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Foreword

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Narragansett Bay has been considered the greatest natural resource of Rhode Island, supporting a variety of activities including recreational boating, swimming and other aquatic sports, transportation and shipping, and recreational and commercial fishing; as well as the simple, quiet enjoyment of the aesthetics of the coast. Narragansett Bay also serves as a dumpsite for many of the unwanted byproducts of our modern society. Inevitably, conflicts arise from the multiple uses of the Bay and other coastal waterways.

The commercial shellfishing industry of Rhode Island annually provides $15 million (ex-vessel price) in quahogs (Mercenaria mercenaria) to seafood markets. This fishery, the largest in Rhode Island state waters, provides a livelihood for about 800 full-time fishermen. Quahogs and other bivalve mollusks are filter-feeders that accumulate pollutants ranging from metallic and organic chemicals to pathogenic bacteria and viruses. No one wants to see public health threatened by contaminated shellfish, but areas closed to shellfishing harbor a tremendous potential resource. Fishing pressure in the areas open to shellfishing is a problem. The shellfishing industry, more than just about any other, depends upon a high degree of water quality.

Now that the sobering 1990s are upon us, concern is increasing for the economic well-being of hard-working shellfishermen and their families. The convenors of this conference hope that the presentations and interchange here will help to focus concerns and provide a rational basis for management discussions.

This volume presents papers delivered at the First Rhode Island Shellfisheries Conference, cosponsored by the Rhode Island Shellfishermen’s Association, Rhode Island Cooperative Extension Service, and Rhode Island Sea Grant. The aim of the conference was to provide an educational forum and a starting point for the rational resolution of multiple-use conflicts.
Figure 1. Geographic features of Narragansett Bay, Rhode Island (Narragansett Bay Project).
The Narragansett Bay Shellfish Industry: A Historical Perspective and an Overview of Problems of the 1990s

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Synopsis. The history of the quahog industry in Narragansett Bay is outlined from its early beginnings in the late 1800s to the present. The industry developed from a small fishery that, from the early days up to the 1950s, was based on tending from small wooden skiffs. Technological innovations such as bullrakes, fiberglass-hulled boats, outboard engines, and electronic navigation equipment have made it possible to harvest in deeper waters that were previously inaccessible. As a result, estimated hard-shell clam landings from Rhode Island have exceeded 15 million pounds (shell-on weight) in recent years. Key problems facing the industry during the 1990s are degradation of water quality in traditional shellfishing grounds, conflicts with other user groups in Narragansett Bay, and effective marketing of the Rhode Island quahog.

Introduction

Narragansett Bay is Rhode Island’s greatest natural resource. Its waters host an abundance of flora and fauna, resulting in a diverse and complex estuarine ecosystem. Narragansett Bay covers an area of 146 square miles, and the coastline is 450 miles long. The Bay provides recreational opportunities such as sport fishing, sailing, power boating, diving, and swimming for a great number of Rhode Islanders, as well as people from out-of-state. The Bay also supports a number of commercial activities including lobstering, trawling, conch (snail) trapping, eel, and the harvesting of hard-shell clams (locally known as quahogs). Quahogging is currently the most important commercial fishery in Narragansett Bay, in both net harvest and dollar value. Estimates by the National Marine Fisheries Service (NMFS) suggest that more than 15 million pounds (shell-on weight) of quahogs were harvested from the Bay in 1989.

History

Quahogs have been commercially harvested in Narragansett Bay since the late 1800s, according to NMFS records. During the period between 1880 and 1938, the oyster was the most sought-after shellfish in the Bay. The majority of oyster harvesting took place on some 20,000 acres of leased beds, most of which were located in the upper Bay and Providence River (Figure 1). These beds produced millions of pounds annually; the largest reported harvest of 15.3 million pounds occurred in 1910 (Olsen et al, 1980). The oysters harvested in Narragansett Bay were known as the most flavorful grown anywhere, and commanded top dollar in shellfish markets. At current market prices that harvest would be worth approximately $43 million.

The oyster industry declined during the 1930s due to a number of factors, including pollution from upriver metropolitan areas, poaching by unauthorized harvesters, and the 1938 hurricane. It was after this period that the quahog became the most important commercial shellfish in the Bay. A steady rise in quahog landings is illustrated in Figure 2. The sharp decline after 1955 was due primarily to increasing pollution in the upper Bay, forcing the closure of this important harvesting area. Mechanical harvesting of quahogs from dredge boats during the 1955 peak was bitterly contested by shellfishermen who were using traditional hand tongs and bullrakes. These men successfully argued that dredge boats could efficiently wipe out an area of quahogs, leaving little or nothing behind for the traditional methods of harvesting. Consequently, dredge boat operations were prohibited from fishing in areas worked by traditional methods. This situation may have contributed to the decline in quahog landings after 1955, as dredge boats were eliminated from upper Bay grounds.
Shellfishermen have always worked Narragansett Bay in wooden work skiffs that were produced locally, often by the fisherman himself. Many skiffs were 16 to 19 feet in length and constructed of oak and mahogany, providing a sturdy and dependable workboat. During the mid-1970s, the fiberglass hull became more popular due to its lighter weight and low maintenance. Perhaps the best feature of these hulls was the raised decks, incorporating scupper holes through the transom that facilitated the removal of rainwater from the deck. This important feature eliminated the need to bail out a boat after significant rain storms. It is no longer necessary to wake up in the middle of a rainy night to check the boat. Wooden skiffs do not have a self-bailing deck, but long-time owners are adamant that a wooden skiff provides the best work platform. The flat bottom and sharp chine of the wooden hull minimize the rolling motion of the boat when working. Fiberglass boat owners far outnumber the few remaining wooden skiffs, however, particularly because a fiberglass hull is a superior riding boat when underway.

In the early years of shellfishing, fishermen were often towed together in tandem by a larger motor-powered boat. After being dropped off in a favorite location on the Bay, the fisherman would then have to row his skiff in order to move about. Outboard motors became more popular during the early 1940s as technology caught up to the inshore fisheries. These small outboards, 10 to 15 horsepower (hp), enabled the shellfishermen to harvest in areas farther from their home port and provided more flexibility in the work day. Currently, outboard motors are much more powerful, up to 235 hp, and a lot more expensive. The cost of a new 90 hp outboard is approximately $5,000, approximately one-half the price of a moderately-priced pickup truck. The outboard motors used today allow the shellfisherman to travel longer distances and work a variety of areas during the course of a work day. It is especially important in winter conditions to have a motor capable of pushing the boat through ice floes. This situation is particularly evident in the coves where shellfishermen dock their boats. The ice becomes very thick due to
large quantities of freshwater input from streams empty-
ing into these areas.

Another popular feature of the modern shellfish fishing
boat is the cabin or "dog house." These cabins are
produced by the boat manufacturer or handmade by
individual boat owners from quarter-inch plywood
overlaid by fiberglass mat/cloth and resin, producing an
extremely durable structure. Many cabins are construct-
ed to comfortably accommodate two people with such
amenities as sliding top hatch, console-mounted throttle
and steering controls, AM-FM stereo, and various
electronic instruments. Some of the more popular elec-
tronic gear are VHF radios, depth recorders, and lorans.
The last two can be beneficial in locating desirable areas
for the shellfisherman to work. The depth recorder
allows the fisherman to determine the necessary length
of "stale," the aluminum pole attached to the rake, by
displaying the depth of the water underneath the boat.
The lanor makes it possible to return to the same area on
subsequent work days, and is especially useful when
land-based ranges are not visible due to weather such as
tog or heavy snow.

Traditionally, oysters and quahogs were harvested
with hand tongs. This tool consists of opposable steel
baskets or "tong heads" mounted on the bottom end of
long wooden shafts, which are scissors by the fisher-
man to open or close the baskets. The fisherman simply
anchors the boat over a bed of shellfish, drops the open
tongs into the water, works the shaft until closed, and
then hauls up shellfish caught in the baskets. The longest
shafts available for tongs are 20 feet, limiting the hand
tonger to waters approximately 16 feet or shallower.
Tonging is still a method used by a few shellfishermen
today; however, the majority of shellfishermen use
rakes. In recent years, hand tongs have bitterly com-
plained about divers harvesting quahogs from the shal-
low waters that tongers are limited to, claiming that the
divers have virtually eliminated quahogs from these
areas. These men have a legitimate argument against
such activity, as divers can see what they are harvesting
and may take all the quahogs from one locality.

The most important tool of the shellfisherman is the
bullrake. This tool is an arrangement of thin metal
spikes or "teeth" aligned along a steel basket. This
basket has a shank allowing the rake to be attached to a
state with large clamps. Most racks are constructed of
3/16-inch-diameter round wire steel stock welded side-
by-side along a flat bar forming a basket. These racks
are made by hand and average about $100 each. Some
fishermen prefer stainless steel baskets but they cost 60
percent more than regular steel baskets. The rake is
attached to various sections of extruded aluminum pole
that are bolted together to create the desired length. The
general rule of thumb is to use slightly more than twice
as much stale as depth of water. The top of the stale is
capped by an aluminum T-handle that allows the fisher-
man to grab on and pull the rake through the Bay
bottom.

The old style of bullrake was referred to as a "key-
port" rake, and was a crude version of modern light-
weight and more-efficient models. This rake was de-
veloped on Long Island in the late 1940s and became a
replacement for the tong. The invention of the bullrake
was a technological advancement in the harvesting of
quahogs, because now the quahogger could drift across
the bottom during the course of a day, covering greater
areas than the tongers. This attribute was especially
useful in areas of soft mud, where the bullrake could
harvest quahogs much more efficiently than the tongs.
The keyport rake was replaced by the predecessor of
modern models, a rake constructed of round steel wire
stock. This style rake was introduced during the early
1960s, again by Long Island fishermen. In Rhode
Island, similar-style racks were also being manufac-
tured at about the same time by industrious individuals,
especially by the Arnold and Madelina families and
another fisherman in Portsmouth. By the 1970s, local
shellishermen had a wide variety of bullrake styles to
choose from. Of course, heated discussions still result
between fishermen as to which type of rake is best and
why.

Before the use of aluminum stale became available,
wood was used exclusively. These tools were more
fragile and demanded care by the fisherman to prevent
breakage, especially in hard-running tides. The modern
aluminum stale is a high-quality extruded product that
can be cut to various lengths, and assembled by the
fisherman to create essentially any length desired.
Some quahoggers have experimented with fishing in
extremely deep water (approximately 50 feet) with
good success. Unfortunately, to work in this depth of
water requires almost perfect conditions (slack tide and
light winds) to effectively harvest quahogs. The long
stale length necessary for deep waters creates tremen-
dous surface area for a hard-running tide to grab, rendering the whole effort useless.

**Problems**

The discharge of raw untreated sewage and contaminated stormwater through combined sewer overflows (CSOs) is the major environmental problem facing the shellfish industry. Combined sewer overflows are the result of antiquated municipal sewage systems where sewage and stormwater runoff are transported by the same piping network. Millions of gallons of sewage and contaminated stormwater bypass sewage treatment facilities and discharge directly into the Bay and its tributaries. An estimated 4 billion gallons of contaminated water are discharged annually by more than 100 CSOs surrounding Narragansett Bay (Zingarelli and Karp, 1991). The majority of these outfalls are located in municipalities at the upper reaches of the Bay, specifically the Providence area (see Figure 3). The pollution from these illegal sources has resulted in the closure of some of the Bay’s most productive shellfish beds. These conditional areas (Figure 4) are closed for approximately 50 percent of the year, resulting in significant financial losses to shellfishermen. The cleanup of CSOs in the next decade should be a high priority for state and federal governments.

Nonpoint sources are also significant contributors of pollutants to Narragansett Bay. Several shellfish areas have recently been closed due to elevated fecal coliform levels in excess of the state’s water quality criteria for shellfish harvesting waters. The failure of old individual septic disposal systems in densely populated areas near the shore has resulted in the transport of waste to the Bay during and immediately following a rainstorm. This situation threatens to close additional and important shellfish resources within the Bay, including the salt ponds. The coastal ponds are experiencing even more pressure from septic system pollution as more people convert summer homes into year-round homes. This problem of septic system input to coastal waters is further exacerbated by new development in these coastal areas. Failed septic systems must be identified and replaced with new systems to reduce pathogenic bacteria and viruses that enter waters where people swim and obtain shellfish.

The expansion of new coastal development reduces the buffer of natural vegetation and creates more impervious areas (e.g., roads, driveways, parking lots, and buildings) that substantially increase the amount of stormwater runoff. This runoff may contain sediments, heavy metals, nutrients (i.e., nitrogen and phosphorus), bacteria and viruses, pesticides, and a host of other chemical pollutants. These contaminants have the potential to impact shellfish-growing areas by degrading the aquatic environment. Nonpoint pollution can be reduced through effective stormwater management methods including source reduction, stricter zoning requirements, and structural practices (e.g., detention ponds, infiltration basins, created artificial wetlands, and vegetated swales).

Recently, the national media has portrayed the consumption of raw shellfish as hazardous to human health due to the potential of illness from enteric pathogens that might be present in the shellfish. This media programming has resulted in the unfair accusation that hard-shell clams from the northeastern states are vectors of deadly diseases. A report by the U.S. Public Health Service shows that in the last two years of data on disease outbreaks from the consumption of raw shellfish, all outbreaks were due to the consumption of shellfish other than hard-shell clams, most notably oysters from Gulf Coast states (Rippey, 1989). The media is responsible for creating bad publicity about shellfish, causing unnecessary fear in the shellfish-consuming public.

The proper marketing of hard-shell clams must be a priority if the industry is to thrive in the future. Perhaps the poor perception of the quality of product is best exemplified by the manner in which shellfish are shipped to market. Almost without exception, hard-shell clams are transported in used nylon onion bags. It is unbelievable that $80 to $100 worth of shellfish are shipped in bags that were used by an onion farmer to ship $10 worth of onions. No wonder people don’t handle and market hard-shell clams as properly as they should! Consider how much more desirable hard-shell clams would be if they were shipped in bags with the shellfish dealer’s name and a description of the geographic location where the shellfish were harvested.
Figure 3. Combined sewer overflow locations in Narragansett Bay (Narragansett Bay Project).
Figure 4. Shellfish closure areas in Narragansett Bay in May 1990 (Narragansett Bay Project).
A strong economic climate during the 1980s created a substantial increase in the number of recreational boaters in Rhode Island. This resulted in the expansion of marina facilities, including mooring fields, to accommodate the growing number of pleasure boats. Unfortunately, the expansion of some dockage and mooring areas within shellfish harvesting waters resulted in larger seasonal shellfish closures around the periphery of these facilities. Mooring areas pose another hazard due to the physical presence of the mushroom anchor and attached chain. These objects can snag hullwakes or anchors and result in losses of shellfishing equipment. Large mooring fields within shellfish growing waters can effectively prohibit the use of those areas for the procurement of shellfish, for both the recreational and commercial fisherman.

CONCLUSIONS

If the shellfish industry wants to attain the best management of the resources, it must enlist the assistance of state and local agencies and officials. Perhaps the best example of this cooperative effort is the Green-which Bay management program. Through the dedicated work of the Rhode Island Department of Environmental Management’s Division of Enforcement, Rhode Island Senior Shellfish Biologist Arthur Ganz, and local fishermen, tons of shellfish have been relayed into Greenwich Bay each year for the last several years. This program has replenished depleted shellfish stocks in this area through the addition of undersize and mature legal-size quahogs. The transplant of shellfish during spring months assures that quahog larvae will be distributed throughout the area and increase the local quahog population. The Greenwich Bay management area is open from December through March and is particularly important to shellfishermen during this time of year when weather is at its worst. Greenwich Bay is more sheltered from howling winter winds than most other areas of Narragansett Bay and provides shellfishermen a place to work on marginal days.

The quahog industry continues to thrive in Rhode Island, despite obstacles that inhibit the potential growth of this important fishery. The quahog will remain a popular and desired food item, as long as there is a persistent demand. The positive reinforcement of the healthy and wholesome qualities of quahogs from certified waters of Narragansett Bay will continue to be a high priority for shellfishermen. Recent improvements at the Narragansett Bay Commission’s municipal wastewater treatment facility in Providence have decreased the number of shellfish closures by improving water quality in the upper Bay. Wastewater treatment facility renovations are now economically feasible for Rhode Island municipalities through low interest loans provided by the Clean Water Protection Finance Agency. This agency was established by a state referendum that was passed overwhelmingly by the people of Rhode Island this past November.

The Rhode Island Shellfishermen’s Association (RISA) is an organization of area fishermen dedicated to the preservation and enhancement of the hard-shell clam industry. This organization has an active membership that promotes quahogs and participates in environmental issues affecting Narragansett Bay and the shellfish industry. RISA will continue to play an active role in preserving the traditional shellfish industry and protecting Narragansett Bay.

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REFERENCES


Questions and Answers

Q: (Dr. Walter Blagoslawski, National Marine Fisheries Service, Milford) Connecticut shellfishermen successfully sued various local towns that had contaminated shellfish grounds, and used the loss of income from a day’s closure to defend their suit. Have you considered legal action here?

A: (Mr. James Boyd) We have. Legal action is in progress now. Along with Save the Bay, we have initiated legal action against the Blackstone Valley Commission. I cannot elaborate too much now because we have a number of irons in the fire, so to speak.

Q: (Mr. Jeff Kassner, Brookhaven, New York) You never mentioned anything about stock size and abundance. Are yields a problem now?

A: (Boyd) Not specifically. This year we are doing pretty well in the Bay. There is a fair amount of product out there. I believe that one of the reasons for seeing an abundance of product, of uniform size, is that we have been throwing a lot more undersized quahogs back into the water over the past four to five years. Especially with the implementation of the 1-inch hinge size limit (which is fairly uniform up and down the East Coast). There are problems in other areas, but our main problem now is to get back into traditional shellfish grounds which have been closed to pollution.

Q: (Mr. William Munger, Rhode Island Marine Trades Association) I would like to see more research on the impact of mooring fields to the shellfisheries. I think that the situation in Jamestown will prove that the impact of recreational boaters on the shellfisheries is little to nonexistent. We need to reevaluate the Interstate Shellfish Sanitation Conference (ISSC) formula to see how realistic it actually is, and look at this issue under a microscope to see if the impacts are really there.

A: (Boyd) The fact is that the impacts are there. This is not just a water quality issue, but an issue of physical space as well. When moorings are put in a shellfishing area, you cannot work in that area. You can catch your anchor or bullrake on the large mushroom anchors. This effectively excludes shellfishing. What we would prefer to see is a positioning of mooring fields away from “pristine” areas such as Jamestown. Mooring fields would be better in closed areas such as the Providence River, which will most probably never be certified for shellfishing because of the metals and toxic chemicals in the sediments. Let’s put boating in SC classified waters rather than SA classified waters. But you are correct, more research in this area is important.

Q: (Munger) If hardware is the issue, we could focus on the hardware, but let’s not bring pollution into the picture because it may not be a problem.

A: (Boyd) In Jamestown, the mooring field areas are closed to shellfishing right now. Those areas were expanded this year, in fact, tripled in size. The areas are closed from May to October. We cannot fish there even if we wanted to. It is closed by the State of Rhode Island, period.

Q: (Mr. Phillip Colarusso, Environmental Protection Agency) Addressing the issues of impacts, in addition to the sewage, the disinfectants have been shown to be very toxic to shellfish larvae.

A: (Boyd) That is a good point.
Links Between Water Quality and Shellfisheries in Narragansett Bay, Rhode Island

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Synopsis. Observed declines in the abundance and distribution of commercial shellfish species are often declared to be a result of degraded water quality conditions. A historical review of changes in commercial shellfish landings, fishing effort, species abundances and distributions, and changes in water quality in Narragansett Bay, Rhode Island, was undertaken to assess these correlations. It was found that changes in shellfisheries within Narragansett Bay had little correlation to changes in water quality parameters from an ecological and biological perspective. For Narragansett Bay, it was found that changes in shellfish landings were more closely related to changes in harvest technology, fishing effort, economics, politics, and habitat degradation than to water quality degradation.

Introduction

Historically, a variety of shellfisheries have existed in Narragansett Bay. Since the early 1900s all but one, the hard-clam fishery, have suffered dramatic declines and are no longer viable. Scalloping was once an important fishery in Narragansett Bay during the 1800s, but subsequent landings were sporadic. Many years of poor juvenile set were punctuated by population booms, and the fishery could not be sustained. Soft-shell clams also were once abundant in Narragansett Bay, and supported a limited commercial fishery during the early and mid-1800s. Abundances of this species fluctuated from year to year and never gained ground as a major Bay-based fishery. A lobster fishery in the Bay was once a major presence, but the Bay fishery declined rapidly when new technology enabled fishermen to fish in the more productive, deeper waters outside the Bay. American oysters dominated shellfishery markets and effort in Narragansett Bay from the mid-1800s to the early 1900s. The oyster fishery declined dramatically in the 1930s and was replaced by a fishery for hard clams in Narragansett Bay waters.

Today, Narragansett Bay is home to one of the major U.S. fisheries for hard clams. It is quickly becoming the leader in the U.S., as New York and Florida hard clam landings decline (Haynes, 1989). The hard clam harvest is therefore of major economic importance in Rhode Island, and symbolizes the state of environmental conditions in the Bay. Soft-shell clams, blue mussels, several species of conch, hard clams, and surf clams are presently fished only on a recreational basis within Narragansett Bay (surf clams are fished in a small scale commercial operation within the Sakonnet River mouth).

There are four probable causes that are thought to have affected declines in Narragansett Bay's once abundant shellfisheries: water quality degradation, loss of habitat, overfishing, and natural changes in the distribution or abundance of the species or their food source. The decline has been blamed more often than not on degraded water quality conditions in Narragansett Bay.

Commercial landing records date back into the mid-1800s for several species, and although they do not necessarily reflect the natural abundance of the target species, they act as a reliable proxy. By combining commercial landing data for hard clams and oysters with state licensing records, fishing effort can be determined. A reasonable picture of changes in Narragansett Bay shellfisheries can then be related to changes in water quality and other conditions that may have affected changes in the fishery.

The Oyster Industry

Historically, oysters were the most important shellfishery within Narragansett Bay. The oysters originally were fed to swine and burned to produce lime. By the late 1800s, two oyster fisheries existed: (1) harvest and storage for use as a personal food item during winter
months; (2) harvest by full-time commercial oystermen who sold their product to shucking houses (Kochiss, 1974). The commercial fishery grew rapidly, and by the early 1830s oyster seed stock had to be imported from Chesapeake Bay and Long Island Sound to keep pace with product demand (Kochiss, 1974). Many of the tributaries to Narragansett Bay still had prolific oyster beds, but it was evident that the oyster beds in the upper Bay were not replenishing themselves naturally, possibly a result of the overfishing of adult breeding stocks.

Although oyster beds in the Seekonk River were kept open for public use, commercial growers regularly moved small oysters from these beds to privately leased tracts down Bay. Naturally occurring oyster beds in the tributaries to Narragansett Bay were depleted of brood stock. Recreational oystering essentially stopped, due to a lack of adult oysters on non-leased bottom, and poor natural reproduction. By 1887, the decline of the natural oyster beds was attributed to overfishing, and no indication of pollutants harming oyster stocks was documented (Goode, 1887).

Leasing of grow-out areas throughout the Bay originated for two reasons: Since many of the best oyster growing grounds in the Providence and Seekonk Rivers were open to public harvest, oystermen could increase their profit by removing oysters from public to private tracts down Bay; and oysters were moved to higher salinity waters where they grew better, produced a better-flavored meat, and lost the “greenish” meat color common to Seekonk River oysters. However, the higher salinity lower Bay waters were not conducive to oyster spawning and spat settlement, further reducing the potential for natural propagation of oysters in the Bay.

The oyster market continued to grow as demand for “succulent” Narragansett Bay oysters increased. The oyster culturing system expanded rapidly throughout Narragansett Bay. Harvests increased until 1866, when a population boom of predatory starfish in the Bay caused a significant drop in the oyster harvest. The industry responded with starfish removal practices, recovered quickly, and continued its rapid growth.

During this same time period, industrial expansion and population growth in the Providence area were bringing pollution problems to upper Narragansett Bay. Great Bed (located around Starve-Goat Island south of

Field’s Point), one of the prime oyster growing sites, was abandoned by 1895 due to contamination of the oyster crop with oily effluents from the coal gasification plant. The oysters in the area acquired the taste and odor of coal tar, making them unmarketable (R.I. Comm. Shell Fish., 1905). Great Bed was later filled in, as Field’s Point expanded to serve the sewage treatment facility and the Port of Providence. The oyster industry moved farther down Bay, away from the industrial sprawl, and into deeper water.

The lease of deepwater bottom opened the door for a major boom in the oyster industry between 1900 and 1910 (Figure 1). At the industry peak in 1910, schooner loads of seed oyster were imported into the Bay every year from Long Island Sound and Chesapeake Bay, and more than 21,000 acres of bottom were leased for oyster culture (Figure 2).

Examination of shellfish from beds in the Providence River during 1914 found them to be grossly polluted with fecal coliforms, and the Commissioner of Shellfisheries prohibited the taking of shellfish for food from the upper portion of the Providence River and from all of the Seekonk River. The oyster industry again shifted down Bay to the remaining workable bottom sites, which were now becoming limited in availability.

Chesapeake Bay and Long Island Sound oyster spat became scarce due to a number of poor sets in succeeding years, limiting the number of spat available, and increasing the cost of those spat which could be purchased. The economics of the industry progressed to the point where it was becoming too costly to import boatloads of spat for grow-out in Narragansett Bay.

Due to the combination of minimal natural set of oysters occurring in Narragansett Bay, a depletion of adult oyster stock since the mid-1800s, and reduced availability of imported spat, the once mammoth oyster industry sharply declined after 1915. By 1924, the numbers of both acres leased and oysters landed were reduced to the levels of the early 1880s (Figures 1 and 2).

A slight rebound in the oyster harvest occurred during the mid-1930s (Figure 1). But the economic impact of the Great Depression, plus the 1938 hurricane which moved oysters outside of lease sites and covered them over with silt, drove the remaining oystermen out of business.
Links of Oyster Fishery Trends to Water Quality

The oyster industry in Narragansett Bay declined and became extinct principally for economic reasons—the oystermen's profit was not sufficient to justify the lease fees, seed stock prices, loss to predators, and market competition with oystermen farther south in the Chesapeake and Delaware Bays.

The oyster industry was, for the most part, a large-scale aquaculture project from the mid-1800s to its complete collapse in the early 1920s. Oystering was not a fishery in the usual sense of the word. The propagation of the Narragansett Bay oyster industry was artificially maintained by tons of young "seed" imported for growth in favorable Bay waters. Successive years of poor natural set of oyster spat in both Chesapeake Bay and Long Island Sound occurred simultaneously, which severely limited growth and even maintenance of the Narragansett Bay oyster industry. Most oyster growers were forced out of business, driving the industry to extinction in Narragansett Bay. The decline of the Narragansett Bay oyster populations as a commercial resource was due primarily to overfishing of the natural stock as early as the mid-1800s, with habitat degradation in the Providence and Seekonk Rivers playing a major role (e.g., siltation and filling, dredging of the deepwater shipping channel). The decline was not directly caused by water quality degradation.

The Hard Clam Fishery

During the reign of the oyster industry as the premier Narragansett Bay fishery, hard clams were of minor commercial importance. During the early 1900s, as the oyster industry collapsed, hard clams became increasingly important. The natural availability of hard clams in the Bay drew many former oyster growers to a resource not ruled by imported seed stocks and other economic conditions.

In 1928, 2 million pounds of hard clams were landed, but landings more than doubled to 5 million pounds by 1955 (Figure 3). The expansion of the hard clam fishery during this time was related to the opening of new clamming areas in formerly privately-leased oyster grounds (Pratt, 1988). Clamming in the Bay was a natural fishery, not a culturing operation, and was carried out mainly by state residents, who relied upon the natural abundance of unexploited clam beds in the Bay as a "free and open fishery."
After peaking in 1955, the harvest of hard clams declined through 1974, apparently the result of overexploitation of the stock, and possibly the failure of the depleted stocks to properly recruit (Pratt, 1988). Overfishing was accomplished by the large number of clammers working in a limited area in the Bay. As more persons purchased clammers licenses, the available bottom in the Bay was overworked and produced fewer clams, despite increased fishing effort (Figure 4).

The marked increase in clam landings beginning in 1974 resulted from the introduction of a new technology—the bullrake (Pratt, 1988). Use of the bullrake enabled clammers to work more varied bottom types in deeper waters. With a bullrake, the workable water depth jumped to 26 feet from the 13 feet that could be worked with hand tongs. This increased the amount of workable bottom available to clammers in the Bay by nearly a factor of two (Pratt, 1988).

With the opening of previously unexploited clam beds, the harvest increased to 4 million pounds in 1984. The harvest has since dropped to about 2 million pounds per year (Pratt, 1988) (Figure 3). Pratt suggests that the clam resource is being heavily used, and that the addition of more labor to the work force will not yield proportionally more clams. Some portion of the recent increase in hard clam landings can be attributed to the conditional opening of clam beds in the upper Bay. These beds were formerly closed due to excessive fecal coliform contamination from untreated sewage discharges in the Blackstone, Seekonk, and Providence Rivers (Figure 5). Dramatic increases in clam landings in Narragansett Bay are not to be expected in the future unless presently closed beds are opened to harvest.

Links of the Hard Clam Fishery to Water Quality

A hard clam survey conducted in closed and conditional areas of the Providence River and upper Bay by Pratt et al. (1988) found clam distributions to be similar to those reported from surveys in 1957 (Stringer, 1959) and 1965 (Saila et al., 1967). Thirty years of exposure to upper Bay pollutants has apparently not changed hard clam population distributions. Pratt et al. also found good numbers of smaller clams in the upper Bay and Providence River, suggesting that conditions for spat settlement have been suitable in the recent past. Some size/growth limitations were noted in sampled clams (e.g., reduced size according to age), suggesting some potential effect by upper Bay pollutant concentrations, but that could equally be a result of high clam densities and lack of disturbance of the clam bed (Pratt et al., 1988).

Other than limiting the area available for clammers to work, water quality has not seemed to be detrimental to the Narragansett Bay hard clam fishery or hard clam populations. As with the oyster industry, water quality affects the economics involved in the hard clam fishery (i.e., closed areas due to high fecal coliform concentrations), but has apparently little effect upon the clams. The increases and decreases observed in the commercial landings data reflect changes in technology, and overfishing of the resource.

Recent improvement in water quality in the upper Bay has instigated the suggestion of opening some of the conditionally closed clam beds on a permanent basis. This idea has met with much opposition from fishermen, who claim the opening of these areas would create a glut of clam meats on the market, lower prices, attract new fishermen, and thereby decrease profits to the point where the industry was no longer a worthwhile way to make a living. As a consequence, no new areas have been opened on a permanent basis in the upper Bay, and harvests are expected to remain stable at present levels.
Conclusions

The available information does not justify the assumption that changes in commercial shellfish landings in Narragansett Bay are caused directly by water quality degradation. In both the oyster and hard clam industries, water quality degradation limited the potential harvest of stocks by closing certain areas to fishery practices, but did not appear to impact the actual populations of shellfish. Loss of oyster brood stock in the Providence and Seekonk Rivers may have been caused by water quality degradation, but these areas were abandoned by the late 1800s. The oyster industry continued to expand for another 30 years until its peak in 1910, despite the fact that untreated sewage and chemical wastes were being discharged into the Bay throughout that time period.

The changes observed in hard clam landings in Narragansett Bay during the 1900s further suggests that water quality has had only a minor effect upon Bay-based shellfisheries. Using dissolved oxygen concentrations in the Seekonk River as an indicator of water quality conditions in the Bay over time (Figure 6), it is seen that dissolved oxygen conditions were at their worst during the late 1940s. As water quality conditions worsened in the Bay from 1923 through 1947 (Figure 6), hard clam landings in the Bay increased (Figure 3). From 1947 through 1983, dissolved oxygen concentrations in bottom waters increased considerably, suggesting improvement of water quality as untreated waste discharges were diverted to treatment plants. Yet from 1955 through 1975, the hard clam fishery exhibits a major decline indicated by a nearly four-fold decrease in landings. Hard clam landings declined again from 1985 to 1989, even as water quality further improved from reductions in PCBs, organic toxin loading (Latimer, 1988), metals loading (Nixon, 1990), and hydrocarbons (Quinn, 1988). These data all suggest that change in the hard clam fishery is driven by factors other than water quality problems in Narragansett Bay.

Despite improvements in water quality during the past 20 years (Desbonnet and Lee, in press), neither phytoplankton nor zooplankton species composition or abundance has changed significantly (Hinga et al., 1988). Filter-feeding bivalves have been prevalent in Narragansett Bay through history, with some species such as the blue mussel increasing in population through the 1900s. This implies that filter feeders have generally not been food-limited in Narragansett Bay. It can therefore be surmised that changes in plankton abundance and/or species composition have not been directly responsible for the observed changes in Narragansett Bay shellfisheries. Similarly, water quality degradation cannot be isolated as the responsible factor in the declines observed in Bay-based shellfisheries landings. Recent reports produced for the Narragansett Bay Project by a variety of researchers on a suite of water quality and related parameters all suggest that water quality in the Bay has improved dramatically in the past decade, and the improvement is continuing.

Figure 5. Number of bottom acres placed in permanently and conditionally closed status in Narragansett Bay. Data is intermittent from 1947 through 1988 (RIDEM records).

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QUESTIONS AND ANSWERS

Q: (Dr. Walter Błosławski, National Marine Fisheries Service, Milford) Have there been historical impacts of algal blooms in Narragansett Bay?

A: (Mr. Alan Desbonnet) In the late 1800s, there were a number of minor algal blooms in the upper Bay, red tide events essentially. In the 1890s, there was a major red tide event which not only affected shellfish populations, but finfish populations as well. It is difficult to explain why those blooms occurred then, but the timing coincides well with the maximum nutrient loading by untreated sewage. The first sewage treatment plant in the upper Bay came on-line in 1901. After that point you don’t see any reference to red tide. My assumption is that there is a correlation here. The red tides did devastate shellfish populations in the upper Bay. At that time (late 1800s), the hard clam industry had not yet come into its own. Most of the oystermen simply picked up their product and moved down Bay, and when the red tide passed, they moved back to the upper Bay. The best oyster-growing waters were in the upper Bay.

Q: (Błosławski) You stated earlier that there were low dissolved oxygen values due to the shutting down of sewage treatment plants because of the war effort (early 1940s). Were there reports of algal blooms then?

A: (Desbonnet) To my knowledge there were no reported algal blooms. The sewage treatment plants were not shut down completely. There was some initial settling and minor chlorination, so that there were some solids present. There does not seem to be any specific trend in this case. In the 1970s, the main sewage treatment plant was broken down for a two-year period, allowing discharge of essentially raw sewage. Again you do not see any algal blooms in that time span. Nutrients in the water may not be the only condition necessary for an algal bloom.

Q: (Dr. John Sutinen, Department of Resource Economics, University of Rhode Island) I'm a little confused. Earlier you stated that the decline of the oyster industry is not well-correlated with changes in water quality, yet you just said that oystermen moved down Bay to find higher dissolved oxygen. Could you go over your story again?

A: (Desbonnet) There is not enough information available from the late 1800s to clearly establish a link between sewage loading and algal blooms. It is a relatively good guess that there may be a correlation. The low oxygen conditions did not result so much from the algal bloom, but the die-off afterward. The low oxygen is simply a temporary thing. The oystermen simply moved their product down Bay. When the adverse conditions cleared up, they came back to their original areas.

There was an effect on the shellfish and fish in the upper Bay. The fish kills are documented. But this did not stave off the oyster industry to any degree, because there were no major native stocks of oysters at that time. The oyster industry was an aquaculture grow-out operation. I'm not trying to say that there is no impact of pollution on shellfisheries, but in the case of the oyster industry, the major discharges of raw sewage were not a major factor in the decline of that industry.

Q: (Mr. Robert Ricault, Spatco Ltd.) I think that we should mention the 1985–86 brown tide that wiped out what was left of the scallop industry. I'm interested in the quahog landing data. Two thousand metric tons seems to be a lot less than Dr. Sutinen's data of 15 million pounds in 1987–88, which translates to be about 7,000 metric tons. Can you comment?

A: (Desbonnet) I am not sure, but these data were taken from National Marine Fisheries Service statistics. Some of these are not going to be Narragansett Bay quahogs. But our indication from a number of sources is that the majority of those landings were from Narragansett Bay.

Q: (Mr. Jeff Kassner, Brookhaven, New York) You said that the rise in quahog landings during the 1970s resulted from technological improvements in fishing gear. It was my understanding that the aluminum poles and Rhode Island rake heads were invented in the 1960s and were in place by 1970. Can you comment?

A: (Desbonnet) The invention of the new gear may have occurred before 1970, but there is a certain lag time between invention and widespread adoption. I don't know how long that lag time is, but we did note a rise in landings in the 1970s, with the technology increasing the working depths from 13 to 26 feet.
Editor’s comment: A number of “old-timer” fishermen say that the bullrake was invented during the 1950s. There were approximately 20 families in Greenwich Bay who used bullrakes with wooden stales (handles). The wooden stales were held together by iron rings and enabled them to fish in about 20 feet of water.

Q: (Ms. Aimée Keller, Graduate School of Oceanography, University of Rhode Island) I was wondering about your oxygen data. Were those actual annual means? Were they bottom-water samples?
A: (Desbonnet) For the most part, those were one-time-only surface-water and bottom-water measurements. Most of the data were from August, but all were from either July, August, or early September. In other words, these were late-summer conditions.

Q: (Keller) We generally note a big difference in dissolved oxygen (DO) between July and September in the Bay.
A: (Desbonnet) That is true. What those DO measurements generally portray are worst-case oxygen minima.

Q: (Keller) Were they bottom measurements?
A: (Desbonnet) In general they were surface and bottom measurements. But Sweet’s measurements in 1913 were surface.

Q: (Sutinen) Just to get back to explaining landing trends, I think that another factor would be the unemployment rate. It has been argued by some that the shellfishery landings are inversely related to the state of the economy. During the 1970s the Rhode Island economy was not too healthy.
A: (Desbonnet) We are aware of this, and have been trying to gather information of this type. There is no consistent data from earlier dates, to provide a clear picture of this. But you are right, the amount of fishing effort is known to increase in tight times.
Public Health Concerns Regarding Shellfish in Rhode Island: A Risk Assessment Perspective

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Synopsis: The Rhode Island Department of Health is responsible for implementation of the shellfish sanitation standards set forth by the Interstate Shellfish Sanitation Conference (ISSC). As part of the Department of Health, the Office of Risk Assessment is responsible for developing estimates of public health risk due to consumption of shellfish products harvested from Rhode Island waters. The protocol for determining public health risks associated with consumption of microbiologically or chemically contaminated shellfish is presented. The procedure for issuance of a Rhode Island Public Health Advisory is outlined.

Introduction

The primary public health concern regarding consumption of shellfish in Rhode Island are contamination by microbial agents and contamination by chemicals. From a risk assessment perspective, the microbial contamination of shellfish results in significantly more observable morbidity (illness) and, in general, appears to be a substantially more prevalent problem than chemical contamination. Rhode Island residents consume more shellfish, on average, than most of the rest of the U.S. As a result, the potential exposures to shellfish contaminants, both chemicals and microbial agents, are greater for Rhode Island residents.

Microbial Agents

Prevalence and Reporting of Shellfish-related Disease

The major sources of microbes that contaminate shellfish in Rhode Island’s Narragansett Bay include untreated residential sewage and septic tanks, sewage from boats, combined sewer overflows and other sewage overflows, and with regard to such agents as viruses and giardia, treated sewage. Current conventional sewage treatment is generally not effective at removing or destroying many of the microbial agents that pose a public health concern with regard to potential shellfish contamination. These agents of concern include some bacterial species, many viruses, and some parasites such as giardia. In addition, improper handling of shellfish following harvesting can introduce microbial contamination. The primary public health concern from microbial contamination of shellfish is fecal-oral transmission of pathogens contained in the sewage, which results in the development of gastrointestinal (GI) diseases. The severity of these GI diseases varies across a wide spectrum. It ranges from very mild gastrointestinal distress, with nausea, abdominal discomfort, mild diarrhea, and flu-like symptoms, to severe gastroenteritis with severe nausea, vomiting, diarrhea, cramps, severe abdominal pain, anorexia, dehydration, and possibly fever. Persons with significant pre-existing illnesses, persons who are immuno-compromised, and the very young and very old are particularly at risk of developing severe cases of illness. In some cases, the gastroenteritis that is induced by these agents can be fatal. The prevalence of shellfish-related GI disease in Rhode Island is unknown but is likely to be high. It is very difficult to quantify this prevalence for a number of reasons. In general, there is a poor recognition of shellfish-related GI disease by patients and physicians. Related to this is a low degree of attribution of GI disease to its proper cause.

The failure to attribute GI disease to shellfish contamination occurs for a number of reasons. Individuals who contract shellfish-related GI diseases often suffer only from mild symptoms, and the resulting symptoms often mimic the flu or other similar viruses. GI diseases are extremely common. There is nothing special about most shellfish-related GI diseases to distinguish them from the common communicable viral causes of GI illnesses that regularly occur in communities, particularly for mild to moderate cases.
In addition, the onset of symptoms related to the GI illness can be very slow. Extended incubation periods (i.e., the time lag between exposure to the pathogen and the onset of noticeable symptoms) make it difficult for consumers of contaminated shellfish to identify the cause of their disease. The incubation period for salmonella, for example, can range from six to 72 hours. The incubation period for hepatitis can be many weeks. These long incubation periods for shellfish-related GI diseases distort their relationship to food.

It is not uncommon, therefore, for an individual to attribute his or her symptoms to the prevailing viral illness in the community. The likelihood that an affected individual will pinpoint the cause of his or her symptoms as being a foodborne illness is extremely low, particularly when the symptoms are mild and the incubation period is fairly long.

In addition to poor recognition and attribution by patients, there is also poor recognition of and attribution to the proper underlying cause by health care providers. Physicians often dismiss mild to moderate GI symptoms as being due to a nonspecific viral syndrome.

When a patient is seen in a physician’s office or emergency room complaining of mild GI distress, nausea, abdominal discomfort, and related symptoms, the physician often treats the patient without determining the specific cause of the illness. From the practical perspective of treatment, mild to moderate GI disease generally requires the same treatment regardless of the specific underlying cause of the symptoms. Most of these GI illnesses are self-limiting and, in general, even the moderate diseases require only mild fluid replacement. In addition, there is generally a very low index of suspicion among most physicians to consider foodborne causes of gastroenteritis; this probably reflects a general lack of training of medical professionals with regard to sanitation and public health.

Therefore, from the perspective of the physician, there is little practical value to be gained from identifying the specific cause of a typical GI illness. There is similarly little practical value to such identification from the perspective of the patient, who generally desires only to be rid of the disease.

Another factor that makes the determination of prevalence of shellfish-related GI disease difficult is poor reporting of those GI illnesses that do occur. Affected individuals very seldom report mild GI diseases to their physicians. In fact, patients will generally seek medical attention in only a small percentage of cases, even for moderate to severe GI disease.

Gastroenteritis, itself, is not a reportable disease. Therefore, physicians will only rarely report any cases of gastroenteritis to public health officials, even if there is a suspicion that the case is food-related. As a result, public health officials generally receive reports of shellfish-related GI disease only from those moderate-to-severe cases that are very clear, or from those instances that involve an outbreak of disease in a fairly large group of people.

In the case of outbreaks of GI disease, epidemiological follow-up will generally identify the food source that caused that outbreak. By contrast, in cases of sporadic GI disease that occur among persons who consume raw shellfish, particularly in the home, it is extremely unlikely that the case will ever be reported as a foodborne shellfish-related disease to public health officials or to the U.S. Food and Drug Administration (FDA).

Another important factor that makes determination of the prevalence of shellfish-related disease in the population difficult is incomplete diagnostic workups by physicians for those cases that do come to medical attention. The diagnostic workup for GI disease can be expensive and time-consuming, particularly for viral causes and for such parasites as giardia. In addition, since most cases of GI disease are self-limited and most cases seen by physicians require only mild fluid replacement or similar supportive treatment, a knowledge of the underlying cause of the GI disease usually does not affect the treatment for the patient. Consequently, there is little incentive or need for physicians to perform a potentially expensive and time-consuming exhaustive workup to identify the actual cause of the GI disease.

In fact, given the rapidly rising cost of medical care, the average physician is encouraged not to perform an exhaustive diagnostic disease workup in those cases where it will have no impact on treatment. From a health care standpoint, it is not necessary to know which virus caused the patient’s particular GI disease, when the patient will simply be instructed to drink more fluids and the disease will resolve itself. However, this low level of exhaustive diagnostic workups of GI diseases on the part of physicians contributes significantly to a low level of reporting of shellfish-related disease by physicians to public health officials.
In summary, only a small proportion of GI diseases are brought to medical attention for treatment, only a small percentage of these are properly attributed to the actual underlying cause, and only a small proportion of these are reported to public health officials. It is not surprising, therefore, that published numbers of reported cases of shellfish-related disease vastly underestimate the true likelihood prevalence. Unfortunately, because it is not known what percentage of the total occurrence of GI disease in the population is shellfish-related, it is not possible to predict the degree of under-reporting.

**Health Risks and Mitigation**

The underlying microbial causes of shellfish-related GI diseases include some bacterial species (such as *Salmonella, Shigella, and Campylobacter*), viruses, and a number of parasites (such as giardia). The most common causative pathogens appear to be viral agents, including the Norwalk virus.

The contamination indicators currently used in shellfish monitoring programs, i.e., total and fecal coliform levels, are questionable as guides to the presence of pathogenic agents, particularly viral agents. Unfortunately, there are no widely accepted, better alternatives available.

The indicators used, total and fecal coliform, do serve some very valuable purposes with regard to indicating whether or not sewage contamination has taken place. Contamination of shellfish by microbial agents, however, can occur in the absence of obvious sewage contamination. Current conventional sewage treatment systems are ineffective at adequately eliminating many viruses of concern or such treatment-resistant organisms as giardia. Furthermore, poor handling and transport after harvesting of the shellfish may foster microbial growth of these agents that get into the shellfish. Consequently, even with thorough conventional treatment of sewage, microbial contamination of shellfish can be expected to occur, with subsequent GI diseases resulting in the consuming public.

The techniques of quantitative risk assessment cannot readily be adapted to determining the health risks posed by microbial pathogens. In other words, determining what constitutes a safe number of pathogenic particles in a shellfish, even presuming that all relevant pathogens could be adequately detected and sampled, is effectively not possible.

This is largely due to the impracticality of identifying and measuring the enormous number of variables that affect whether or not a given concentration of microbes in a shellfish will produce an illness in any particular potentially exposed individual. Host susceptibility of the consuming individual is highly variable for any population. Individual variability in genetic predisposition and in responsiveness to diseases is tremendous. Further, concurrent exposures to other agents and to other diseases, diet, and susceptibility to the disease-causing agent within a given host environment are other important factors that will affect how likely it is that a given dose of pathogen will actually produce disease.

In principle, even a single pathogenic organism in a shellfish could potentially cause disease in an individual under proper conditions. Therefore, in theory at least, there exists no threshold of exposure below which safety could be assured for all members of the population. In other words, a quantitative risk assessment would indicate that no concentration of pathogenic organisms in shellfish could be reliably demonstrated to represent a safe exposure for a population of individuals. While it would theoretically be possible to estimate a safe exposure to a given pathogen for a given individual under given circumstances, it would effectively be impossible to accurately measure all of the variables needed to make this determination; further, the safe exposure level would then vary as any change in circumstances occurs.

In the absence of a risk assessment approach, there are at least two ways in which to address the health risks of microbial contamination of shellfish in Rhode Island. One way is to eliminate the entry of microbial pathogens into Narragansett Bay waters. This represents the approach currently taken in Rhode Island. If the access of pathogenic microbes into shellfish is prevented, then the shellfish will be pathogen-free and will be safe to consume.

This approach has the advantages of being logical and straightforward. Preventing contamination of shellfish effectively renders the shellfish contaminant-free. Unfortunately, preventing shellfish contamination by pathogenic microbes to any degree of certainty by eliminating the access of these pathogens to the shellfish is extremely impractical and extremely expensive.

A large number of sources of pathogenic microbes can potentially contaminate Narragansett Bay shellfish. All of these sources would need to be effectively ad-
dressed in order to eliminate contamination. It is theoretically possible to ensure that all sewage entering the Bay from point sources is treated at a minimal level, with appropriate filtration, sedimentation, chlorination, etc. It is also at least theoretically feasible to eliminate uncontrolled combined sewer overflows (CSOs). The economic barriers to these solutions are likely to be far greater than the technological barriers.

However, conventional sewage treatment is not sufficient to eliminate shellfish contamination. Many of the pathogens that contaminate Bay shellfish, including many of the key pathogenic viruses, survive conventional treatment. And since these viruses appear to be responsible for most of the shellfish-related GI disease, it is possible that after spending tremendous amounts of money to conventionally treat all point-source releases of sewage, there would be little measurable public health benefit. In order to produce a significant impact on the prevalence of shellfish-related GI diseases, it may well be necessary to modify conventional sewage treatment to assure destruction of these resistant pathogens. Given current technologies, these modifications would probably be extremely expensive.

Furthermore, the treatment of all point-source releases of sewage still fails to address nonpoint sources of microbial contamination. Eliminating these nonpoint sources of contamination is likely to be exceedingly impractical and, in any case, will require significant additional expense.

Rather than trying to eliminate entry of pathogens into Narragansett Bay, an alternative approach is significantly reducing the risk of shellfish-related pathogen ingestion is to thoroughly cook all shellfish before consumption. Most shellfish pathogens are destroyed by thorough cooking of the meat.

Any practical system developed for sewage treatment will still result in some pathogenic microbes entering the Bay. It will not be possible to remove 100 percent of these microbes of concern, and some residual risk will remain. In addition, there are a number of important pathogens, such as *Vibrio vulnificus*, which are naturally-occurring and unaffected by sewage treatment. Thoroughly cooking shellfish before consumption, therefore, serves not only as an alternative approach to prevention of pathogenic microbe contamination of shellfish, but also as a necessary adjunct to prevention.

The Rhode Island Department of Health is responding to the public health concerns regarding microbial contamination of shellfish by developing a health advisory that cautions the public against the consumption of raw shellfish. This health advisory regarding raw shellfish consumption will be part of a broader health advisory addressing the consumption of a number of raw foods, including shellfish, fish, meats, eggs, and milk. This raw-foods health advisory will recommend, among other things, that milk and certain cheeses be pasteurized before consumption, and that raw meats, including fish and shellfish, be thoroughly cooked before consumption. It is important for the public to be aware that consuming raw shellfish carries a very real risk of contracting disease. It is the Department of Health's position that there is really no way to adequately protect the public from the risk of microbial pathogens without giving the public the information it needs to wisely make decisions on its own.

**Chemical Contamination**

**Prevalence of Contamination and Health Effects**

The issues regarding chemical contamination of shellfish are somewhat different than those for microbial contamination. A number of sources of chemicals can potentially contaminate shellfish, including sewage discharge, nonpoint source pollution, and direct chemical discharge. Sewage discharges that contain chemicals include both industrial and residential sewage, and these include both treated and untreated sewage. Much of the contamination of the Bay by toxic and hazardous chemicals originates in residential discharges of cleaning materials, solvents, and other chemicals used in the home. Nonpoint source pollution includes runoff of rainwater from paved surfaces (carrying with it petroleum products, spilled chemicals, etc.) and runoff from agricultural lands (carrying with it nitrates, ammonia, pesticides, etc.). Direct discharges of chemicals include chemical spills from boats, chemical releases from ruptured tanks and piping, and intentional discharges of chemicals. Although spills and catastrophic events can have major impacts, most chemical contamination of Narragansett Bay results from slow, continual discharges.

With respect to shellfish contamination, chemicals which persist in the environment or in shellfish or chemicals that bioaccumulate are of particular concern. These
chemicals include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs; which include some of the larger chemicals found in many petroleum products), many pesticides, some synthetic chemicals commonly found in Rhode Island industries, and metals.

The prevalence of chemical contamination of Narragansett Bay shellfish is not known. Available monitoring data do not allow an accurate assessment of the degree or extent of chemical contamination of shellfish in the Bay. Monitoring needs to be expanded for a wide variety of chemicals in a large number of commercially important species. In addition to developing a statewide program to monitor the chemicals of concern in the shellfish species of interest, it is necessary to develop appropriate responses to situations when chemical contamination is detected.

The types and severity of the health effects that may result from consuming these chemicals of concern cover a very wide range, from mild gastrointestinal irritation and stomach upset to cancer. Many potential carcinogens can accumulate or persist in shellfish; they carry a risk of cancer for those who consume them. Eating shellfish contaminated with PCBs or PAHs, for example, does not automatically result in the development of cancer. However, by consuming shellfish contaminated by a potential carcinogen, the risk for developing cancer will be increased. The amount of contaminated shellfish consumed and the levels of potential carcinogens in those shellfish directly impact the overall risk.

Shellfish contaminated by potentially carcinogenic chemicals are by no means the only source of cancer risk for individuals who consume that shellfish. In the United States today, exposures to variable amounts of potential carcinogens in air, food, water, and other environmental media are very commonplace. It is far more difficult to avoid such exposures than to encounter them. In addition, carcinogens are not all alike; chemicals that potentially cause cancer vary tremendously in their ability to do so.

**Risk Assessment**

Fish and shellfish are important and valuable dietary components for many people. Therefore, messages regarding the safety of contaminated fish and shellfish must be put into proper perspective. Alternatives to fish and shellfish for consumers may also be potentially unsafe or carcinogenic. Certain meats, such as beef, pork, and lamb for example, have been strongly implicated as potential causes of colon cancer as a result of their fat content. Eating many of the common alternatives to chemically contaminated fish or shellfish, therefore, may carry a carcinogenic risk that equals or exceeds the risk of the contaminated fish or shellfish. In making decisions regarding the safety of consuming chemically contaminated seafood, one needs to take into account the benefits of consuming fish and shellfish.

For those chemicals that have an FDA Tolerance Limit, or for which an equivalent standard for ingestion can be derived, a quantitative risk assessment can be performed. In other words, a numerical analysis to derive a theoretically "safe" concentration of the chemical can be performed. The protocol in Appendix I has been developed by the Department of Health to deal with this type of situation. Unfortunately, this does not represent the usual type of situation. In the usual situation, there is insufficient information to develop a standard for a chemical, and different approaches need to be taken. A number of alternative approaches for addressing these more difficult chemicals are under consideration at both the federal and state levels, but satisfactory solutions will take some time.

The "Protocol for Issuing Health Advisories on Consumption of Fish and Shellfish" (Appendix I) is designed to issue four levels of health advisories. Level 0 of the protocol represents a situation where no health advisory is issued because chemical contamination is not considered sufficient to warrant issuing any advisory.

At Level 1, a health advisory is issued which recommends that the general population restrict consumption of the contaminated food to one meal per week. It also advises that sensitive subpopulations consume none of the contaminated food.

At Level 2, a health advisory is issued that recommends consumption of the contaminated food by the general population no more frequently than once per month. Again, sensitive subpopulations are advised to consume none of the contaminated food. In addition, a Level 2 contamination also requires that commercial sale of the contaminated species be banned and that applicable shellfish bed(s) be closed.

At Level 3, the health advisory advises that no one in the general population consume the contaminated food. Commercial sale of the contaminated species is banned and the applicable shellfish bed(s) are closed.
The criteria for assigning a particular contamination situation to a given health advisory level allows consideration of both statistical factors and contamination by multiple chemicals. The issue of multiple contaminants is dealt with by the calculation of a hazard index (see Appendix 1). The hazard index represents a summed risk for developing a given health effect from the multiple agents that are present as contaminants; it is assumed that the individual risks of these agents can be added. (See Appendix 1 for an explanation of hazard index calculation.)

To date, this new protocol has been used for a pair of finfish species, striped bass and bluefish, that are contaminated with PCBs. When the protocol was applied to the data for PCB contamination in these species, the following results were obtained: Health advisories were issued for consumption of striped bass—Level 2 for lengths between 26 and 40 inches, and Level 1 for any shorter or longer length. A Level 1 health advisory was issued for consumption of bluefish that were 25 inches or longer.

The size differences for striped bass reflect the fact that multiple distinct populations of striped bass (age cohorts) comprise the total population, and these different size cohorts have different ambient levels of PCB contamination. In addition, the significant impact on Rhode Island fishermen due to a ban on commercial sale for species that are issued Level 2 health advisories made it important to consider size slots to differentiate subpopulations of striped bass, and the protocol allows this type of flexibility.

The "Protocol for Issuing Health Advisories on Consumption of Fish and Shellfish" makes the process of evaluating and responding to situations of shellfish contamination by chemicals more consistent and objective. However, the protocol is only a tool and its useful application requires that appropriate data be collected. As such, the current monitoring of Narragansett Bay shellfish for chemicals of concern, in all relevant species of interest, needs to be significantly improved.
APPENDIX I

Protocol for Issuing Health Advisories on Consumption of Fish and Shellfish
Office of Environmental Health Risk Assessment, Rhode Island Department of Health
January 18, 1990

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>CRITERIA</th>
<th>ACTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Less than 10% of the samples of a valid sampling exceed the U.S. FDA Tolerance Limit or the State of Rhode Island Action Level for any contaminant, and The Hazard Index* of that valid sampling does not exceed unity (1)</td>
<td>No Health Advisory</td>
</tr>
<tr>
<td>1</td>
<td>10 to &lt;30% of the samples of a valid sampling exceed the U.S. FDA Tolerance Limit or the State of Rhode Island Action Level for any contaminant, and The Hazard Index* of that valid sampling does not exceed Two (2); or The Hazard Index* of a valid sampling exceeds unity (1) but does not exceed Two (2);</td>
<td>Health Advisory recommending that this species of fish or shellfish not be consumed by &quot;sensitive&quot; populations, such as pregnant women, women who may become pregnant, nursing mothers, children, and other persons determined to be in a high risk group (sensitive populations to be determined on a case-by-case basis), and recommending that all others limit consumption of this species of fish or shellfish to one meal per week; in addition, if the contaminant is a fat-soluble agent, provide recommendations for food preparation to minimize exposure to the contaminant (e.g., removing skin, trimming off fat, avoiding dark meat, cooking so as to allow removal of fat)</td>
</tr>
</tbody>
</table>

* The Hazard Index of a sample is calculated as follows:
For one or more contaminants, the Hazard Index (HI) is the sum of the ratios of the measured concentration of each contaminant to its respective Tolerance Limit or Action Level.

A separate HI is calculated for each toxic endpoint of concern, for example cancer, kidney damage, nervous system damage, liver damage, etc. All detected contaminants capable of inducing (as determined from animal or human data) the given toxic endpoint are included in the calculation of the HI. For purposes of conservatively biasing toward overprotection of human health in situations where necessary information is incomplete, all contaminants known or suspected of being carcinogenic (EPA Cancer Categories A, B1, B2; IARC Classification 1 or 2) are included in the calculation of a cancer HI. The HI for any toxic endpoint is calculated as follows:

\[ HI_{\text{endpoint}} = \sum_{i=1}^{n} \frac{C_i}{L_i} \]

Where \( C_i \) = contaminant detected, \( L_i \) = mean measured concentration of contaminant, and \( L = \) U.S. FDA Tolerance Level or State of Rhode Island Action Limit for the contaminant.
| 2 | 30 to 50% of the samples of a valid sampling exceed the U.S. FDA Tolerance Limit or the State of Rhode Island Action Level for any contaminant, and The Hazard Index* of that valid sampling does not exceed Five (5); or The Hazard Index* of a valid sampling exceeds Two (2) but does not exceed Five (5) | Health Advisory recommending that this species of fish or shellfish not be consumed by "sensitive" populations, such as pregnant women, women who may become pregnant, nursing mothers, children, and other persons determined to be in a high risk group (sensitive populations to be determined on a case-by-case basis), and recommending that all others limit consumption of this species of fish or shellfish to one meal per month; in addition, if the contaminant is a fat-soluble agent, provide recommendations for food preparation to minimize exposure to the contaminant (e.g. removing skin, trimming off fat, avoiding dark meat, cooking so as to allow removal of fat) and Ban on the Sale of this species of fish or shellfish (covering those populations of the affected species meeting these contamination criteria; e.g. all fish of the given species caught in Rhode Island waters) and/or Closure of Applicable Shellfish Beds to harvesting |
| 3 | >50% of the samples of a valid sampling exceed the U.S. FDA Tolerance Limit or the State of Rhode Island Action Level for any contaminant; or The Hazard Index* of a valid sampling exceeds Five (5) | Health Advisory recommending that no one consume this species of fish or shellfish, and Ban on the Sale of this species of fish or shellfish (covering those populations of the affected species meeting these contamination criteria; e.g. all fish of the given species caught in Rhode Island waters) and/or Closure of Applicable Shellfish Beds to harvesting |

U.S. FDA = United States Food and Drug Administration
QUESTIONs AND ANSWERS

Q: (Mr. Richard Bellavance, Seven Seas Shellfish) You made the statement that a considerable amount of shellfish comes from closed areas. What is the basis of your information?

A: (Dr. Bela Matyas) Mostly Department of Environmental Management reports, and reports from the Narragansett Bay Project. They are very disputable values. I would be willing to make a firm argument that some shellfish comes from polluted areas, but not how much comes from those areas, because the values I have seen are highly variable. It only takes a little polluted shellfish to cause problems if it finds its way to the right population and causes an epidemic.

Q: (Bellavance) Have there been any documented cases of gastroenteric diseases or hepatitis traced to shellfish from Rhode Island?

A: (Matyas) I don’t know about Rhode Island, but there have been documented cases in New York, the Gulf States, and California. I have been in Rhode Island for only a few years, and there has not been a case during my time here. I cannot give you an answer about epidemics in Rhode Island beyond two years ago.

Q: (Mr. Jamal Kadri, Save The Bay) You mentioned the Narragansett Bay Project’s recommendations for studies prior to issuance of health advisories, particularly the estimation of severities of outbreaks. Is the Health Department going to issue health advisories anyway, or do you want to better document actual outbreaks?

A: (Matyas) We have made every effort to better document, and I have listed a number of reasons in the prevalence portion of the discussion about why this is not practical. What it would require is to educate everybody in Rhode Island to be especially suspicious of all GI diseases, seeing their physician each time. Then it would require re-educating all physicians to do a complete GI workup on all these patients, basically committing the state to spending millions of needed health care funds to get an answer which confirms that which is logically unimpeachable. There is no practical way of better documenting. What we can do is rely on existing information. That existing information consistently tells us that the incidence of shellfish-related GI problems is under-reported by at least 100-fold, which means that there is a lot of disease out there.

Q: (Dr. Walter Blogoslawski, National Marine Fisheries Service, Milford) Has the state considered depuration as a means for reducing shellfish-associated health risk?

A: (Matyas) There have been numerous discussions between the Narragansett Bay Project and shellfishermen’s groups concerning depuration. I believe that the discussion is ongoing. The Health Department is in no position to require depuration. The decision would have to be made by the industry itself; the state will not make moves in that direction without the consent of the industry. If depuration is done and it is shown to be effective, then obviously there would be no need for a health advisory. But many forms of depuration effectively result in a cooked product in terms of taste or palatability, so you are replacing one with the other.

Q: (Blogoslawski) You mentioned Giardia as a potential problem. Have there been any documented cases of giardia surviving salt water to the point that it could be a health hazard in shellfish?

A: (Matyas) I have not seen any cases of problems in shellfish beds well out in a bay. I have seen reports of incidences of giardia in shellfish from beds well up river, in areas which are certainly tidal, but not in areas continuously immersed in seawater. So to answer your question: Yes, I have seen reported cases of giardia from shellfish, and giardia is a health risk, depending on how sensitive you are. With all of these diseases, the severity of the disease is very individualized. For most people, the disease will be self-limited and will not result in a problem. If you are only concerned with mortality, only a very small portion of the population is at risk from that. As a physician, I think that people getting the runs on a regular basis is pretty gross, and that this is one thing that people do not need to be exposed to. They need to be told that they could avoid that by cooking shellfish. Morbidity, to me, is as important to prevent as mortality.
Shellfish Safety: Human Health Implications of Toxic Contamination in Narragansett Bay, Rhode Island

Katrina Kipp
U.S. Environmental Protection Agency Region I, Boston, MA 02203

Synopsis. Like most urban estuaries, Narragansett Bay in Rhode Island has serious problems with contamination of its waters and sediments from toxic pollutants, including metals and organics. A major concern is the potential risk to human health from consumption of contaminated seafood. Research has shown that organisms such as fish and shellfish that are exposed to toxics tend to accumulate the compounds in their tissues. At high enough levels, these compounds pose a threat not only to the fish themselves, but also to humans who may catch and eat fish from contaminated areas.

A series of risk assessment analyses were conducted, using chemical levels measured in Narragansett Bay quahogs (Mercenaria mercenaria). These analyses provide a measure of the potential risks to humans from exposure to various chemicals through consumption of Narragansett Bay quahogs. The results of the risk assessment indicate that the highest potential risks of adverse health effects are associated with Providence River quahogs, and with high levels of consumption. The risks are due primarily to organic, oil-based polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), and possibly the metal cadmium. Although estimated risks associated with consumption of Narragansett Bay quahogs are not high enough to be an immediate health threat, in some instances, estimated risks may be unacceptable. Chemical contaminants that appear in measurable quantities in foods should always be a concern because the presence of toxics in fish tissue is indicative of contamination of water, sediments, and/or the food source. Until this is addressed through source reduction and other pollution abatement strategies, seafood contamination and the associated potential health threats will remain a problem.

Introduction

A major concern for Narragansett Bay and for other coastal areas throughout the U.S. is the safety of seafood for human consumers. Urban estuaries and coastal areas have serious problems with chemically contaminated waters and sediments associated with chronic point and nonpoint source discharges. Municipal and industrial effluents, combined sewer overflows, and stormwater runoff, as well as atmospheric deposition, contribute toxic chemicals to coastal waters. These toxics tend to adsorb to particles that eventually settle to the bottom, resulting in accumulation of the toxics in the sediments. Bottom-dwelling marine organisms accumulate chemicals from the sediments and water to which they are exposed, and when they consume food that contains toxics, tissue concentrations of contaminants in these organisms tend also to be high. This toxic transport process has led to a growing concern by seafood consumers about potential health risks from eating fish and shellfish that may contain toxic chemicals.

The Narragansett Bay Project (NBP), a U.S. Environmental Protection Agency (EPA) National Estuary Program, was established in 1985 for the purpose of evaluating water quality problems in Narragansett Bay and developing a comprehensive management plan to protect and improve the Bay. The NBP identified seven priority issues for research. These issues were toxic contamination, nutrients and eutrophication, health of living resources, fisheries management, health risks from contaminated seafood, land uses, and recreational uses. This paper summarizes the project’s efforts to address the issue of health risks associated with contaminated seafood.

Because of the importance of seafood to the state, early in the Narragansett Bay Project, the NBP Management Committee identified potentially contaminated...
seafood and associated possible health risks as a priority issue. Specific management questions related to seafood contamination were developed and research was designed to answer these questions. The answers will allow resource managers and public health officials to most effectively manage the fisheries and reduce potential health risks. The questions posed by the Narragansett Bay Project regarding chemically contaminated seafood were as follows:

- Does Narragansett Bay seafood from approved harvest areas pose a risk to human consumers if consumed in moderate amounts? In large amounts?

- In the event that shellfish beds currently closed due to pathogens may be considered for reopening for harvest, are there areas that should remain closed due to unacceptable risks from chemical contaminants in the quahogs?

- Are improvements in water quality due to implementation of pollution abatement strategies likely to result in a reduction of tissue contaminant levels and an accompanying reduction in health risk?

- Are current government regulatory programs and risk management efforts effective in protecting

<table>
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<th>Data Set*</th>
<th>Species</th>
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<th>Organics*</th>
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<td>Quahog</td>
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<td>PAHs</td>
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<td>Quahog</td>
<td></td>
<td>PAHs, PCBs</td>
</tr>
<tr>
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<td>Cullen, 1984</td>
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<td>DDT, DDD, DDE</td>
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<td></td>
</tr>
<tr>
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<td>PAHs, PCBs, DDE</td>
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<td>Cadmium, Chromium, Copper, Lead, Nickel, Zinc</td>
<td></td>
</tr>
</tbody>
</table>

* See References for full citation

* Other chemicals may have been analyzed but were not included in the Narragansett Bay risk analyses.

* Project funded by the Narragansett Bay Project

* Table 1. Data sets used in Narragansett Bay risk assessment.
consumers from risks associated with contaminated seafood?

To help answer these and other questions, the Narragansett Bay Project funded a number of studies to measure chemical levels in tissues of important commercial and recreational species. Assessments of the potential health risks to consumers of Narragansett Bay quahogs and winter flounder were conducted using these tissue levels as well as other available data. This paper only deals with the findings for quahogs. The purpose of the risk assessment was to provide a framework for evaluating the potential hazards to human health from eating Narragansett Bay seafood. The next step will be to determine the regulatory risk management activities necessary to reduce any unacceptable hazards and protect human health.

Research Results

Studies used in the risk assessment analyses are listed in Table 1, along with the chemicals and species evaluated in each study. Thibault/Bubly Associates (1989), Cullen (1984), Cullen and King (1990), and the Rhode Island Department of Health (unpublished) measured metal levels in the quahog. Pruell et al. (1984, 1988) and Quinn et al. (1989) evaluated levels of organic compounds in quahogs.

Analyses of tissue residues of shellfish from Narragansett Bay generally show some correlation between tissue levels and water and sediment levels. Organics and copper are more closely correlated with sediment concentrations and other metals are more closely correlated with water column concentrations (Quinn et al., 1989; Cullen and King, 1990). Tissue levels of metals (Thibault/Bubly Associates, 1989; R.I. Dept. of Health, unpublished; Cullen, 1984; Cullen and King, 1990) and organics (Pruell et al., 1988; Quinn et al., 1989) are highest in the contaminated Providence River, located in the most urbanized area of the watershed. The water, sediment, and tissue concentrations tend to follow a decreasing down-Bay gradient with concentrations lowest in the lower Bay. Figure 1 shows this down-Bay gradient for several metals. This type of pattern is similar to other urban estuaries such as New Bedford Harbor.

![Graphs of Silver, Cadmium, Copper, and Nickel concentrations](image)

*Figure 1. Narragansett Bay dissolved trace metal concentrations (Bender et al., 1987).*
Risk Assessment Methodology

Risk assessment is a tool used to determine the magnitude and probability of potential harm to human health by exposure to toxic substances. Risk assessment is based on scientific information combined with certain assumptions. Although a number of uncertainties exist in this approach, it can be an effective tool for quantifying risks and providing estimates of potential health risks from various sources, in this case from consumption of seafood containing toxic contaminants. It also is used in making regulatory risk management decisions on the appropriate course of action to protect human health. The objective of the risk analysis described in this paper was to evaluate the magnitude of contamination of quahogs in Narragansett Bay and the implications for human health, if any.

EPA has developed guidelines for performing risk assessments and has issued a guidance manual, Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish (U.S. EPA, 1989), specifically for seafood risk assessment. This manual was the basis for most of the risk assessment analyses for Narragansett Bay. Basically, the risk assessment procedure for seafood consists of determining the dose of a chemical a human would be exposed to during a lifetime based on certain consumption rates of seafood with observed tissue levels, and predicting the likelihood of adverse health effects from this dose based on EPA toxicity values.

A risk assessment usually consists of the following steps:

1. Hazard identification. This step involves the identification of the chemicals of concern and the potential health effects that could occur as a result of exposure to those chemicals. Key data sets are identified and the chemicals of concern are selected based on their presence in significant quantities and their known health effects.

2. Exposure assessment. This step consists of identifying the human populations that may be exposed to the chemicals of concern and estimating the rate of exposure. Both the averagely exposed (mean exposure level) and maximally exposed individuals are identified ("maximally exposed" usually represents the upper 1 percent or 0.1 percent of the population) and exposure (consumption) rates are also determined.

3. Dose-response assessment. This is an assessment of the potential toxicological response to various doses of the chemicals of concern, usually based on laboratory animal toxicological tests. The likelihood of adverse human health effects are extrapolated from the animal tests. This information is usually obtained through EPA’s Integrated Risk Information System (IRIS) and other sources.

4. Risk characterization. This is the estimation of the potential risks of adverse health effects based on dose-response data and exposure data. The dose is estimated based on contaminant levels and exposure rate. The dose estimates are combined in the risk assessment model with the dose-response toxicity values to generate upper-bound estimates of the likelihood of potential health effects.

The dose is calculated using the following equation:

$$Dose = \frac{C \times CR \times BW}{CR_{fish}}$$

Where: $C = \frac{consumption\text{\ of\ contaminant\ in\ the\ fish\ tissue}}{BW = average\ human\ body\ weight\ (70\ kg)\ \text{of population}}$

Standard assumptions that are made include: (1) exposure over a 70-year lifetime, (2) average human body weight of 70 kg during the lifetime exposure, and (3) 100 percent of all chemicals ingested (10 percent for mercury) are absorbed.

The dose is then combined with dose-response toxicity values (from EPA) to estimate risks. Risk characterization for humans is conducted separately for carcinogens (cancer-causing) and non-carcinogens (non-cancer health effects such as neurological disorders). Generally, organic chemicals such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides fall into the carcinogen category and metals into the non-cancer category for oral exposure. Some chemicals are in both categories and therefore are included in both types of risk assessment.

The cancer risk estimates are generated using the following equation:

$$Dose \times CPF = \text{Increased Cancer Risk}$$

Where: CPF = Cancer Potency Factor (from EPA).
The toxicity value, or CPF, is a statistically derived value that attempts to quantify the finite risk of cancer at various doses.

Potential increased cancer risks are calculated for each chemical. Carcinogenic risk estimates can then be summed across all chemicals and all species to provide a probability of increased cancer risk from exposure to the chemicals of concern. This approach to additivity does not account for possible antagonistic or synergistic effects of the chemicals.

The carcinogenic risks are expressed in terms of predicted additional cases of cancer in an exposed population over a lifetime as a result of exposure to the chemical(s) of concern (e.g., 2.7 additional cancer cases in 100,000 individuals = 2.7 x 10^-5). There is no single level of risk that is considered acceptable. Various EPA regulatory programs define acceptable risk differently, with levels ranging from a higher level of risk of 1 in 10,000 (10^-5) to a more conservative and protective level of 1 in 10 million (10^-7), depending on the particular program. Generally, risk estimates less than 10^-3 are considered acceptable. Determination of an acceptable risk is a risk management decision to be made by the responsible regulatory agency (e.g., a state health department). The non-cancer risks are evaluated using the following equation:

\[
\text{Hazard Ratio} = \frac{\text{Dose}}{\text{RfD}}
\]

Where: RfD = Reference Dose (from EPA).

The estimated highest average daily exposure to humans over a lifetime unlikely to cause adverse health effects is the reference dose (RfD).

Because the RfD reflects the "acceptable dose" below which no adverse health effects would be expected, any observed dose below the RfD would be considered acceptable. This means that if the hazard ratio is less than 1, the dose is safe. If the hazard ratio is 1 or greater, then adverse health effects may be likely, with the likelihood increasing as the hazard ratio increases. Similarly to cancer risks, non-cancer risks are considered additive, but only when the chemicals affect the same target organ. The significance of the hazard index, the sum of additive hazard ratios, is also evaluated by comparison to 1.

A number of conclusions can be made based on the results of a risk assessment. However, the risk assessment methodology has numerous assumptions and uncertainties associated with it. It should be kept in mind that the risk numbers should be considered estimates of plausible, upper-bound risks that can be used to evaluate the relative hazard associated with exposure to various toxics and routes of exposure. These risks are not to be considered indicative of the actual risks one might experience but are most likely much higher, because safety and uncertainty factors are incorporated into the development of toxicity values. The risk assessment methodology used by EPA is purposefully very conservative and this must be kept in mind when evaluating risk management alternatives.

RISK ASSESSMENT FOR NARRAGANSETT BAY QUAHOGS

For hazard identification, seven data sets were identified (Table 1) and compiled into a data base for use in the risk assessment process. Figure 2 shows the sampling stations for the data sets. Seven data sets may seem like an excellent data base but there are a number of limitations on the data. Most importantly, as can be seen from Table 1, not all data sets include the same species and chemicals. Four data sets contain data on metals in quahogs, but not all the same chemicals; three data sets contain organics data for quahogs, but not all the same ones. Secondly, although there were numerous sampling locations throughout the Bay, there are still gaps in the coverage and many areas of the Bay were not sampled. Outfalls and hot spots were not targeted, and Mount Hope Bay was not sampled near pollution sources. The data for each chemical were compared between data sets, where possible, and most were statistically similar; however, there is some variability between and within data sets. It is impossible to tell if this is due to sampling variability, different analytical techniques, or some other factor.

Of the numerous chemicals measured in species of interest (i.e., quahogs), several were identified as chemicals of concern (Table 1) and were included in the risk analyses. These chemicals were selected based on their presence in significant quantities in the water column and in sediments in Narragansett Bay and because they are known to cause health effects. Some chemicals were not included because they were either found in extremely low concentrations or no toxicological information was available.
Figure 2. Narragansett Bay quahog sampling stations. Shading indicates areas permanently closed to shellfishing. Seasonal and conditional closure areas are not shown.
<table>
<thead>
<tr>
<th></th>
<th>Cancer Risk</th>
<th>% Variation from Open Areas</th>
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</thead>
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<tr>
<td><strong>Average Consumption</strong></td>
<td></td>
<td></td>
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<tr>
<td>1.2 g/day quahog meat</td>
<td></td>
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<tr>
<td>Open Areas</td>
<td>7.8 in 1,000,000</td>
<td></td>
</tr>
<tr>
<td>Providence River</td>
<td>13.0 in 1,000,000</td>
<td>58.0</td>
</tr>
<tr>
<td>Mount Hope Bay</td>
<td>7.7 in 1,000,000</td>
<td>-1.4</td>
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<tr>
<td><strong>Maximum Consumption</strong></td>
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<tr>
<td>15.5 g/day quahog meat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Areas</td>
<td>1.9 in 10,000</td>
<td></td>
</tr>
<tr>
<td>Providence River</td>
<td>3.0 in 10,000</td>
<td>64.1</td>
</tr>
<tr>
<td>Mount Hope Bay</td>
<td>1.6 in 10,000</td>
<td>-18.7</td>
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</table>

Table 2. Estimated total upper bound lifetime cancer risks associated with consumption of Narragansett Bay quahogs.

In the exposure assessment, the magnitude and duration of the exposure of humans to the chemicals of concern in Narragansett Bay were determined. Dose estimates were calculated based on site-specific consumption rates and observed tissue concentrations of the chemicals for each species. Consumption rates for Rhode Island were developed on four national seafood consumption surveys summarized by Hu (1985), EPA-suggested rates (U.S. EPA, 1989), and preliminary results of a Rhode Island consumption survey currently being conducted by investigators at the University of Rhode Island.

Consumption rates were developed for two populations, average consumers and maximum consumers, based on the standard assumptions of a 70 kg human over a 70-year lifetime. The average consumer represents the "typical" Rhode Island consumer who eats about 3 meals per month of a variety of seafood from various sources, some of which may come from Narragansett Bay. It should be noted that for the average consumer, surveys indicate that canned tuna accounts for most of the seafood eaten. The maximum consumer (in this case, assumed to be 0.1 percent or less of the population) represents the worst-case scenario and was assumed to be a recreational or subsistence fisherman who would consume large quantities of seafood harvested from the Bay. The estimated consumption rate of Narragansett Bay quahogs for the average consumer is 1.2 g/day (about 2.9 meals/year) and for the maximum consumer is 15.0 g/day (about 36.5 meals/year). The meal size in this case (1/3 lb) is based on U.S. EPA (1989) data, but can be varied without changing the results of the risk analyses.

Exposure (= dose) was calculated from the consumption rates and the actual measured concentrations of chemicals in the clam tissues. For the average consumer, the mean tissue concentration and the average consumption rate were used to calculate the dose. The dose for the maximum consumer was calculated using the highest observed values of the chemicals and the maximum consumption rate.

The dose estimates were combined in the risk assessment model with the dose-response toxicity values to generate upper-bound estimates of the risk of potential health effects associated with the consumption of Narragansett Bay quahogs contaminated with specific chemicals.

Risk estimates for Narragansett Bay were calculated for several scenarios. Estimates were made for both average and maximum consumers. Data for quahogs were segregated and analyzed according to the geographic area from which the clams were collected. Separate risk calculations were done for clams from the following areas:

1. open areas (includes seasonal and conditional closure areas)
2. Mount Hope Bay (closed)
3. Providence River (closed)
4. seafood stores.

Figure 2 shows Mount Hope Bay and the Providence River as shaded areas. Data collected at stations within these areas were included in that particular risk scenario. All unshaded areas were included in the open areas category.

A summary of the cancer risk analyses for quahogs from Narragansett Bay is shown in Table 2. Cancer risk is calculated using organic chemical data only, since metals are not known to be carcinogenic via oral exposure. The results indicate that for average consumers, quahogs from any area are within generally acceptable levels (10⁻⁵ to 10⁻⁴). Although consumers of average quantities of quahogs from any area have little increased risk, consumers of maximum quantities of quahogs may have one or two orders of magnitude (10 to 100 times) more risk (10⁻³) than average consumers. These risk
<table>
<thead>
<tr>
<th></th>
<th>Consumption Rate</th>
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<th>Copper</th>
<th>Mercury</th>
<th>Nickel</th>
<th>Zinc</th>
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<td></td>
<td>Max.</td>
<td>0.21</td>
<td>0.24</td>
<td>0.15</td>
<td>0.11</td>
<td>0.049</td>
<td>0.088</td>
</tr>
</tbody>
</table>

Table 3. Hazard ratios for metals in Narragansett Bay quahogs.

Values are at the margin of acceptable risk and should be evaluated closely by state regulators, particularly if the R.I. Department of Health has reason to believe that the population is exposed to elevated levels from other sources (e.g., lead from paint or pesticides from produce). The highest risks for both groups of consumers are associated with quahogs from the Providence River; however, the risk is less than two times that from quahogs in open areas. Risks associated with quahogs from Mount Hope Bay are similar to open areas. Risk estimates for maximum consumers were about 20–25 times higher than for average consumers.

When the cancer risks attributable to the various chemicals for the different scenarios were determined, 59-72 percent was due to PAHs and 27-41 percent to PCBs. The various other organic chemicals contributed less than 1 percent of the total cancer risk.

Risk estimates for quahogs purchased from seafood stores were calculated based solely on PAH levels; these clams were found to have acceptable levels of risk. The cancer risk for average consumers was 1.2 x 10⁻⁴ and 4.2 x 10⁻⁸ for the maximum consumer. Levels of contaminants in clams from stores were about 10 times higher than clams collected from a control location on Dutch Island in the lower Bay (see Figure 2 for location). This may reflect the fact that more shellfish activity occurs in the upper Bay which is in closer proximity to sources of toxics.

The results of the risk assessment for noncarcinogens are presented in Table 3. Any hazard ratio greater than 1 represents a potential for adverse health effects. For metals in Narragansett Bay quahogs, cadmium is the only metal with a hazard ratio greater than 1 (in open areas and the Providence River). Mount Hope Bay is less than 1. This is probably a result of the methodology for calculating the hazard ratio for the maximum consumer. The maximum cadmium concentration observed was used to calculate the dose; however, a close examination of the data reveals that the cadmium maximum for both open areas and the Providence River are probably outliers. Recalculating the hazard ratio using the next lowest value for each data set results in a hazard ratio of 0.59 for open areas (instead of 1.5) and 0.20 for the Providence River (instead of 5.0).

As with cancer risks, non-cancer risk estimates can be summed across all chemicals and all species to provide a probability of increased cancer risk from exposure to the chemicals of concern. However, risk additivity only applies when the chemicals affect the same target organ. This type of analysis was not possible for the non-cancer risk because none of the chemicals were additive by oral exposure.

Lead is not included in Table 3. Because of the severity of health effects associated with lead and the numerous sources of exposure, EPA no longer recommends using the simplistic method of calculating a hazard ratio for lead. EPA has developed an uptake/biokinetic computer model that allows all routes of exposure to be evaluated at once. Lead concentrations in seafood tissue and local consumption rates can be input and the model can predict increased blood lead levels based on the specified exposure. Preliminary work with this model indicates that dietary exposure from Narragansett Bay quahogs and winter flounder probably would result in minimal increases in blood lead levels, especially considering other major sources such as dust.
and air. Further work with this model using Rhode Island-specific lead data is in progress.

To put risk estimates in perspective, it is helpful to present the results in a format that is easier to understand than lists of risk numbers. It is also useful to compare the results to other similar activities and to results from other areas. Figure 3 shows the estimated cancer risk for various levels of quahog consumption. A person can determine their own rate of consumption in meals per year and see what additional risk is associated with it. This figure also clearly shows the difference in risk between clams from different areas. At low consumption rates, the differences are minimal but they become more significant at higher rates.

Table 4 compares the results of the risk assessment for Narragansett Bay quahogs to risks from other eating and drinking activities, including consumption of seafood from highly contaminated areas. Quahogs from Narragansett Bay are relatively safer than fish from New York Harbor or Lake Michigan; or clams, lobster, and flounder from Quincy Bay (Note: There are no quahogs in Quincy Bay.) Comparisons of average tissue concentrations in Narragansett Bay quahogs to national averages for various chemicals and to levels measured in other areas show that Narragansett Bay levels are similar and are not elevated relative to the rest of the country (Bender et al., 1989; Capar, 1988; Hoffman, 1990).

It should be noted that this risk assessment is subject to a number of uncertainties, assumptions, and limitations that may contribute to a potential overestimation of actual risk. In particular, it does not account for interactive effects of chemical mixtures, sensitive populations, effects of cooking, or other sources of the same chemicals. Limitations of the data have also been discussed. Site-specific consumption information is needed to validate the consumption rates used in this analysis. Despite these limitations, the results of the risk assessment can be used to make some preliminary judgments about the risks associated with consumption of Narragansett Bay quahogs and to identify areas where additional monitoring and analyses are needed.
Table 4. Estimated average lifetime cancer risks associated with various eating and drinking activities.

<table>
<thead>
<tr>
<th>Source of Risk</th>
<th>Average Lifetime Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York Harbor fish - average - 30 lb/yr</td>
<td>9 in 1000</td>
</tr>
<tr>
<td>Lake Michigan fish - average - 13 lb/yr</td>
<td>6 in 1000</td>
</tr>
<tr>
<td>Quincy Bay seafood (including tomalley) - average - 2.5 lb/yr</td>
<td>1 in 1000</td>
</tr>
<tr>
<td>Diet Soda (saccharin) - 12.5 oz./day</td>
<td>7 in 10,000</td>
</tr>
<tr>
<td>Peanut Butter ( aflatoxins) - 4 tsp/day</td>
<td>6 in 10,000</td>
</tr>
<tr>
<td>Puget Sound seafood - average - 10 lb/yr</td>
<td>2 in 10,000</td>
</tr>
<tr>
<td>Milk ( aflatoxins) - 1 pt/day</td>
<td>1 in 10,000</td>
</tr>
<tr>
<td>Quincy Bay seafood - average (excluding tomalley) - 2.5 lb/yr</td>
<td>8 in 100,000</td>
</tr>
<tr>
<td>Miami/New Orleans drinking water - 2 liters/day</td>
<td>7 in 100,000</td>
</tr>
<tr>
<td>Narragansett Bay winter flounder - average - 1 lb/yr</td>
<td>2 in 100,000</td>
</tr>
<tr>
<td>Narragansett Bay quahogs - Providence River - average - 1 lb/yr</td>
<td>1 in 100,000</td>
</tr>
<tr>
<td>Narragansett Bay quahogs - Open Areas - average - 1 lb/yr</td>
<td>8 in 1,000,000</td>
</tr>
<tr>
<td>Narragansett Bay quahogs - Mount Hope Bay - average - 1 lb/yr</td>
<td>8 in 1,000,000</td>
</tr>
</tbody>
</table>

**RISK MANAGEMENT**

After the risk assessment is completed, the next step is for the responsible regulatory agencies to decide the appropriate risk management response. The risk assessment provides the scientific basis for regulatory decision-making. In risk management, risks are interpreted in the context of economics, politics, law, and social factors, and the appropriate actions (e.g., consumption advisory) are determined. The regulatory agency must weigh the risks associated with an activity such as eating contaminated fish against the potential benefits associated with that activity (e.g., decreased heart disease), and then identify acceptable risks and implement control strategies.

There are several federal and state agencies with jurisdiction to regulate contaminated seafood. These agencies have differing regulatory mandates; and therefore, often have different risk management responses to incidences of seafood contamination.

The U.S. Food and Drug Administration (FDA) is responsible for establishing and enforcing safe levels (tolerances and action levels) for contaminants in fish and shellfish in interstate commerce. FDA does not have jurisdiction over recreational fisheries and FDA tolerances or action levels are not designed for the protection of local consumers of recreationally caught seafood. Such consumers may ingest substantial quantities of seafood caught from a limited geographic area over a long period of time.

The U.S. EPA does not have the authority to regulate consumption of contaminated fish, but it can conduct site-specific risk assessments, using local consumption rates (usually much higher than the national average rates used by FDA in setting levels), and can recommend that states take action to protect public health. The responsibility for regulation of sport fisheries belongs to the state, which may take regulatory action such as an advisory, based on an assessment of the level of contaminant found locally and on local fish consumption rates.

Currently, no mechanism exists for states to address interstate or regional fish contamination problems, except on a state-by-state basis. States usually act independently; rarely do they coordinate risk management activities, and the federal government does not provide much guidance or assistance in dealing with regional issues.

**Conclusions**

As previously discussed, the NBP posed a series of management questions related to chemically contaminated seafood. The risk analyses discussed above were designed with the purpose of answering these questions to the best degree possible. The results of these risk analyses regarding the safety of Narragansett Bay sea-
food allow us to at least draw some preliminary conclusions regarding the answers to the questions, and are discussed below. Based on these preliminary answers, some decisions about risk management strategies or the need for further monitoring and analyses can be made.

Does Narraganset Bay seafood from approved harvest areas pose a risk to human consumers if consumed in moderate amounts? In large amounts?

Generally, results indicate that there is no immediate health threat associated with an average level of consumption of quahogs from any area. This is based on the assumption that cancer risks in the $10^{-2}$ to $10^{-4}$ or lower range are “acceptable.” For persons that eat average or moderate amounts of shellfish, there is little increased risk of adverse health effects. However, persons that eat very large quantities of quahogs harvested from open areas face probable increased risks in the $10^{-4}$ range, above acceptable risk levels. It should be noted that the tissue contaminant levels for quahogs from Narraganset Bay are similar to levels found in other urban estuaries in the Northeast.

It is necessary to closely examine the maximum consumers, especially when the risks are above acceptable levels as in this case. Consumption rates should be closely evaluated to ensure appropriateness. It is also important to consider certain subpopulations when evaluating the need for regulatory action. Some groups may be at relatively greater risk. Sensitive populations, usually pregnant or nursing women and children under 12 years, are often targeted for special protection due to possible reproductive or developmental effects of chemicals. Subsistence fishermen, often ethnic groups in urban areas, may consume large quantities of seafood. This seafood may be routinely harvested from contaminated, closed areas. In addition, these groups may have cultural differences in food preparation resulting in higher exposure, as when fish livers are eaten.

Other sources of the same chemicals should also be examined to determine if seafood is the major route of exposure. In this case, regulatory action may be appropriate. If seafood is a minor source, then regulatory action should focus on the other sources to achieve the maximum benefit.

In the event that shellfish beds currently closed due to pathogens may be considered for reopening for harvest, are there areas that should remain closed due to unacceptable risks from chemical contaminants in the quahogs?

The two currently closed areas considered in the risk assessment for quahogs were the Providence River and Mount Hope Bay. Major contamination problems in these areas from pathogens will have to be addressed before these areas can be considered for reopening. Only then will the toxic contamination of quahogs from these areas become an important issue, except in the case of subsistence fishing. Strategies for eliminating pathogens may reduce inputs of toxics to some degree.

Based on the limited data available, there appears to be no difference in risks associated with quahogs between Mount Hope Bay and currently open areas. However, no sampling stations in Mount Hope Bay were located in likely areas of high toxics contamination (e.g., near major sources such as Fall River and the Taunton River). Metal concentrations in Mount Hope Bay quahogs may have actually increased in recent years (Leigh Bridges, pers. comm.). It would be necessary to collect and analyze quahogs from this area before any decision could be made about reopening all of Mount Hope Bay.

Quahogs collected from the Providence River have a slightly higher risk than quahogs from open areas. This risk is less than twice as large. However, as in Mount Hope Bay, sampling locations were not close to major sources of toxics in the upper Providence River.

Are improvements in water quality due to implementation of pollution abatement strategies likely to result in a reduction of tissue contaminant levels and an accompanying reduction in health risk?

This question cannot be answered based on the risk analyses or available data. It is impossible to discern any long-term trends in tissue contaminant levels, because levels of toxics in fish tissues from Narraganset Bay have only been measured during recent years, not much data exists, and analytical procedures have improved, making it difficult to compare data sets. Examination of existing data has shown no long-term trends (Bender et al., 1989; Quinn, 1989; Latimer, 1989).

The toxics in fish tissues most likely result from either absorption through the skin from contact with contaminated sediments, or bioaccumulation through the food chain. Either way, the only way these levels will be reduced in the long term is through reducing or removing the contamination sources. Because water quality improvements will eventually translate into reduced toxics in the sediment, it can be expected that pollution
abatement strategies will be likely to result in reduced tissue contamination. This process will be slow and improvements will not be immediately evident.

Are current government regulatory programs and risk management efforts effective in protecting consumers from risks associated with contaminated seafood?

At this time, it is impossible to determine if current government regulatory risk management activities have been effective in protecting consumers from potential risks associated with quahogs. Regulatory agencies have essentially taken little action to protect consumers from contaminated seafood, with the exception of bluefish and striped bass. Fortunately, levels of risk for quahogs are relatively low, regardless of the area harvested, except for maximum consumers. This should not be a reason for complacency, as the presence of any toxics in fish tissue is cause for concern. There always exists the potential for discovering higher tissue levels, especially if sampling is focused near known sources or contaminated hot spots. These areas have not been monitored adequately or at all. Additionally, current programs may not be protective enough of certain sensitive populations (e.g., pregnant women) or maximum consuming populations (e.g., subsistence fishermen).

In summary, the risk assessment conducted for Narragansett Bay quahogs indicates that there is little increased health risk associated with a typical rate of consumption of Bay quahogs. Additional research is necessary to further substantiate this finding, and management actions toward toxics reduction will be needed to lower tissue contaminant levels. In the interim, there are some precautions that consumers can take to minimize these risks, including limiting consumption of seafood harvested from known contaminated areas, avoiding consumption of extremely large quantities of seafood from any area, and using proper cooking techniques to reduce contamination levels. Based on this preliminary risk assessment, and following the above precautions, consumers can continue to eat and enjoy Narragansett Bay quahogs without risking a serious threat to their health from toxic contamination.

REFERENCES


Cullen, D. and J. King. 1990. Relationships between Cu, Ni, Cd, Cr and Pb levels in soft tissues of Narragansett Bay Mercenaria and sediments. DRAFT report to the Narragansett Bay Project.


QUESTIONS AND ANSWERS

Q: (Mr. James Boyd, Rhode Island Shellfishermen’s Association) I find it difficult for you to make comparisons in risk assessment between open areas and the Fall River data set. You have an increase of errors in Mount Hope Bay, especially because of lack of data near Fall River. It is known that there has been considerable release of toxics, including PCBs, in the area. To the average lay person, when they look at your data they see that the shellfish from Mount Hope Bay poses less risk than shellfish from the open areas. Aren’t you adding a different twist to the shellfish safety story?

A: (Ms. Katrina Kipp) No, I understand that. One of the drawbacks of risk assessment, or any other quantitative process, is that you are limited by the data you have. There are other caveats besides lack of data from the Fall River area. I am sure that before consideration of opening closed shellfish areas, there would be a need for more monitoring, especially in contaminated areas. Maybe I should clarify this by saying “lower Mount Hope Bay.”

Q: (Mr. Joseph Migliore, Rhode Island Department of Environmental Management, Division of Water Resources) Katrina, I might add that these are chemical parameters. At present, the only criteria for bed closures are based strictly on bacteriological parameters.

A: (Kipp) Yes, and along that same line, if you get to the point when you are about to reopen areas, hopefully if you take care of the pathogen problem, you will also take care of the toxics problem as well.

Q: (Mr. Robert Rheault, Spatco Ltd.) Katrina, as you have pointed out, the Interstate Shellfish Sanitation Conference has only come out with guidelines for PCBs and mercury. How can the state justify coming up with guidelines when the ISSC cannot come up with levels that it feels are safe?

A: (Kipp) The states have the jurisdiction to take site-specific actions and develop their own action levels. If the state were to undertake such an effort, they would want to expand their monitoring capabilities. Fortunately, the levels that we are seeing in Rhode Island do not pose much of a problem. The action levels, if developed, might affect small, heavily contaminated areas such as Allen’s Harbor.
A Raw Deal: Combined Sewer Overflow Pollution in Narragansett Bay

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SYNOPSIS. Combined sewer overflows (CSOs) have long been identified as chronic pollution sources to Narragansett Bay. This paper examines the history of CSO pollution—its environmental effects, economic impacts, and legal implications—and summarizes technical solutions and local CSO abatement efforts.

INTRODUCTION

Most Rhode Islanders do not associate their waterways with raw sewage, yet an estimated four billion gallons of untreated waste will flow into Narragansett Bay and its tributaries this year (Narragansett Bay Project, 1990). As a result, more than 30 percent of Narragansett Bay is permanently closed to shellfishing and another 11,000 acres are conditionally closed when rainfall triggers raw sewage overflows (R. I. Department of Environmental Management, 1990).

The sources of this pollution are the antiquated combined storm and sanitary sewer systems built in the region’s older urban areas before the turn of the century. When it rains, storm sewers in these cities collect millions of gallons of urban runoff. This runoff combines with wastewater flows from homes and industries. These combined volumes often exceed the capacity of the combined sewer system leading to sewage treatment facilities. When this occurs, the excess untreated sewage and urban runoff is discharged directly into the rivers and the Bay. These wet weather overflows are referred to as combined sewer overflows, or CSOs.

HISTORY

Providence experienced tremendous growth during the 19th century, and as the population grew, so did the problems associated with waste disposal. Early industrial development used the flow of the region’s rivers to power machinery, and used the same waterways for the disposal of industrial wastes. Domestic wastes from the growing population of factory and mill workers were also dumped into the rivers or into open cesspools.

By the early 1800s, the number of cesspools, large excrement collection ponds, and “privy vaults” grew to the point that they created nuisances and health hazards. As a result, work began on a combined sanitary and storm sewer system to solve Providence’s waste disposal problems. The combined system carried sewage from households and businesses as well as stormwater from city streets to downtown rivers. This “single pipe” approach was considered ideal for two reasons: First, two kinds of waste were removed by one system, saving time and money; and second, it was believed that dilution and natural processes would render the waste harmless. While this may have been true for the smaller pollutant loadings of the past, the growing population soon overburdened the rivers and harbor with sewage.

By the mid-1800s, Providence rivers had become so grossly polluted that they led to the city’s cholera epidemics of 1849 and 1854. When Dr. Edwin Snow, Providence Superintendent of Health, investigated the Moshassuck River to see if it posed a threat to the health of the city, he found that:

With regard to the deaths in the neighborhood of the canal (Moshassuck River), I answer unhesitatingly that the canal itself was the cause... The condition of the Moshassuck canal during the summer was such that the common sense of the whole city regarded it as a great nuisance. It was as filthy as any common sewer, and the stench arising from it at times pervaded the whole neighborhood. At any time during the summer, numerous fishes might be seen floating on the surface which had been killed by the poisonous water... the water of the river is polluted and rendered exceedingly foul and offensive before it reaches the city... It is certain that much filth is turned
into the river from the city and it must be still more filthy when it reaches the harbor (Edwin Snow, 1854).

According to a city engineer writing in 1884, ". . . upwards of 2,735,000 gallons of filthy liquid wastes [are] emptied daily into the Moshassuck and West Rivers and upwards of 2,088,000 gallons of filthy liquid, aside from the sewage, [are] emptied into the several rivers during 12 or 14 hours out of the 24." A headline in the Providence Journal in 1892 summarized the state of the city's waterways: "Woonasquatucket and Moshassuck: Simply Open Sewers."

Before the turn of the century, the city decided to develop a system to collect and treat its wastes. The construction of a central wastewater treatment facility to provide chemical and physical treatment of these wastes was proposed. Older European cities served as design templates for Rhode Island engineers, who decided to construct interceptor sewers along the banks of the rivers to carry the waste from sewer outfalls to a treatment facility. Where the interceptors connected to the original combined sewers (designed to discharge both stormwater and wastewater directly to the rivers), perpendicular slots and connector pipes were installed (Figure 1). These structures acted, and still act, to regulate the amount of wastewater transferred to the intercepting system. Each slot and connector pipe has a maximum flow capacity—when flows exceed this limit, sewage bypasses the interceptor and discharges directly into the river or other water body. By controlling the
amount of wastewater transferred to the intercepting system, the wastewater regulators limit the maximum flow delivered to the treatment plant.

By 1900, the original Field’s Point sewage treatment plant in Providence was operational. This plant became the central repository and basic treatment facility for the domestic and industrial wastes that had been previously discharged into the city’s rivers. The rivers, however, continued to receive untreated wastes from cities upstream of Providence as well as the discharges from combined sewer overflows. In 1906, Herman Stabler of the U.S. Geological Survey wrote *A Report on Results of an Examination of the Conditions Causing the Pollution of the Moshassuck, Woonasquatucket, and Providence Rivers*. In describing the condition of the Moshassuck River, that still received wastes from the cities of Lincoln and Pawtucket, he quotes from Dr. Edwin Snow’s report written 52 years earlier, and then states that “the description of the stream is not very different from the true conditions as they exist there today. The causes, however, have changed somewhat. Dead fish are now rarely to be seen; all fish in the stream have long since been killed.”

**Sources of Combined Sewer Overflow Pollution**

The combined sewer system built in Providence before the turn of the century is the same one that serves the city today. The Narragansett Bay Commission (NBC) owns 61 CSOs in Providence and a bypass prior to secondary treatment at Field’s Point. The Blackstone Valley District Commission (BVDC) is responsible for 28 CSOs in Pawtucket and Central Falls, as well as a bypass known as the North Diversion Structure that diverts raw flows from its Bucklin Point treatment plant directly to the Seekonk River during wet weather. Newport has three CSOs that discharge directly into Narragansett Bay. In Massachusetts, Worcester has a CSO that discharges into Mill Brook, a tributary of the Blackstone River. The city of Taunton has one CSO that discharges into the Taunton River. Fall River has four CSOs that discharge to the Taunton River, eight that discharge to the Quaquachan River, and seven that discharge directly to Mount Hope Bay (Narragansett Bay Project, 1990). The location of CSOs in the Narragansett Bay watershed is illustrated in Figure 2. When the combined sanitary and storm systems in these cities overflow they dump raw sewage, untreated organic and inorganic pollutants, and metals into our waters. The CSOs and treatment plant bypasses in the Narragansett Bay watershed discharge approximately four billion gallons of urban runoff, raw sewage, and industrial wastes to the Bay and its tributaries every year (NBP, 1990). The Woonasquatucket, Moshassuck, Blackstone, Seekonk, Providence, and Taunton Rivers are all seriously impacted by CSOs, and the wastes discharged to those rivers degrade the water quality of upper Narragansett Bay and Mount Hope Bay.

While the sheer quantity of wet weather discharges is alarming, the concentration of pathogens and toxins released during dry weather can warrant an even greater concern. Because the CSO bypass regulators can become clogged with debris, lack of proper maintenance can lead to continuous and undiluted discharges during dry weather. The localized impacts of undiluted dry weather discharges can be even more severe than those of high volume wet-weather overflows, because the contaminants present in the raw sewage discharges are much more concentrated.

**Environmental Effects**

The estuarine and marine environments found in Narragansett Bay are extremely valuable natural habitats. The Bay supports many important species of aquatic vegetation, phytoplankton, fish, shellfish, birds, and mammals due to its high natural productivity. Marine resources in Narragansett Bay include quahogs, soft-shell clams, crabs, sponges, and lobsters.

Upper Narragansett Bay is a spawning ground for finfish—winter flounder, herring, cod, and fluke; and open-ocean species such as bluefish, striped bass, and menhaden. Because of its wealth of natural resources, Narragansett Bay—like other estuaries around the country—became a center for early settlements, followed by urban-industrial development. The impact of human “progress” is reflected in our estuaries by the polluted waters, contaminated sediments, reduced fish and wildlife populations, and loss of species diversity. The untreated wastes from CSOs pose many threats to the health of the Bay, its marine inhabitants, and their human consumers. Untreated CSO discharges contain
Figure 2. Location of CSO discharges in the Narragansett Bay watershed.
raw sewage, industrial wastes, and toxic urban runoff, all with innumerable impacts on the environment.

**Raw Sewage**

Two common effects of discharging raw sewage into water bodies are eutrophication and hypoxia. Eutrophication occurs naturally when a body of water becomes rich with dissolved nutrients such as nitrogen and phosphorus. This process is accelerated by the discharge of raw sewage and other nutrient-rich pollutants. High nutrient levels result in dramatic population explosions of algae and aquatic plants. As more waste is added, more plants and algae grow, die, and decay. Organic matter accumulates and the water body becomes shallower. In addition, the microorganisms which feed upon the decaying organic material deplete available oxygen in the water, which may cause severe depression of dissolved oxygen levels (hypoxia).

Some investigators have suggested that recent explosive algal blooms have resulted from anthropogenic (human-derived) nutrient inputs from sewage. These algal blooms can pose threats to the Bay’s marine organisms, as evidenced by Narragansett Bay’s “brown tide” algal bloom in 1985. As a result of this algal bloom, Rhode Island’s scallop population was unable to feed or reproduce successfully and was decimated. Scallops in Narragansett Bay had been a significant shellfishing resource and harvesting Bay scallops was a tradition enjoyed by both commercial and recreational shellfishermen. In 1978, an estimated 50,000 bushels were harvested. Since the brown tide, the Bay scallop population has not supported a commercial fishery. The Rhode Island Division of Fish and Wildlife estimated that the 1989 recreational harvest was a mere 10 bushels.

Increased waste concentrations also lead to high biological oxygen demands on the receiving waters and can lead to hypoxic (dangerously low levels of oxygen) or anoxic (zero oxygen) conditions. Oxygen is as important to fish and other marine life as it is to terrestrial life, and anoxic conditions have been linked to fish kills in the upper Narragansett Bay. Suspended solids lower the oxygen levels further by clouding the water and preventing photosynthesis. This disruption kills algae and leads to increased decomposition and decreased dissolved oxygen concentrations.

Bacterial and viral contamination from raw sewage is also a serious problem. Pathogenic bacteria found in sewage may cause typhoid, cholera, and dysentery. Viruses present in the sewage may lead to infectious hepatitis and gastroenteritis. Gastroenteritis, which has symptoms similar to the flu—and often mistaken for it—is the most common effect of ingesting contaminated shellfish. Viruses are a special concern because they are often harder than bacteria, sometimes surviving in salt water for longer than a week (Berg, 1978).

In 1925, the first water-quality standard for shellfish was established after a typhoid epidemic was linked to the ingestion of contaminated shellfish (Frost, 1925). Since then, there have been numerous other reported health problems linked to ingestion of shellfish, and consequently water quality standards have become more stringent. The health threats posed by sewage-contaminated shellfish result from the filter-feeding nature of shellfish and the fact that they are often consumed raw. Filter feeders pass large volumes of water through their systems. If the water that is being filtered by the shellfish is clean, they will be safe to eat. However, if the water contains high levels of pathogens as it would after a raw sewage discharge, then pathogens will become concentrated in the intestinal tract of the shellfish. In the days following an overflow, the shellfish deparates itself, expelling the pathogens from its gut. As a result of this natural purification process, the Department of Environmental Management (DEM) can safely reopen conditionally closed shellfishing beds seven days after most CSO events. DEM staff is confident that if combined sewer overflow pollution controls were implemented, the upper Bay’s condition areas could be permanently opened (David Chopy, pers. comm.).

**Industrial Wastes and Urban Runoff**

Untreated wastes from industrial discharges and urban runoff are potential health threats. Many of the toxic metals and chemicals that are discharged into municipal sewer systems by industries are possible carcinogens. Stormwater runoff in urban areas has also been found to contain pesticides such as DDT and chlordane as well as polychlorinated biphenyls (PCBs), selenium, lead, mercury, arsenic, chemical solvents, dioxins, and hydrocarbon compounds from petroleum products. Chemicals that can accumulate in the tissues of marine animals are of the greatest concern. Fish have shown evidence of lesions and tumors caused by these substances. The human health impacts of ingesting contaminated sea life...
could be a serious problem that has not been adequately investigated.

Sediments act as repositories for many chemicals that are released into the water. Bottom-dwelling, or "benthic," organisms that live and feed in sediments absorb these pollutants. As they are consumed in turn by other animals, pollutants such as petroleum hydrocarbons, PCBs, and DDT move up through the food chain. The pollutants become more concentrated in each successive organism, and by the time humans consume the seafood, pollutant levels can be extremely high.

Studies by the U.S. Environmental Protection Agency (EPA) estimate that CSOs account for more than one-third of this contamination (U.S. Congress, Office of Technology Assessment, 1987). The Rhode Island Department of Health periodically tests shellfish tissues for coliform levels and heavy metal concentrations (lead, cadmium, selenium, and mercury). However, neither sediments nor shellfish are tested routinely for toxic chemicals such as pesticides and petroleum products, which are present in overflows and are equally hazardous to human health (Pratt, 1988).

Organic chemical contaminants often persist for decades or centuries and can remain in the tissues of shellfish and finfish for life. A 1977 study found that adult hard clams from the Providence River were likely to retain accumulated hydrocarbons for 120 days after being placed in clean water (Boehm and Quinn, 1977). Other investigators have found that PCBs never leave hard clam tissues, and that some percentage of heavy metals are retained for long periods of time (Courney and Denton, 1976; Boehm and Quinn, 1977).

Potential human health risks are unknown for more than 90 percent of all chemicals. For the remaining 10 percent, only the short-term effects on the marine environment have been evaluated (U.S. Congress, Office of Technology Assessment, 1987). The federally-funded Narragansett Bay Project has analyzed quahog tissues and sediments for organic chemicals in an attempt to assess overall impacts. Within conditional areas A and B (Figure 3), studies have found that metals and pesticides in the tissues of shellfish are within the safety limits proposed by the U.S. Food and Drug Administration (FDA) (Kipp, this volume; Interstate Shellfish Sanitation Conf., 1971). The FDA has performed similar testing on quahogs in Mount Hope Bay. If CSOs were eliminated, both of these areas could be permanently opened to shellfishing without threatening human health.

The health threats incurred by those who come in contact with CSO-contaminated waters, as when swimming, fishing, waterskiing, or boating, are also undocumented. The DEM currently classifies both the Seekonk and the Providence Rivers as "SC" waters, unsafe not only for shellfishing but also for contact recreational activity. However, the Narragansett Boat Club (the first rowing club of its kind in the U.S., established in 1838) has its boathouse on the Seekonk River. Some members have complained of rashes and infections contracted from exposure to Seekonk waters. The Boat Club's president testified that they regularly see people fishing and swimming in these polluted waters.

Bay Closures

To protect human health from the threats created by raw sewage overflows, the R.I. DEM closes the Bay to shellfishing when CSOs are known to be discharging. Since rain causes the combined sewer system to overflow, total rainfall is used to determine the degree of shellfish contamination and the duration of closure periods. If 1/2 inch of rain falls in a 24-hour period, conditional area A in the upper Bay is closed to shellfishing for seven days. Areas A and B are closed for seven days if more than 1 inch falls. If more than 2 inches fall, both areas are closed for 10 days (R.I. DEM, 1990).

In 1989, 20,059 acres of Narragansett Bay were permanently closed to shellfishing (R.I. DEM, 1990). The permanently closed areas include Mount Hope Bay, which has been closed since 1947 due to raw sewage discharges from Fall River. In 1987, researchers for the FDA found that CSOs in Fall River account for greater than 95 percent of the contamination entering Mount Hope Bay, as indexed by fecal coliform strength (Rippey and Watkins, 1987). In addition to these permanently closed areas, 11,213 acres were conditionally closed due to combined sewer overflows (Figure 3).

As a direct result of raw sewage contamination, between 1985 and 1990 the conditional shellfishing beds were closed an average of more than 210 days a year (R.I. DEM, 1990).
Figure 3. Shellfish closure areas in Narragansett Bay, May 1990 (Narragansett Bay Project).

<table>
<thead>
<tr>
<th>Year</th>
<th>Days</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>184</td>
<td>50%</td>
</tr>
<tr>
<td>1986</td>
<td>217</td>
<td>59%</td>
</tr>
<tr>
<td>1987</td>
<td>201</td>
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<td>1988</td>
<td>186</td>
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<tr>
<td>1989</td>
<td>263</td>
<td>73%</td>
</tr>
<tr>
<td>1990</td>
<td>281 (Area A)</td>
<td>77%</td>
</tr>
<tr>
<td></td>
<td>232 (Area B)</td>
<td>64%</td>
</tr>
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**Economic Considerations**

Rhode Island is a major supplier of quahogs. Compared to Long Island Sound and Florida, two other productive regions, Rhode Island is presently landing the largest percentage of quahogs, between 25 and 30 percent of the national total. Estimates place Rhode Island revenues at $12 to $30 million annually (Metcalf and Eddy, 1983). Shellfishing restrictions, however, are economically devastating, costing the industry millions of dollars in lost revenue. With large areas of the Bay closed to shellfishing, it is difficult for the roughly 2,500 licensed commercial fishermen to earn a living.

It is useful to consider the impacts of the periodic closures of conditional areas A and B on the shellfishing industry and the economy, since those are the areas that will benefit most directly from CSO abatement. These areas also contain some of the Bay's most productive shellfish beds. Seventy percent of Rhode Island’s annual shellfish harvest, more than 1.7 million pounds, comes from conditional areas A and B, despite the fact that these areas represent less than 12 percent of the Bay’s total acreage and are subject to frequent closures (Ganz and Dinsdale, 1990). The abundance of shellfish in these areas is the result of several factors. The sediments are composed mostly of sand and silt, and shellfish do better in this environment than in the unconsolidated sediments more common farther down the Bay. In Greenwich Cove, which has sediment characteristics similar to the upper Bay, quahog population density was found to be 190 animals per square meter, yielding about 12,000 metric tonnes of shucked meats per acre (Rice et al., 1989). The shallower waters of the upper Bay also make the shellfish accessible to fishermen's bullrakes. Harvesting quahogs in the deeper waters of the lower Bay is more difficult. Of those areas of the lower Bay that are shallow enough for the fishermen to use, only about one-third are economically viable (Philip Holmes, pers. comm.).

When the conditional areas are closed, fishermen are forced to ply their trade elsewhere, and often they become concentrated in smaller areas of the lower Bay. This situation has resulted in overfishing of these areas, and places such as the East Passage have already become far less productive due to overharvesting. When areas A and B are open, almost all of the fishermen converge on these areas, causing overcrowding in the upper Bay.

If Mount Hope Bay and areas A and B were permanently opened, fishing pressure on all areas would be reduced. Shellfishermen would be able to harvest shellfish over a larger area of Narragansett Bay, resulting in a more even distribution of shellfish in only a few years. Regional economic benefits from shellfish harvest and sales would increase as a result of the new permanently opened areas, and shellfishing resources could be managed more efficiently with a larger portion of the Bay available for harvesting.

Conditional areas A and B currently provide about 70 percent of the total annual revenues reported by Rhode Island shellfishermen, despite the fact that these areas are open only about 40 percent of the time. The value of hard-shell clam landings in Rhode Island was $15 million in 1990. The value of shellfish reported to have been harvested from areas A and B in an average year (even when the areas are open less than 40 percent of the time) is approximately $10.5 million. If the conditional areas were permanently opened, it is estimated that they could yield $26 million of shellfish per year, though this harvest level may only be temporary.

The Rhode Island Shellfishermen's Association has estimated that a sustainable yield for the permanent opening of conditional areas A and B could result in as much as $4 million per year in additional income to commercial shellfishermen. In addition to these direct economic benefits, an important consideration is the “multiplier effect” of the shellfishermen’s additional earnings, which go back into Rhode Island’s economy in many different ways. The shellfishing industry has the highest multiplier of any industry in Rhode Island (Conservation Law Foundation of New England, 1988). When a shellfisherman earns money, he spends most of that money on things that will help the local economy,
such as buying a home in the area, and purchasing boats, outboards, trucks, etc. Also, shellfish are purchased by dealers who sell to local restaurants where many tourists eat, and the profits of shellfish dealers and restaurant owners pump more money into the regional economy. The accepted multiplier for the Rhode Island shellfishing industry is 4.5, which means that if opening up conditional areas A and B to increase Rhode Island shellfishermen's profits by $4 million annually, then the state's economy would see $18 million of added revenues each year.

Improvements in wastewater treatment plant performance were cited by the Rhode Island DEM in May of 1990 when it was announced that water quality improvements in the upper Bay warranted new rules for conditional area B. The new rules will allow for 9,000 acres of the Bay's most productive shellfishing areas to be open more frequently. Narragansett Bay oysters, which had been nearly wiped out by pollution, overfishing, and hurricanes, are coming back to the Providence River and the upper Bay. The Bay's oyster industry peaked at 7,000 metric tonnes (15.3 million pounds) per year between 1908 and 1914 (Olsen et al., 1980). At today's prices, the lost fishery would provide $50 million a year and sustain hundreds of jobs. The return of oysters to the Bay is evidence that the investments in pollution controls are beginning to pay off. However, progress that has been made in treatment plant performance is being undermined by CSOs.

CSO pollution control projects would create additional benefits for recreational users by providing a more attractive water body for swimming, sportfishing, boating, sailing, and other activities. Water quality degradation caused by CSOs weakens the ecological integrity of estuarine zones, and limits the survival and propagation of important species. CSO abatement can help reverse the damage that is done to these habitats. Aesthetics would be greatly enhanced by CSO pollution controls, which would eliminate many of the odors, unsightly shore deposits, surface slicks, and other visible pollutants which adversely affect residential property values on or near the shoreline.

Cost-benefit analyses of CSO projects must consider the values of those benefits that are not so easily quantifiable. These include the importance of the Bay to traditional communities and lifestyles, the existence value of non-commercial species, and the intrinsic benefit of endowing future generations with a cleaner Bay.

**Technical Solutions**

The integrity of our environment continues to be threatened by CSOs. Bay closures have far-reaching economic ramifications and should be viewed as an unacceptable, interim response to dealing with CSOs. The situation requires a more environmentally responsible remedy. Admittedly, the capital construction projects required to control or eliminate CSOs are expensive. There are, however, a number of options available to eliminate CSOs or minimize adverse environmental impacts:

1. **In-line storage:** This option uses the existing system, with minor modifications, to store water that would otherwise overflow during wet weather. An example is the use by the NBC of an 84-inch sewer in the Mount Pleasant/Smith Hill area. The NBC repaired structural damage to the pipe and built dam structures that allowed dry weather flows to pass underneath but held back high wet weather flows with stop logs. This "wet weather dam" effectively stores excess water, releasing it slowly to the treatment plant without overloading the facility.

2. **Off-line storage:** Off-line storage requires the construction of holding tanks or deep-rock tunnels to store wet-weather flows which would otherwise be discharged directly. The contained overflow is stored until the storm event is over, and then conveyed to the treatment plant. A significant advantage of both in-line and off-line storage is that the wet-weather flows that are captured receive secondary treatment at the wastewater treatment facility, as opposed to the primary treatment offered by "flow-through" CSO facilities.

3. **Swirl concentrators/Primary treatment facilities:** Swirl concentrators are "flow-through" facilities that remove solids from the overflow using centrifugal force. The remaining liquid wastes are usually chlorinated before being discharged. Although this process removes some of the settleable solids and kills a portion of the harmful bacteria, its removal rates rarely equal primary treatment, and discharges from such
facilities may still violate water quality standards. Further, where chlorination is used, residual chlorine levels can create problems, as chlorine itself is toxic and can pose a threat to water quality.

4. Separation of storm and sanitary sewers: Most sewer systems do not have overflows because they were built with separate stormwater and sanitary lines. Fifty percent of Rhode Island's sewers are separated. Several communities around the country that previously were served by older, combined sewers have separated their systems. While this eliminates combined sewer overflows, it is extremely expensive and it creates new stormwater management problems. The separate stormwater system conveys runoff from highways, parking lots, and residential areas. This runoff can contain toxics such as PCBs, polycyclic aromatic hydrocarbons, and metals. As more is being learned about the effects of these "nonpoint" pollutants, the EPA has promulgated stormwater management regulations that place more stringent requirements on the control of stormwater. Communities which separate their systems could be substituting a future problem for a present one. As we learn more about pollutants from diffuse sources, controlling nonpoint runoff may become as urgent as CSO abatement.

CSOs, CONTRADICTIONS, AND THE LAW

Considering all the known impacts, and the threat of the unknown effects from the many chemicals and pathogens found in raw sewage, it is a disturbing fact that CSOs are not effectively regulated. Although federal legislation has been passed concerning CSOs, existing federal regulations and guidance policies are contradictory and have proven ineffective.

Because CSOs have irregular and intermittent discharges, those responsible for CSO abatement projects have argued that CSO policies must allow enough flexibility for each outfall to be evaluated on a case-by-case basis. In allowing for such "flexibility," state and federal guidelines have proven difficult to define and virtually unenforceable.

Out of the jumble of policies and legal precedents, one may focus on several pertinent facts:

1. It is unclear whether combined sewer overflows are considered municipal "point sources" of pollution. According to the Clean Water Act, all municipal "point sources" of pollution must receive at least secondary treatment before July 1, 1988. A point source is defined in Rhode Island's water quality regulations as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well... from which pollutants are or may be discharged." It would appear from these policies that CSOs are point sources subject to secondary treatment requirements, and that any CSO discharge which does not now receive secondary treatment is illegal. This position is supported by the EPA Region I's policy statement on CSOs which states: "CSOs also are point sources subject to both the technology-based and water quality-based requirements of the Clean Water Act."

However, in 1980, a U.S. Circuit Court in Washington, D.C., concluded that a CSO is not a "treatment work" subject to the secondary treatment standards of the Clean Water Act. According to the court's interpretation, a CSO discharge must not violate water quality standards, but need not meet secondary treatment levels. Instead, criteria for CSO discharge controls are to be based on case-by-case assessments of water quality impacts.

The Natural Resources Defense Council has argued convincingly that the court's decision was mistaken. The national industrial pretreatment program is built, they argue, on the premise that industrial discharges to a municipal sewer system always receive a minimum of secondary treatment before they are discharged to open waters. If sewer overflows are not required to receive at least secondary treatment, then industries must meet the far more stringent limits required of direct dischargers before dumping into combined sewers.
2. The lack of a technology-based requirement for CSOs is one of the major factors that has made their regulation complicated and their abatement elusive. The Federal Clean Water Act originally mandated that CSOs comply with water quality standards by July 1, 1977 (Section 301(b)(1)(c)). But the irregular and intermittent discharges from CSOs make it difficult to obtain wet-weather monitoring data, and it is extremely costly to demonstrate, on a site-specific basis, the water quality impact of each CSO discharge. Though CSO discharges have been violating water quality standards for the 13 years since this deadline has passed, the Rhode Island DEM has not had the resources to take appropriate enforcement actions based upon water quality violations.

Long experience with the failures of a purely water quality-based permitting program led Congress to conclude in the 1970s that a national technology-based “floor” of discharge controls for industry and publicly owned treatment works was needed. Instead of leaving regulators with the burden of proving a direct link between a specific discharge and a violation of water quality standards, new legislation was passed requiring dischargers to use all available methods of treatment prior to discharge—regardless of the quality of the water to which the wastes are discharged. The environmental gains in the 1970s and 1980s were largely due to the imposition of these kinds of technology-based controls.

The Water Quality Act Amendments added to the Clean Water Act in 1977 mandated that all CSO discharges meet the “best practicable treatment, best conventional pollutant control technology, and best available technology” requirements on or before March 31, 1989. EPA, however, has never defined the best available technology for CSOs. Instead, federal criteria for CSO discharges revert to water quality standards, on a case-by-case basis. To ascertain the degree to which water quality is being violated, the CSO discharger must prepare a facilities plan that outlines abatement measures and assesses the impacts of the overflow. The EPA has tied regulations and discharge permits for CSOs to each discharge’s composition, toxicity, and anticipated water quality impact. As a result, regulatory oversight has been poor, and only a few of the CSOs that discharge to Narragansett Bay have had pollution control facilities constructed.

Some of the facility plans that have already been completed (e.g., NBC’s) contain recommendations that conflict with the current technology-based requirements of Rhode Island’s CSO policy that was adopted on March 23, 1990. Rhode Island’s policy requires primary treatment up to the one-year, six-hour storm event, unless significant beneficial water quality improvements can be shown to occur when incorporating a level of treatment that is less than equivalent primary treatment. (The one-year, six-hour storm is a rain event that occurs, on average, once per year and has a duration of six hours.) However, facility plans for the NBC have been based on studies that were conducted before the current state policy was adopted. When the work was done, NBC’s consultants had recommended storage and treatment for only the flows generated by a three-month storm event.

3. State and federal environmental laws requiring CSO controls are not being enforced by the agencies responsible for regulatory oversight. The EPA administers the National Pollutant Discharge Elimination System (NPDES) program as part of its authority under the Clean Water Act. In Rhode Island, DEM has been delegated the authority to implement NPDES regulations under the auspices of the Rhode Island Pollution Discharge Elimination System (RIPDES). This program issues permits to industries with direct discharges and publicly owned treatment plants, setting effluent levels for metals, biological oxygen demand, total suspended solids, polycyclic aromatic hydrocarbons, fecal coliform, and other organic and inorganic pollutants.
DEM’s CSO policy was intended to bring CSO communities and sewer authorities in Rhode Island into compliance through the issuance of RIPDES permits, with administrative orders that require CSO abatement programs to proceed according to an enforceable schedule. However, permits issued since the policy was adopted (e.g., BVDC), have not been consistent with the policy, and have not included any deadlines on the design and construction of CSO pollution controls.

**Current Situation**

Combined sewer overflows are a serious water quality problem nationwide, and different parts of the country have responded differently to their local CSO problems. The state of Washington passed a CSO policy that calls for “the greatest possible reduction in the least possible time” and has required control plans from every municipality by July 1988. Cities such as Sacramento, California; Atlanta, Georgia; Bowling Green, Ohio; and numerous others have been implementing solutions to their combined sewer overflow problems in time periods much shorter than the proposed plans for Rhode Island. Several of those who are charged with enforcing environmental laws in Rhode Island have been heard to proclaim, “I will not see CSO controls implemented in my lifetime.” Why haven’t Rhode Island’s CSOs been dealt with in an aggressive manner similar to other states? The answer is political.

It is quite clear that a clean Narragansett Bay is a priority in the minds of the citizens of Rhode Island. This priority needs to be reflected in the policies and plans of the legislature and governmental agencies in charge of CSO abatement.

But abatement will not come without expense to the citizens of Rhode Island. Previously, federal funds were available for construction and planning efforts through the Construction Grants Program, which provided up to 75 percent of eligible construction costs and required a state match of 15 percent, requiring local governments to pay for only 10 percent of the capital costs of new facilities. Since 1973, more than $425 million in federal funds have been spent on wastewater treatment facilities in Rhode Island. This construction grant program has now ended, and other federal programs, such as the Marine CSO Abatement grants, have also been phased out.

Of the Rhode Island CSO communities, Newport was the only one to receive any federal funding for CSO pollution controls. During the construction grants program, many of the treatment plants in the Narragansett Bay watershed were being upgraded to provide secondary treatment, and CSOs were not identified as a top priority. In 1972, the U.S. Senate report which accompanied the Clean Water Act noted that the EPA administrator at the time opposed the extension of construction grant eligibility to CSO correction, based on the idea that the cost of cleaning them up would be prohibitive (Sharon et al., 1989).

With the realization of the significant water quality degradation caused by CSOs, this attitude has changed, but the costs have not gone down. The implementation of CSO controls will probably depend upon the public’s willingness to pay for a cleaner Bay. The NBC estimates that if sewer user fees were used to fund CSO abatement projects in Providence, the costs for residential users of the Providence sewer system would increase from $65 per year to $260 per year.

**Summary of Local Efforts**

What follows is a brief summary of how selected CSO communities in the Narragansett Bay watershed have progressed in their CSO abatement efforts:

**Newport**

In the 1970s, Newport received 90 percent federal funding for a project to outline areas where it would be cost-effective to separate combined sewer systems, and to apply “innovative technology” to treat the remaining runoff-related sewer overflows. In 1978, the city used this federal money to build a micro-strainer with a rotating drum screen (technology that was originally intended for drinking-water treatment, not waste removal). The screen size was too small, the gaseous chlorine disinfection system often broke down, and the facility was only used intermittently. As a result, the city’s plans to build another micro-strainer for the Long Wharf CSO were scrapped in the 1980s.

In conjunction with the permit and compliance order for Newport’s Connell Highway treatment plant, DEM issued schedules for Newport’s CSO pollution control projects. The Wellington Avenue facility was supposed to be complete and operational by September 1, 1988, and the Long Wharf CSO project was to be
finished by June 1990.

In November of 1987, Rhode Island voters approved a referendum authorizing Newport to finance the construction and renovation of its CSO facilities and to issue $8.4 million in bonds. The city also applied for and received a $4.6 million federal maritime CSO grant for the Long Wharf (Washington Street) project.

Almost immediately after the construction began in the spring of 1989, the site for the Washington Street facility (located behind the Marriott and the Visitors Center at the southeast corner of the Gateway Block) was found to contain lead-contaminated soils, and workers also unearthed an abandoned fuel-oil storage tank. It is unclear how soil borings done prior to the project failed to detect the lead- and oil-contaminated soils that caused delays and considerable additional expenses.

Newport was able to receive some additional funding from the state Aquafund to deal with a portion of the contamination-related expenses, and the city has plans to sue the former property owner for reimbursement.

Since the state of Rhode Island promulgated its CSO policy (March 23, 1990), questions have arisen concerning whether Newport will be in compliance even after the projects in progress are complete. When in operation, the Washington Street facility will be able to store 87,500 gallons of combined sewage that will be pumped to the Connell Highway plant for secondary treatment. This will be adequate for small storms; the city estimates that these tanks will fill and be pumped to the treatment plant 20 times per year. For combined wastes in excess of the facility’s storage capacity and up to levels generated by the three-month storm, flows will be screened for removal of floatables and settleable solids, and effluent will be chlorinated before being discharged near the Goat Island causeway. Several times every year, however, flows of raw sewage and stormwater in excess of the facilities’ design capabilities will continue to be discharged into the corner of the harbor at Perrotti Park.

Narragansett Bay Commission

The NBC was formed in 1982 to take charge of the Field’s Point treatment plant and the 61 CSOs associated with it. Since that time, NBC has been trying to establish a solid flow model and cost-benefit assessment for its CSOs so that it can better prioritize regions and allocate funds. Wherever possible, cost-effective measures to decrease flows have been taken. Simple maintenance of separator slots, as well as repair of tide gates and pipes have almost eliminated dry overflow and lessened wet-weather volume. (Tide gates prevent the inflow of receiving water during high tide. The repair of nonfunctional tide gates significantly decreases flow to the treatment plants, and can substantially reduce the number of dry weather overflows.) In 1991, the NBC will have completed the first phase of its CSO facility planning process, and will be ready to proceed with design and construction of CSO abatement projects.

Blackstone Valley District Commission

For years, the BVDC and the communities of Pawtucket and Central Falls struggled with questions about who had responsibility for CSOs instead of taking actions to resolve the pollution problems caused by them in the Blackstone Valley. On September 18, 1990, Save The Bay filed a lawsuit in federal court alleging that the BVDC’s overflows are in continuous and ongoing violation of the Clean Water Act. The suit seeks to restrain and enjoin the BVDC, Central Falls, and Pawtucket from discharging pollutants into the Blackstone, Moshassuck, and Seekonk Rivers, and to have the court enforce a compliance schedule for the design and construction of CSO pollution controls. Since the lawsuit was filed, the BVDC has been issued a new discharge permit by DEM; it has initiated a CSO study, and legislation has been introduced in the Rhode Island General Assembly to merge the BVDC and the NBC.

Fall River

On July 24, 1990, a federal court ruled that Fall River violated the Clean Water Act by allowing untreated sewage to overflow from its combined sewer system. The city is working on finalizing a draft CSO facilities plan, and the court will be holding a status conference on what remedies or sanctions will be imposed because of the proved violations.

Conclusion

Our history is catching up to us—yesterday’s solution to waste disposal problems has become the biggest single water quality threat to the health of Narragansett Bay. The progress we have made in upgrading wastewa-
ter treatment plants is being undermined by some of the
antiquated sewer systems that serve those facilities. As
water quality continues to be degraded by CSOs, time
and money continues to be spent on studies of specific
water quality impacts while CSOs continue unabated.

The environmental effects are well documented and
the public health threats and economic impacts are
recognized as serious problems. Technical solutions
exist, and state and federal environmental laws require
that they be implemented.

The solution that is now required is a political one.
Deadlines for CSO abatement must be set and enforced
by the state of Rhode Island. DEM must update and
reissue RIPDES permits for CSO communities and
sewer authorities. The permits must be consistent with
the State’s CSO policy, and should include legally
enforceable compliance orders mandating technology-
based, minimum treatment requirements, and require
periodic monitoring and analysis of CSO discharges.

CSOs require immediate attention and expedited
abatement. Actions necessary to provide the impetus for
this abatement should be taken to ensure that the health
and beauty of Narragansett Bay may be restored for
future generations.

The continual degradation of Narragansett Bay by
CSOs has many temporary and permanent ramifications
that should be of concern to everyone, but if policymak-
ers are going to prioritize CSO abatement, it will be
because CSOs have become a public issue. Citizen
action and support from environmentalists and the
commercial fishing community will be required to
hasten this process.

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Questions and Answers

Q: (Dr. John Sutinen, Department of Resource Economics, University of Rhode Island) If the CSO problem were solved, do you have any estimates as to how much of the toxics and microbial contaminants would be reduced?

A: (Mr. Jamal Kadri) There have been studies by Applied Sciences Associates as to sources of fecal contaminants and how the discharge patterns have changed with systems improvement. The pollution closure lines move a considerable distance up the Bay. I have not included these data in the slide show because the design criteria that they use for CSO abatement is questionable. The state has adopted a CSO policy that sets some guidelines for equivalent primary treatment as a baseline. The Narragansett Bay Project did a wet weather study and they showed that CSOs and bypasses are the single largest source of fecal contaminant input to the Bay. CSO abatement would move the pollution closure lines well up the Bay, but how far would depend on which abatement technology is implemented. Rhode Island is talking about a design that would capture the six-month, one-hour storm. There is federal legislation which seeks to mandate capture of waters from the 10-year maximum storm, but the federal government seems to be reluctant to fund such projects.

Q: (Mr. Craig Swanson, Applied Science Associates) A point of clarification. You have mentioned some of the receiving water impacts of CSOs, but as of now only some of the individual CSOs in the area around Providence have been studied by the various consulting engineers involved in the individual projects. Plans have been developed for individual projects, and we have looked at relative improvements by each CSO. It is only now that the Narragansett Bay Commission has funded a system-wide study by Ray Wright of the Civil Engineering Department. Hopefully, there will be cost-benefit analyses to find the worst CSOs to concentrate on first to maximize benefits.

Q: (Dr. Michael Rice, Fisheries and Aquaculture, University of Rhode Island) Jamal, considering the various municipalities and sewage treatment facilities around the Bay, which of the units are doing a reasonable job of cleaning up their act and which ones are not?

A: (Kadri) Unfortunately, I cannot point to a shining example of an aggressive effort to control CSOs in the state. There are other areas around the country where they have done considerably more than Rhode Island. I think the problem is that when there was federal money available for upgrading sewage treatment plants, Rhode Island was concerned with upgrading the plants to secondary treatment. As was mentioned, the current system-wide study by the Narragansett Bay Commission should identify the worst CSOs and how they should be addressed in the order of highest priority. But the schedule they envision in the capital improvement program will have us dealing with this problem 10 years down the road. Save The Bay is pushing for a much more aggressive schedule. Newport has built some facilities using a technology they have used for drinking water, using a screen and filtration system, but they have had chronic problems. They are planning an off-line storage system behind the Marriott Hotel, but this system may have as many as 12 wet-weather discharges per year. Unfortunately there is nobody who is ahead of the game.

Q: (inaudible name, Coastal Resources Management Council) The estimated cost of CSO abatement in Providence alone is $147 million. Without political backing and pressure from the general public, how will the funds be raised?

A: (Kadri) That is a good point. The improvements will not happen unless people recognize the importance of the problem. We need to do a lot of grass-roots education to gather support for this, and let our policymakers know that this is very important to us.

Q: (inaudible) Save The Bay is the largest grass-roots environmental organization in Rhode Island. Does it have the grass-roots education program?

A: (Kadri) Yes, we have focused our efforts on the Seekonk and Blackstone Valley. We intend to sue for violations of the Federal Clean Waters Act, but before that suit is filed, we intend to exhaust administrative remedies to get the job done. We are talking to people in the affected communities, and we are involved in the Bay Commission's rate case—trying to get the schedule for CSO projects pushed forward and [ensure] that the revenues that they need may be projected into the rate base. CSOs are one of our major priorities.
Regulatory Requirements of Shellfish-Growing Areas

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291 PROMENADE STREET, PROVIDENCE, RI 02908-5767

SYNOPSIS: Responsibility for shellfish sanitation is shared by three divisions of the Rhode Island Department of Environmental Management. Rhode Island's water quality classification code system, standards, and sampling techniques are discussed. Current pollution problems and recent classification changes are examined. Editor's note: This paper is an edited transcript of the oral presentation by Mr. Migliore.

RHODE ISLAND'S CLASSIFICATION SYSTEM

I have put together a few overheads and slides to show you what a regulatory agency has to do with the certification of shellfish-growing waters, and how we manage the opening and closing of shellfish areas.

The Department of Environmental Management's Division of Water Resources is only one portion of the state's shellfish sanitation program. The program starts (Figure 1) with the U.S. Food and Drug Administration (FDA) in cooperation with the Interstate Shellfish Sanitation Conference (ISSC). At these levels policy is made, and it filters down to the state level to the Rhode Island Department of Health and the Rhode Island Department of Environmental Management (DEM). The Department of Health takes care of the product as it comes out of the water and goes to the marketplace, shipper, packer, or any interstate dealer. The DEM's responsibility is divided among three divisions. The Division of Fish and Wildlife takes care of the resource end of the program, namely the management of stocks. The Division of Enforcement enforces the regulations of both the Division of Water Resources and the Division of Fish and Wildlife. In the Division of Water Resources, we take care of the water quality aspects of the program. We certify the waters for taking of shellfish for direct human consumption.

Our rules and regulations come from Part 1 of the National Shellfish Sanitation Program (ISSC, 1989). This manual is produced by the ISSC and the FDA. Using the ISSC guidelines, we have developed a map (Figure 2) which governs the status of shellfish bed closures in Narragansett Bay. To develop this closure map, we annually gather together all of our microbiological data and compare them to the standards set by the ISSC.

In the ISSC guidelines, there are several water quality classes (Appendix). Shellfish may be taken directly for human consumption from approved areas. The second classification is for conditionally approved areas. Examples of conditionally approved areas are areas A and B in the upper Narragansett Bay (Figure 2). Rainfall events affect these areas; combined sewer overflows and nonpoint-source runoff raise the coliform counts. Another type of conditionally approved areas are seasonally approved areas. These are areas largely impacted by boating. An example of this type is outer Wickford Harbor (Figure 2), and anywhere where we suspect potential sewage discharge from vessels. Exam-
Figure 2. Pollution closure areas in Narragansett Bay, 1991.
samples of restricted areas are found in the Providence River and Mount Hope Bay.

In Rhode Island, we have a water quality classification code system which roughly corresponds with the ISSC guidelines. Table 1 presents the classification code system and the bacteriological criteria for each of the classes. The water quality classifications for salt water range from SA for "clean" waters to SC for extremely polluted waters, and roughly correspond to the five ISSC classifications. In like fashion, the water quality classifications for fresh water range from FA to FC. All of these water classifications are based on either total coliform or fecal coliforms as determined by a multiple-tube fermentation technique (Greenberg and Hunt, 1985, that gives a most probable number (MPN) of bacteria per 100 milliliters of water. SA waters are our standard for open shellfishing areas. SB waters are our swimmable standard as well as our standard for shellfish areas able to be harvested for relay or transplant. SC waters are closed to shellfishing and swimming.

In addition to the MPN standards, we conduct sanitary shoreline surveys. This is a procedure by which

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Class SA</th>
<th>Class SB</th>
<th>Class SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved oxygen</td>
<td>≥ 6mg/L except as naturally occurs</td>
<td>≥ 5 mg/L except as naturally occurs</td>
<td>≥ 5 mg/L during at least 16 hours of any 24-h period and ≥ 4 mg/L at any place or time except as naturally occurs</td>
</tr>
<tr>
<td>Sludge deposits, solid refuse, floating solids oils, grease, scum</td>
<td>none allowed</td>
<td>none allowed</td>
<td>none except that amount that may result from discharge from an appropriately operating waste treatment facility</td>
</tr>
<tr>
<td>Total Coliform bacteria/100ml</td>
<td>not to exceed a median MPN of 70 and not &gt;10% of the samples shall ordinarily exceed 330 MPN in a 3-tube decimal dilution</td>
<td>not to exceed a median MPN of 700 and not &gt;10% of the samples shall ordinarily exceed 2,900 MPN</td>
<td>none in such concentrations that would impair any usages specifically assigned to this class</td>
</tr>
<tr>
<td>Fecal Coliform bacteria/100ml</td>
<td>not to exceed a median MPN of 15 and not &gt;10% of the samples shall ordinarily exceed 50 MPN</td>
<td>not to exceed a median MPN of 50 and not &gt;10% of the samples shall ordinarily exceed 500 MPN</td>
<td>none in such concentrations that would impair any usages specifically assigned to this class</td>
</tr>
<tr>
<td>Taste and Odor</td>
<td>none allowed</td>
<td>none allowed</td>
<td>none in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in the edible parts of the shellfish</td>
</tr>
</tbody>
</table>

Table 1. Rhode Island Department of Environmental Management Division of Water Resources' class-specific criteria for sea waters.
we cover all 606 miles of coastline in Rhode Island, sampling all areas of known discharges. These include sewage treatment plants, tributary streams, and stormwater runoff culverts. These discharges are bacteriologically monitored and compared to the ambient water quality. This procedure helps us to identify sources of pollution. At present, one of our biggest problems is nonpoint-source inputs. Our shoreline surveys have identified failing septic systems as a key problem. Storm drains with unrecorded or illegal tie-ins are a problem, so we spend a great deal of time trying to locate the source of discharges through these "mystery" pipes.

We have 16 different shellfish growing areas in Rhode Island. From these areas, we collect approximately 1,500 water samples per year. Conditional areas are sampled a minimum of 12 times a year, whereas approved areas are sampled a minimum of five times a year. Most samples are taken under "pollution threshold conditions" or worst-case conditions. This essentially means that samples are taken during wet weather conditions during outgoing tides.

**Sampling Methods and Recent Changes**

I wish to call your attention to the conditional areas A and B in the upper Narragansett Bay (Figure 2). This past year we were able to change the criteria for those areas. Formerly, the entire upper Bay acted as one unit. This area would be closed over a seven-day period under conditions of one-half-inch of rain in 24 hours, or a bypass of 500,000 gallons or more. Based on the monitoring data we have collected, and with the aid of dye dispersion studies, we have been able to determine that conditional area A should remain closed for a seven-day period when one-half-inch of rain falls within 24 hours. Conditional area B now is closed over a seven-day period when there is 1 inch of rain within 24 hours. This gives significantly more open time. We estimate this to be about 30 percent more fishing time in the upper Bay. This past year has been a little wetter than usual, so this has not worked as well as we had anticipated, but we await a year with "normal" rainfall.

In short, our goal is to maintain water quality for our approximately 800 full-time shellfishermen and the numerous recreational diggers. We aim to work toward better water quality and more bed openings throughout the Bay.

**References**


**Appendix I**

ISSC Water Quality Classifications (ISSC, 1989)

**Approved Areas**

Growing areas may be designated as approved when the sanitary survey and marine-biotoxin surveillance data indicate that fecal material, pathogenic microorganisms, and poisonous and deleterious substances are not present in the area in dangerous concentrations.

**Conditionally Approved**

Growing areas that are subject to intermittent microbiological pollution may be classified as conditionally approved. This option is voluntary and may be used when the suitability of an area for harvesting shellfish for direct marketing is affected by a predictable pollution event. The pollution event may be predicated upon the attainment of an established performance standard by wastewater treatment facilities discharging effluent, directly or indirectly, into the area. In other cases, the sanitary quality of an area may be affected by seasonal population, non-point source pollution, or sporadic use of a dock or harbor facility.

**Restricted Areas**

An area may be classified as restricted when a sanitary survey indicates a limited degree of pollution. This option may arise when levels of fecal pollution or poisonous or deleterious substances are low enough that relaying or purifying as provided for in Part I, Section D, and Part II, Section I, of the manual will make the shellfish safe to market. State shellfish control authorities should establish a restricted area only when sufficient relaying or depuration (purification) studies have been conducted that have established raw product quality
requirements; and when they have sufficient technical 
and administrative resources necessary to survey the 
area, monitor pollution sources, and control harvesting.

Conditionally Restricted Areas
Growing areas that are subject to intermittent microbiological pollution may be classified as conditionally 
restricted. This option is voluntary and may be used 
when the suitability of an area for harvesting shellfish 
for relaying and depuration is affected by a predictable 
pollution event. The pollution event may be predicated 
upon the attainment of an established performance 
standard by wastewater treatment facilities discharging 
effluent, directly or indirectly, into the area. In other 
cases, the sanitary quality of an area may be affected by 
seasonal population, non-point source pollution, or 
sporadic use of a dock or harbor facility.

Prohibited Areas
A growing area shall be classified prohibited if there 
is no current sanitary survey or if the sanitary survey or 
other monitoring program data indicate that fecal mate-
rial, pathogenic microorganisms, poisonous or deleteri-
ous substances, marine biotoxins, or radionuclides may 
reach the area in excessive concentrations. The taking of 
shellfish for any human food purposes from such areas 
shall be prohibited.

QUESTIONS AND ANSWERS
Q: (Mr. James Boyd, Rhode Island Shellfishermen's 
Association) Joe, with respect to failing septic systems 
and illegal tie-ins, how can the state go to a homeowner 
to ask them to repair a failing septic system that might 
be 30 or 40 years old that has never been maintained 
and has been discharging for unknown periods of time? 
There are problems of this type that are of concern, 
especially in our shellfish management areas in Green-
wich Bay, Brushneck Cove, and the Kickamuit River.
A: (Mr. Joseph Migliore) You are absolutely right. Any 
time we note in our shoreline survey a discharge or 
falling septic system, we send out our full-time mitigative 
enforcement team to verify the failing system or 
discharge. We then notify the health department and 
issue a notice of violation. Many of these are tied up in 
court; a number are hardship cases in which the owners 
have been living there for 70 years and are elderly. But 
we still proceed, trying to find funding in an attempt to 
mitigate those situations. In the interim, we must close 
down those areas because of the threat to public health. 
The nonpoint-source water quality program now under 
development will hopefully address some of these 
issues.

Q: (Mr. William Burns, Rhode Island Scallop Project) 
What is your role in the monitoring of toxic algal 
blooms?
A: (Migliore) The R.I. Department of Health really has 
the responsibility for the RFPF monitoring program. In 
the water resources area, we have an algal monitoring 
program. We have a contract with Dr. Smayda at 
the URI Graduate School of Oceanography to do some 
algal identifications. If we note a changing color during 
our routine monitoring, we will submit samples to Dr. 
Smayda for microscopic examination and identification.

On a routine basis, the Department of Health 
actually collects mussel meats from primary stations 
located in Narragansett Bay. If there is an elevation of 
any kind of biotoxin, our secondary stations are 
automatically activated. I have been in the program for five 
years, and we have had a few scares but never any 
blooms which would require closures.
Shellfish Management Projects in Rhode Island

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SYNOPSIS. The goal of the Division of Fisheries and Wildlife is to protect open shellfishing areas from overexploitation. Techniques for managing shellfisheries in Rhode Island include management closures of heavily impacted areas, transplants of adult shellfish from polluted areas, planting of commercially produced juveniles (seeding), and maintaining "spawner sanctuary" areas. Ongoing shellfish projects in Rhode Island are described.

INTRODUCTION

So far you have heard from the people who manage the resource from a water quality standpoint. I manage what is left—shellfish in certified waters. We do this on a shoestring with the help of numerous volunteers and students. I personally thank them all.

My main goal is to provide more shellfish for harvest, and at the same time, protect the resource from overfishing. Much of what we do is to attempt to make more resources available to the fishery. By so doing, we hope to reduce the fishing pressure in heavily exploited areas.

These goals are achieved using several basic techniques: (1) restoration by simply closing an area and letting natural recruitment occur undisturbed; (2) transplanting stocks into a depleted area; (3) planting juveniles (seeding areas); and (4) operating "spawner sanctuaries."

ONGOING PROJECTS

Transplants

The direction taken most successfully is the use of "surplus" to benefit some of the overfished areas. The use of shellfish from uncertified waters to repopulate depleted areas requires the cooperation and approval of several agencies and a large work force. Permission must be received from the Department of Health. This project requires stepped-up surveillance from the Division of Enforcement.

Three areas receive transplants each year. The largest and most successful is in Greenwich Bay. Management of the Greenwich Bay winter fishery has been carried out since 1981. In that year, the newly formed Rhode Island Shellfishermen's Association met with the staff of the Division of Fish and Wildlife to discuss the depletion of Greenwich Bay. Greenwich Bay had been a productive shellfishing ground throughout the history of the quahog fishery, but it was no longer economically viable to fish there.

Restoration of the Greenwich Bay fishery was accomplished by closing the area for two years and transplanting from the uncertified Greenwich and Apponaug Coves. During the transplants, fishermen planted more than 300,000 pounds (whole shell-on weight) of quahogs into the area. During the winter of 1982–83, the area was reopened with harvesting restrictions on time-to-fish and a reduced daily limit. Each spring, Greenwich Bay is closed to shellfishing and transplants are conducted prior to the summer spawning period. Animals in this management area spawn and purge their systems of contaminants picked up in the uncertified coves. Limited harvesting has occurred in subsequent years only during the wintertime.

The Greenwich Bay management program has many positive benefits for the fishermen. They have a somewhat sheltered waterway to fish each winter when other areas are not accessible. The annual harvest from Greenwich Bay alone approaches one million pounds annually, representing a substantial fraction of the total Rhode Island landings. Over the years, fishermen have reported improved recruitment of the resource, and the project is well received and supported by the fishing community. Another indirect benefit of the transplant program is the periodic reduction of the resource in uncertified waters. This reduces the incentive for illegal...
harvesting and reduces fishing pressure in other areas when Greenwich Bay is harvested.

The high natural productivity of quahogs in Greenwich Bay is what really makes the program successful. Other smaller transplant operations are not as successful because the actual transplant is not supplemented by additional recruitment. In effect, these smaller transplant programs are "put and take" in nature.

Spawner Sanctuaries

Two areas of the state contain "spawner sanctuaries." These are areas that are closed to harvesting and stocked with brood stock that hopefully will repopulate the area and its surroundings. Programs have been under way in Quonochontaug Pond and Winnapaug (Brightman's) Pond since 1980. Shellfish surveys revealed that once-rich shellfish resources in these ponds were seriously depleted. Quahog populations were less than one animal per square meter. Closure of these areas for three years did little to restore the stocks. In 1980, 50 bushels of quahogs were placed in each of the sanctuaries. Results of the 1988 shellfish survey in Quonochontaug Pond indicated that the overall quahog population density has increased from 0.7 animals per square meter to 2.04 per square meter, indicating a slow recovery. This summer (1990) new brood stock were planted into these two sanctuaries.

Pawcatuck River Studies

The feasibility of conducting a Pawcatuck River/Little Narragansett Bay transplant is being investigated. The ultimate goal would be to stock the seasonally opened waters of Little Narragansett Bay with quahogs and oysters. This may encourage fishermen to harvest in Little Narragansett Bay, reducing fishing pressure elsewhere. Preliminary bacteriological data on shellfish meats are encouraging. Stock assessments in the river indicate that a rich quahog resource exists. More information is being gathered as manpower becomes available. Several financial and operational hurdles must be overcome before a transplant becomes a reality.

Scallops and Oysters

Between 1977 and 1985, we transplanted bay scallops from Westport, Mass., into 27 different areas in Rhode Island. This program was terminated when the availability of scallop seed from Massachusetts ended in 1985. Several attempts have been made to plant hatchery-reared juvenile scallops, without much success (see Burns in this volume). This year's scallop proposal will be for planting on natural bottoms and for cage culture to protect the juveniles until they grow to larger size.

Oysters have been transplanted from growing areas to new, better growing areas. Oysters have been reintroduced into Brightman's Pond and have been stocked in Ninigret Pond and Quonochontaug Pond with the help of marine technology students from South Kingstown. More of this type of work needs to be done. Since our major oyster-producing areas are in uncertified waters (Narrow River, Green Hill Pond, and the Pawcatuck River), the potential stocks for transplant programs exist.

COMMENTARY

What I have presented here are the ongoing shellfish projects of the Division of Fish and Wildlife. Each has been successful on a small scale, but could be much more successful with greater financial and personnel support. Increased funding could improve the quahog yield simply by increasing the ability to move the product to cleaner waters. This year, with funding from the oil spill settlement, $70,000 was available for transplants, and we ran over-budget. The annual legislative appropriation of $20,000 is no longer enough to finance the shellfish programs, including the transplants. Virtually all of this $20,000 goes to pay shellfishermen for their efforts in the transplants; Department of Environmental Management expenses are extra. Certainly this $20,000 is a very small price to pay for a return in excess of $1 million from Greenwich Bay alone.

If personnel and funding are kept at their current and historically low levels, shellfish management will remain at a level where issues are addressed in response to crises. Project work can only be done when volunteers or student interns are available.

Considering the importance of our shellfisheries in terms of revenue and employment, they deserve better. Personnel for management, enforcement, and applied research are absolutely necessary.

You will be hearing about the level of commitment in some New York towns that are working to improve their fisheries. You will also hear about a town that provides more support for smaller fishery than Rhode Island does for a statewide industry. We, too, can undertake these types of projects if given sufficient resources.
QUESTIONS AND ANSWERS

Q: (Unidentified) I would just like to say that I enjoyed hearing that the Pawcatuck River is part of Rhode Island. I have been here all morning and this is the first time I heard the river mentioned. Thank you.

A: (Mr. Arthur Ganz) It has been a fun summer, we have been spending about a third of our time on the Pawcatuck. The Pawcatuck has always been considered a “polluted area,” so we have not been rushing to take a look at it, but there are considerable shellfish resources in the area. I was pleased with the information we received from the Health Department, so things look good there.

Q: (Mr. Richard Bellavance, Seven Seas Seafood) Have you looked into possible federal grant money for the transplant program?

A: (Ganz) Yes, we have looked into this. There is some money available for fish that move or migrate. There is a greater chance of interjurisdictional or interstate cooperation on those types of projects. For sessile animals such as quahogs, it is felt that the states should be responsible. There are some programs, but it is hard to justify things. One of the things we did look into is an interstate study on the Pawcatuck because it forms the border, but that did not fly too well. Federal money is hard to get. There is plenty of money for pollution studies, but stock management is considered purely a state and local issue.

Q: (Dr. John Sutinen, Department of Resource Economics, University of Rhode Island) I'm interested in the sanitary quality of the transplanted stocks. Can you comment?

A: (Ganz) We really have to go through the wringer on this. We first make a proposal to the Health Department. Then we have to go and take a series of samples for meat analysis. Samples from the area to be harvested are taken to the Health Department, where they do standard fecal coliform analysis and a metals screening, including cadmium, chromium, mercury, manganese, and others. If these levels are acceptable to the Health Department, we are given approval to transplant. The transplant-receiving waters are designated by the Rhode Island Marine Fisheries Council. They are closed by regulation to all shellfishing. Temperature of the receiving waters is monitored after the transplant. The animals (and I use the word transplant here rather than relay because of the long time period involved) remain in certified waters six to eight months.

Prior to the opening of the transplant bed to shellfishing, another set of samples are taken. These are then analyzed by the Health Department and they approve the bed opening. We might add that Joe Migliore went through some of the Interstate Shellfish Sanitation Conference criteria. The Rhode Island Health Department makes us meet the requirements that would be applicable to shellfish going through a depuration plant, which are stricter than simple relay requirements. There have been two occurrences, about three years ago, in which the Health Department has not approved the opening of transplant beds. These were the Bristol and Grinnell’s Beach beds. We had to wait an additional six weeks for final approval of the bed openings. So, we are scrutinized very heavily.
Toward Understanding and Improving the Abundance of Quahogs (*Mercenaria mercenaria*) in the Eastern Great South Bay, New York

JEFFREY KASSNER, ROBERT CERRATO, AND THOMAS CARRANO

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SYNOPSIS. The Great South Bay, New York, supports an important fishery for the quahog (*Mercenaria mercenaria*). Since 1986, an annual census of the quahog population in the eastern Bay has been undertaken to obtain data essential for management of the fishery. The censuses have revealed stable areas of high abundance of quahog interspersed with areas of low quahog abundance. To determine the characteristics of these high and low clam abundance areas, various population and environmental parameters have been documented. Ontogenetic growth and the abundance of four-year and older clams is the same in high and low abundance areas, but the abundance of one-year-olds is more than an order of magnitude greater in the high abundance area. The transition from an area of low clam abundance to high clam abundance corresponds with an increase in sediment compactness, and the transition occurs over relatively short distances. Compared to low abundance areas, high abundance areas have reduced biogenic reworking, and shells or shell fragments are generally present in or on the sediment surface. Based on these observations, surf clam shell fragments were distributed in a low abundance area that lacked shell to see if the addition of shell would enhance recruitment. The shell planting is currently being monitored.

INTRODUCTION

The Great South Bay is a shallow embayment located on the south shore of Long Island, New York. The Bay, which has an area of approximately 23,000 hectares, has historically been an important producer of the quahog (*Mercenaria mercenaria*). During the period 1980 to 1989, the mean annual quahog harvest reported for the Great South Bay was 170,000 bushels (National Marine Fisheries Service, unpublished data). However, during the preceding 10 years, the average annual harvest was 576,000 bushels (National Marine Fisheries Service, unpublished data).

As a result of 17th century colonial patents, the ownership of the Great South Bay is divided among three townships. This ownership confers primary management authority for the shellfish resources contained thereon to the respective townships (from west to east, Babylon, Islip, and Brookhaven). Each of the townships manages its shellfish resources through regulations and a variety of programs to maintain and enhance quahog abundance.

The Town of Brookhaven, which has jurisdiction over the eastern 6,000 hectares of the Great South Bay, initiated an annual census of the hard clam population as part of its shellfish management efforts in 1986. The initial intent of the census program was twofold: (1) to determine quahog distribution and abundance, and (2) to obtain information on quahog population dynamics. In addition to providing this management information, it became apparent upon completion of the third annual census that the distribution of quahogs was heterogeneous and that the eastern Great South Bay could be subdivided into distinct and stable areas of high and low quahog abundance. Because this observation had significant implications for the management of the shellfish resource, a series of research projects to determine the characteristics of high and low abundance areas have been initiated. It is hoped that by identifying the attributes of high and low abundance areas, strategies to increase the productivity of low abundance areas can be devised.

THE QUAHOG CENSUS

The quahog census is undertaken in an approximately 4,000 hectare area of Town of Brookhaven waters lying between Blue Point and Howell's Point (Figure 1). The census area is divided into a fixed grid of 232 elements measuring 412 meters by 402 meters...
(17 hectares). Sample stations are chosen randomly within each element with position determined by loran.

At each station, two replicate grabs are taken using a commercial clamshell bucket that samples a surface area of 1 square meter. For the 1986 and 1987 censuses, each grab was sieved through a 12-millimeter screen; but since 1988, a 6-millimeter screen has been used. The larger screen retains clams greater than or equal to 20 millimeters in shell length, while the smaller screen retains clams greater than 10 millimeters in shell length. Shell length and width are measured on all quahogs that are collected, and beginning with the 1988 census, shell height is measured as well. A random sample of clams are retained for later cross-sectional analysis of age and growth. Sediment type is qualitatively assessed for each station.

Quahogs enter the fishery at 25 millimeters in shell thickness, which corresponds to 48 millimeter in shell length and an age of 3 to 4 years (Greene, 1978).

Quahog abundance, using the mean of the replicate samples, is therefore reported for each station for the following clam size categories:

- Juvenile: < 19.9 mm in shell length
- Sub-legal: 20.0 mm ≤ 47.9 mm
- Pre-Fishery Recruit: 40.0 mm ≤ 47.9 mm
- Legal: > 48.0 mm
- Total: > 20.0 mm

Plots of quahog abundance and contour maps of abundance are prepared for each census, using a commercially available software package (SURFER, Golden Software, Inc.).

The mean quahog abundance for total, sub-legal, and legal categories of the 1986 to 1989 censuses is given in Table 1. During this period a slight decrease in abundance for each of these size categories is evident.

When contour maps of the Bay are compared for the 1987, 1988, and 1989 census years (Figures 2, 3, and 4), it becomes evident that there are several areas of
Table 1. Mean quahog abundance in quahog census area. Abundance expressed as the number of individuals per square meter.

<table>
<thead>
<tr>
<th>Census Year</th>
<th>Number of Quadrats</th>
<th>Total (≥20 millimeters)</th>
<th>Sub-legal (20-48 millimeters)</th>
<th>Legal (≥48 millimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>181</td>
<td>6.79</td>
<td>4.71</td>
<td>2.08</td>
</tr>
<tr>
<td>1987</td>
<td>233</td>
<td>6.67</td>
<td>4.51</td>
<td>2.16</td>
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<td>1988</td>
<td>232</td>
<td>6.27</td>
<td>4.25</td>
<td>2.03</td>
</tr>
<tr>
<td>1989</td>
<td>232</td>
<td>6.03</td>
<td>4.25</td>
<td>1.78</td>
</tr>
</tbody>
</table>

Figure 2. Contour map of total abundance (all quahogs ≥20 millimeters in shell length) for the 1987 census. Contour level is mean abundance.

Figure 3. Contour map of total abundance (all quahogs ≥20 millimeters in shell length) for the 1988 census. Contour level is mean abundance.

Figure 4. Contour map of total abundance (all quahogs ≥20 millimeters in shell length) for the 1989 census. Contour level is mean abundance.

Figure 5. The location of the high and low density regions used for the determination of quahog population characteristics.
consistently high quahog abundance interspersed with regions of low clam abundance. To objectively define areas of high and low clam abundance, several alternative statistical methods (mean abundance, median, quantities, minimization of variance, and cluster analysis) were tested. Based on the best balance between simplicity and precision of the estimates, mean total abundance as a single contour level produced the most reasonable geographic stratification of the census area. Accordingly, stations above the mean are classified as high abundance and those below the mean are classified as low abundance.

Using the mean total abundance, the number of grid elements classified as high abundance (1987, 1988, and 1989 censuses) ranges from 66 to 70, with a mean abundance of 15.2 clams per square meter. The number of low-abundance grid elements ranges from 160 to 165, with a mean abundance of approximately 2.6 clams per square meter. When the classification of each grid element is compared for this three-year period, 131 elements were low all three years and 42 were high all three years. The remainder were high for one or two years, but it is not clear if this variability is due to a change in hard clam abundance or to position within grid elements that contained both high and low abundance regions.

**Population Characteristics**

To characterize population parameters, an area of high quahog abundance and an area of low abundance were identified (Figure 5). A subsample of hard clam valves retained during the 1987 and 1988 censuses from each area were cross-sectioned and analyzed for age and growth. Results from the aged subsample were then used to constrain age and growth estimates derived from length-frequency distributions. This method is a modification of an iterative maximum likelihood technique developed by Hosmer (1973).

Population characteristics of the high and low abundance areas reveal several interesting similarities and differences:

- There is no difference in the abundance of clams greater than four years old, but one-year-old clams are more than an order of magnitude more abundant in the high density area (Figure 6).
- Ontogenetic growth was slightly higher in the low density area (Figure 7).
- Recruitment to the fishery was seven times greater in the high density area (Figure 8). These results indicate that differential settlement and/or survival to age 1 can account for the difference in abundance between the two areas.

**Environmental Relationships**

When the census contour maps are compared, eight areas of consistent high abundance and 10 areas of consistent low abundance are apparent. This pattern suggests that quahog abundance is determined by localized conditions or processes. When the distribution of quahog abundance is compared to the distribution of sediment type, high abundance areas coincide with regions of the Bay characterized by low silt-clay sediments and often with the location of relic oyster reefs. The sediments of low abundance areas are generally silt or mud.
Figure 7. Shell length vs. age estimate for the high density areas. Error bars are +2 SE.

Figure 8. Estimated recruitment to the fishery in the high and low density areas.

Although the distribution of hard clam abundance qualitatively correlates with sediment type, it is not clear which property or properties of the sediment is determining abundance. Bottom morphology and roughness, sediment porosity, cohesion, water content, organic matter content, bio-turbation rates, and refugia from predators, for example, may be playing significant roles in quahog settlement and survival rates. To evaluate associations between quahog abundance and sediment parameters, the sedimentological environment needs to be characterized on a variety of scales. For this reason, a sediment profile camera was used to determine bottom micro-morphology, benthic fauna, and micro-stratigraphy of the uppermost few centimeters of the sediment column; a side-scan sonar was used to map the areal distribution of sediment type and morphology; and an ROV was deployed to determine the sediment surface features.

Sediment-Profile Characteristics

Sediment profile photographs were obtained and analyzed from 89 locations (48 with low clam density and 41 with high clam density; see Figures 9a and 9b respectively for representative photographs), using the Remote Ecological Monitoring Of The Seafloor (REMTS) system (Rhoads and Germano, 1982). All REMTS stations were within 200 meters of a quahog census station and station-specific quahog abundance data were available at approximately half of the REMTS stations. Although REMTS provides data for 21 different variables, only four were used to characterize high and low clam abundance areas: sediment type (mean major sediment mode), camera penetration (a measure of sediment compactness), apparent redox potential discontinuity (RDP) depth, and sediment boundary roughness. In addition, the sediment photographs were examined separately for the presence of shell and the extent of the surficial flocculent layer.

When data from the stations in areas of high clam abundance are pooled and compared with the pooled low clam abundance area data, the following differences in REMTS parameters are revealed:

- The mean major sediment mode was 3.6 phi units for the high-abundance stations, compared to 3.3 phi units for the low-abundance stations.
- The mean camera penetration was 11.1 centimeters for the high-abundance stations, compared to 13.2 centimeters for the low-abundance stations.
- The mean apparent RDP depth was 2.2 centimeters for the high-abundance stations, compared to 2.4 centimeters for the low-abundance stations.
- The mean surface boundary roughness was 1.2 centimeters for the high-abundance stations, compared to 0.9 centimeter for the low-abundance stations.

Thus, in high clam abundance areas, the sediment was coarser and firmer, had less reworking, and had a more complex surface topography compared to the sediment in low clam abundance areas. In addition, high abundance areas had a higher abundance of shell fragments and a thinner flocculent layer.
To facilitate the comparison of sediment characteristics of high and low abundance areas, the sediment profile photographs stations were arrayed in 11 transects that crossed a total of 18 high abundance–low abundance transitions, with stations spaced 200 meters apart. Although relationships between clam abundance and the sediment parameters are sometimes difficult to discern, the change in sediment characteristics in transition areas between low and high abundance is quite apparent (see Figure 10 as a representative example). Across all of the low-to-high clam abundance transitions, there was a sharp drop in the camera penetration. Across two of the low-to-high clam abundance transitions, RPD depth increased; but at 16 of these transitions, RPD depth decreased. Boundary surface roughness increased at nine low-to-high clam abundance transitions, decreased at two, and remained the same at four. Major sediment mode decreased at 10 low-to-high clam abundance transitions, increased at two, and remained the same at three.

**SIDE-SCAN SONAR CHARACTERISTICS**

A side-scan sonar was used to map the distribution of sediment type and sediment surface roughness in
Figure 10. Changes in the sediment-profile parameters and quahog density on a transect that crosses from an area of low abundance to an area of high abundance.
approximately half of the census area. Geographical changes in sediment characteristics are indicated as variations in grey tone and texture on the sonograph. The REMOTS photographs and census sediment data were used to “ground-truth” the sonograph.

In low abundance areas, the sonograph was generally uniformly light and without texture, indicating muddy sediments without reflective elements (e.g., shells) and a flat surface topography. High abundance areas were darker and had a matted texture indicative of sandy sediments, the presence of shells, and a greater bed roughness. The change in sediment characteristics occurred over distances generally less than 100 meters—a striking observation.

**ROV Characteristics**

To characterize the features of the sediment surface, an ROV was deployed at 28 locations, all of which coincided with the REMOTS sediment profile photograph stations. Low abundance areas were generally flat and the sediment surface was relatively soft. In high clam abundance areas, the sediments tended to be firmer. Clumps of oyster shells, quahogs shells, and unidentified shell fragments less than 15 millimeters in size were often present in the sediment surface or rising above the bottom, with coverage ranging from scattered to dense.

**Characterization of Quahog Abundance**

The quahog census revealed that the census area can be subdivided into distinct areas of high and low abundance areas that persist over time. These areas can best be defined with respect to their abundance, relative to the total mean abundance for a census. The abundance of clams in the high abundance areas is approximately seven times that of low abundance areas. There is no difference in the abundance of clams older than four years, but one-year-old clams are more than an order of magnitude more abundant in high-density areas. Growth is slightly faster in low abundance areas. The population data suggest that differential settlement and/or survival to age 1 may be responsible for the differences in quahog abundance.

The distribution of clam abundance correlates with the distribution of sediment type. The sediment characteristic that appears to be most related to clam abundance is sediment stability. Based on changes in the sediment-profile camera’s depth of penetration, the sediment in high abundance areas is more compact than in low abundance areas. Low density areas typically had a thicker surface layer of soft, unconsolidated, high pore water content sediments. High-density areas had a much thinner layer or lacked this surficial layer completely, and shells and shell fragments were often present either on or rising above the sediment surface.

The surficial sediments of low abundance areas are thus more unstable and more erodible than the sediment occurring in high abundance areas. Sediment instability could adversely impact quahog abundance in several different ways. Quahogs may, for example, avoid setting in unstable sediment. If clams do set, they may experience high mortality due to either predation by the resident infauna inhabiting this type of sediment or to physical and/or biological disturbance. In addition, quahogs may be susceptible to transport out of these areas during erosional events.

If sediment instability is responsible for low quahog abundance, there are several ways in which quahog abundance could be increased. For example, the bottom could be worked with a scallop dredge to disperse the flocculent layer. Alternatively, hatchery-raised seed clams of a size that is not affected by sediment instability could be planted.

The role of shells, if any, in determining quahog abundance is not clear. Shells may serve to confuse predators, stabilize the surface sediment layer, or actively or passively accumulate pediveligers or small clams. To evaluate the possibility that shells play a role in increased hard clam abundance, an experiment was started in 1989. One hundred cubic meters of surf clam shell fragments were distributed in two 0.4 hectare areas located in a muddy, low clam abundance area that lacked shells. The two sites are being monitored to see if they experience increased recruitment relative to the adjacent area with no shells. Based on the 1990 census, it does not appear that the artificially shelled area experienced enhanced settlement in 1989.

The studies of hard clam distribution and the associated environmental characteristics have provided considerable insights into the factors that may be related to quahog abundance. Additional research is needed to determine if the difference in abundance is due to either
differential settlement or differential survival and what specific factor is responsible. New quahog enhancement strategies have been suggested but require detailed evaluations.

ACKNOWLEDGEMENTS

The continuing support of Town of Brookhaven Supervisor Henrietta Acampora, the Brookhaven Town Board (particularly Councilman John LaMura), and the Brookhaven Baymen's Association is gratefully acknowledged. The town's research effort was partially funded by a grant from the New York State Department of Environmental Conservation, which also provided vessel support. The ROV was made available by a loan grant from the National Underwater Research Program, Avery Point, Conn.

REFERENCES


QUESTIONS AND ANSWERS

Q: (Mr. William Burns, Rhode Island Scallop Project) How do you get financial support for this type of research?

A: (Mr. Jeffrey Kassner) As I mentioned, in New York, shellfish management resides at the township level, and the towns have traditionally been very active in shellfish management. In the 1800s, all of the towns were involved in oyster management in one way or another. In the 1970s, the shellfish industry was much bigger than it was today. Landings were up, and in Brookhaven alone we had 1,500 licensed Baymen, and they harvested 300,000 bushels worth over $5 million in 1976. Now the industry is on a decline, and everybody is hoping that we can increase the abundance of hard clams. In all fairness, some funding was from the State Conservation Agency that was interested in hard clam abundance as well. In Brookhaven, our budget for hard clam management is around $200,000 per year. We do this type of work out on the Bay. We do spawner transplants, seed planting, and a whole host of activities to support our shellfish industry.

Q: (Dr. Michael Rice, Fisheries and Aquaculture, University of Rhode Island) Jeff, I was struck by your data, especially the age-frequency data from both of the density areas. The age-frequency values seem to be considerably lower than areas that we would call management areas. How are stocks managed? Or what are the basic tenets of stock management in Brookhaven?

A: (Kassner) The basic stock management plan in New York is to go out and catch whatever you can. We have not embarked on the plan of rotational closings; although I think that our data suggest that may not work. If you want to manage hard clams, you have to manage on a location-by-location basis, much as they managed oyster reefs during the turn of the century. Our efforts are geared toward stock augmentation, because it is politically more acceptable.

Q: (Dr. John Sutinen, Department of Resource Economics, University of Rhode Island) Can you completely rule out the possibility that the flocculent layer is an effect of quahog populations rather than the other way around?
A: (Kassner) You could make the argument that the flocculent layer is not present in high abundance areas and those are the areas that are being harvested. So the harvesting action could be resuspending and aerating the sediments. It could be that a certain threshold density of hard clams is preventing the biological reworking of sediments, leading to the lack of the flocculent layer. The causality is very hard to determine but the correlation between density and sediments is clear. That is why we are planning to go in there to try to remove the flocculent layer in an attempt to improve hard clam abundance.

Q: (Sutinen) Are there any dredge operations?
A: (Kassner) No, they are all hand operations, mostly bullrakes.
Shellfish Management and Restoration Programs in Connecticut
(Abstract only)

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ABSTRACT: Shellfish, as well as other common or communally held resources, have traditionally been managed for the benefit of all. Guardianship of such resources that are held in trust is usually exercised by individual states. However, in Connecticut, two jurisdictions exist for the management of shellfish resources. In 1881, legislation enacted by the Connecticut General Assembly created a headland-to-headland jurisdictional line. Inward of the line, Connecticut’s coastal towns have the responsibility for managing shellfish resources. The offshore waters are administered by the Department of Agriculture–Aquaculture Division based in Milford, Connecticut. Some town waters (City of New Haven, West Haven, Milford, and Westport) are under state jurisdiction. Both town and state waters have private aquaculture enterprises (leased or deeded acreage) and public shellfisheries.

QUESTIONS AND ANSWERS

Editor’s note: Mr. Visel’s presentation touched on program details not covered in the submitted abstract; this is reflected in the following questions and answers.

Q: (Mr. Joseph Migliore, Rhode Island Department of Environmental Management, Division of Water Resources) In your bag relay system, when you move the shellfish from restricted waters, is there a mechanism for doing a meat analysis?
A: (Mr. Tim Visel) Yes, every batch is tested.

Q: (Mr. Arthur Ganz, Rhode Island Department of Environmental Management, Division of Fish and Wildlife) In your bag relay system, what is to prevent piracy?
A: (Visel) The trawls are set in-line. A heavy weight is put at the end of the line, so that they are retrievable only by hydraulics. It is pretty hard to do during the day, but at night shellfishing is banned.

Q: (Mr. Robert Rheault, Spartco Ltd.) Tim, I was wondering if your cultivators require any permits, or if they have any environmental impacts?
A: (Visel) They certainly do have an environmental impact. It’s much like rotoiling. Use of cultivation on private leases is OK, because of the broad range of allowable activities on the leases. On public grounds, it is a different story. Cultivation is received somewhat positively, with concern. The concern is that someone might come in and remove 8 feet of black flocculent material. Usually, we are dealing with only a few inches of this fine sediment, which is no more than an outboard wash. A lot of people do not bother with a hydraulic pump. They simply take the bag off their oyster dredge and go back and forth across their grounds. It’s a matter of technology—are you going to make this guy take the bag off his dredge and go back and forth, or allow him to use hydraulic equipment? The same amount of sediments are moved, but the hydraulics do it in a shorter time.

Q: (Rheault) In effect, wouldn’t you be sitting up the bed downstream?
A: (Visel) That’s a good point. Most fishermen are not close to another bed. They try to do the cultivation during maximum tide. It does have a high suspension time, and once you get the sediments up in the water column, they stay there for a while. It is done mostly in the winetime when there is more available oxygen, to minimize local in-situ oxygen depletion. Yes, the bottom cultivation does have environmental impacts, but probably no more than tilling a field on land. In both cases, there are organisms affected.

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Growth of Seed Quahogs (*Mercenaria mercenaria*) in Nursery Trays in Great Salt Pond, Block Island, Rhode Island

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**SYNOPSIS.** The Town of New Shoreham, Block Island, has undertaken a shellfish aquaculture project in order to enhance the shellfisheries in the Great Salt Pond. Hatchery-reared seed was planted in intertidal nursery boxes containing a sand and gravel substrate. Quahogs held at 6,700 individuals per square meter in the protected nursery boxes reached field-planting size of 15-millimeter valve length in two years or less. Overall mortality of quahogs is about 20 percent, assuming that nursery boxes are moved to a subtidal location for overwintering. This project demonstrates the technical feasibility of bivalve aquaculture in the Great Salt Pond of Block Island.

**INTRODUCTION**

The Town of New Shoreham authorized creation of a municipal shellfish management program in 1987. Due to declining natural stocks and the loss of the shellfishery during the summer months due to water quality degradation, seed quahogs (*M. mercenaria*) were purchased for intermediate grow-out in nursery trays. The purpose of this undertaking was twofold: (1) to provide increased numbers of sub-legal-sized animals for later recruitment to the fishery, and (2) to demonstrate the feasibility of small-scale mariculture on Block Island. The community is noted for seasonal unemployment and a strong dependence on tourism and tourism-related economic activity. Shellfish aquaculture may be a viable year-round economic alternative for the town.

**METHODS**

About 150,000 4 to 6 millimeter, hatchery-raised *M. mercenaria* were purchased and planted at a density of 6,700 per square meter in a sand/gravel substrate in submerged plywood trays 1.2-by-2.4 meters by 9 centimeters deep. The trays were placed intertidally during the summer months at approximately mean low water. The trays were covered with removable screened frames of 6.35-millimeter plastic mesh (Vexar) to exclude predators. The quahogs were planted in June of 1987 and 1988, and their valve lengths were measured regularly with vernier calipers during the months of July, August, and September 1988. Mortality was assessed by assessing the ratio of empty gaping shells to live animals at the time of measurement. Between November and April, the nursery trays were moved so that they were about 2 meters below mean low water to reduce overwinter mortality. When animals reached 15 millimeters or greater valve length, they were planted in shallow, accessible shellfishing areas to supplement natural recruitment. The first plantings of seed clams occurred in the spring of 1989, and have continued in 1990.

**RESULTS**

Figure 1 shows the growth (valve length in millimeters vs. Julian date or numerical date of the year) for 1987 and 1988 seed quahogs during the summer of 1988. The 1987 animals increased in size from approximately 11 millimeters to 17 millimeters, while 1988 animals increased in size from approximately 5 millimeters to 13.35 millimeters during the same period. Figure 2 is a size-frequency distribution for the 1987 quahogs after they had been held for two years. The mean valve length of the last measurement of the season was 17.35 millimeters. The maximum value was 25 millimeters. The minimum value was 7 millimeters. Greater than 70 percent of the animals held for two years had valve lengths greater than or equal to our planting size of 15 millimeters. Mortality was approximately 20 percent annually overall; however, mortalities ranged from 30 percent to 5 percent in individual trays.

As of this date (fall 1990), legal-sized (about 48-millimeter valve length) cultured quahogs are now being captured by shellfishers. More than 50 percent of
The animals have the distinctive brown markings associated with the hatchery-reared *M. mercenaria* subspecies *M. m. novata*, making them easily distinguishable from natural stocks.

**DISCUSSION**

It is most often economically efficient to purchase relatively inexpensive small quahog seed (2 to 4 millimeters in mean valve length) from hatcheries. Although inexpensive, direct planting of this small seed will not be successful because of losses due to predators. Castagna (1984) suggested the use of wooden nursery trays with predator protection screens as a means to lessen the impacts of predators on small seed quahogs until they reach a predator-resistant size. We have modified Castagna’s methods for this study.

The Great Salt Pond appears to be well suited to quahog mariculture. The data indicate that most seed quahogs reach 15 millimeters in less than two years. The harvest of legal-sized, previously seeded quahogs suggests that a quahog may be grown to market size in three to five years. This growth rate is similar to that reported by Malinowski (1986) for quahogs grown on nearby Fisher’s Island, New York. The growth of the Great Salt Pond quahogs appears to be faster than those in the West Passage of Narragansett Bay, which take about 6.5 years to reach a legally harvestable size of 48-millimeter valve length (calculated from data of Rice et al., 1989).

A number of studies have suggested that growth of *M. mercenaria* in intertidal trays is affected by planting density. For example, Eldridge et al. (1979), working with fairly large 13.5-millimeter seed, showed that...
In conclusion, this project has demonstrated the technical feasibility of bivalve mariculture in the Great Salt Pond. The project is expected to continue, with the aims of working out optimum stocking densities of animals in the nursery trays and improving winter survival.

ACKNOWLEDGEMENTS

Many individuals are responsible for the success of this project. The New Shoreham Shellfish Commission and the Town Council are to be commended for their foresight and dedication to innovative shellfish management. Arthur Ganz, senior marine biologist of the Rhode Island Department of Environmental Management, was instrumental in obtaining regulatory authorization for the project and has been a continuous supporter of shellfish and shellfisheries on Block Island. Michael Rice of the Department of Fisheries, Animal and Veterinary Science at the University of Rhode Island has provided technical support and is responsible for design and analysis of the growth data. Rachelle Fallon is due special thanks for her efforts in measurement of the quahogs.

REFERENCES


QUESTIONs AND ANSWERS

Editor’s comment: In addition to the municipally-sponsored quahog fishery enhancement program, the Town of New Shoreham has sponsored a program that offers a floating pump-out facility designed to service visiting boats moored in the Great Salt Pond during the summer. This is an effort to mitigate downgraded water quality due to the high numbers of transient, live-aboard boats. Mr. Littlefield spoke about this program in his oral presentation, so this is reflected in the following questions and answers.

Q: (Mr. Tim Visel, Connecticut Sea Grant) Have you had any problems with algal blooms?
A: (Mr. Christopher Littlefield) We had the “brown tide” events in 1985, 1986, and 1987. I have been around the pond since I was a little kid, and that was the worst water clarity I had ever seen. It began to clear up last year. This year it is very clear; you can walk along the dock and see the bottom in 15 feet of water.

Q: (Visel) During the blooms, did you notice any shellfish mortalities?
A: (Littlefield) In 1985, the pond was still open. I distinctly remember an algal mat on the bottom and the low water clarity. The animals (quahogs) were crawling on the bottom, at least 50 percent of them. They were stressed. This year boat numbers are down, and that is our major source of pollution.

Q: (Visel) Did the algal mats break up?
A: (Littlefield) Yes, what happens is that bubbles form below the mat and they float to the surface. Then we get calls about sewage on the beach. Of course it is not sewage but these rotting algal mats. I think that this public concern for “sewage” on the beach is what precipitated the close look at water quality by the Water Resources Division.

Q: (Dr. John Gates, Department of Resource Economics, University of Rhode Island) I was at a conference some years ago, and they were talking about something that might be of use to you in your winter mortality problem. They were collecting clams in the fall and storing them in a root cellar; keeping them at low temperature and high humidity.

A: (Littlefield) Yes, I think that Mike Rice gave me some information about that. I think that Bob Rheault was trying it.

A: (Mr. Robert Rheault, Spatco Ltd.) Yes, apparently it works with oysters. We tried it with quahogs with no luck.

Q: (Mr. William Munger, Rhode Island Marine Trades Association) Chris, you indicated that your boat numbers are down this year. What would you estimate your average weekend numbers to be now?
A: (Littlefield) This year it is averaging about 700 to 800 per weekend, perhaps less, which is quite low. If we have good weather over Labor Day weekend, we could see 1,800 boats.

Editor’s comment: There was good weather over the 1990 Labor Day weekend, and an estimated 1,700 to 1,750 boats were in the Great Salt Pond.

Q: (Munger) Back to your pump-out vessel—I was impressed by that. I’m a recreational boater. Your Romarine with the inner compartment seems to be pretty slick. What kind of action is that getting on a typical 700 or 800 boat weekend?
A: (Littlefield) The boat numbers seem to be down by about 50 percent this year, yet the calls for pump-out have doubled over last year. One thing I did not get into about the system is that until we get more industry standardization of pump-out facilities, the mobile system may work very well. Once people find a mooring in the Great Salt Pond, they do not want to leave their spot.

Q: (Mr. Jamal Kadri, Save The Bay) How are you enforcing the no-discharge ordinance? Are you putting dye tablets in the marine heads?
A: (Littlefield) No, we don’t use dye, but if we see a discharge, we do issue violations. We would like to go to a higher level of enforcement, that is one of the goals for next year, but that will require more people and more money.

Q: (Kadri) When people are cited, what happens? Are they fined?
A: (Littlefield) We are allowed under our local ordinance to fine up to $200. This is a pretty good deterrent.
The Relationship Between Harbor Management Planning and Shellfishing in Rhode Island

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SYNOPSIS: In September 1988, the Rhode Island Coastal Resources Management Council (CRMC) required each coastal community in the state to develop and implement a local harbor management plan (HMP). The aim of the local HMP is to provide a basis for integrated resource management, balancing the fundamental needs for environmental preservation and economic development. This is accomplished through a public decision-making process in which shellfishermen can actively participate. Key multiple use conflicts include rezoning and changes in shoreline use away from traditional use patterns. Other conflicts stem from the fear of pollution and shellfish bed closures as a result of harbor development and expansion. It is too early to assess the true impacts of HMPs, but fishers are important to the planning process, providing a necessary balance with other user groups that perceive the need to use local waters only for their own special interests.

INTRODUCTION

In September 1988, the Rhode Island Coastal Resources Management Council (CRMC) began the Rhode Island Coastal Harbors Project. Under the project, each coastal community within the state is required to complete a local harbor management plan (HMP). These plans and implementing ordinances will serve as management and development guidelines, specifying the activities each community wants to encourage in its coastal waters and on adjacent land.

The CRMC knew that developing an HMP would be difficult for many of Rhode Island’s coastal communities. Therefore, the first action taken by the CRMC under the new harbors project initiative was the establishment of a harbors project advisory committee. The committee members, representing a broad spectrum of marine interests, were asked to develop guidelines to assist the towns as they put together their HMPs. The guidelines, drafted with the input of these key industry personnel and incorporating the viewpoints and concerns of each particular interest group, were officially adopted by the CRMC in November 1988.

Representatives of Rhode Island shellfishing organizations were important and integral members of the committee. Since the unique value and contribution of shellfishing is recognized in the Rhode Island Constitu-


tion, the relationships between the shellfishing industry and other users of the state’s coastal waters required careful attention. Many shellfishermen claim that their constitutional protection has been severely eroded; for example, by the permanent and seasonal closures of acres of shellfish grounds.

It may be too early to assess the impacts of harbor management planning on shellfishing in Rhode Island. Nonetheless, it is worthwhile to examine the specific aspects of harbor planning that may affect the lives and livelihoods of shellfishermen in Rhode Island.

ISSUES
Rezoning and Shorefront Use Changes

The HMP Guidelines discuss shellfishing in a number of contexts, most notably in reference to the displacement of traditional fishing-vessel docking and service locations by residential and recreational boating uses. Prior to the recent implementation of harbor management planning, land use and coastal facility changes took place without the benefit of waterfront planning goals that were approved by the state and formulated by public input. Developers were granted zoning change requests and other modifications that could substantially alter the use of a piece of waterfront property. Although existing legal procedures were followed, and existing
policy demanded the so-called “highest and best use” of the land, communities ignored impacts on fishermen when new uses produced greater tax revenues or were “more attractive.”

In spite of these attitudes, commercial shipping and offshore fishing enterprises obtained assistance from the state and federal governments to develop and maintain necessary waterfront port facilities. However, the in-shore shellfishmen of Rhode Island have not received this kind of support. The harbor planning process enables shellfishmen to gain commitments from local coastal communities to establish satisfactory land-side support facilities for this critical and historic operation. Once the CRMC approves a local HMP, the provisions identified in the plan form the basis for CRMC decision-making concerning the use of that particular coastal environment. For example, if a local developer proposes to construct a dockominium in an area that was approved as a shellfish landing location, the request will be denied. This process gives a significant amount of control to the individual communities, and allows them to direct the growth and use of their coastal zone, within the limitations of state and federal law.

Fear of Pollution Impacts

Thousands of acres of shellfish grounds in Rhode Island waters are permanently closed due to the presence and continued input of various pollutants. These pollutants pour out of factories, power plants, sewer overflows, and various nonpoint sources, such as runoff from rainstorms, failed septic systems, and on-water activities such as boating. Pollution results from the disposal of heavy metals, trash and garbage (including plastics), hydrocarbons, and sewage. Shellfishmen have good reason to be concerned about these pollutants, because their presence can have a direct impact on the fishermen’s ability to harvest the resource.

In recent years, these varied pollutant sources have been under attack by fishermen, regulators, and local environmental organizations. Their common goal is to reduce, and preferably eliminate, the continued pollution of state waters. Harbor management planning empowers every coastal city and town to promote and implement a water quality management program that strives to achieve the highest possible water quality and ensure that shellfishing can continue in local waters. Communities can act to control point and nonpoint sources of pollution that may be harmful to their shellfish resources.

One of the most common concerns of shellfishermen is the increase in numbers and locations of recreational boat moorings. Not only do moorings present physical obstructions to the digging of quahogs, but many of the moored boats are potential sources of sewage pollution. State interpretations of the Federal Water Pollution Control Act of 1972 and subsequent amendments, known as the Clean Water Act, prohibit the harvesting of shellfish from marinas. The State has interpreted a marina to be a site that accommodates more than four boats. Not only can shellfish not be harvested from the bottom lands within the marina, but a buffer zone around the marina is also off-limits. The conflict is obvious: More boats mean more marinas which mean more buffer zones resulting in less shellfishing potential.

Harbor management planning provides an acceptable means of restricting the number and location of moorings and boats in coastal waters. By designating where moorings can be located and setting limits on the number of moorings, each municipality helps to limit the proliferation and expansion of mooring fields. This, in turn, reduces the potential for conflict among shellfishermen, recreational boaters, and marina operators.

However, the designation and recognition of “official” mooring areas has been challenged as a de facto degradation of water quality and therefore a violation of the Clean Water Act. Unfortunately, regardless of the validity of this argument, moorings will continue to spread unless action is taken at the local level to identify and limit where they can be placed.

For many fishermen this is a catch-22. They have two choices: They can fight against HMPs that designate “mooring fields,” which many fishermen believe to be in violation of state and federal law; or they can accept the designations. If they fight the designations, they can expect moorings to go unregulated and proliferate as they prepare a legal challenge, without any assurance that they will win. If they choose to accept the “official” designations, then they know that the waters in and around those new mooring fields will probably be closed to shellfishing. From the perspective of the shellfishermen, it appears to be a lose-lose situation in which the only choice is between the lesser of two bad alternatives.
Other Issues

Harbor management planning enables shellfishermen to provide input into regulations that control the movement of boats and the activities of boaters. Since shellfishermen depend on the water to make a living, they are concerned about regulations affecting the speed of boats, the behavior of boaters, identification of anchorages for transient boaters, waterskiing locations, sailing regattas, and more. Contributing to the establishment of common-sense harbor and waterway rules and regulations is important, and shellfishermen are deliberately sought out to participate in this process.

Quahoggers frequently trailer their boats to and from the shellfish grounds around the state. Feedback from fishermen and recreational boaters seems to indicate that more ramps and adjacent parking areas are needed within a reasonable distance to the fishing grounds. An HMP can be used to designate lands for these purposes and provide guidance for changes to local ordinances for implementation.

Conclusion

Harbor management planning was never intended to provide perfect solutions to multiple-use conflicts. But it is a start toward integrated resource management, incorporating the fundamental need to preserve the environment while attempting to advance the well-being of the state. The development of an HMP offers a unique opportunity for shellfishermen to participate in the public decision-making process in their own community, or in those towns where they fish or use waterfront facilities.

Input from shellfishermen is essential to HMPs. They are more familiar than the average resident with the activities that take place in the marine environment. Their experience with weather conditions, tides and currents, and knowledge of critical natural resources provide important information that must be addressed when deciding where certain types of water-related activities should occur. Fishermen also provide a necessary balance to other user groups that perceive the needs only of their own special interests. The balance of opinions and interests is a key component in the makeup of a harbor planning committee, and shellfishermen represent one of the major interest groups.

Questions and Answers

Q: (Mr. Tim Visel, Connecticut Sea Grant) Tom, where are the teeth in these management plans? Are they mandated by some state agency?

A: (Mr. Thomas Brillat) Each coastal town must develop a harbor management plan. The teeth come from each community writing the ordinance that implements the plan. That is the hard part. A number of towns have shied away from developing an effective ordinance. The CRMC has required all towns to develop an ordinance, so all towns are working on it.

Q: (Visel) In relation to the mooring fields in shellfish management areas, about 10 years ago the people of Cape Cod realized that there was a conflict between mooring fields and shellfishing. They partially resolved this by requiring that moorings be removed in the fall and placed back in the spring. Has this been considered at all?

A: (Brillat) Yes, and there have been mixed reactions. It is highly dependent upon location, because there are some areas that are more important than others from a fisheries standpoint. Then there is the problem of who is going to pay for the removal and replacing. Then there is the question of environmental impacts from constant setting and resetting of the moorings. There have been no studies on this. All of these issues have come up. There is at least one town that is proposing a winter removal system, but they are trying to find a way to fund it.

A: (Mr. Chris Littlefield, Harbormaster, Block Island) I'd like to add to that that we have a mooring contractor on Block Island that hauls and sets every year. This is cost-effective because a few years ago we lost a substantial number of moorings due to ice. I dive, and my observation is that once you get into that black flocculent sediment, the moorings hold a lot better and there are few quahogs or other shellfish in that area. Our town mooring fields are off the hard bottom. It is rather amazing what these moorings can do to the soft bottom areas. They just continue to go into the bottom, creating cone-like depressions as they go. These depressions can be as much as 6 feet deep. It has been my practical experience that if you have moorings in hard-bottom areas, it would be a good idea to move them occasion-
ally. You might have the beneficial effect of cultivating, but this must be tested.

Q: (Mr. Arthur Ganz, Rhode Island Department of Environmental Management, Division of Fish and Wildlife) How far along are many of these towns in the development of their plans and ordinances? Are most done?

A: (Brillat) No, most are not done. It's ongoing in Cranston, Portsmouth, Bristol, South Kingstown, and Narragansett. Warwick, East Greenwich, Tiverton, and Charlestown are done. East Providence and Barrington have started; so this process is very much ongoing. I think that the first push got a lot of media attention, and it got a lot of attention by CRMC directly. CRMC has been involved in all of the harbor plans.

Q: (Mr. Robert Rheault, Spatco Ltd.) One of the problems we are finding in South Kingstown is that the town does not have the responsibility for regulating shellfishing; it must be done by the Department of Environmental Management. As much as the towns may want to regulate shellfishing, or regulate failing septic systems, the plans and ordinances have no "teeth" in these very important areas. All we can do is make recommendations back to the state agency. This is certainly not a comprehensive plan.

A: (Brillat) Art Ganz from Fish and Wildlife can probably address that better than I can. We invite Art and other appropriate state officials to these meetings to outline town options. In terms of failing septic systems, the towns can certainly pass ordinances and enforce them, as long as they fall within state and federal guidelines. This has already been done in Tiverton.

Q: (Mr. James Boyd, Rhode Island Shellfishermen's Association) In respect to who is going to pay for mooring removal, what I think it comes down to is the user of that mooring. The reason that people are on moorings is that either there are no docking facilities or they do not want to pay the $1,200 or more to use a slip. The moorings that most people use might cost them from $25 to a couple of hundred dollars a year. If a town or mooring contractor hauls out the moorings every year for the going rate of about $150 to $200, you could then charge the user a fee which would still be considerably less than the dock fees.

A: (Brillat) I agree, that's the way it should be, and that's the way it will probably wind up. The recreational boating community, which is very large in this state, does not like this. One of the fears of the shellfishing community is the sheer numbers of recreational boaters who fear another new tax.

Q: (Boyd) Another problem with moorings left in the winter is that recreational boaters will attach 2-by-4s for extra flotation and protection of their moorings during the winter. These have the effect of holding ice in coves and inlets, preventing boats from going in and out. Ice is often trapped for an extra two or three weeks in the coves.

A: (Brillat) That is an interesting argument that I had not heard before.

Q: (Boyd) Yes, if the mooring fields were taken out each year, the ice would clear out a lot sooner.

Q: (Mr. Chris Blansfield, Block Island Harbormaster's Department) There is a maintenance issue here, too. Moorings that are taken out each year are more likely to survive storms.

A: (Brillat) I agree with you, that is one of the classic problems of harbor management. Annual maintenance is the only way to assure that you will have something of quality and substance there.

Q: (Mr. Tim Rockwell, shellfisherman) In relation to that: As a raker, your worst nightmare is a lost mooring. A mooring with a float on it you can see, and you can avoid it. The lost mooring, the one you cannot see, it's a surprise.
The Rhode Island Scallop Restoration Program

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SYNOPSIS. Rhode Island’s bay scallop (Argopecten irradians) fishery historically has been indigenous to a large number of salt ponds and other estuarine waters located in the coastal regions of the state. In the 1980s, the populations in these areas declined severely, due in part to predation, weather, and man-made influences. But it was the algal blooms of the mid-1980s that all but eliminated these populations in the state. A restoration program, the Rhode Island Scallop Project, was initiated to address the factors expected to affect the fishery in the future. The project’s goal, to reestablish the fishery in a five-year period, was set after examining prior programs. The project was designed as an integrated, comprehensive program. During its first two years of existence, the project began a reseeding effort that, although conservative in nature, has placed scallop seed in selected areas within the state.

INTRODUCTION

The Rhode Island Scallop Project, Inc. is a not-for-profit organization. In a cooperative effort with the Department of Environmental Management’s Division of Fish and Wildlife, the project hopes to restore the bay scallop fishery in Rhode Island waters. The project’s advisory staff is comprised of recreational and commercial shellfishermen, staff members from DEM’s Division of Fish and Wildlife, and private citizens.

Rhode Island Scallop Project secures funds for its reseeding efforts from the private sector by soliciting individuals, companies, and other organizations. The Division of Fish and Wildlife, using a unique funding approach, matches the private sector money on a dollar for dollar basis and secures bids for the supply of scallop seed. The management of the fishery, including site selection and evaluation of predation, growth, and other factors, is overseen by the division’s marine biologists. They, in turn, are supported by volunteers from the Scallop Project who assist them in insuring the success of each year’s placement.

HISTORY

The bay scallop developed as a commercial and recreational fishery in the 1800s when scallops were recognized as a viable food staple in the region. Previously, many had believed scallops to be poisonous. This fallacy may have been derived from the vast array of colors exhibited by the internal organs of the species. The suspicion has carried over until today, as only the adductor muscle is shucked and consumed. In Europe and elsewhere, scallops of many varieties are consumed whole, and various organs are considered a delicacy.

The advent of the bay scallop as a commercially viable fishery prompted the design of appropriate vessels and gear to maximize catch and minimize effort in harvesting the species. In the early days of the fishery, the species could be found in relative abundance in areas of Narragansett Bay and the Sakonnet River, and also in the salt ponds. As in the case of many fisheries, the bay scallop population decreased significantly when overexploitation occurred in the early part of this century.

In the later part of the century, up until the 1980s, scallop populations fluctuated widely in the state. A harvest of 50,000 bushels was recorded in 1975, and an average harvest of 2,500 bushels in the next decade. In 1985 and again in 1986, in what were considered rare occurrences, severe brown algal blooms all but eliminated scallops in the state except in some isolated areas. These blooms devastated scallops not only in Rhode Island but also in the overwhelming majority of populations throughout the northeast region from Long Island to Maine.

As an integral part of its shellfish program, the state had been purchasing and transplanting scallops from nearby Massachusetts, but with the severity of the algal
blooms in the region, that program was ended in 1986. 
Private aquaculture firms that were started as a direct 
result of the blooms enabled seed stock to be purchased 
again for the implementation of a new program in 1989.

Several other natural occurrences, such as coastal 
storms and hurricanes, also affected scallop habitat, and 
therefore, their populations in the state. Human impact, 
such as an increase in pollution from sewage and runoff 
caused by the dramatic expansion of shoreline development 
in the 1980s, has also had an adverse affect on 
scallop habitat.

The Restoration Program

As mentioned previously, the advent of aquaculture 
farms throughout the region has enabled the Scallop 
Project to begin a program to reestablish the state’s 
scallop populations. The commercialization of hatchery 
operations is, for the most part, still in its infancy. The 
number of firms is increasing on a yearly basis. Al-
though there exists some animosity regarding these 
operations, particularly among traditional shellfishers,
men, the general perception shared by marine biologists 
and others is that aquaculture is presently the best and 
only alternative available to enhance fisheries of this 
kind. Rhode Island, along with several other states and 
municipalities, has been securing seed stock from these 
firms in the last few years with varying degrees of 
success.

One problem in securing seed stock from these 
firms is that the actual number of scallops delivered 
does not match the actual number contracted for within 
any given year. This problem hopefully will diminish as 
the number of firms increases and proprietors develop a 
better understanding of the actual numbers that can be 
produced in a given year. The bids for the scallop seed 
are normally secured in the spring, for delivery in the 
fall of each year. The scallops must measure a minimum 
of 7/8-inch to 1-inch in diameter, to minimize predation 
when they are placed in a natural environment. By the 
following fall, they may have normally grown to legal size for 
harvest.

Another hindrance in the attempt to reestablish the 
fishery has been the bay scallop’s relatively brief life-
span. As short as one year, and usually no longer than 22 
months, the scallop’s short life complicates biologists’ 
understanding of the life cycle. A single-year class 
usually does not seem to have any direct correlation to 
those preceding it, and although the populations may 
increase dramatically in one year, the following-year 
populations may decline with no direct causality to be 
found.

As a direct result of this problem, and the predation 
that has occurred in the past, this year the project will 
begin placing a large number of scallops in cages. The 
caged scallops will be placed in the same locations as 
those placed without cages and will act as a control 
group that can be monitored throughout the year. This 
experiment will enable the project to further assess 
predation, growth, and other factors that have been 
adversely affecting the fishery. The project anticipates 
caging approximately 10,000 immature scallop seeds. In 
doing so, the project will also have developed its own 
brood stock, in the hope that millions of larvae will be 
released the following spring.

The Scallop Project has also acted to change the 
present statutes governing the fishery, which were 
enacted in the 1950s. These statutes are considered 
antiquated, given the present status of the fishery and 
what the project envisions the fishery to be in the future. 
This legislative initiative has the backing of both recre-
tional and commercial users, and seeks to eliminate 
user conflicts and gear conflicts and to retard the de-
struction of the species habitat. Opening days are not 
affected, nor are certain ponds to be closed to divers. 
The following is a summary of the legislation that will be 
introduced this fall:

• Only commercial users will be allowed to utilize 
dredges in harvesting scallops. In effect, this will 
stop the recreational use of dredges and therefore 
limit the destruction of eel grass that is so vital to 
the scallops’ survival.

• Commercial harvesting will be allowed on 
weekdays, and recreational users will be allowed 
to harvest scallops throughout the week. This 
will negate somewhat the gear conflicts among 
user groups and also help to promote the harvest-
ing of the species among recreational users.

• A fine will be imposed for the destruction and/or 
removal of a cage(s), not to exceed the actual 
cost of the scallops and cage(s), but not less than 
$1,000. (This fine would also protect any private 
aquaculture operation(s) holding a permit for 
state waters.)
To date, although the project is initiating these steps and considering others, the project's primary emphasis has been the collection of funds needed to purchase seed stock on a yearly basis. The project's intent is to develop a large-enough base of donors so that in the future the project could place approximately one million scallop seeds each year. In the process, the project will also be building a large constituency for the fishery that will further the goal of encouraging awareness of the scallop's habitat and its intrinsic ecological value. With this in mind, the Scallop Project views the restoration program as not simply another shellfish issue, but as a reflection of concern for the overall quality of the environment. A majority of those who donate are doing so out of their general concern for the fishery and all that it represents.

Q: (Mr. Dennis Earkin, Coastal Resources Management Council) Has there been any thought given to permit or user fees to harvest shellfish?
A: (Burns) The commercial shellfishing license is $100. What we want to do in the legislature is to suggest legislation that will require a commercial license for the use of the hand scallop dredge. These dredges tear up the eel grass, and the people that use them often do not use all of the scallops they catch. That is the only change proposed for the licensing fees.

Q: (Earkin) What I mean here is along the lines of a restricted fund for shellfish only.
A: (Ganz) Quite frankly, when the "804 account" was created in the early 1970s, there was an increase in license fees to fund the account. This was intended to be the dedicated fisheries account.

Q: (unidentified, inaudible) What is the status of the natural scallop stocks in the ponds?
A: (Burns) The only natural stocks that I am aware of are in Quonochontaug Pond.

A: (Ganz) What we have had since 1985 is a token population in Quonochontaug Pond that somehow survived the brown tide. That population reproduced itself, and there were about 16 bushels harvested in that particular year. The following year we had a "bumper crop" of 75 bushels. We are doing our scallop census right now, and we are finding token populations again. If conditions were right, we could see a rebound.

Q: (Ms. Eugenia Marks, Rhode Island Audubon Society) Are there any limits on the taking of scallops either in the commercial or recreational fisheries?
A: (Ganz) The laws allow for the taking of quite a few scallops. The laws were written to reflect the fact that scallops have a two-year life cycle. If the scallops are not harvested in two years, they will essentially die of old age. So, for many years there has been a one-bushel-per-state-resident limit. The commercial limit was reduced a few years ago to five bushels per boat per day. This was down from 10 bushels per license per day, so if you had three licensed fishermen in a boat, you could harvest 30 bushels. The daily limit for scallop harvest has not been much of an issue.
Clam Market Trends

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SYNOPSIS. Production and trade data for bivalve molluscan production are reviewed at the world, national, Northeast, and Rhode Island levels to determine what trends exist that can be used for planning purposes. The data do not appear especially promising for Rhode Island. An alternative scenario is considered and some suggestions offered for the changes needed to achieve the alternative scenario.

INTRODUCTION

This paper presents trends in production and value of selected bivalves at a world, national (U.S.), regional (Northeast), and state (Rhode Island) level. The data used for the graphs were compiled by Ms. Nida Ty and taken from various sources, including several documents from the recent Narragansett Bay Project that were obtained from Mr. Sheldon Pratt. This brief overview will be followed by some speculative interpretations of possible scenarios and how the Rhode Island clam industry might wish to respond.

WORLD TRENDS IN BIVALVE PRODUCTION

Figure 1 is a graph of trends in world landings of bivalves, showing selected bivalve species (clams, oysters, and scallops) on the vertical axis against time (1962 to 1988) on the horizontal axis. It is apparent that, historically, oysters were the largest of the three groups with nearly double the landings of clams, the second most important group. However, clam production exhibited a much faster rate of growth than oyster landings, circa 1974–76. Since then, clam production has continued to outpace oyster production, and by 1987 had attained a level almost triple that of oyster production. The world production of scallops has also grown during the quarter-century period shown in Figure 1. However, the growth rate for scallops, while more rapid than oysters, has been lower and more erratic than that of clam landings.

DOMESTIC (U.S.) TRENDS FOR BIVALVES

Production

Figures 2a and 2b show the time trends for selected bivalve production (clams, oysters, and scallops) and the landed values of these bivalves. It is apparent from Figure 2a that, as with world production, clam production in the U.S. has shown the most rapid growth of the three species. The most positive thing to be said for trends in U.S. oyster production is that the seemingly relentless slide of the past century has been halted, and oyster production is now fairly static. The value trends of Figure 2b indicate rapid growth in nominal values for all three groups of bivalves, showing an approximately five-fold increase in gross value (unadjusted for inflation). It is difficult, at least without statistical analysis, to assert that the growth rate for the gross value of landings has differed significantly between the three groups of bivalves. However, it is notable that the landed value of clams grew at a comparable (or higher) rate than the other groups of bivalves, despite a much more rapid growth rate in production. This suggests that a growing demand for clams, rather than price declines, may be at work.

Imports

Figures 3a and 3b indicate trends in the quantity and value of U.S. bivalve imports. Clams, oysters, and scallops have all experienced roughly similar growth rates in quantities imported. However, in nominal value terms, clams have been the “slow” grower, showing a barely perceptible trend. In constant dollar terms, the value of imports has been declining. Also, the absolute level of imported value is far lower for clams (and oysters) than for scallops.
Figure 1. World trends in bivalves (FAO statistics).

Figure 2a. U.S. trends in bivalves, in thousands of pounds (NMFS statistics).

Figure 2b. U.S. trends in bivalves, in thousands of dollars (NMFS statistics).

Figure 3a. U.S. imports of bivalves, in thousands of pounds (NMFS statistics).

Figure 3b. U.S. imports of bivalves, in thousands of dollars (NMFS statistics).
DOMESTIC (U.S.) TRENDS FOR CLAMS

Figures 4a and 4b show trends for hard clams, soft clams, surf clams, and ocean quahogs. These figures are analogous to Figures 3a and 3b, but have narrowed the focus to clams. The dominant clams in landings are the surf clams and ocean quahogs; each of which has double or triple the landings of hard clams. The trends of the two have been out of phase but in total, ocean quahogs and/or surf clams have been the main source of growth in total U.S. clam production. The production trend for hard clams and oysters in the U.S. exhibits a minuscule downward trend. The value trends shown in Figure 4b are much more dynamic, and clams lead the increase, registering a nearly seven-fold increase from 1966 to 1988.

NORTHEAST TRENDS FOR CLAMS

Figures 5a and 5b continue our gradual narrowing of focus by depicting time trends for clam landings and landed value for the Northeast Region of the U.S. Here the trends are very similar to those reported for the U.S. as a whole. However, since 1980, the nominal landed value of hard clams in the Northeast has tumbled significantly.

Figure 7, based on data from Pratt (1988), indicates a dramatic change in market shares for hard clams in the decade preceding 1985. Prior to 1985, New York dominated the market with almost 50 percent of the U.S. hard clam market. Beginning circa 1977, Rhode Island production surged dramatically while New York’s share began a precipitous decline. The difference was partly compensated for by the entry of Florida into the market, with the result that, as indicated above, the overall U.S. trend for hard clams showed only a minuscule downward trend.

RHODE ISLAND TRENDS FOR HARD CLAMS

Figures 6a and 6b carry the process to a logical (for us) conclusion by displaying trends in Rhode Island landings and nominal landed value. These figures suggest a sinusoidal pattern in landings with the last peak in the early 1980s and a subsequent decline that is continuing in the most recent data. The nominal value of landings, however, rose steadily until 1986. Since 1986, landed values have declined somewhat. Although I did not compile data prior to 1962, I was gratified to find that Pratt (1988) had done so. His data show that the 1975 to 1985 “bulge” in Rhode Island landings of hard clams was far less pronounced than that which occurred in the Northeast.
clams was preceded by an even larger bulge from 1950 to 1960. Thus, a sinusoidal pattern in Rhode Island landings seems a reasonable characterization.

**Rhode Island Landings and Effort Indices**

Figure 7 shows time trends for indices of landings, effort (see below), productivity, and transplants. Each series was normalized by its base year value; hence, each is an index and all start in 1962 at 100. This procedure enables one to see trends of disparate variables in a common reference scale. The effort index is based on the number of licenses. However, since the mid-1980s, licenses are no longer issued specifically for clam digging but are issued for multipurpose fishing including hard clamming (quahogging). The indices were spliced together and the end effect is an index that I think is plausible in the short run because of inertia in the ratio of quahoggers to non-quahog fishermen. With the passage of time, however, this ratio may change significantly, so the plausibility of this index for effort will deteriorate over time.

The productivity index is the ratio of the landings and effort indices. The most striking aspect of this productivity index is its relative stability. This is all the more surprising given the weaknesses of the effort index. An interpretation of this constancy could be that it reflects the minimum catch-per-unit-effort level needed to attract effort. The obvious "lead" of effort over landings during the 1980s is curious. Such a lead suggests that in some sense, effort increases are a "cause" of increases in landings the following year. Three possible hypotheses to explain this apparent correlation are: (1) by increasing raking activities, effort increases may stimulate better sets; (2) effort responds, *ceteris paribus*, to increases in the unemployment rate; and (3) random chance (the null hypothesis).

The transplant index was not available after 1975. Some partial data were obtained from Arthur Ganz, of the Rhode Island Department of Environmental Management, but the magnitude of this partial data relative to the transplants of earlier years were trivial. It was decided that including such partial information after 1975 would be primarily uninformative, so that data were excluded. With the available data on transplants, it is possible only to say that the effect of transplants during 1962–68 is not evident.
Figure 7. Rhode Island hard clam fishery—landings and effort.

Figure 8 examines the unemployment/effort question raised above. The trends in this figure suggest that effort has tended to respond positively to increases in the unemployment rate. However, one would expect this effort response to also be modulated by relative economic returns in the fishery. Unfortunately, nothing is known (in the sense of published information) about the economics of quahogging, especially over time. Even more unfortunately, there seems to be no interest in studies to obtain such information. About 20 years ago, I worked with numbers such as these. I do not remember much about what I found, but I do recall that the simple correlation between number of Rhode Island quahog licenses and the Rhode Island unemployment rate was about 0.8 during the post-World War II to 1970 period.

It would appear that this fishery, like many natural resource industries throughout the world, has acted as a "sponge" in times of macroeconomic instability. In this sense, natural resource industries, especially open-access ones, tend to act as an employer of last resort in times of economic recession. The relative stability of the productivity index and its relevance is consistent with data in Pratt (1968, Figure 5) that shows inflation-adjusted revenue per fisherman in 1967 dollars. His index is closer than my productivity index to the idea of an economic "break-even," and his indicator is also relatively stable from 1951 through 1985, exhibiting only temporary (annual) fluctuations about a horizontal line.

Another study by Holmsen and Horsley (1981) indicates a significant income-effort response in this fishery. They found that if income were projected to decrease, then some fishermen said they would leave the fishery. The exit rates are shown in Table 1 and Figure 9. Table 1 indicates that a 50 percent drop in income from quahogging would induce 79 percent of the fishermen to leave, and a 76 percent decrease would induce an 86 percent decline in effort in the fishery. We do not know the bias or precision of the responses shown in Table 1 and the curve in Figure 9 as predictors of what fishermen would actually do.

<table>
<thead>
<tr>
<th>% Drop in Income</th>
<th>Cumulative Fraction of Fishermen Who Say They Would Leave the Fishery</th>
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<tr>
<td>10</td>
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<td>25</td>
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<td>50</td>
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<td>75</td>
<td>86</td>
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<td>90</td>
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Table 1. Effect of hypothetical income decreases on fishing effort.
Figure 9. Income decreases and effect on effort—responses of quahog fishermen (Holmsen and Horsley, 1981).

Figure 10 illustrates a Lorentz curve showing the relationship between the percent of income derived from quahogging vs. the percent of respondents whose dependence on quahogging income was no greater than the percentage indicated on the horizontal axis. If dependence were uniformly distributed from zero to 100, the curve would be a 45° straight line connecting the “south-east” and “northwest” corners of the graph rectangle in Figure 10. Where the curve is bowed upward from a 45° line, it indicates that a greater-than-uniform percentage have that degree of dependence. This appears to be the case for low levels of dependence (below 40 percent). Conversely, where the curve is bowed downward from the 45° line, a less-than-uniform distribution is indicated. This appears to be the case at high (above 60 percent) dependence levels. This pattern is consistent with the hypothesis that there are two distinct clusters of fishermen; one with low dependency and the other with high dependency on quahogging. One presumes that these clusters correspond to the common labels “part-timers” and “full-timers.”

Scenarios and Conjectures

There is an irresistible impulse, given some trend lines, to extrapolate those lines into the future. Unfortunately, forecasting is always difficult. One would like to be able to check what is projected for plausibility. For example, on what basis can one extrapolate the growth in production of clams? Clearly, the emergence of new stocks, new technology for harvest or aquaculture, or development of new products for hitherto untapped markets can have unforeseen impacts on extrapolation of the trend. We do not even have a good study of demand determinants for hard clams. Cheng (1985) did a very good analysis of household consumption data. Unfortunately, his study is not very useful for us because the categories he used for clams were “canned,” “other processed,” and “total clams.” These categories are dominated by surf clams and ocean quahogs, and there is little reason to expect his findings are applicable to hard clams. Almost nothing is published about these matters, leaving us the not-unusual task of inferring the future from an inadequate base of economic information.

The most plausible extrapolation for world and U.S. production of clams would be a continued upward trend. Whether this is true for landed value and price is more problematic since there are few studies on the demand side of the clam market. The other complicating factor is that consumers are becoming more nervous about food quality in general and shellfish in particular. Thus, there does not seem to be much of a basis in the trends re-
viewed above for optimism about clam production in Rhode Island, the Northeast, or indeed the U.S. If world production of clams continues its rapid growth, there may be an emerging potential for international trade in clams. To pursue this possibility, however, would require collecting data from field interviews with marketing and distribution people; the trade potential cannot be inferred from tables of production statistics. The fact that various types of clams are biologically related is not necessarily a reliable guide to their substitutability in demand, but it seems a reasonable starting point.

Often, trade hinges on very detailed information about specialized markets. For example, it is reported that a clam culturist in this region has developed a specialized, direct market in Japan for a specialty product. Imports into the U.S. have increased in recent years, but the product forms have been relatively low-valued and enter markets quite different from the fresh market where much of our Rhode Island quahog production is sold. It would seem plausible that the oscillating, null trend patterns of recent decades can continue indefinitely in Rhode Island, unless forces emerge to change the status quo. Such change would require some constructive leadership from the private sector. There are some serious obstacles that industry would have to address if it wishes to establish a different trend for the future.

It is customary in most economic studies of industries to presume that the activity that produces output is done for profit. This is an acceptable approximation for many industries. However, even economist Adam Smith noted the importance of “non-pecuniary” motivations of people in their choice of occupation. As a consequence, certain occupations are awarded less monetary return than others because an adequate supply of persons are willing to work for less than they could earn elsewhere when they enjoy their occupation. In more recent times, we have seen the emergence of theoretical and empirical studies measuring the “extramarket value” of sport fisheries, improved safety, wilderness areas, etc. An implication of this body of research would be that some quahoggers may be willing to work for less or even lose money for the sake of the enjoyment derived from the activity. A second implication is that cost-effectiveness may not carry the weight it does in a strictly commercial environment. For example, there is a presumption, which may not be valid, that power dredging would be a more cost-effective way to harvest quahogs. However, if enjoyment is derived from hand-digging quahogs, cost-effectiveness may be partially or totally irrelevant.

If the Rhode Island quahog industry wished to develop a different scenario for the future, how might it go about doing it? After all, trends are not written in stone; they can be altered by humans who are not happy with the existing trend. It seems to me that any plausible scenario for change must include elements for marketing, technological, and institutional change.

In marketing, quahogs are largely dependent on the same market niches and geographic distribution that have existed for a very long time. A growth scenario would try to identify consumer preferences that could either be changed by advertising or adapted to via food science research. These strategies could open up previously untapped markets in different geographic areas, seasons, or product form.

The technology of production is unchangeable, due to common consent to retain the known manual techniques, although these alternatives are presumed to be relatively costly. I say “presumed to be” because if power dredges were not more cost-effective, there would be no need to ban them. This could be changed, but it is unlikely to be changed, in my judgement, unless it is part of a larger institutional change concerning open access.

Such institutional change would give existing quahoggers a preferential claim to the resource. Suppose quahog fishermen were to request a policy which restricts access to the fishery in order to “professionalize” the harvest sector. Eastern bloc commentators speak despairingly of the “anonymity of capital in a socialist society.” or in Anglo-American vernacular, “everyone’s property is nobody’s property.” This change might be a way to begin the difficult process of converting from a socialist fishery toward a capitalist fishery. Suppose these professional quahoggers (PQs) were to band together as a cooperative for the purpose of enacting a production and marketing plan. Because the PQ concept creates a barrier to entry, it might become rational for their cooperative to invest in longer-range alternatives in either production or marketing without undue fear of new entrants. That is not the case today. As with many socialist institutions, there is little or no incentive for private sector initiatives that improve long-run economic
productivity in a fugitive resource, since much of the gain from innovation and ingenuity is realized by new entrants.

A cooperative could self-fund a transplant program. This would be beneficial since the existing state-operated plan is sometimes severely limited by insufficient legislative appropriations. The question of whether a more intensive form of aquaculture would make sense could be handled by a committee that stays abreast of developments in clam aquaculture elsewhere in the U.S. and around the world. More intensive approaches are probably unnecessary now but could become so if the marketing plan is successful over a period of years or decades. This scenario resolves the worst aspects of the fugitive resource problem by converting the fugitive resource to one of common property. In this alternative future, effective resource control (though not "ownership") is exercised by the PQs through their cooperative. Effective resource control then makes it possible to appropriate the gains from improved production and marketing strategies. For example, the cooperative might wish to use power dredges since increased profits would accrue to the membership. Conversely, it might choose to use manual methods for the non-pecuniary rewards alluded to earlier. An intermediate position would involve use of both technologies and could be achieved by appropriate internal pricing of manual vs. power methods of harvest. Suppose, for example, that manual harvest costs $10 per cubic weight and power dredges cost $8 per cubic weight harvested. Cooperative members might be offered $8 per cubic weight harvested manually, i.e., the least cost rate. The $2 per cubic weight savings is part of the year-end profit to be divided among the members. This would enable the membership to mix the least cost technology with as much manual harvest as desired. An ability to do so is important if, as noted earlier, there is a significant consumption or recreation benefit associated with hand harvest per se.

It is plausible, though not demonstrable, that the scenario just outlined would be quite effective in reducing the safety/quality image which has afflicted quahogs in recent years. Whether this image is justified by objective analysis is somewhat beside the point from a marketing viewpoint. If consumers think there is a problem then there is a problem for persons trying to sell the product. The scenario just outlined gives each PQ a stake in a system with significant value. A violator who faces ejection for the common good is less likely to engage in activities that could deprive him of his share in the common economic wealth. This might not be very effective, however, unless there were quite severe penalties for quahogging without a professional certificate or cooperative membership. While better use rights can alleviate some problems, problems such as the taking of clams from prohibited waters will persist. This is a public health issue that will continue.

The open-access institutional problem also interacts negatively with market structure and pricing issues. For example, a potato producer regards his harvest as a stock to be marketed seasonally based on expectations for prices during the next 12 months. If current prices are lower than "next" month's expected price by more than storage costs plus interest charges, the potatoes stay in inventory. He can do so because he has private property rights to his harvest. With a property rights system, there is even a futures market for potatoes. These provide good estimates of expected future prices. A Rhode Island quahogger enjoys no such options about when to harvest and market. The clams are not his until they are "reduced to possession"—that is the definition of a fugitive resource. If he refrains from harvest this month, he has no assurance that clams will still be there next month. As long as current prices exceed daily operating costs, someone will be harvesting the clams whether he participates or not. In extreme cases, this may mean that Rhode Island clams are transported to a neighboring state and stored on lease beds until prices rise. This is beneficial to consumers and to producers outside Rhode Island, but it would seem better for Rhode Island to have deferred the harvest in the first place and to plan harvest according to orders for product.

The Rhode Island quahog industry should not delude itself into thinking that by maintaining the status quo it can sustain market price. Technological and market developments can be expected to proceed elsewhere irrespective of what Rhode Island does. The question then is whether the Rhode Island industry will maintain market share in a growing market or see its share decline as growth occurs outside the state. That is what simple trend extrapolation would forecast. Which scenario will industry choose?
ACKNOWLEDGEMENTS AND NOTES

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Since this paper was written, a copy of the Marine Fisheries Review arrived that contains much more detailed data in an article by MacKenzie (1989).

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REFERENCES


QUESTIONS AND ANSWERS

Q: (Mr. James Boyd, Rhode Island Fishermen's Association) Dr. Gates, you have brought up two very important issues that I wish to address. Firstly, I find it very frustrating that the scientific community looks at the catch data, particularly the landing peak of the early 1980s and the subsequent decline of catches with respect to effort, and these academics interpret this as a declining, overexploited fishery. They do not look at some of the facts.

One of the key facts that is often overlooked is that in the early 1980s, we had this opening in the upper Bay that had been closed for a number of years. There was public notification in the Providence Journal of this opening, and 700 shellfish licenses were issued in one day. At the end of one week, over 2,000 licenses were issued. Essentially, you had a doubling of the size of the fleet. Of course you will see this giant peak and a gradual decline as time goes on. As it becomes increasingly difficult to make a living off the "gravy" or "bonanza," the part-timers and nonprofessionals will go back to other jobs. There has been a constant trend throughout the 1980s in terms of numbers of full-time, professional shellfishermen.

The other issue, and somewhat related because it would restrict the "bonanza" mentality, is that we would like to see all commercial licenses issued during a one-month period rather than being available throughout the year. If this could be done, the people who rely on the shellfishery for a full-time income would not be bothered by the large-scale influxes that occur when well-publicised bed openings occur.

A: (Dr. John Gates) I don't know how to interpret the first part of your comment—whether I'm in the scientific or academic group or both. Basically, I don't think that there can be much of a case made for conservation in terms of worrying about resource depletion. I really don't stay awake worrying about possible depletion of the stocks.

Q: (Boyd) My point is that data have been misconstrued and misinterpreted. There are published reports with these misinterpretations.
A: (Gates) Well, I get the impression that something like the following is operating. Here is a fishery where people have tried very hard to make it better and nothing happens. And so we have slipped into a mode of trying to minimize the cost to the taxpayer; after all, nothing is going to happen anyway. In addition, the data are lousy, ambiguous, you really don't know what it means.

There are a series of costly problems about which we have had a lot of discussions lately. I think that this is part and parcel of the way we look at the resource. We are not looking at it like a business, trying to manage toward a goal of rational objectives. I do not know how to get from here to there, that is why I outlined the possible scenarios. In order for us to do some of the things we heard talked about today, like the things down in Brookhaven for example, we have to have a totally different approach. We know how to do that. Art has spent hours talking about how things could be done better, but if every year you have to go back and beg for a few thousand dollars from the legislature, I do not see that happening, particularly now at a time of tight budgetary constraints.

Q: (Mr. Robert Rheault, Spalco Ltd.) I think that a logical extension of some of what you were saying can be illustrated by what the Dutch do. They have a huge clam resource that is harvested by three boats. Each of these boats pays for a several-hundred-thousand-dollar permit to the government. They pay good wages on the boats, and the resource is harvested very efficiently. They rotate their harvesting grounds, and have the most efficient harvesting technology available. I'm not saying that this is right for Rhode Island, you would certainly have to change the constitution, but this is another way of doing things. I must admit that I felt a little stupid when a Dutchman laughed when I told him that we still use handrakes.

Q: (Mr. Tim Rockwell, shellfisherman) That may be a very efficient way of harvesting clams, but it is also the most efficient way of putting 400 or 500 guys out of work.

A: (Gates) Well, OK, what I was saying had to do with a cooperative concept. There might be different ways of going about this. One way might be to say: Let's suppose that it costs you 10¢ a pound to harvest by hand, and 8¢ a pound to harvest by dredge. Anybody who wants to hand harvest for the co-op gets paid 8¢ a pound, that's the least-cost way. The 2¢ difference becomes part of the profits of the co-op. At the end of the year, the profits get distributed to all the members. So, the gains in technological improvement get passed back to the members of the co-op. There is incentive to do it a better way. On the other hand, if as a member I wanted to go out and handrake because I enjoy it, I could go out and do it. It then becomes a decision within the co-op.

Q: (Mr. Tim Visel, Connecticut Sea Grant) Does your idea of co-ops involve transplants, with the money rationally distributed among the membership?

A: (Gates) I gave that as an example. I think that a co-op would have a very important marketing function.

Q: (Visel) That gets into my next question. Right now the price of quahogs is reasonably good, which is not always the case. Would such a co-op have the ability of saving stock to sell when prices are better?

A: (Gates) I would hope so. The question of constitutionality has been raised. I don't know, I get different answers about this. I'm sure of one thing. If the industry does not want it to happen, it will not happen. If, on the other hand, the industry wants it to happen, I suppose that there are ways around the constitution.

Q: (Dr. Wayne Durfee, Professor Emeritus, University of Rhode Island) We have heard a number of times in recent years that aquaculture will somehow depress the prices of quahogs. Could you give us some estimation as to what type of harvesting or increase in quahog product would affect long-term prices?

A: (Gates) Let me tackle that from two directions. If you recall the figures on hard clams in the U.S., I think that it is difficult to explain the ups and downs of prices in Rhode Island based on aggregate production. That suggests to me that there is something strange going on in the marketplace, and that it is segmented geographically, lacking an effective distribution system that gets the product from areas of high supply to areas of short supply. I'm assuming that complaints about prices are very real; in areas of high supply, producers are hurting. I think that this is part of the marketing question. I could not find much work on it. I found a reference to one demand study.
The other level here is that whatever else you can say about this marketing question, improvements are being made. We should not fall into the trap of thinking that Rhode Island exists in a vacuum. When you start talking about what happens to the market in Rhode Island, the question should be, “What happens if we stand still?” Because that market will be filled by people in other states. I don’t think that we have any choice in this. If we don’t have the methods of doing it at least at lower cost, we will not remain competitive. The state has its small local and regional markets. If we want to get into a larger market scene, then we have to compete effectively.

Q: (Durfee) I think that I’m hearing you say that there is a possibility of markets out there that Rhode Island could not possibly begin to fill.

A: (Gates) I would think so, but the marketing studies have not been done. We know from a number of consumer studies that fish consumption does not go very far from the shore. These were basically surveys of household consumption. Historically this is understandable because there was no ability to transport fresh fish very far.

Oysters are a possible exception, and I suppose clams too. An anecdote about this is that years ago I was with the South County Jaycees and they had a booth for the Heritage Festival at the Washington County Fair that served clams. We could not serve a clam. People would look at them and say, “Yuck, you actually eat that?” That is only a few miles inland. The Good Book says don’t hide your lamp under a bushel basket. We don’t do that, we hide ours under a Texas onion bag. What kind of marketing strategy is that?
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