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A REVIEW OF SHELLFISH RESTORATION AND MANAGEMENT PROJECTS IN RHODE ISLAND

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ABSTRACT Shellfish management and restoration efforts in Rhode Island date back to the late 19th century. From the late 1890s to the Second World War the Rhode Island Fisheries Commission operated a lobster hatchery in Wickford Harbor in response to a perceived decline in lobster catches in Narragansett Bay. Berried lobsters were collected, eggs hatched, larvae reared, and postlarval fifth stage juveniles were released to the bay. The project was discontinued primarily because of costs and a failure to demonstrate the efficacy of juvenile seeding in improving lobster catches. From the 1930s to the 1980s, there have been several similar efforts to establish hatcheries to produce juvenile bivalve mollusks for public and private reseeding efforts, but none of these efforts were economically sustainable. The longest running efforts to improve shellfisheries have been state programs to relay northern quahogs, *Mercenaria mercenaria*, from dense population assemblages in waters closed to shellfishing. Large-scale relays began in the 1950s in response to heavy fishing pressure but ended in the 1960s when commercial power dredging for shellfish was banned in Narragansett Bay. A small-scale state program existing since the late 1970s pays a modest fee to supervised shellfishers for hand digging quahogs in closed waters and planting them in management areas for depuration and eventual harvest. The amounts of shellfish relayed annually has varied widely since 1977, ranging between 7 and 322 metric tonnes, with an average of 98 metric tonnes per year. A new relay program has been underway since 1997. It involves assessing the shellfish stocks in the closed Providence River and hiring dredge boats to relay shellfish into down bay management areas. Based on maximum sustainable yield (MSY) considerations, annual relays should not exceed 10.3% of the standing crop (or 2721 metric tonnes) in the Providence River. An effort to restore lobsters onto monitored artificial reefs is underway using settlement funds from a 1989 oil spill in Narragansett Bay. Finally, the Rhode Island Public Benefit Aquaculture Project, a joint educational effort with commercial fisheries involvement, is involving secondary level students in the nursery culture of shellfish (though marina-based upwellers) for seeding of public shellfish beds.

KEY WORDS: Shellfish restoration, Rhode Island, shellfish relay, shellfisheries, Narragansett Bay

INTRODUCTION

Since the King Charles Charter of 1663 uniting the Rhode Island Colony of Newport to the mainland colony of Providence Plantations, there has been a codified recognition of the importance of fish and fisheries to all the citizens of Rhode Island. Although the charter is best known for its early establishment of religious freedoms, it also set forth the first principles of a public trust doctrine by entrusting the stewardship of coastal waters to the colonial assembly. All citizens were assured of free access to the waters for fishing and the collection of seaweed. In 1842 these public trust principles were incorporated directly into Article 1, Section 17 of the state constitution, and they now form the basis of all fisheries and coastal management efforts undertaken in Rhode Island's tidal waters. Nixon (1993) provides an overview and analysis of Rhode Island's public trust doctrine as it relates to shellfisheries and aquaculture in coastal waters.

The history of Rhode Island's shellfisheries can be broadly characterized as having three distinct periods. During the first period, which began in pre-Colonial times with the Narragansett Indians, shellfishing was usually a summer activity. Roger Williams (1643) the founder of Providence Plantations Colony noted that the Narragansetts would ". . . wade deepe (sic) and dive . . ." for oysters and quahogs. Shell middens found along the shore of Narragansett Bay, notably in the Potowomut area of what is now Warwick, are testament to the importance of shellfishing in the pre-Colonial era. Even the scientific name of the northern quahog—*Mercenaria mercenaria* (Linnaeus, 1754)—is testimony to the fact that the white and purple beads made from their shells were an important trading currency. From the Colonial period and early statehood until the Civil War, shellfisheries were essentially subsistence or small-scale commercial operations as authorized under the King Charles Charter or under the Article 1, Section 17 provisions of the 1842 Rhode Island State Constitution. Oysters were harvested as feed for swine and for storage as a personal food item during winter. The shells were burnt to produce lime (Kochiss 1974).

The second major period in Rhode Island's shellfisheries began with the passage of the Oyster Act of 1864 and the establishment of the Rhode Island Shellfisheries Commission. This act of the legislature allowed, for the first time, the leasing of tracts of submerged public trust lands for the purpose of cultivating oysters (Nixon 1993). The early oystermen in Rhode Island readily recognized that the waters in Narragansett Bay were very good for

growout, or maturation, of oysters (*Crassostrea virginica*). But, the seed beds in the state were not particularly productive and recruitment was very sporadic, so tons of seed oysters were brought annually into Narragansett Bay from Long Island Sound and as far away as the Chesapeake Bay (Hale 1980). This massive transplantation of oysters onto extensively managed aquaculture beds might be considered Rhode Island's first successful program of shellfish restoration, albeit the direct beneficiaries were the oyster leaseholders. In 1910, during the height of Rhode Island's oyster aquaculture industry, 8100 ha of Narragansett Bay was leased to private companies for oyster culture and 7000 metric tonnes of oysters were harvested annually (NMFS landing statistics as cited in Olsen and Stevenson 1975).

Throughout the period of massive oyster aquaculture leases in Narragansett Bay, state efforts to boost shellfish production included programs to monitor and control shellfish predators. The former Rhode Island Shellfisheries Commission and the oyster companies initiated an annual starfish census. These are reliable estimates of starfish populations in Narragansett Bay from 1880 to 1940 (Pratt et al. 1992). From time to time—when the predator populations became particularly high—there were starfish "bounty" programs (Hale 1980), and as part of regular oyster bed maintenance the oyster vessels were rigged with starfish mops similar to those still used on oyster beds in Connecticut (Olsen et al. 1980). The old-time oystermen recognized that predator control programs were a very effective way to increase shellfish production, but there was a lack of understanding that starfish could regenerate from body parts. One common practice of starfish "control" was to cut landed starfish in half and throw them overboard (Luther Blount, former President of Warren Oyster Company, pers. comm. 1993).

Beginning in the 1920s, the oyster aquaculture industry began a slow decline, culminating in a near collapse following the Great Hurricane of 1938. A number of causes have been attributed to the decline of the oyster industry in Rhode Island. These include changes in upland land uses and increased sedimentation of prime beds (Hale 1980), increased metal pollution due to a burgeoning metal-plating industry (Nixon 1995), and increased eutrophication and hypoxia in the upper reaches of Narragansett Bay due to sewage disposal (Desbonnet and Lee 1991). The Great Hurricane of 1938 was certainly a major blow to the oyster industry. Most of the shoreside docking and processing facilities were severely damaged by the storm (Olsen et al. 1980), and the recovery of the industry was hampered by the lack of a readily available workforce due to the onset of World War II (Hale 1980).

Another reason for the decline and eventual demise of Rhode Island's oyster industry may lie in the major socio-political changes that occurred in Rhode Island during the mid-1930s. In many ways, Rhode Island's oyster industry was a product of the "mill town" social system that grew up during the Industrial Revolution and the heyday of Rhode Island's textile industry in the late 19th and early 20th centuries. The oyster industry, as it was constituted, was extremely labor-intensive, very much like other industries of the era. Beginning in 1935, political shifts in the state government (known locally as Gov. T. F. Green's bloodless revolution) toward more populist policies may have had some impact upon the oyster industry. McLoughlin (1978) argued that this change in political philosophy had a profound impact on the textile industry and other industries that failed to adapt in a changing political climate.

The third period of Rhode Island's shellfisheries, reviewed by Hale (1980) and Boyd (1991), arose immediately after World War II. Many of the troops returning from Europe or the Far East in the 1940s began tonging for quahogs, largely because the old oyster beds were no longer tended and the oyster companies were not hiring. In the late 1940s the keyport bullrake was invented in the Mid-Atlantic region and was quickly introduced to Rhode Island. After several technical refinements, the bullrake became the most widely used commercial shellfishing implement by the 1960s (Boyd 1991).

The two key controversies in the shellfisheries during the 1940s and 1950s were fees paid by fishermen to oyster leaseholders for the privilege of fishing on the beds, and the introduction of power dredges for harvesting quahogs. When oyster production on the old leases declined, there was little or no effort by the state to revoke the leases and return the grounds to the open fisheries. Only after the demise of the last Rhode Island oyster company, the Warren Oyster Company in 1952 ceased culture operations, were all of the old oyster leases eventually revoked. The creation of a Coastal Resources Management Council in the late 1970s and changes in the aquaculture laws (General Laws of Rhode Island 20-10-1) in the early 1980s included provisions against aquaculturists retaining leases in public trust waters when active aquaculture operations cease (Olsen and Seavy 1983).

Throughout the 1950s and 1960s, there were countless discussions about how the quahog fishery should be managed. The main issue was whether the fishery would consist of a large number of small-scale operators using hand tongs and bullrakes or a relatively small number of operators using power dredges. The rakers and tongers argued strongly to management officials that power dredging was environmentally damaging. This prompted a number of studies, including that of Glude and Landers (1953) which showed that while dredging did allow individuals to harvest more shellfish in a shorter period of time, it was no more damaging than the cumulative impacts of large numbers of handrakers. By the early 1960s, state management officials set into statute the banning of power dredges in most of Narragansett Bay (General Laws of Rhode Island 20-6-7). Thus the strategy was to allow greater numbers of fishermen through limits on individual effort. Under this system of limiting individual effort, the fishery grew and flourished. When the Rhode Island quahog fishery reached its peak in 1985, there were an estimated 1000 full-time commercial shellfishermen, landing 2200 metric tonnes (meat weight) of shellfish, worth $15 million dockside, representing about 25% of all quahog production nationally (Boyd 1991; Pratt et al. 1992).

During the decade of the 1990s there has been a steady decline in quahog catches and a decrease in the number of active full-time shellfishermen. According to the Rhode Island Department of Environmental Management statistics in 1997, there was an estimated 500 full-time fishermen landing about 651 metric tonnes (meat weight) of shellfish. Rhode Island's national market share in quahogs has dipped to about 8%. This erosion of the fishery since the 1980s has caused concern in the industry and generated calls for means to rebuild the fishery through expanded relays, seeding, and other public aquaculture projects.

OVERVIEW

Concern about declining shellfisheries is certainly not new in Rhode Island. Through the years there have been numerous attempts to use aquaculture techniques to enhance fisheries. As previously noted, oysters were transplanted onto lease beds for maturation, but this was more of a directed private enterprise practice

on privately held lease beds. The first genuine public aquaculture for a marine species was a lobster hatchery established in Wickford Harbor in 1898 by the Rhode Island Inland Fisheries Commission in response to declining lobster fisheries (Meade 1901). As one contemporary account put it, "It is no exaggeration to say that in practically every known natural region of the North Atlantic coast, the lobster fishery is either depleted or in a state of decline" (Herrick 1909). Personnel from the hatchery would gather berried female lobsters from the Narragansett Bay trap fishery, and carefully incubate the eggs until hatching. They maintained larvae in floating fine mesh net cages and fed them a diet consisting of ground beef liver and cooked chicken eggs. While in the floating cages, larvae were gently agitated with a mechanical apparatus to keep them suspended to reduce cannibalism (Meade 1908). After reaching fourth or fifth postlarval stage, they were released into Narragansett Bay. In the first rear of lobster releases, 1901, only 9000 juveniles were released into Narragansett Bay. But in 1908, the Wickford station was releasing 400,000 lobsters, and by 1920 the facility was releasing over 1 million lobsters yearly. Peak production of the facility was in 1934 when lobster releases reached over 1.5 million (IFC 1934). The lobster hatchery program continued by the Inland Fisheries Commission (IFC) until 1935, when the agency was reorganized into the Department of Fish and Wildlife. The Wickford lobster hatchery continued under Fish and Wildlife until the 1940s (Carlson 1954). After nearly a half century of operation this remarkable pioneer program was eventually discontinued as a cost cutting measure. The site of this first state lobster hatchery is now used by the Rhode Island Department of Environmental Management's Division of Fish and Wildlife as a fisheries laboratory and a base for the patrol craft of state fisheries conservation officers.

The first Rhode Island oyster hatchery was established by Paul Galtsoff in the late 1930s at the end of South Ferry Road in Narragansett, on what is now the campus of the University of Rhode Island's Graduate School of Oceanography (GSO). The intent was to establish a facility similar to the successful oyster hatchery in Milford, Connecticut, operated by Victor Loosanoff of the Bureau of Commercial Fisheries (the forerunner of the National Marine Fisheries Service) to aid the Long Island Sound oyster industry. Galtsoff operated the hatchery for a time but it had little impact on the then moribund Rhode Island oyster industry; however, it became the forerunner of the National Marine Fisheries Service Narragansett Laboratory. The hatchery building itself remains on the GSO campus as the Mosby Center, the campus cafeteria building. The other legacy of the period is Galstoff's valuable reprint collection used as reference material in his classic (1964) treatise on the American oyster. The collection is housed currently at the nearby Pell Marine Science Laboratory.

As the quahog fisheries began to develop in the late 1940s and early 1950s, much of the quahog stocks in Narragansett Bay were located behind pollution closure lines. The first baywide wide assessment of quahogs in Narragansett Bay showed that greater than 60% of the quahogs in the bay resided in the closed Providence River and Mount Hope Bay sections of the bay (Stringer 1959). There was intense fishing pressure on the remaining open areas by both hand-diggers and dredge boats. In 1954, the Division of Fish and Wildlife initiated a shellfish relay program to dredge quahogs from the closed areas and deposit them in management areas in certified waters that would eventually be open for fishing. Between 1954 and 1968, the relay program typically moved an average of 1140 metric tonnes of shellfish annually (Table 1).

TABLE 1.

Quahog relays in Narragansett Bay in metric tonnes whole shell weight (Source: Division of Fish and Wildlife Annual Reports).

	Method of Harvest		
Year	State Dredge Vessels	Hired Dredge Boats	Handraking
1954	—	5774	—
1955	—	4697	—
1956	5163	1725	—
1957	4998	—	—
1958	4374	2767	—
1959	4695	—	—
1960	3125	—	54.4
1961	2932	—	20.4
1962	4027	820	138
1963	1169	—	83.6
1964	—	7016	—
1965	—	7487	361
1966	—	7702	361
1967	—	6412	—
1968	—	2916	99.2
1971	329	—	—
1977	—	—	66.9
1978	—	—	85.7
1979	—	—	71.8
1980	—	—	86.5
1981	—	—	87.7
1982	—	—	81.6
1983	—	—	49.9
1984	—	—	108.2
1985	—	—	59.8
1986	—	—	103.4
1987	—	—	88.5
1988	—	—	133.5
1989	—	—	101.7
1990	—	—	322.4
1991	—	—	25.1
1992	—	—	108.1
1993	—	—	7.0
1994	—	—	78.3
1995	—	—	7.5
1996	—	—	60.3
1997	—	—	122.2
1998	238	—	290.5

After 1968 and the banning of power dredging in Narragansett Bay, the transplant program changed character. Beginning in 1977, under the leadership of Arthur Ganz, the state-conducted relay program began paying a modest fee to supervised shellfishermen to dig quahogs and move them to the management areas in certified waters. On average over 22 y, 98 metric tonnes of shellfish were moved annually (whole shell weight; ranging from 7 to 322 metric tonnes per year). This program remains popular with the shellfishing community and has been ongoing until the present.

In spite of their popularity in the shellfishing community, the value of relay programs has long been in dispute in Rhode Island. The reluctance by state officials to dedicate permanent funding for a long-term shellfish transplant program has led to intermittent stocking attempts, primarily into already highly productive areas such as Greenwich Bay. Critics have classified the program as a "put & take" subsidized fishery, while shellfishermen contend they are denied access to highly productive areas due to long standing

sewage treatment deficiencies and argue for just compensation. Since the 1980s, shellfishermen have become dependant upon the Greenwich Bay transplant area for economic survival during the winter months. While a limited number of shellfishermen traditionally participate in transplants, hundreds of fishermen are observed harvesting upon the reopening of management areas.

Another effort to restore shellfisheries in Rhode Island included an effort by the Shellfish Commission of the Town of New Shoreham (Block Island) between 1987 and 1990 to rear hatchery seed quahogs in plastic-mesh-covered trays (Littlefield 1991). In 1989, about 120,000 *Mercenaria mercenaria* (*notata* strain) 15–20 mm in size were seeded into the Andy's Way section of the Great Salt Pond. In 1990, about 130,000 more were seeded into the same area. Littlefield (1991) reported that legal-size (about 48 mm valve length) *notata* quahogs were showing up in the 1990 fall fishery, but he did not estimate a percentage recovery rate. This project was discontinued in 1991 when Mr. Littlefield resigned from town government.

In addition to quahogs, scallops have been an important shellfishery in Rhode Island. Beginning in the early 1970s there were three major pushes to restore scallop (*Argopecten irradians irradians*) fisheries using hatchery reared seed. Scallop fisheries were historically abundant in the shallow Greenwich Bay region of Narragansett Bay and the barrier beach lagoons and estuaries along the south shore of the state (Olsen and Stevenson 1975). By the late 1960s and early 1970s, scallop catches were small and sporadic. As a result the Division of Fish and Wildlife established a hatchery for scallops at the old ferry terminal in Jamestown in 1973. The operation was moved to better facilities at the Division of Fish and Wildlife Coastal Fisheries Laboratory in Jerusalem in 1978. During its 7 y of operation, several thousand scallops were distributed to coastal barrier beach ponds. The hatchery ceased operations in 1980 for lack of continued state funding (John Karlsson, Division of Fish and Wildlife retired, personal communication 1998).

The next scallop restoration effort, in 1988–1991, was the Rhode Island Scallop Restoration Project. This effort arose in to response to massive scallop and other bivalve mortalities as a result of blooms of the picoplankton *Aureococcus anophagefferens* in Narragansett Bay and coastal estuaries during the summers of 1985 and 1986 (Tracey 1988). This 'brown tide' event occurring on two successive years decimated scallop (*Argopecten irradians irradians*) populations in the coastal salt ponds and estuaries. The aim of the restoration project was to solicit funds as a nonprofit corporation and to work cooperatively with the Division of Fish and Wildlife and Spatco Ltd., a private hatchery, to hatch and rear juvenile scallops for release in the coastal ponds (Burns 1991). As a result of this collaborative project, 60,000 seed scallops (15–20 mm size) were released into Point Judith Pond in 1989. In 1990, 20,000 seed (15–20 mm) were released in the Great Salt Pond of Block Island, and 5 million seed (1–3 mm) were released into Point Judith Pond due to lack of adequate nursery facilities. Also that year, 250,000 seed (15–20 mm) purchased from a Maine hatchery were distributed to Quonochontaug, Ninigret, and Winnepaug ponds (Robert Rheault, Spatco Ltd., personal communication, 1998; Division of Fish and Wildlife records). The project was discontinued in 1991 because the nonprofit corporation could not raise sufficient funds to continue, and the intricacies of state bid-procurement regulations made advance seed orders from the private hatchery participating in the project a challenging process.

CURRENT SHELLFISH RESTORATION

Scallop

The third scallop restoration effort, the Restoration and Enhancement of Bay Scallop Populations in Narragansett Bay Project, has been underway since 1995 through the Rhode Island Department of Environmental Management Aqua Fund. The aim was to reintroduce bay scallops, *Argopecten irradians*, to areas of historical abundance in Narragansett Bay, using both hatchery-reared scallops and scallops gathered from mesh spat collector bags similar to those recently used for scallop restoration in nearby Westport, Massachusetts (Tammi et al. 1998). Seed averaging 20 mm (range 15–24 mm) was both free planted and placed in protective cages for overwintering at sites with suitable habitat. The scallops were monitored for growth, survival, and predation rates. A total of 1 million seed had been planted in Narragansett Bay as of Fall 1998, producing small sets of bay scallops in adjacent areas of some of the sites. While overall recovery of planted scallops has been minimal, several areas of the bay supported a recreational harvest of bay scallops for the first time in decades.

In 1997, additional funding was received to add scallop stocking of the south shore coastal ponds, utilizing the same methodology as the Narragansett Bay study. The coastal pond study provided control sites for comparison with the existing sites in the bay. A total of 80,000 hatchery-reared scallops were planted in the fall of 1997 and again in 1998. Growth and survival rates of scallops placed in the coastal ponds were significantly higher than at any of the sites in Narragansett Bay, despite observations of equally high predation and fouling. Additionally, populations of seed scallops have been observed in the vicinity of caged animals, as well as being found in two of the five ponds where spat collectors were deployed. The project is in its final year of monitoring and as of December 1998 there is no dedicated funding on the horizon to continue scallop enhancement efforts.

Lobster Fishery

After nearly a 50-y hiatus, there has been a revival of the idea of restoring and enhancing Narragansett Bay lobster fisheries beginning in 1996 in a cooperative study between the University of Rhode Island and the National Marine Fisheries Service (Cobb et al. 1998). Funded by restoration and remediation funds from a 1989 oil spill in Narragansett Bay, the aim of this modern effort is to increase lobster habitat, assess the survival of lobsters naturally recruiting onto artificial reefs, and assess the survival of hatchery-reared lobsters on the artificial reefs. This approach of focusing on habitat differs from the earlier approach of releasing juveniles directly into the bay without protective habitat. Six artificial reefs (10×20 m) consisting of either cobbles or boulders were placed in Narragansett Bay. Soft bottom and naturally rocky bottom control areas served as control areas. In 1996 and 1997, natural lobster recruitment into the areas was monitored. In 1998, about 2400 fifth stage, tagged juvenile lobsters ($4.3/m^2$) were released into the test sites (Kathleen Castro, University of Rhode Island, personal communication 1998). This enhancement program should run until 2001 and yield valuable data about habitat enhancement as a means for reducing predation on released hatchery-reared stock.

Quahog

In response to declining quahog fisheries in the 1990s, the Rhode Island Department of Environmental Management (DEM),

Division of Fish & Wildlife (DFW) began a population and utilization study of the uncertified shellfish resources in the Providence River (funded by a grant from the U.S Department of Commerce). Evaluating shellfish relay programs as a tool for enhancing Rhode Island's quahog fishery is essential to the development of a statewide shellfish management program. Judicious utilization of shellfish resources in uncertified waters for either relay stocking or depuration may provide revitalization of Rhode Island's shellfish industry. Project activities included a survey to determine current quahog biomass in the Providence River, calculation of estimates of maximum sustainable yields, and development of a rational plan for the transplanting of uncertified shellfish stocks. One of the key work elements of the project was a pilot project to test the feasibility of transplants. The DFW is evaluating different methodologies of transplanting for optimum benefit for the resource and the industry.

During 1997, DFW conducted shellfish dredge surveys in the Providence River to assess quahog population densities. This area had not been surveyed since 1977. The survey was conducted from onboard the 29′ R/V *Inspector Clambeaux* utilizing the same random stratified procedures pioneered in a DFW study of quahog populations in the West Passage of Narragansett Bay (Russell 1972). These techniques have been used annually since 1993 for assessing quahog populations in other areas of Narragansett Bay (Lazar et al. 1995). The Providence River stations were divided into 500 × 500 m grids and a 30-m tow was made using a hydraulic dredge. From these samples the DFW determined quahog abundance, size structure, and densities, and the maximum sustainable yield (MSY) that could be transplanted without depleting the stock. The total of 51 tows completed had a mean density of 9.37 ± (1.34 se) quahogs/m^2. Total standing stock biomass for the Providence River was 26,400 metric tonnes. The biomass was 86% top necks (60 mm valve length or larger); few sublegal or count necks were observed over the course of the survey. Subsamples of the quahogs were measured and morphometric comparisons calculated between shellfish in certified and uncertified waters. A baywide MSY was calculated using a biomass dynamic model that integrates catch per unit effort (CPUE), landings, and survey data. Data analysis indicated a maximum of 2721 metric tonnes could be removed annually from the Providence River for relay purposes without impairing stock production. For year 1 (1998), DFW recommended a minimum of 238 metric tonnes be harvested by dredge vessel for transplanting during this prototype project.

Prior to commencement of the transplant, several areas were evaluated for appropriate bottom types, existing shellfish densities and current fishing effort, predation, and proximity to depleted areas. The "High Banks" Shellfish Sanctuary was established as a management area and closed to commercial harvesting of shellfish for a period of 2 y (Fig. 1). The expectation is that this dense concentration of large adult clams will repopulate adjacent areas. The RV *Captain Bert* from the University of Rhode Island was contracted to dredge from July to November 1998. A total of 238 metric tonnes of shellfish were moved from the Providence River; all tow positions were logged using global positioning system (GPS) coordinates. Data collected onboard included tow coordinates, depth, bottom type, density, and shell measurement. These data will be utilized to update the 1997 biomass assessment. Additionally, the donor area and the adjacent highly productive "Area A" (or Upper Narragansett Bay area) will be monitored through annual dredge surveys to provide estimates of the impacts of the large-scale relays and of quahog recruitment in those areas. The

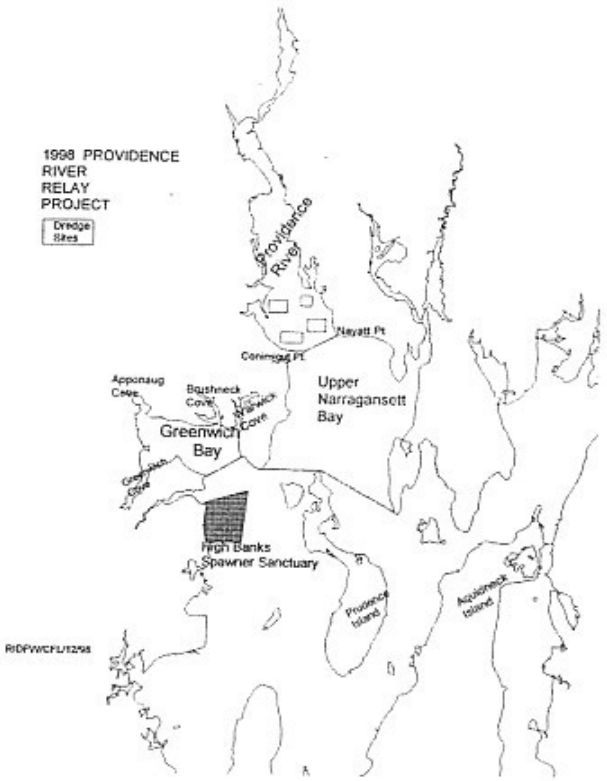

Figure 1. The source area of quahogs for the 1998 Providence River Relay Project and the recipient High Banks Sanctuary Area in Narragansett Bay Rhode Island. Also shown are the shallow coves of Greenwich Bay that serve as the source areas of quahogs for handraking relays into the Greenwich Bay Management Area.

High Banks relay area will also be monitored over 1999–2000 to address the efficacy of large-scale relays of the Providence River stock. To address recovery, growth, predation, fishing pressure, and mortality, a portion of the relayed stock has been tagged and their location logged by GPS coordinates. They will be monitored by SCUBA and DFW's dredge research vessel in 2000.

Cost analysis of the dredge relay program indicates $0.09/kg was expended to move shellfish, compared to a range of $0.08 to $0.13/kg typically expended by contracting handrakers. Expected costs for utilizing handrakers in the Providence River would likely have been well in excess of $0.13/kg, due to the added expense of daily contracting of transport vessels and the additional personnel costs for monitoring and enforcement. Also, logistically it is unworkable to provide adequate supervision of individual rakers in a relatively large area in the midst of a major shipping channel. However, contracting handrakers to move shellfish from smaller coves immediately adjacent to recipient areas appears to be an economical option, as is the case for the current Greenwich Bay relay program.

In addition to the relay efforts, there has been interest in using nursery-reared quahog seed stock for replenishing public fishing grounds. In 1996, John Williams of Warwick Cove Marina seized upon the idea of nursery culture of shellfish in marina waters (Rheault and Rice 1989) using existing floating upweller techniques (Hadley & Manzi 1984) being developed and employed by Robert Rheault of the Moonstone Oyster Company. At the incep-

tion of the Rhode Island Public Benefit Aquaculture Project, Mr. Williams' concept was to incorporate secondary education into the physical activities of raising shellfish. The project would be a means of teaching science, math, and language arts, and the product would be used to restore fishing beds in Narragansett Bay. The project, which began in 1997 with some seed monies from local foundations, had as its a mission to develop a true public benefit aquaculture project that would integrate well with current uses of the public waters of Rhode Island, without compromising the integrity or quality of the state's aquatic resources. The Rhode Island Seafood Council began assisting in the development and coordination of a team to guide this effort. The Project team realized early on that in order to be fully beneficial to the state, all stakeholders needed to be educated about the project goals.

The Project goals include:

- Strong skills-based curriculum development for secondary level education that is tied to natural resources, and the application of aquaculture principles to inject applied learning into the curriculum.
- The inclusion of commercial and recreational shellfishermen in order to build their understanding of the potential of public aquaculture to rebuild shellfish stocks, and to utilize their experience in guiding educational activities and assisting in the determination of survival of seeded stock
- The development of a self-sustaining resource restoration plan for Rhode Island incorporating aquaculture techniques to restore declining shellfish resources.

To meet the goals, a strong team of state, local, and educational representatives committed to guide the development of the Project. Initial advisors to the project were university personnel with expertise on scientific issues and independent commercial fishermen and personnel from marine trades organizations to assist in developing an economically viable plan of work that minimized user conflicts. The advisory team grew to include representatives from the following organizations:

Rhode Island Department of Labor and Training
Rhode Island Manufacturers Extension Service
Rhode Island Legislative Commission on Aquaculture
Rhode Island Economic Development Corporation
Rhode Island Department of Environmental Management
Coastal Resources Management Council
Rhode Island Seafood Council
University of Rhode Island-Department of Fisheries and Veterinary Science
Roger Williams University Center for Economic and Environmental Development
Newport, Warwick, Chariho, and Cranston Area Career and Technical Centers
Middletown Alternative Learning Program
Rhode Island Quahog Company
Warwick Cove Marina
Ram Point Marina
East Passage Yachting Center
Newport Yacht Club
The Rhode Island Shellfishermen's Association

Students from four technical high schools began building upwellers in the spring of 1998. These schools were partnered with marinas in the local area, and high school students were partnered with college-level mentors from the Marine Biology Program at Roger Williams University in Bristol. Three of the high schools built five upweller units that were deployed early summer at partner marina facilities. The five units were stocked with a total of 100,000 seed of *Mercenaria mercenaria*. Due to an unusually high rainfall in the spring, quahog seed was very difficult to obtain from local suppliers. As a result, quahog seed (2.5 mm) was purchased from Virginia after satisfying strict state importation guidelines. In addition, one unit was stocked with local oyster seed donated by the Rhode Island Sea Grant Marine Advisory Service and another unit was partially stocked with scallop seed donated by National Marine Fisheries Service Milford Laboratory.

As the quahog seed reached the presumed "predator resistant" size of 20 mm they were given to the DFW and planted in a management sanctuary had been opened for public harvest in December 1999. Current Rhode Island shellfish regulations define shellfish seed as a shell dimension of 20 mm or less for quahogs and 32 mm for oysters (RIDEM 1998). To assure public health, shellfish seed can be grown in uncertified waters of marinas, but they must be moved to certified waters for final growout and depuration once they reach the prescribed size limits. These seed definitions allow a minimum 1-y depuration period based on local growth rates.

Shellfish growth was monitored weekly by students from the partner schools and all data on growth, salinity, and temperature were recorded. As the shellfish grew students were able to apply math, science, writing, and public speaking skills to the project through presentations at their respective schools and at the Third Annual Rhode Island Aquaculture Conference, held in October 1998. This was a perfect way for students to start building a portfolio and to create a network of professional mentors. After the conference, there have been several other schools and marinas that expressed interest in participating in the project.

This collaboration has also allowed students to work alongside state biologists and to be involved in data collection for the tagging and transplant-restoration project at the High Banks Management Area being carried out by DFW. All students that have taken part in the tagging and relay-restoration effort have a better understanding of occupations within DFW, and have more direction in their education and future career choices. Additional statewide partnerships are being built: the Rhode Island Department of Health has become eager to expose students to the workings of a USFDA-certified shellfish testing lab and is making the lab available for interactive tours for the students involved in the aquaculture program.

As of December 1999 there are two proposed plans with potential to assist ongoing shellfish restoration projects in Rhode Island. One proposal is to start a commercial shellfish hatchery by the Hope Shellfish Company LLC at the Quonset Point Industrial Park, which would be partially funded from private investors, the Rhode Island Economic Development Corporation, and the Rhode Island Economic Policy Council. Part of the stated mission of the proposed hatchery is to provide shellfish seed for public aquaculture and mitigation projects in the state. The other proposal is a plan to mitigate damages caused by the January 1996 grounding of the barge *North Cape* and the devastating oil spill that resulted on the south shore beaches of Rhode Island. The National Marine Fisheries Service in cooperation with Rhode Island state agencies is proposing an ambitious multi-year plan to re-seed molluscan shellfish beds in the coastal barrier beach salt ponds and estuaries near the spill site.

CONCLUSIONS

Shellfish restoration efforts in Rhode Island have a long history. It is very instructive to examine past projects to discover the

reasons for either success or failure, and to apply these lessons to current and planned efforts. There are a number of attempted projects and a number that got started but did not prove to be sustainable in the long run. Some of the projects that have arisen out of a sudden "windfall" of funds or out of short-term public concern have been particularly susceptible to not building long-term sustainability. Some projects have flourished due to individual initiative, but failed to continue when the principals either "got tired" or moved from the area. The most successful projects in terms of longevity are those that have had perennial support by commercial and recreational fisheries clientele, local communities, and state government agencies. For successful shellfish restoration projects, there must be melding of good science, consensus on policy, public acceptance, economic feasibility, multisector cooperation, and a measure of good luck.

A cautionary note, however, is needed. In recent years there has been an increasing trend in academia and government toward collaborative, multi-agency, and multisector projects for greater cost effectiveness, sharing of talent, and sharing of resources. Although the potential benefits of collaborative multisector projects are great, there are some risks. It is short-sighted to underestimate the amount of time and effort required to bring people and organizations together and to maintain continued collaboration toward a common goal. This problem of coordination and management is not intractable; it simply needs to be recognized and planned for.

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LITERATURE CITED

Boyd, J. 1991. The Narragansett Bay shellfish industry: A historical perspective and an overview of problems of the 1990s. pp. 2–10. *In:* M. A. Rice, M. Grady & M. L. Schwartz (eds.). Proceedings of the First Rhode Island Shellfisheries Conference. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island.

Burns, W. G. 1991. The Rhode Island scallop restoration program. pp. 89–91 *In*: M. A. Rice, M. Grady & M. L. Schwartz (eds.). Proceedings of the First Rhode Island Shellfisheries Conference. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island.

Carlson, F. T. 1954. The American lobster fishery and possible applications of artificial propagation. *Yale Conserv. Stud.* 3:3–7.

Cobb, J. S., K. Castro, R. A. Wahle & J. Catena. 1998. An artificial reef for lobsters (*Homarus americanus*) in Rhode Island, USA. pp. 75–78. *In*: Proceedings of a Workshop on Lobster Stock Enhancement, held in the Magdalen Islands (Quebec) October 29 to 31, 1997. Canadian Industry Report of Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, Ottawa, Canada.

Desbonnet, A. & V. Lee. 1991. Links between water quality and shellfisheries in Narragansett Bay, Rhode Island. pp. 11–18. *In*: M. A. Rice, M. Grady & M. L. Schwartz (eds.). Proceedings of the First Rhode Island Shellfisheries Conference. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island.

Galtsoff, P. S. 1964. The American oyster, *Crassostrea virginica. U.S. Fish Wildl. Serv. Bull.* 64:1–480.

Glude, J. B & W. S. Landers. 1953. Biological effects of hullraking vs. power dredging on a population of hardshell clams, *Venus mercenaria. Natl. Shellfish. Assoc. Addr.* 1951:47–69.

Hale, S. O. 1980. Narragansett Bay: A Friend's Perspective. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island. 130 pp.

Herrick, F. H. 1909. Natural history of the American lobster. *Bull. Bur. Fish.* 29:149–408.

Inland Fishery Commission (IFC). 1934. Sixty-fourth Annual Report of the Commissioners of Inland Fisheries of Rhode Island for 1934. Providence, Rhode Island.

Kochiss, J. M. 1974. Oystering from New York to Boston. Wesleyan University Press, Middletown, Connecticut. 251 pp.

Lazar, N., A. Valliere & A. Ganz. 1995. Quahog stock assessment and implementation of an interim management plan in Greenwich Bay, Rhode Island. pp. 5–29. *In*: M. A. Rice & E. Gibbs (eds.). Proceedings of the Third Rhode Island Shellfisheries Conference, Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island.

Littlefield, C. N. 1991. Growth of seed quahogs (*Mercenaria mercenaria*) in nursery trays in the Great Salt Pond, Block Island, Rhode Island. pp. 81–88. *In*: M. A. Rice, M.Grady & M. L. Schwartz (eds.). Proceedings of the First Rhode Island Shellfisheries Conference. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island.

McLoughlin, W. G. 1978. Rhode Island: A Bicentennial History. W. W. Norton, New York. 240 pp.

Meade, A. D. 1901. Habits and growth of young lobster, and experiments in lobster culture. pp. 61–80. *In*: Thirty-first Annual Report of the Commissioners of Inland Fisheries of Rhode Island for 1901, Providence, Rhode Island.

Meade, A. D. 1908. A method of lobster culture. *Proc. Fourth Intl Fish. Congr., Bull. Fish.* 28:219–310.

Nixon, D. 1993. A legal history of shellfish regulation in Rhode Island. pp. 19–22. *In*: M. A. Rice & D. Grossman-Garber (eds.). Proceedings of the Second Rhode Island Shellfish Industry Conference. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island.

Nixon, S. W. 1995. Metal inputs to Narragansett Bay: A History and Assessment of Recent Conditions. Rhode Island Sea Grant, University of Rhode Island, Narragansett, Rhode Island. 85 pp.

Olsen, S., D. D. Robadue & V. Lee. 1980. An Interpretive Atlas of Narragansett Bay. Coastal Resources Center, University of Rhode Island, Narragansett, Rhode Island. 82 pp.

Olsen, S. & G. L. Seavy. 1983. The State of Rhode Island Coastal Resources Management Program as Amended. Rhode Island Coastal Resources Management Council, Wakefield, Rhode Island.

Olsen, S. B & D. K. Stevenson. 1975. Commercial marine fish and fisheries of Rhode Island. Coastal Resources Center Marine Tech. Rep. No. 34, University of Rhode Island, Narragansett, Rhode Island.

Pratt, S. D., A. R. Ganz & M. A. Rice. 1992. A species profile of the quahog in Rhode Island. Rhode Island Sea Grant Report no. RIU-T-92-001, University of Rhode Island, Narragansett, Rhode Island. 117 pp.

Rheault, R. B. & M. A. Rice. 1989. Nursery culture of shellfish seed in marinas. pp. 207–230. *In*: N. Ross (ed.). Proceedings of the First National Marina Conference. International Marina Institute, Wickford, Rhode Island.

Rhode Island Department of Environmental Management (RIDEM). 1998. Rhode Island Department of Environmental Management Regulations Part XIX, aquaculture of molluscan shellfish in Rhode Island Tidal Waters (promulgated May 21, 1998). Providence, Rhode Island.

Russell, H. J. 1972. Use of a commercial dredge to estimate hard-shell

clam populations by stratified random sampling. *J. Fish. Res. Board Can.* 29:1731–1735.

Stringer, L. D. 1959. The population abundance and effect of sediment on the hard clam. Appendix E. *In*: Hurricane damage control, Narragansett Bay and Vicinity, Rhode Island and Massachusetts. U.S. Fish and Wildlife Service, Washington, D.C.

Tammi, K. A., S. J. Soares, W. Turner & M. A. Rice. 1998. Settlement and recruitment of bay scallops, *Argopecten irradians* (Lamarck 1819), to artificial spat collectors in the Westport River Estuary, Westport, Massachusetts. pp. 8–25. *In*: J. Woodley & G. Flimlin (eds.). Proceedings of the 1994 Annual Meeting of the National shellfisheries Association Shellfish Stock Enhancement Session. Publication number EPA 842-R-98-004, Office of Water, United States Environmental Protection Agency, Washington, D.C.

Tracey, G. A. 1988. Feeding reduction, reproductive failure and mass mortality of mussels (*Mytilus edulis*) during the 1985 'brown tide' in Narragansett Bay, Rhode Island. *Mar. Ecol. Prog. Ser.* 50:73–81.

Williams, R. 1643. Chapter XIX, of fish and fishing. pp. 122–125. *In*: A Key into the Language of America. Gregory Dexter Press, London. 205 pp.