covering a total area of 1,200 square meters. The reefs will be established with a barge and crane operation with the rocks being placed on the bay bottom by the crane.

In order to locate the reefs in a suitable area where they will not be covered by moving sand, or be placed on top of existing lobster habitat, a survey using side-scan sonar will be conducted. The results of the survey will be interpreted using information about current speed in the area (available from earlier work by M. Spaulding, URI)

Release of hatchery-reared lobsters

Approximately 600-1000 juvenile (fifth-stage), hatchery-reared lobsters will be released onto each reef each of the first three years in the early summer to determine the effects of stocking on lobster population size on the reefs. Each individual will be tagged with a coded microwire tag. The tags are retained through molting and thus can be used to identify individuals seeded onto the reef and distinguish them from individuals that settled naturally.

The early benthic stage lobsters seeded on the reefs will be the progeny of females captured in Narragansett Bay. Egg bearing females will be brought into a laboratory at the University of Rhode Island's Graduate School of Oceanography and allowed to hatch their eggs on a normal schedule. The larvae will be reared, using standard techniques, in kriesels designed to keep the larvae moving and apart from one another. Animals will be maintained in the kriesels until the fifth stage is reached. At that point, they will be tagged, held for two or three days in individual compartments to ensure that tag-related mortality is low, and then released by divers on the reefs.

Monitoring

Monitoring will be conducted over a period of five years to quantify the impact of the deployment of the artificial reefs on the local lobster population. Divers using standard visual and air-lift census techniques will assess the number and size of lobsters on the reef at defined intervals for five years. Nearby natural lobster grounds also will be monitored. The population density, size and sex composition of natural and artificial lobster habitat will be compared. To monitor the development of the lobster population on the reefs, divers will census each reef on a regular basis. At least one (if possible, more) census will be made during the month before the reefs are installed. Monitoring is also proposed for the presence and relative abundance of species of larger invertebrates, fishes, and macroalgae (% cover) on the reefs. All small lobsters captured on the reef and in nearby natural areas will be screened for the presence of a microwire tag. This will allow us to determine the effect of stocking, and, depending upon emigration, provide estimates of mortality and carrying capacity. To provide an estimate of the longer-term effectiveness of the larval stocking effort, commercial and scientific fishing on the artificial reefs will be performed on a weekly basis in the final year of the project. All captured lobsters will be scanned using a magnetic scanner to determine the presence of the coded micro-wire tags. Monitoring activities will address the following:

- To quantify the impact of the reefs on the density of lobsters, the number of lobsters in nearby sandy habitat will be compared to those at the reef site.
- Do specific population parameters (density, size distribution, sex ratio) of lobsters on the artificial reef differ from those of lobsters in natural rock and cobble areas nearby?
- Do the measured population parameters (above) change over time as the reef ages?
- Does the size of the cobble affect the recruitment of lobsters to the reef?
- Does the seeding of early benthic phase lobsters affect population density on the reef when compared to unseeded reefs?
- Does the rate of loss of seeded lobsters vary with cobble size?
- Is there movement of marked lobsters from areas of small cobble to areas of larger rocks as the lobsters grow larger?

Costs

1. Six 10m x 20m artificial reefs, as described above will cost approximately $50,000 for purchasing and hauling the cobble and boulders and labor for operating the barge, crane, and tug.

2. Personnel, supplies and boat time for tagging, seeding, and monitoring for five years is estimated at $220,000.

Environmental Consequences

Establishing six cobble/boulder reefs appropriate for a wide size range of lobsters should attract and retain newly settling lobsters as well as "walk-ins." This should allow the reef to develop a population of lobsters similar in size and structure to those found in natural substrate areas. The reefs will displace the existing sandy substrate and its associated fauna. A total of 1,200 square meters of bottom will be covered by the reefs. In its place the reefs should attract fauna associated with rocky subtidal environments typical of those in Narragansett Bay. This type of community consists of such species as tautaog, cunner, sculpin, sponges, sea anemones, crabs, lobsters, encrusting algal species, sea stars, barnacles, bryozoans, gastropod molluscs, mussels, and others.

Criteria Evaluation

This project addresses injuries to lobsters caused by the *World Prodigy* oil spill. Artificial reefs for lobsters have been successfully implemented in a variety of locations and settings (Scarrat, 1968, 1973; Sheehy, 1976; Jensen, *et al.*, 1994). In addition, lobster habitat has been studied extensively in Narragansett Bay and elsewhere (Incze and Wahle, 1991; Wahle and Steneck, 1991;1992; Wahle, 1993;). This project will attempt to create lobster habitat which mimics their habitat found in nature. Based on previous studies, it is expected that the reef will be colonized rapidly by lobsters and other organisms. The cost of creating the habitat is relatively inexpensive given the potential benefit to injured fishery resources. An additional amount of the project budget is devoted to monitoring to ensure the success of the project, to make any necessary mid-course corrections, and to develop new information on the relative effectiveness of artificial reefs.

B. Quahog Spawner Sanctuary in Narragansett Bay (Preferred Alternative)

During the *World Prodigy* oil spill the entirety of Narragansett Bay was closed to all shellfish harvesting as a precautionary measure to protect public health. Though no documented injuries occurred to adult quahogs, commercial and recreational clammers lost access to the quahog resource for the closed period and shellfish larvae were killed by the spill. To address these injuries, NOAA proposes to transfer a portion of the settlement funds to the Rhode Island Department of Environmental Management (RIDEM) quahog spawner sanctuary program to expand their efforts. The RIDEM has a long history of transplanting quahogs from restricted areas to areas of the bay open to harvesting to allow shellfishermen access to the resource. The spawner sanctuary program attempts to reestablish clam beds in selected parts of Narragansett Bay. The objective of this project is to increase the number of harvestable quahogs to compensate recreational and commercial shellfishermen for the lost use of the bay during the oil spill. An additional objective of the project is to re-establish quahog populations in areas which previously, but no longer contain significant quantities of the resource.

Spawner sanctuaries have been used as a fishery management tool for decades. Such areas are closed to harvesting of living resources for a defined period of time to protect local populations of the resource so they can increase in abundance. A quahog spawner sanctuary established by the State of Rhode Island in Quonochontaug Pond has resulted in increased density throughout the pond over a four-year period (Ganz, 1988). The Rhode Island Marine Fisheries Council has recently established two quahog spawner sanctuaries in Narragansett Bay. The State of Rhode Island also has funded annual quahog transplants from areas that are closed to harvesting (due to fecal coliform contamination) to management areas to allow for spawning, depuration, and subsequent harvesting. Both the transplant and sanctuary programs rely on members of the industry to collect and move shellfish to the selected sites.

Methodology

Two areas of Narragansett Bay have been designated as spawner sanctuaries through regulations promulgated by the Rhode Island Marine Fisheries Council (Figures 2 and 3). One site is located at the mouth of Greenwich Bay (Figure 2). The site is irregularly shaped and encompasses the waters south of a line between the flagpole at the Warwick Country Club and the seaward end of Sandy Point; north of a line between the Warwick lighthouse and the seaward end of Pojac Point including all the waters of the Potowomut River. The second location is in the upper Sakonnet River in the vicinity of Gould Island (Figure 3). This rectangular shaped site includes most of the waters of the upper Sakonnet River to the north of

Gould Island. These sites were selected because they were once productive areas which are currently depleted.

Shellfish densities and presence of predators in the sanctuaries will be determined prior to transplant operations. If predators such as starfish, crabs, and whelks are determined to be a potential problem, they will be removed from the sanctuary sites by dredging or mopping to protect newly settled quahogs from predation while the bed is being established. Once the bed is established newly settled clams will no longer need the added protection that mopping provides.

Shellfish will be transplanted to each site in two successive years. Quahogs will be harvested and transplanted in the spring by commercial shellfishermen or a dredge boat from uncertified waters and used as the brood stock in the established spawner sanctuaries. Transplanting in the early spring will enable the quahogs to undergo a normal spawning cycle during the summer months. The quahogs will be transported by vessel to the sanctuary sites and planted. It is expected that approximately 200,000 pounds of quahogs will be transplanted to the sanctuary sites in each of the two years of the project. Harvesting from the sanctuaries will be prohibited for two spawning seasons. Increasing the spawning population density within these areas is expected to improve fertilization and larval distribution within the sanctuaries and adjacent waters. The presence of potential predators will be monitored by direct observation using divers, test tows, and mopping on a seasonal basis and controlled during the course of the two years. A population survey will be conducted prior to reopening the areas to harvesting.

Costs

Costs for RIDEM enforcement staff, monitoring, equipment, and contracts with local shellfishermen or a dredge boat to harvest and transplant quahogs will be approximately $75,000.

Environmental Consequences

Transplanting quahogs from one area of the bay to another will have minimal impact on the environment. Commercial shellfishermen will harvest quahogs from closed areas using bullrakes; a method that is normally used to harvest these resources in the bay. Rhode Island DEM enforcement staff and the Department of Health will ensure that quahogs harvested from the closed areas are transported to the sanctuary site and that harvesting from the sanctuaries is prohibited until after the quahogs have safely depurated.

Criteria Evaluation

Transplanting quahogs from closed areas to areas that are open to harvesting is a proven method of increasing fishermen's access to an otherwise unharvestable resource. Spawner sanctuaries have been used for a variety of species of fish and shellfish and have proven successful for enhancing local populations of these species. This project will compensate the public for the lost use of quahog beds during the oil spill. The cost of moving the shellfish is relatively inexpensive. Shellfishermen are paid a fee (usually $.10/lb) to harvest the shellfish to be transplanted. This resource in turn is then made available to the public for harvesting.

C. Eelgrass bed restoration (Preferred Alternative)

Personnel from the National Marine Fisheries Service's (NMFS) Beaufort, North Carolina laboratory will transplant eelgrass, *Zostera marina*, to approximately 10 different locations in Narragansett Bay to enhance fishery habitat as a compensatory measure for lost resources. Sites will be identified following site surveys and consultation with local investigators, and selection will be based on water quality conditions, sediment particle size, historical evidence of presence of eelgrass, and degree of exposure to waves and tidal currents.

Eelgrass is an important component of the marine ecosystem. Eelgrass meadows serve several important functions including stabilizing sediment, providing nursery areas for fish and shellfish, filtering suspended particles and nutrients from the water column, and providing an important source of organic matter to the ecosystem (Thayer, *et al.*, 1984). Eelgrass meadows serve as important habitats for forage fish and numerous commercially and recreationally important marine fish and shellfish including bay scallops (*Argopecten irradians*), quahogs, tautog (*Tautoga onitis*), winter flounder (*Pleuronectes americanus*), and sticklebacks. (Thayer *et al.*, 1984, Heck *et al.* 1989, and Peterson *et al.*, 1984).

Eelgrass beds were drastically reduced throughout their range in North America and Europe, including Narragansett Bay during the 1930s but have generally recovered since that time (Thayer *et al.*, 1984). However, in some areas, such as Narragansett Bay, recovery has been limited (Kopp *et al.*, 1995). The cause for the catastrophe, termed "wasting disease," has been determined to be the protozoan *Labyrinthula zosterae* (Muehlstein *et al.*, 1991). More recently water quality degradation has inhibited and caused the decline of seagrass in many locations (Short *et al.*, 1993). The loss of eelgrass has caused several severe adverse impacts to the coastal ecosystem including coastal erosion, changes in the sedimentary environment with concomitant changes in the benthos, and a near complete disappearance of the bay scallop in some locations including Narragansett Bay (Thayer *et al.*, 1984).

While a complete recovery of eelgrass has not occurred in Narragansett Bay, remnant beds still persist in numerous locations. Several reasons may have conspired to prevent greater recolonization of eelgrass in the bay. When seagrass losses occurred during the wasting disease of the 1930s substantial erosion of shorelines apparently occurred (Dexter, 1944). Concomitant with this erosion, one would expect substantially higher turbidity, a factor that reduces light availability and thus, potential eelgrass habitat. Over several decades, it is likely that erosion and sediment resuspension would have abated as an equilibrium between available, erodible substrate and water motion developed. However, at this time, widespread coastal development was on the rise which would have exacerbated turbidity, nutrient loading, and epiphytization, all factors which have been shown to severely limit the growth and survival of seagrass beds. Thus, dispersal from surviving stocks may not have found suitable areas to colonize or were so chronically disturbed that they could not form critical patch sizes to survive (Olesen and Sand-Jensen, 1994).

Other factors, such as increased shellfish harvesting which disturbs the bottom, anchor damage, propeller scarring, all could work together to create localized impediments to recolonization. Moreover, seagrass restoration research has demonstrated that shortly after transplanting seagrass, when the plants are at a low density (much like early stage colonization), significant losses can be effected by bioturbation (Fonseca pers. com., 1994). One vector of this disturbance in New England is the European green crab. The advent of this introduced species may also have limited the recolonization of the bay.

Given the importance of eelgrass to commercially and recreationally important marine resources and the marine ecosystem as a whole, restoring this seagrass has been attempted in numerous locations and transplanting techniques have been fairly well developed (Fonseca *et al.*, 1982, 1994; Fonseca, 1990, 1994). The historical existence and persistence of eelgrass beds in Narragansett Bay provides the strongest evidence that restoration of this seagrass in the bay is possible. In addition, with continued and planned improvements in sewage treatment in the bay, water quality is expected to continue to improve, thus enhancing conditions for the survivability of eelgrass.

Personnel from the NMFS Beaufort lab will implement the proposed eelgrass restoration project jointly with the University of Rhode Island's Graduate School of Oceanography and the Rhode Island Department of Environmental Management's Narragansett Bay Project. With funding provided by the *World Prodigy* settlement, the Rhode Island Aqua Fund and the NOAA National Estuarine Research Reserve Program each institution will contribute funds and expertise to accomplish the restoration of eelgrass in the bay.

Methodology:

NOAA will select up to 10 locations throughout Narragansett Bay to transplant eelgrass. These sites will be selected based on sediment type, water quality and clarity, wave energy, and human activity. At each of the 10 planting sites six planting plots will be established in a single block. Each plot will measure 5m x 5m. Each plot will be caged to protect the plants from bioturbation. Each plot will consist of two rows of five planting units (1-5 shoots per planting unit) each. One pair in each plot will receive fertilizer at the time of planting. Total planting would entail 1,000 to 3,000 plants spread over 540 square meters of seafloor. Eelgrass plants will be harvested from existing beds in Ninigret Pond or other suitable locations.

Monitoring:

The objective of the monitoring efforts will be to determine the degree of success of establishing the eelgrass beds. Specifically, monitoring to determine percent survival, areal coverage, number of shoots per planting unit, and benthic colonization will be undertaken on a regular basis for three to five years. Significant cost savings will be realized by the joint monitoring efforts of NMFS, URI, and R.I. DEM.

Cost:

The costs for personnel, equipment, transplanting, travel, and monitoring is approximately $100,000.

Environmental Consequences

This alternative will alter the topography of the bottom. The added vegetation will alter the flow regime and function to stabilize sediments. This will also increase the accumulation of organic and inorganic materials and will reduce erosion as a result of sediments binding with the roots (Fonseca, 1992; Kirkman, 1992). The added vegetation will have a positive increase in the amount of detrital nutrients contributing to the food web and will increase nursery areas for fish and shellfish (Fonseca, 1992; Kirkman, 1992). The eelgrass plants to be used for transplanting will be harvested in small patches from a healthy source bed in Ninigret Pond. It is expected that the harvested areas will be rapidly recolonized.

Criteria Evaluation

The objective of this project is to establish a number of eelgrass beds throughout Narragansett Bay to provide habitat for a variety of resources which were injured by the oil spill. While eelgrass beds were not directly affected by the spill, resources that use this habitat during their lifecycle were injured and will benefit from its restoration. The literature documents successful techniques to establish seagrass beds and provides information on the relative value of created or restored beds versus natural beds. Costs to establish beds are relatively inexpensive, though transplanting is labor-intensive. In addition, our URI partners in this project will be examining other lower-cost techniques (seeding) to establish eelgrass beds.

D. Sachuest Point Salt Marsh Restoration (Preferred Alternative)

Salt marsh ecosystems are among the most productive natural systems on earth and serve as spawning, feeding and nursery areas for numerous species of fish and shellfish and as a valuable habitat for shorebirds and waterfowl (Teal, 1986). Salt marshes also maintain water quality by trapping sediment and pollution, provide flood and storm damage protection, and recreation to the public. Salt marshes have also been subject to a wide variety of development activities which have severely altered their diversity and productivity. Along the New

England coastline railroads, roads, and other forms of development have often restricted the natural tidal flow into marsh systems. As the natural hydrology of the salt marsh system changes and the salinity is reduced the natural salt marsh vegetation (*Spartina spp.*) begins to change (Roman *et al.*, 1984; Roman *et al.*, 1995). Often common reed (*Phragmites australis*), an invasive brackish water plant, will colonize such areas. *Phragmites* is thought to be of limited value to fish and wildlife. Tidal restrictions also reduce the area of marsh available to estuarine dependent fish and reduce the outflow of detrital material from the marsh system.

The objective of this proposed alternative is to enhance estuarine fish habitat by restoring the natural salt marsh vegetation and associated organisms to a portion of the Sachuest Point salt marsh in Middletown, RI (Figure 4) as a compensatory action for lost resources. As described earlier, numerous species of estuarine finfish larvae were injured by the *World Prodigy* oil spill and this project is designed to restore the losses of finfish and their associated habitat injured by the spill. The marsh restoration will be accomplished by restoring tidal flushing to a portion of the marsh where flow has been restricted.

The salt marsh within the Sachuest Point National Wildlife Refuge has been adversely affected by road construction and an inadequately sized culvert that has severely reduced tidal flow into this marsh. Tidal flow is the key factor for the health of a salt marsh. As a result of the decrease in tidal flow, salinity has decreased and *Phragmites* has colonized large areas of the marsh and reduced its value for fish and wildlife. Other significant disturbances over time have adversely affected the salt marsh system in the refuge, including two freshwater reservoirs which supply drinking water to the City of Newport and a now closed and capped municipal landfill. Both the reservoirs and landfill have eliminated large areas of former salt marsh.

A number of recent studies of restoration projects suggest that reintroduction of tidal flow into hydrologically-restricted marshes can restore a number of functions and values of those marshes (Roman *et al.*, 1984; Sinicrope *et al.*, 1990; Barrett and Niering, 1993; Peck *et al.*, 1994). The reintroduction of tidal flow into *Phragmites*-dominated marshes is based on the premise that an increase in salinity and flooding will decrease and kill *Phragmites* and allow natural recolonization of the marsh by *Spartina* spp. and other salt marsh plants. Hellings and Gallagher (1992) found that *P. australis* density, growth, and total above ground biomass decreased significantly with an increase in salinity and flooding. In a project undertaken in Connecticut, Bongiorno *et al.* (1984, cited in Marks *et al.*, 1994) found that with the restoration of tidal flow into a *Phragmites* dominated marsh, a 1- to 3-foot reduction in stem height resulted over each of three years. In addition, plant density declined dramatically from 11.3 plants/m^2 in 1980 to 3.3 plants/m^2 the following year. In following years, *P. australis* continued to decline, although less dramatically. In addition to the decreased height and density of the *Phragmites*, typical marsh flora including *Salicornia* (saltwort), *Distichlis spicata* (spikegrass), *S. alterniflora* (saltwater cordgrass), and *S. patens* (salt meadow grass) returned (Marks *et al.*, 1994).

In a well studied case of salt marsh restoration in Connecticut, a number of studies have concluded that restoration of tidal flow has had a dramatic impact on both the flora and fauna of the tidally-restricted portion of the marsh (Sinicrope *et al.* 1990; Barrett and Niering, 1993; Allen *et al.*, 1994; Peck *et al.*, 1994). A central creek flowing south through the marsh was impounded by a dike in the mid 1940s to create waterfowl habitat. The impoundment converted the former salt marsh to a cattail (*Typha angustifolia*) dominated brackish marsh. Tidal flushing was restored to the area in 1978 and in 1982. Sinicrope *et al.* (1990) found that *Typha*, which covered 74% of the transects in 1976, covered only 16% in 1988, with most stunted. However, they found that *Phragmites* cover increased from 6% to 17%, though 9% of the transect lengths had standing dead *Phragmites*. The authors noted that this species was also relatively depauperate. *S. alterniflora* showed a dramatic increase, from less than 1% in 1976 to 45% in 1988. A variety of other salt marsh species which were not seen in 1976 covered an additional 20% in 1988. In addition, the authors measured peat salinity which showed that *Typha* remained relatively healthy at 10‰ or less, became stunted as the salinity increased and died at about 20‰. *Phragmites* grew best at 20‰ or less and by 30‰, stands of this species were extremely depauperate (0.3-1.0 m tall), and typical salt marsh species tended to dominate.

The authors suggested that there may have been two reasons for an increase in *Phragmites* coverage. Herbicides were used in the early to mid 1970s to control *Phragmites* and may have skewed the baseline data. Secondly, *Typha* may have limited the spread of *Phragmites* in 1976. Once tidal flow was restored, however, *Typha* declined rapidly and allowed for the expansion of the more salt-tolerant *Phragmites*. Average *Phragmites* height in 1976, however, was 2-3 m and was 0.3 to 1.5 m in 1988. Additionally, since the time of the study, it appears that *Phragmites* has continuously decreased in coverage (Scott Warren, Connecticut College, pers. comm.).

Fell *et al.* (1991) and Peck *et al.* (1994) studied the impact of the restoration of tidal flow in this same system on invertebrate populations. Fell *et al.* (1991) compared distribution and abundance of the high marsh snail (*Melampus bidentatus*) above and below the impoundment dike. Peck *et al.* (1994) compared this same species and the ribbed mussel (*Geukensia demissa*) above and below the impoundment and also with a nearby reference marsh. These studies found that populations of *M. bidentatus*, *Geukensia* and other tidal marsh invertebrates were re-established on the restored portion of the marsh system and no significant differences in the numbers of the snail were found.

Site Description

The Sachuest Point salt marsh is located in the Sachuest Point National Wildlife Refuge in Middletown, Rhode Island and is bordered by Third Beach and the Sakonnet River to the west, Second Beach and Sachuest Bay to the east, Gardiner Pond (drinking water reservoir) to the north, and the upland Sachuest Point to the south (Figures 4 and 5). The property is owned by the U.S. Fish and Wildlife Service. The salt marsh is fed by a tidal creek which flows from the Sakonnet River through about 400 feet of beach to a 5.5 foot diameter culvert under Third Beach Road. The tidal creek flows through a relatively healthy salt marsh consisting of *Spartina alterniflora*, *S. patens*, *Distichlis spicata*, and *Juncus gerardi* (Area A on Figure 6). Just after the tidal creek passes through the culvert, a smaller tidal channel branches off in a southerly direction through the marsh. After some distance, this channel is crossed by a road which connects Third Beach and Sachuest Point roads ("connector road"). The channel, which has a maximum width of eight feet, carries tidal flow through a 20-inch culvert underneath the connector road to another pocket of wetlands totaling 12.8 acres (Area B on Figure 6). The channel is silted in and has been colonized by *S. alterniflora* some 250 feet before the channel reaches the culvert. The culvert also appears to be clogged. Immediately south of the connector road an area of salt marsh is present measuring about 1.8 acres in area. The majority of the remainder of Area B (about 11 acres) contains common reed and shrub wetland.

Fish and wildlife use at the site varies throughout the year. Bird nesting species found there include Willow Flycatcher, common yellowthroat, Eastern phoebe, swamp and song sparrows, yellow warbler and others (Table 1). Breeding bird surveys conducted since 1993 indicate that flycatchers, yellowthroats, phoebes, and both swamp and song sparrows are the most abundant nesting species using the site (Table 1).

Table 1. Average number/survey of the ten most abundant songbirds at the proposed wetland restoration site (Point Count site 2) and a nearby saltmarsh (Point Count site 1) at Sachuest Point National Wildlife Refuge.

Species	Average #s Site 1	Species	Average #s Site 2
Song Sparrow	2	Willow Flycatcher	3.9
Common Yellowthroat	1.9	Barn Swallow	3.0
Red-winged Blackbird	1.6	Common Yellowthroat	2.5
Yellow Warbler	1.4	Eastern Phoebe	1.3
Sharp-tailed Sparrow	0.7	Swamp Sparrow	1.1
Willow Flycatcher	0.6	Song Sparrow	1.1
Gray Catbird	0.5	American Robin	0.9
American Goldfinch	0.5	Brown-headed Cowbird	0.5
Mourning Dove	0.4	Yellow Warbler	0.4
Northern Cardinal	0.3	Red-winged Blackbird	0.3

Information on wintering species of birds at the site is sketchy but probably includes black ducks, yellow-rumped warblers, and white-throated sparrow. Wading birds such as rails and bitterns might use the site infrequently but have not been observed. No data regarding small mammals or reptiles exist for this area but probably include meadow vole, short-tailed shrew, and Eastern garter snake as some of the more common species. Fish species found in the tidal creeks include American eel (*Anguilla rostrata*), striped killifish (*Fundulus majalis*), mummichog (*Fundulus heteroclitus*), and Atlantic silversides (*Menidia menidia*) (J. Catena, pers. obs.). The Rhode Island Division of Fish and Wildlife has a permanent juvenile finfish sampling station just off Third Beach. The most frequently sampled fish from 1987-1993 at this station include winter flounder (*Pleuronectes americanus*), windowpane (*Scophthalmus aquosus*), Atlantic silverside, mummichog, tautog (*Tautoga onitis*) and bluefish (*Pomatomus saltatrix*) (RIDEM, unpublished data).

No state or federally threatened or endangered species are known to inhabit the immediate area. Sachuest Point is a state historical site for Sea Beach Amaranth (*Amaranthus pumilus*) a federally listed species. The federally endangered peregrine falcon sometimes uses the Refuge for roosting or foraging during migration but none have been observed at the site. Several "State Interest" species occur in the area including great blue heron, snowy egret, great egret, and glossy ibis. All species use the site for foraging and not nesting. Northern harriers (state endangered) can also be found in the area during the winter and might use the site for foraging only, but are listed only in terms of their nesting status. No state-listed plants are known to occur at the site.

Proposed project description

Under the auspices of the Coastal America Partnership,[1] the U.S. Army Corps of Engineers' New England Division (COE) provided technical assistance to NOAA to develop recommendations for restoring tidal flushing to the restricted marsh (U.S. Army Corps of Engineers, 1994). The COE conducted a hydraulic analysis of the marsh system using data from a limited elevation survey and tidal information gathered from NOAA's nearby Newport, RI tidal gage. Based on this analysis, the COE recommended that twin-30 inch culverts replace the existing 20-inch culvert beneath the road to adequately restore tidal flushing to the marsh south of the connector road. In addition, the channel feeding the culvert will be cleared of vegetation and deepened approximately two feet. Without channel modification, hydraulic scouring may occur through normal tidal flushing. However, the natural process is expected to be significantly slower because of the amount of root mass and silty material which must be removed. A channel south of the connecter road will also be deepened and lengthened to extend the influence of the tidal flow into the *Phragmites* dominated area of the marsh.

The combination of channel modification and placement of twin 30-inch culverts should increase tidal range within Area B by 1.0 to 2.0 feet, providing slightly greater high tide elevations (a few tenths of a foot) and significantly lower low tide elevations (approximately

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[1] The Coastal America Partnership is comprised of Federal agencies with coastal resource management responsibilities (e.g. NOAA, COE, EPA, F&WS, etc.) that have agreed to collaborate and cooperate on identified problems to produce demonstrable environmental results.

one foot). The larger culvert will inherently provide better drainage during low tide conditions. After flow is restored to Area B with larger sized culverts, maintenance of the channel may not be required.

A baseline assessment of the marsh system will be conducted prior to culvert replacement to gather more detailed data on vegetation, fish use, hydrology, and topography. The hydrologic and topographic information will be used to verify the COE's recommendations and to develop an accurate estimate of acreage expected to be influenced by the increased tidal flow. Post-construction monitoring will be conducted every 3 years over a 10 year period to determine the success of estuarine fish habitat enhancement. Specific monitoring elements will consist of rate of colonization by *S. alterniflora* and other marsh plants, plant species composition, plant cover and height, hydrology, soil salinity, and fish use of tidal creeks.

Costs

The costs for personnel, equipment, construction, baseline assessment, and monitoring is approximately $80,000.

Environmental Consequences

Marsh enhancement will have positive effects on floral and faunal species composition. It will create valuable nursery grounds, allow for the reoccupation of salt marsh vegetation, and increase fish use of the tidal creeks.

Based on the literature and past experiences in Connecticut and elsewhere, the restoration of tidal flow into area B should convert the *Phragmites*-dominated marsh into a *Spartina*-dominated system. Salinity and tidal range should increase and slowly allow for the reoccupation by *Spartina* and other of salt marsh vegetation as the less salt-tolerant *P. australis* dies out. Restoration of tidal flow should also enhance the marsh as a habitat for fish and invertebrates that are dependent upon salt marsh ecosystems by making more habitat available for them to exploit. Bird communities should change to those more typical of the nearby saltmarsh (area A). Sharp-tailed sparrows, marsh wrens, and red-winged blackbirds which are typical of the marsh to the north of the connector road (Table 1) should increase on the south side of the road as well when more typical high marsh vegetation is established. Black duck use will probably increase as *Phragmites* retreats from open water areas and wading bird use will probably increase also.

It is quite likely that if no restoration activity occurs at this site, *Phragmites* would continue to colonize the marsh. Available subtidal and intertidal habitat for fish and invertebrates would continue to decline since access to the marsh by these organisms would continue to be cut off. *Phragmites* coverage would likely would reduce numbers of swamp sparrows, common yellowthroats and other wetland associated species.

This alternative will have no effect on the cultural environment.

Criteria Evaluation

The objective of this project is to enhance estuarine fish habitat by restoring the natural salt marsh vegetation and associated organisms to a portion of the Sachuest Point salt marsh in Middletown, RI. While this particular salt marsh was not injured by the spill, resources that use salt marsh habitats during their lifecycle were injured and will benefit from its restoration. Marsh restoration of this type is fairly well documented (Roman *et al.*, 1984; Sinicrope *et al.*, 1990; Fell *et al.*, 1991; Barrett and Niering, 1993; Roman *et al.*, 1995). The cost of restoring tidal flow into the Sachuest Point marsh system is relatively inexpensive given the resource benefits that will accrue. Furthermore, cost-savings will be realized since the property is owned by the U.S. Fish and Wildlife Service and equipment and personnel from that agency will be used in carrying out certain aspects of the restoration project.

E. Construct and operate a hatchery (Not proposed)

The construction and operation of a shellfish and lobster hatchery is a potential method of replacing the biota impacted by the spill as well as their lost progeny. The oil spill resulted in closure of shellfish beds and mortality to larval quahogs and larval and adult lobsters which the hatchery would attempt to replace. Enhancing natural population size by the release of larvae or juveniles reared in hatcheries is a time tested method for some freshwater and a few marine fish species. Hatchery stocking of lobsters and quahogs has been used extensively. However, there has been minimal evaluation of the impact of these stocking activities on the natural populations of these species. For reasons discussed below the construction and operation of a hatchery is not proposed.

Attempting to enhance natural quahog populations with hatchery-reared quahog seeds is a method that has been used extensively. However, there effectiveness has never been adequately evaluated (Malouf, 1985). Hatchery-reared quahog larvae dispersed into the bay are likely to suffer high predation losses and their impact on local populations is likely to be minimal. Research has shown that survival of quahog seed is greatly affected by its size when introduced into the environment. The larger the seed size the greater the likelihood of survival. However, because the space and nutrient requirements increase geometrically with size, hatcheries typically sell the seeds in the 2-4 mm size range. Using such a seed size increases risk of predation, and reduces the probability of success. The probability of survival increases when quahog seed is adequately protected by nets, screens, or other protective measures (Kraeuter and Castagna, 1985; Castagna, 1984). Even with protection and large seed sizes, however, predators can still cause significant mortality (Flagg and Malouf, 1983). In addition, there is no evidence that these introduced juveniles result in long-term enhancement of the population (Malouf, 1985). An on-site hatchery program would provide the necessary seed but would have to be maintained and operated indefinitely. In addition, protected nursery and grow-out areas would be required to give the hatchery-reared seed a chance to survive predation.

Early in this century, lobster hatcheries were very common in Canada and New England as well as France, Norway and England and these hatcheries produced and released between 200,000 and one million larvae each year (Addison and Bannister, 1994). However, the impact of these releases never was evaluated adequately. Lobster hatcheries are rare now, because the costs of larval rearing and release could not demonstrate benefits to the fishery. Recently, a new technique to evaluate effectiveness of hatcheries has been used. This technique involves rearing the lobsters to a larger size (approximately three months old, 15mm carapace length) and tagging them with coded, microwire tags before setting them out in appropriate natural habitat (Addison and Bannister, 1994). The harvested lobsters are then scanned for the presence of the coded tags. Rearing to this size is considerably more expensive than rearing and releasing them at the traditional three to four week stage (stage IV -- as is practiced at the Massachusetts State Lobster Hatchery). The increased expense is due to the need to separate and rear each juvenile lobster in individual containers after stage IV because of their cannibalistic behavior.

Recent studies conducted in England indicate that hatchery-reared lobsters can recruit to the fishery. (Bannister *et al.*, 1994, Addison and Bannister, 1994). Nearly 50,000 three-month old hatchery-reared lobsters were tagged with coded microwires and released into an area that supports a substantial fishery (Bannister *et al.*, 1994). Of these, 621 were recaptured up to eight years later. The recapture rate of tagged lobsters was about 1% of those released. However, when the data were viewed as catch rate per size class, tagged lobsters made up a much higher proportion (10-35%) of all lobsters of that size. Sampling outside the area of seeding gave no evidence of dispersion any distance from the general release area. Bannister *et al.* (1994) estimated that the survival rate from the time of seeding to entry into the fishery (4-8 years depending on growth rate) may have averaged 50%. Despite this, the tagged lobsters were a very small proportion of the fishery catch, suggesting that seeding 50,000 three-month old juveniles over a five year period did not make a substantial difference in catch rates. An additional question remains as to whether the hatchery-reared lobsters added to the natural stock or merely displaced it (Addison and Banister, 1994.) The question of the economic benefit of re-stocking remains open.

Although studies focusing on the introduction of stage X to XII hatchery-reared juveniles show there is initial biological success, long-term enhancement of the fishery has not been shown. With a low experimental recapture rate, it is difficult to determine if the hatchery-reared lobsters that survived are beneficial to the natural population or if they survived at the expense of the naturally existing lobster recruits. It is uncertain if these stocks result in long-term population benefits. One possibility is that hatchery-reared lobsters would need to be released in large numbers to be able to impact a local fishery (Bannister *et al.*, 1994). Future studies will determine if hatchery-reared stocks enhance a natural community or if they increase competition for shelter and displace the natural population. If the introduced lobsters displace the natural population, then what has resulted is not really an enhancement but a restocking. More research is needed to determine effects on the genetic diversity of hatchery-reared lobsters.

Cost

The construction and continuous operation of a hatchery requires funding beyond what is available from the oil spill settlement and natural resources trustees are prohibited from selecting a restoration project that would require funding beyond what is available (43 CFR 11.93(b)). Although the construction of a hatchery is a one-time expense, operational expenses would exceed the available budget since the hatchery would need to be operated in perpetuity to maintain the quahog and lobster populations needed to sustain a fishery. Funding to operate a hatchery would last less than five years with no guarantee that a self-sustaining natural population would result. While the facility could be transferred to other entities (state government or non-profit organization) NOAA has received no commitments for such a transfer. Without such a commitment it would be impractical to build and operate a hatchery for only a few years.

Environmental Consequences

Potential impacts of introducing hatchery-reared organisms into the environment include: introduction of disease organisms or exotic species; reduction of genetic variability in stocks, or masking of the total extinction of local natural stocks; and reduction in growth and survival of natural and planted clams if the local environmental carrying capacity is exceeded (Malouf, 1985). It is not known if hatchery-reared lobsters enhance a natural population or if they increase competition for shelter and displace a natural population. Long-term monitoring studies are needed to determine the effects of introduced juveniles on wild stocks. Although there may be initial biological success with introduced lobsters, it is not known if this success is sustainable without continued human intervention. Hatchery-reared juvenile lobsters artificially elevate the natural population and more information is needed to determine the density dependent factors controlling the balance in the ecosystem (Addison and Bannister, 1994, Bannister *et al.*, 1994).

There should be no effect on the cultural or historical environment of the Narragansett Bay area.

Criteria Evaluation

Lobster and shellfish hatcheries, while having been used quite extensively over the years, remain an unproven technique to enhance populations of these species. New evaluation techniques have been developed for lobsters. However, to employ these on a large scale would be cost-prohibitive. Cost-effectiveness is quite low given the relatively high cost of construction, operation, and maintenance of a hatchery and the lack of proven success. In addition, available funding is insufficient to continue operation of a hatchery beyond a very limited time period. Due to these factors, hatchery construction and operation is not selected as a proposed alternative.

F. Purchasing and seeding juvenile clams and lobsters (Not proposed)

A slight variation on the above alternative is to purchase larval clams and lobsters from existing hatcheries and release them into the Narragansett Bay environment. Larval lobsters and clams would be purchased from hatcheries currently operating in the area. The juveniles would be transported to pre-selected sites and released. Sites would be selected based upon habitat types, water quality, and circulation patterns. While the expense of constructing and operating a hatchery would be saved, this alternative has not been proven to enhance the populations of these species. See the above hatchery alternative for further discussion. For these reasons, this alternative is not proposed.

Cost

This alternative faces operating challenges similar to the hatchery because this program would need to be operated indefinitely. With the funds available for restoration, operating this program in perpetuity is not feasible.

Environmental Consequences

Effects under this alternative are similar to those described under the hatchery alternative since lobsters and quahogs would be placed in the environment in the same manner as described above. Please refer to the discussion of the effects on the biological environment under the hatchery alternative. There would be no effect on the cultural environment under this alternative.

Criteria Evaluation

Purchasing and seeding larval quahogs and lobsters on a scale adequate to enhance the population of Narragansett Bay is not likely to be successful given the level of funding available (see McHugh, 1981). Methods to evaluate effectiveness of seeding have remained elusive until relatively recently. However, the cost for implementing these evaluation techniques described above would reduce the cost-effectiveness of the project relative to the other available alternatives. Given the uncertainty of the relative success of enhancing lobster and quahog populations using the seeding technique, this alternative is not proposed.

G. Quahog habitat enhancement by shelling (Not proposed)

Another potential option to enhance quahog populations in the bay is to select one or more sites for "shelling" the bottom ("cultching") by broadcasting bivalve shell over the bottom.