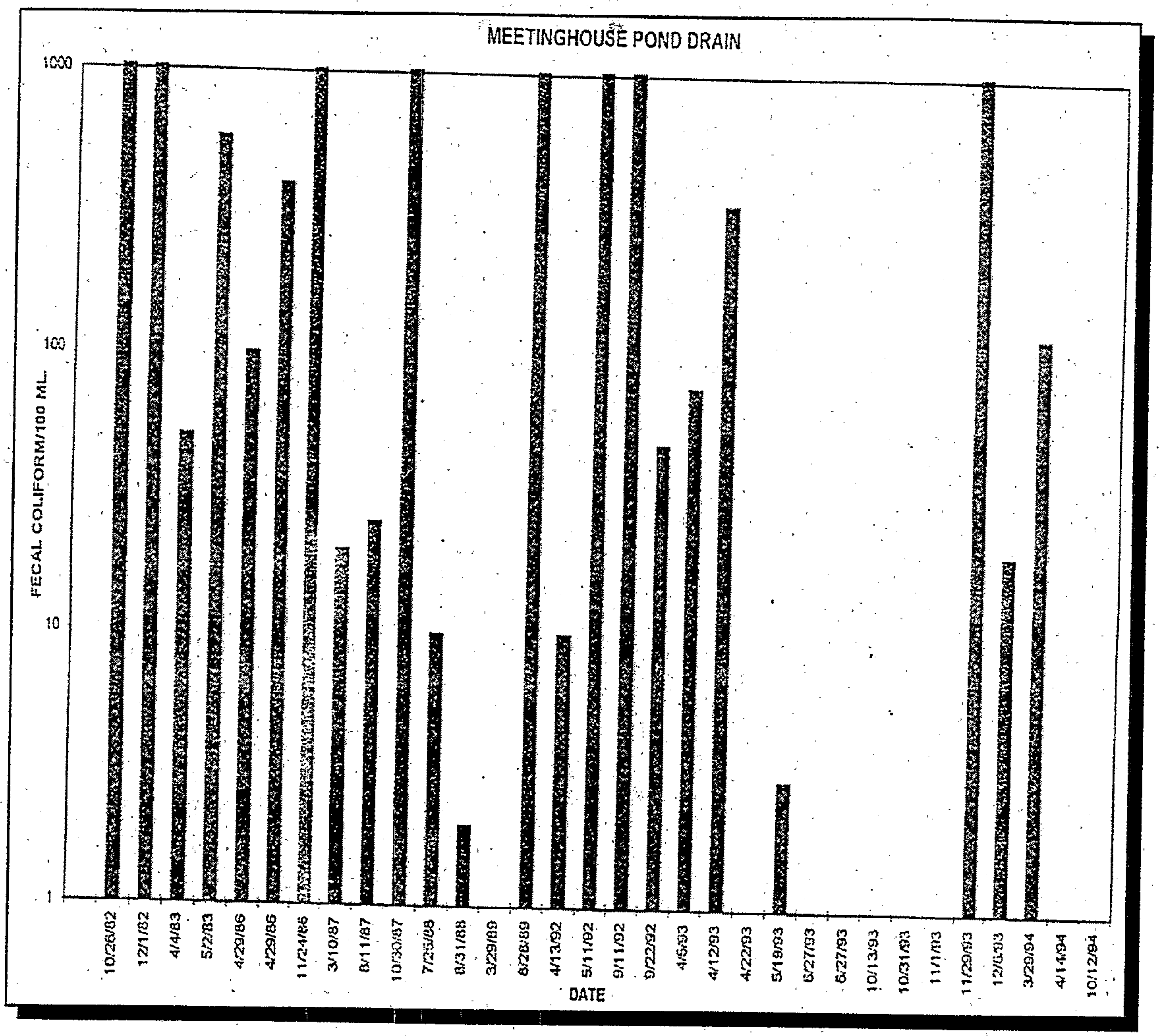

Figure 10

It has been determined that land use practices may seriously impact both the quantity of stock present in the bays through habitat degradation and the harvest readiness of the stock due to fecal coliform contamination. While the Town of Orleans has used available management tools as well as stock enhancement programs, past experience has led to the conclusion that the mitigation of some of the effects of land uses is critical for the continued production of harvestable shellfish from uncontaminated estuaries.

Issue Identification

As a result of the shellfish closures in Orleans, the town formed a Water Quality Task Force in 1987 to identify some of the problem areas and recommend solutions. The Task Force recognized that some areas needed to be cleaned up whereas other areas needed to be protected in order to maintain high water quality. Water quality problems were divided into several broad categories:

1. Stormwater runoff
2. Nutrient enrichment/eutrophication
3. Effects of private docks and piers
4. Erosion

Stormwater Runoff

The Water Quality Task Force identified and mapped all the existing surface drainage systems within the town. Also, a water quality monitoring laboratory was developed to test for fecal coliform bacteria using the membrane filtration technique. Orleans collected water samples from pipes, roads and estuaries. Using the results obtained from the testing, the task force prioritized the drainage systems and recommended remedial measures for the worst drains according to resources affected.

Meetinghouse Pond had been closed since 1982 and since over $100,000 worth of clams had been harvested from the pond in 1987, and two separate road drains were identified as the primary cause of the contamination, remediation projects for those drains were a top priority ***(Figures 11 and 12)***. In addition, two drains collected most of the drainage from the downtown business district and another collected water from the state road and a private corporation. These five drains (see map) became the focus of a drainage remediation program. Over $400,000 was appropriated by the town for initial study of the problem, for final plans and for construction. In addition, the Friends of Meetinghouse Pond, a neighborhood association, donated funds for initial engineering for one of the drains in Meetinghouse Pond (Barley Neck Road site), the state highway drains were retrofitted with leaching catch basins that were installed during a resurfacing project and a private corporation constructed an innovative filter dam system on their property.

Each drainage system was mapped and the contributing area and amount of stormwater was calculated[14]. Each remediation method was sized to handle the first 1 inch (2.5 cm) of rainfall, known as the "first flush" which is the amount of water most likely to contain the majority of contaminants, including bacteria, sediments, nutrients and toxics. In all but one case, infiltration leaching chambers were judged to be the best method of treatment. In each area, a gross particle separator, (a tank with baffles that allows sediment to be deposited in the bottom of the tank and floating hydrocarbons are trapped within the baffled area) was installed prior to the leaching galleys, to accumulate sediments and floating hydrocarbons. Diversion manholes were constructed to divert water to the leaching galleys but to also allow for heavy rain storms to flow freely to the estuaries after the leaching galleys were filled. The leaching galleys were large concrete structures, surrounded by stone, where stormwater could filter through the gravel and percolate to the groundwater where it would enter the estuary in a more diffuse manner.

The Barley Neck Road drain was completed in 1992 and construction of the other drains was completed by May, 1993. A new water quality laboratory was established jointly with Eastham, a neighboring town. Volunteers were trained in laboratory techniques so that the systems could be monitored in a cost-effective manner. Lack of rainfall during the summer of 1993 precluded the monitoring efforts but the results from one test site, Meetinghouse Pond at Main & Beach exhibited a dramatic decrease after May, 1993 when the new system was installed. Even with high water temperature, when bacteria counts have traditionally been in the range of 100,000, either no water was seen coming from the pipe or the bacteria had been effectively removed from the water. These preliminary results have shown that the shellfish growing area was not receiving additional fecal coliform bacteria.

The Barley Neck Road, Beach Road, and Academy Place sites have all been successful. Academy Place is especially effective. Only in storm events much greater than 1 inch (2.5 cm) has there been any water observed coming from the pipe. This is gratifying because of the potential for very serious contamination due to the proximity of this drain to the business district. Water sampling will continue so that we can monitor the effectiveness of these systems over time and judge the amount of maintenance they will need in order to remain effective. In addition, the results of the sampling effort has been forwarded to the Mass. Division of Marine Fisheries so that they can re-sample the closed areas and hopefully open them to shellfishing. In addition to the major pipes, minor drains have been prioritized for remediation. Some of these include roads that have asphalt beams constructed along the side of the road to channel the water off the road but which also serve as a conduit for accumulated stormwater. Many of these roads typically end in launching ramps for boats which means that the stormwater has an unobstructed entranceway to the embayment. These systems will be addressed in order of priority when funds are available.

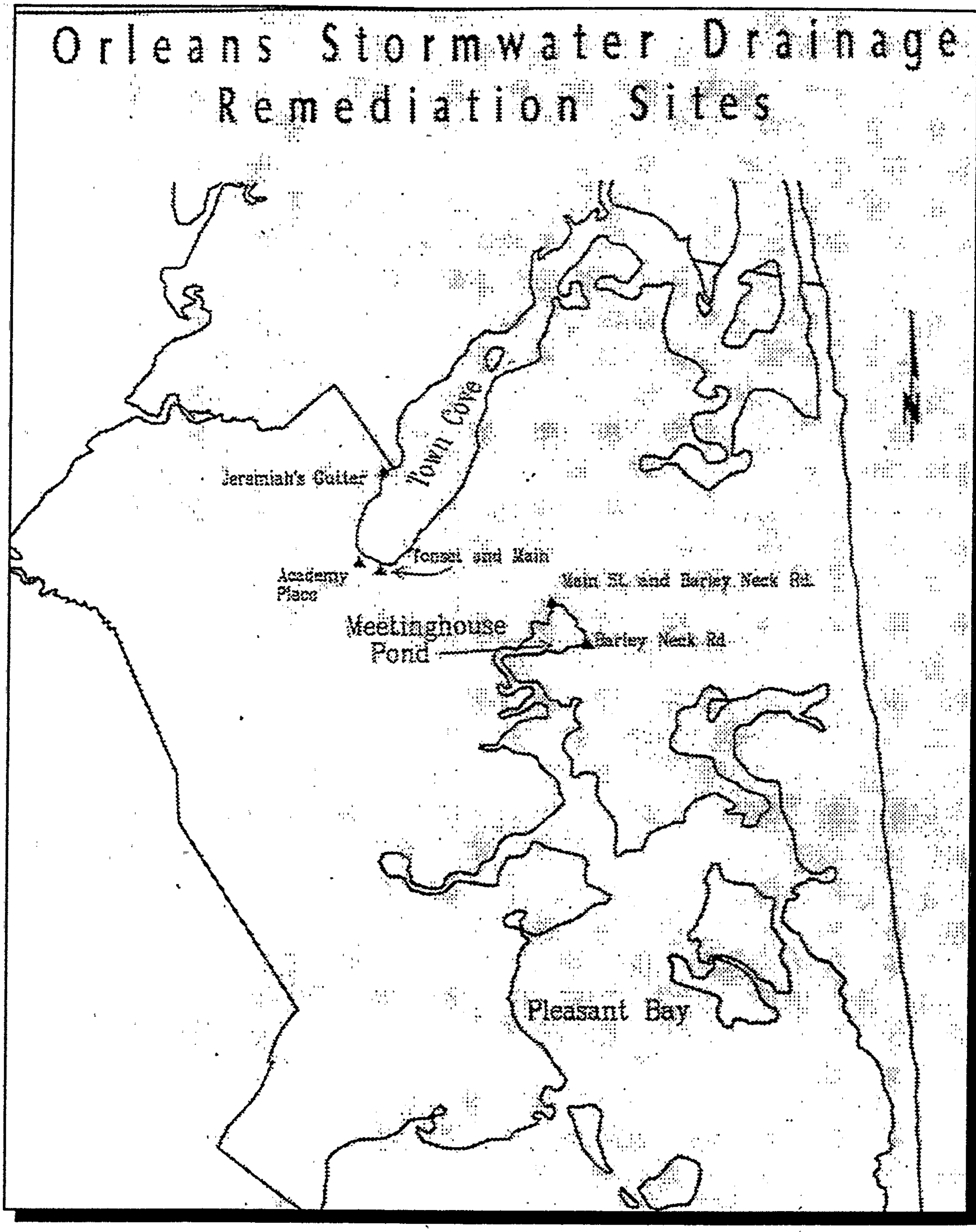
Orleans Stormwater Drainage
Remediation Sites
Town Cove
Jeremiah's Gutter
Academy Place
Main St. and Barley Neck Rd.
Meetinghouse Pond
Barley Neck Rd
Pleasant Bay

Figure 11

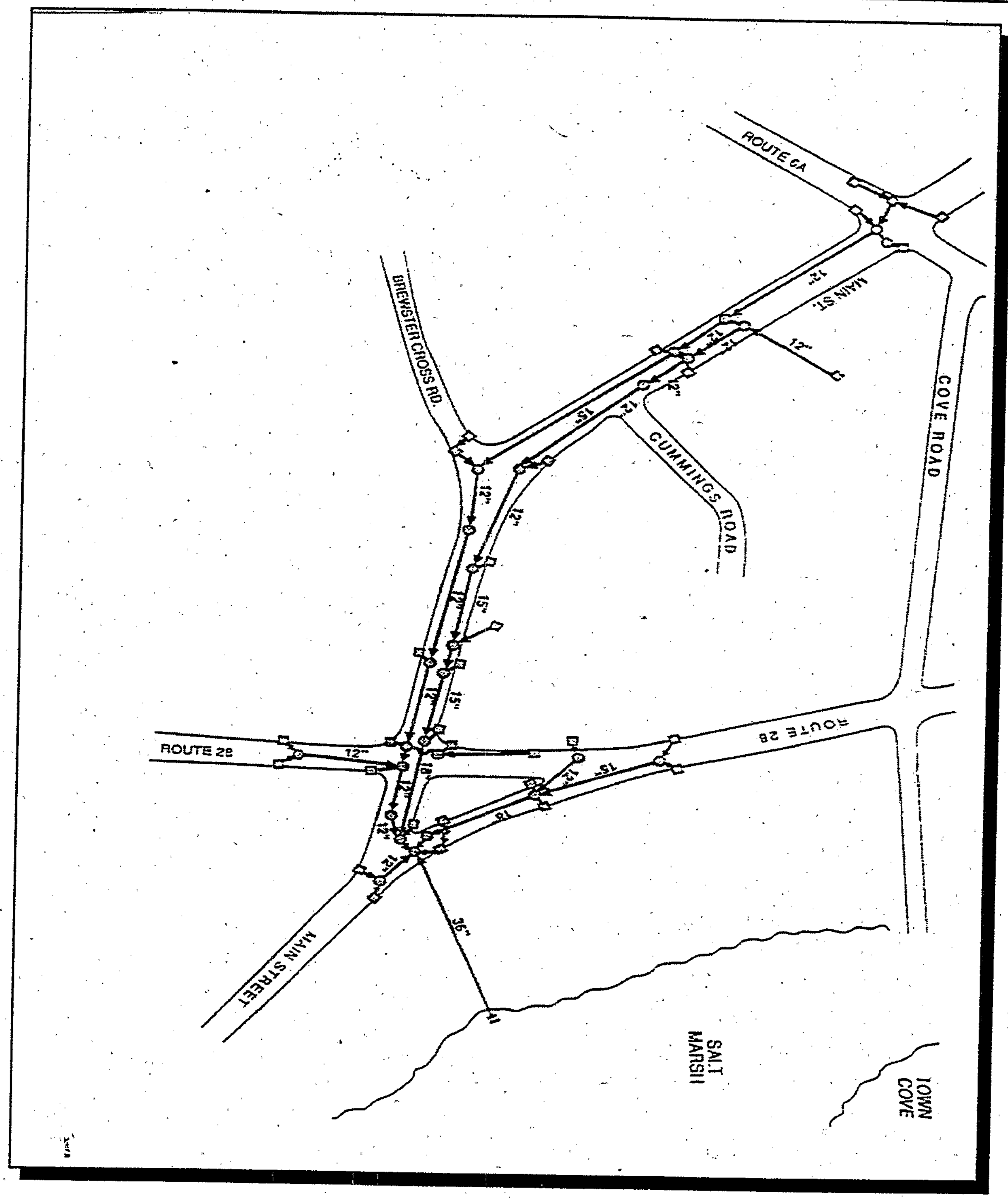
ROUTE 6A
MAIN ST.
BREWSTER CROSS RD.
COVE ROAD
CUMMINGS ROAD
ROUTE 28
ROUTE 28
MAIN STREET
SALT MARSH
TOWN COVE
12"
15"
18"
36"

Figure 12

Nutrient Enrichment/Eutrophication

Nutrients enter the estuaries through natural pathways and through land use practices ([11]). On-site septic systems are the major source of nitrogen from the land, followed by fertilizers, and storm~water. Although a natural component of the estuary, excessive amounts of nutrients can lead to microscopic and macroscopic algal blooms, anoxic conditions, fish kills and sediment changes that result in a loss of shellfish habitat.

Prior to 1987, scattered areas throughout Orleans exhibited effects of nutrient enrichment. Eelgrass in the expanse of Little Pleasant Bay were covered with epiphytic growth and "companion" seaweeds such as Calithamnion sp. Some poorly flushed areas contained pockets of concentrated macrophytic growth and monospecific blooms of phytoplankton (primarily dinoflagellates) were fairly common especially in the upper reaches of Pleasant Bay. Changes in sediment from hard bottom to silty, heavy organic mud were observed in several locations that had previously been clam habitat. Areas of obvious groundwater seeps were very likely to have profuse amounts of sea lettuce (Ulva lactuca) and/or Enteromorpha sp. by the end of the summer. Since groundwater moves relatively slowly through the ground[12] the Task Force recognized that the effects of the building boom would not be observed in the estuary until some time in the future and became concerned as to what steps may he taken to lessen the impact.

In 1987, Orleans received a reprieve of sorts from advancing eutrophication because of a breech in the barrier beach that protects Pleasant Bay. The new inlet, formed in January, 1987, created a set of hydrodynamic circumstances that have changed the flushing characteristics of the bay entirely. The Orleans portion of the bay has experienced a 1 ft. rise and fall of the tide since the break; currents are stronger while channels and exposed flats have been created; eelgrass beds are healthier; blooms of algae were less frequent or widespread; mats of macrophytes have become less abundant; and sediment has changed slightly to harder substrate.

However, these changes are temporary. The inlet is part of a long term cycle[13] and will migrate south again in time. Meanwhile, the building of homes continues. The Task Force identified several steps which were needed to counteract the effects of nutrient enrichment.

First, we needed to have our groundwater mapped. Cape Cod has been designated as a sole source aquifer by the EPA. Several distinct lenses of water have been determined Cape-wide

[11] Buzzards Bay Comprehensive Conservation and Management Plan, 1991.

[12] Tom Cambareri, Cape Cod Commission Water Resources Coordinator, personal communication

[13] Geise, G.S. 1988.

but because of its geographic location at the "elbow" of the Cape, Orleans is situated in a groundwater divide. Soil conditions throughout much of the town are variable and therefore, very little information is known about the groundwater direction of flow. Funds were appropriated in May, 1994 to have the groundwater mapped which we hope will be finished by January, 1995.

Second, once the groundwater has been mapped, watersheds will be delineated to ascertain where the groundwater divide is between the estuaries.

Third, flushing analyses will be undertaken to determine the residence time within each estuary. This will enable us to determine whether areas of high land-based nutrients entering the estuary are likely to tip the balance toward eutrophication.

Fourth, a buildout analysis will be conducted using existing zoning regulations to determine what the town could look like at maximum density. This is a powerful planning tool because of the visual nature of the product and the shock value such a picture portrays especially with the technological advances with GIS systems. This analysis will also project the areas of town where nutrients may be a real threat to the health of the bays.

Finally, using the data, the town can then plan for the nutrients that are presently entering the embayments as well as the nutrients that are heading toward the bays but have not gotten there yet. The use of alternative septic system technology, currently under review by the Massachusetts Department of Environmental Protection, may be approved which will allow the town greater flexibility in dealing with nutrient enrichment in sensitive areas. With this information the town can plan for the future and through regulations, education and guidelines, and use of alternative waste disposal methods, it is conceivable that the nutrient problem can be reduced over time. Since reduction of nutrients entering the estuary is a goal, public education regarding use of fertilizers, septic system maintenance and other sources of nitrogen is critical to achieving the goal.

Docks and Piers

Private docks for boats have been identified as a problem for many reasons. A single dock in a long stretch of shoreline probably poses no threat to shellfish resources. However, the cumulative effects of docks positioned every 150 feet (SOm) (the average waterfront frontage per lot) along the shore of narrow shallow embayments can negatively affect the shellfish resources of an area.

Much of the clam and cowhage populations are located in a ribbon of bottom from the edge of salt marshes that fringe our bays and rivers, to a distance of about 200 feet seaward which is also the area where docks are located. The impacts from the docks can occur from construction, materials/design, and location/use. On-going studies in Waquoit Bay National

Estuarine Research Reserve and the NOAA office in Gloucester, Ma. are attempting to document the environmental effects, both individually and cumulatively from private docks.

Waterfront landowners often feel that they have a right to have a private dock because in Massachusetts, property ownership extends to the mean low water. However, the Colonial Ordinance of 1637 dictates that the area below the mean high water is located in the public tidelands for the purposes of fishing, fowling and navigation. Most of the docks extend beyond the mean high water and into the public tidelands which belong to everyone. Docks in Orleans are supported by galvanized pipes, wood supports or pilings, all of varying size. Some docks are considered "seasonal" where they are put in the water each spring and removed in the fall, or "permanent" where they are put in place once until replacement or maintenance is necessary. A support (pipe, piling, etc.) of any dimension displaces sediment and therefore it also displaces shellfish habitat; the amount displaced depends on the size of the material used. We have observed that when a dock located in soft sediment is put in and taken out each year, the sediment around the support structure can become a "dead zone" of very soft muck. A 10" piling may have a soft muck area of at least 24" in diameter around it where no shellfish will live and therefore the habitat displaced or altered is about double the diameter of the piling. Although it does not seem like much of an impact, multiplied by the number of piles in each dock and multiplied by the number of docks in the similar type of area, the impact can be considerable.

Most docks are constructed with wood. With the introduction of CCA treated wood, advertised to last longer than untreated wood and be especially resistant to destruction by wood boring worms, almost all docks constructed or repaired in the last 15 years has been with pressure treated CCA wood. There has been a debate regarding the toxicity of CCA wood in the marine environment and only recently studies have shown the potential deleterious ramifications of widespread use of this material[14]. In a hearing held in May, 1994, by the Orleans Conservation Commission for a new dock in Pleasant Bay, the applicant proposed to construct the structure with plastic "wood" manufactured from recycled milk containers. This material has promise as an alternative to CCA treated wood but has not had enough use to provide information of its effectiveness as a replacement.

Docks that have decking spaced close together create shading below. The environmental ramifications of shading in northern estuaries is the subject of the continuing research. The length of the structure and the number of bents needed to support the dock is generally a function of depth of water at the end of the float. If a dock is inappropriately sited in a shallow area, a boat approaching or leaving the dock may cause sediment to be displaced by severe turbidity or "prop dredging" and can be a serious consequence which can further alter shellfish habitat. Boats can motor through eelgrass beds to access the dock which can impact scallop

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[14] Weis, J.S. and P. Weis, 1994.

resources. The turbidity of engines can impact newly setting shellfish much as hydraulic harvesting for clams can be an inappropriate method of harvest during the summer[15]. Hydraulic harvesting means using a pump and manifold to jet water into the substrate to dislodge shellfish living beneath the sediment surface. Fishermen use this method where permitted to harvest subtidal clams which would otherwise be very difficult to harvest.

Erosion

Both Pleasant bay and Nauset are protected by undeveloped barrier beaches which are constantly changing. Geise[16] has indicated that the inlet to Pleasant Bay is determined by events that fall within a 150 year cycle. As the barrier beach migrates south, the hydraulic pressure become out of balance and pressure builds on the bay side. Eventually, the beach is breeched and the cycle begins again. In January, 1987, we witnessed day one of the 150 year cycle. What began as a small trickle through the beach became an inlet approximately 1.5 miles wide with numerous sand bars within the harbor.

Although the upper portions of the bay received greater flushing because of the break, the increased tidal amplitude also caused substantial erosion of coastal banks in the bay. Property owners, who own houses on the water, and who pay the highest tax rate, understandably requested relief from the onslaught of erosion before houses were lost to the sea. Several houses were washed into the water in the neighboring town of Chatham, directly across from the new inlet. Orleans has tried to prevent a similar circumstance. In addition to the problems in Pleasant Bay, a similar situation occurred in the Nauset estuary which is smaller but the inlet location is also cyclical[17]. In 1991, a severe northeaster flattened the dunes on the barrier beach and caused severe erosion within the estuary. A new inlet was formed in another storm in 1992. The State allowed eroded banks to be filled and revegetated but the storm in 1992 prevented most of the vegetation the opportunity to become established. Property owners here were also nervous about the loss of land and the failure of "soft" solutions and requested rock revetments to protect their property.

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[15] Macfarlane, S.L. 1983

[16] Geise, G.S. 1988.

[17] Speer, P.E. et. al., 1982,

The local Conservation Commission is charged with the responsibility of permitting or denying applications for erosion control[18], [19]. Since 1987, the Orleans Conservation Commission has permitted the re-vetting of approximately 1.5 miles of shoreline, with no technical basis for knowing whether there will be a long-lasting negative effect on the productivity of the estuary since most of the information available on coastal engineered structures concerns structures on "outside" or oceanfront shorelines, not the embayments. Emotions run high on this issue.

Local Comprehensive Plan

The town is in the process of trying to put these issues into a management framework called a Local Comprehensive Plan. The plan will be based on resources and will encompass diverse elements of planning for the town's future including economic development, housing needs, infrastructure, and natural resources. The natural resources section will have a chapter on the coastal resources.

In the coastal resources chapter, we hope to involve the neighboring towns in the planning process since all our waters are bordered by other municipalities. At this point, a flushing analysis will be conducted in 1994 in the Nauset estuary, shared by Eastham and the groundwork has been laid for cooperative research in Pleasant Bay with the other towns, the Cape Cod Commission and the Friends of Pleasant Bay, a non-profit organization.

Our hope is to identify all the issues, gather data, solicit opinions from residents about the issues and offer recommendations for the future direction of the town. We will be using user surveys, interviews, public meetings and any other tool to arrive at consensus regarding the uses of the water and the land surrounding the water. The items outlined above concerning nutrients are either being planned or will be completed by 1996. Recommendations will probably include regulations and public education or guidelines for development.

If the Local Comprehensive Plan is based on resources and the residents feel that high water quality is desirable for fishing and shellfishing, then restrictions may have to be imposed on certain activities that would degrade the water quality. Such restrictions could include utilizing specific waterfront shorelines for shellfish and others for private docks where the impact to shellfish resources is minimal. However, the town must recognize, and generally does, that the environment and natural resources are its economy.

It is clear to us that shellfish enhancement programs are not enough to maintain a fishery resource. We have found that we must diligently work to resolve the issues identified above and

[18] MGL 131 s. 40 and Chapter 160 of the Orleans Code

[19] Town of Orleans, Chapter 16() of the Orleans Code

that public education and consensus among the residents will be essential to correct the problems of today. We are hopeful that a plan can be developed that takes all these elements into account so that Orleans can continue to be the special place that it is and that shellfishing activity can take place for generations to come.

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