Proceedings of the Second Rhode Island Shellfish Industry Conference

Narragansett, Rhode Island
August 4, 1992

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Second Rhode Island Shellfish Industry Conference

Held at the University of Rhode Island Bay Campus
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August 4, 1992

EDITED BY
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AND
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LAYOUT BY
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CONFERENCE COSPONSORED BY
RHODE ISLAND SEA GRANT
RHODE ISLAND COOPERATIVE EXTENSION SERVICE
RHODE ISLAND SHELLFISH DIVERS ASSOCIATION
RHODE ISLAND WATERMEN'S ASSOCIATION

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Foreword

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This Second Rhode Island Shellfish Industry Conference is intended to follow up on the first shellfish conference that was held in August of 1990 and focused on water quality issues as they relate to the shellfish industry. The focus of this conference is on the management options for shellfish stocks in areas of Rhode Island coastal waters that are certified for shellfishing.

The early 1990s have not been among the best of years for Rhode Island shellfishermen and their families. The poor economy has caused a swell in the number of fishermen; prices for shellfishery products have dropped considerably; and many allege that the traditional shellfish beds are exploited beyond their sustainable capacity. All people connected with the shellfishery, whether in industry, government regulatory agencies, or academia, recognize that the shellfishery is in a severe crisis. This is the time for forward-thinking ideas and tough decision making.

This conference was intended to be an industry-driven forum. Shellfishermen who are out on the water every day have important insights into the status of the shellfisheries. Information from industry members is essential to any successful stock management strategy. For this reason, I wish to thank the members of the conference steering committee who helped in the planning process—Mr. Gerald Carvalho of the Rhode Island Watermen's Association, Mr. Neal Perry of the Rhode Island Shellfish Divers Association, and Mr. Arthur Ganz of the Rhode Island Department of Environmental Management, Division of Fish and Wildlife. This conference was designed to be educational in nature. We have invited a number of speakers from the northeastern region to outline the biological, management, and socio/political issues that surround the quahog fishery of Rhode Island. But most importantly, this conference was designed to be a vehicle for the presentation of ideas that merit further exploration.

This volume presents the papers and discussions that took place at the Second Rhode Island Shellfish Industry Conference, held at the University of Rhode Island's Narragansett Bay Campus on August 4, 1992. I wish to thank all of the cosponsors—the Rhode Island Shellfish Divers Association, the Rhode Island Watermen's Association, Rhode Island Sea Grant, and Rhode Island Cooperative Extension—for their full support of this conference.

Industry Welcome

GERALD M. CARVALHO
Board of Directors, Rhode Island Watermen's Association
Legislative and Regulatory Consultant, Rhode Island Shellfishing Industry
P.O. Box 1363
North Kingstown, RI 02852

I welcome everyone today on behalf of the shellfishing industry here in Rhode Island. I especially welcome those here from the fishery who have taken the time today to participate in this forum. This conference can be looked upon not as a one-day event, but rather as the first day of a new round of cooperation between industry and the academic community. The Cooperative Extension Service and Sea Grant Advisory Services provide us with the opportunity to use their research capabilities to solve some of the many problems in the shellfish industry. This past year, we have seen the Department of Environmental Management's demand for an increase in licensing fees, infighting of user groups within the fishery, overzealous government regulators, dwindling stocks, pollution, falling prices, the lack of a real marketing program, and an all but nonexistent shellfish management program. We, as an entire industry here in Rhode Island, must face these challenges with an open mind and with enthusiasm if we are to continue. I hope that today helps rekindle some of our pioneering spirit and cooperation.

Overview of Research and Extension Agencies in Rhode Island: Transcript of a Panel Discussion

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Robert Miller

Good morning ladies and gentlemen. It is very appropriate in this centennial year of the University of Rhode Island as a Land Grant institution that I speak to you about my role as Dean of the College of Resource Development and as Director of Rhode Island Cooperative Extension. We are here to talk about what we have been doing for one sector of our economy—agriculture—for a very long time. In Rhode Island university/agricultural exchanges have been going on for a little over one hundred years, because the agricultural college had an outreach arm for technology transfer very early in its history. There was agricultural research going on in the earliest days of the university, but it became evident research was useless unless the results reached the ultimate end users, the farmers of Rhode Island. Research in a vacuum is of no real value to anybody. The Cooperative Extension Service, as we now know it, was formed in 1914 by the passage of the Smith-Lever Act in the U.S. Congress, a mere 22 years after the founding of the university. Funded by the U.S. Department of Agriculture, the Cooperative Extension system has been a success. If we look at the success of American agriculture, it is clear that Cooperative Extension has been a major force.

With respect to aquaculture, I believe that we are in an earlier stage of the development process. Here again, a research base is accumulating. Mike Rice mentioned earlier today that purpose of this conference is to find out what the user needs in terms of research. I argue that after the research we need a system, an interactive system, by which the results of the research are brought back to the industry in an unbiased fashion. The history of the Cooperative Extension system is to bring unbiased information back to the user. Usually we try not offer one solution to a problem, but rather a range of alternatives so that the users can choose the one that best fits their needs. I suspect that at times we have done a better job at this than at others, but the ideal is to offer an unbiased set of alternatives to the user.

I am here today to listen to some of the presentations in the research area. I pledge the support of the College of Resource Development through those like Mike Rice, Joe DeAlteris, Kathy Castro, and others in the college who wear many hats in their roles of dealing with their industry constituents.

There is yet one more aspect of this that is very important. If we are to deliver information in a timely manner to industry groups, there is a need for an industry advisory council. This model is widely used by Land Grant and Sea Grant extension outreach. We must have individuals at the industry level who share their needs with us on a regular basis. We do not want to be in an ivory tower at the University of Rhode Island, and especially in the College of Resource Development or Cooperative Extension. We want to know the problems and issues that face the industry, so we can be at your side finding solutions.

Scott Nixon

I would like to pick up where Bob Miller left off. He mentioned that we have been a Land Grant College for one hundred years now. We have been a Sea Grant College for a little over 20 years. The very fact that we are a Sea Grant College is testimony to the great success of the Land Grant system. Sea Grant was based upon the Land Grant system in that basic and applied research are performed and there is an extension or outreach component that takes the research findings to the various user groups. Conversely, the extension or outreach component brings back information about the needs of user groups to the university, so that we can bring the resources of the university to bear on those problems.

The Sea Grant program here in Rhode Island has a very active research and extension group working with shellfish and shellfish management issues. Bob has already identified part of the group, because they work closely with Cooperative Extension—Mike Rice, who has organized this conference, Joe DeAlteris, and Kathy Castro. Sea Grant has some other folks as well, who work closely with government agencies—Virginia Lee and Alan Desbonnet of the Coastal Resources Center, who focus on management issues. There are still other Sea Grant researchers such as Dennis Nixon, who will be speaking later today. We try to address a variety of issues from the biology of fishery species to government structures, management techniques, and economics. On display today is a recently released book on the biology of the quahog, put together cooperatively by DEM and Cooperative Extension. It is a rather lengthy and technical document about the animal we all know and love. Sea Grant has just published a fancier publication for the general public on everything you ever wanted to know about the quahog. One of our main goals for the next year is to work closely with DEM and the industry to develop a quahog management plan. Joe, Kathy, Art Ganz, and others are going to be very much involved in this.

We are beginning a new Sea Grant funding cycle, which lasts two years. We will be soliciting proposals for research and outreach work this September and October. We are soliciting proposals for research and outreach work. If you have any ideas that might be appropriate for investigation, I urge you to contact Mike Rice, Joe DeAlteris, Virginia Lee, Dennis Nixon, or other Sea Grant researchers for help in putting together a proposal.

We do recognize that the industry is in a bit of trouble, but Sea Grant cannot just pass out money because of hard economic times; that's not how the program operates. Sea Grant funding provides for peer-reviewed research and technical information transfer activities. Project proposals must survive a rigorous review by people in the business who can assure that the ideas are sound and the project is worth doing. In conclusion, Sea Grant is an important resource in the state, and we are committed to working with the shellfish industry to help out as much as we can.

David Borden

Good morning. What I want to do is briefly go over the things that we in the Division of Fish and Wildlife do in terms of the shellfish management program. I wish to emphasize right from the start that the state's shellfish management program is quite diversified. A significant portion of the budget goes to the Division of Enforcement that has an annual budget of about $1.4 million. Shellfish enforcement activities take up about 70% of enforcement officers' time. We also have a Department of Health program. The portion of the program that I will focus on is the marine fisheries program as it relates to shellfish; it is administered by the Division of Fish and Wildlife.

Our current shellfish program is divided into nine separate parts. We have a shellfish monitoring project that is essentially a resource assessment project. We have 16 shellfish management areas throughout the state. We have an oyster spat collection program in which we annually collect about 500,000 animals each year for stocking in various areas around the state. We have a scallop stocking program that is a cooperative effort between industry and the department. We participate in the shellfish sanitation program by having our personnel go out and collect samples for Health Department analyses required for us to retain our interstate shellfish shipping certification. We have a PSP monitoring program in which shellfish from three stations in the state are routinely monitored for algal toxins. If we have positive results in any of these primary stations, we then activate six more secondary stations to pinpoint the problem areas. We have a shellfish transplant program as funding is provided by the General Assembly. Funding for transplants over the last few years has been highly variable, with relatively little money allocated recently. We have been working with Department of Health personnel and industry toward the goal of direct interstate shellfish sales by fishermen. We have personnel working on a grant by the National Marine Fisheries Service for data collection on fishery stocks, and we have significant industry liaison activities. These liaison activities include working with the Rhode Island Marine Fisheries Council and with the industry on such issues as the diver-digger controversy.

To meet the various responsibilities of the shellfish program we have only one full time person—Art Ganz. We have other staffers that collect samples on a part-time basis. We will often borrow personnel from any source possible to help out, particularly during the summer months. The biggest problem with the shellfish management program in my own view is funding. There is very limited federal funding available for shellfish. In terms of finfish, especially migratory species, there are a variety of federal programs that will match state funds. So it comes down to money and manpower. In my own view, DEM personnel are doing an excellent job given the present resources, but more can be done for the multimillion-dollar industry.

In terms of what we should be doing, programs would require $300,000 to $400,000 in additional funding. With this we would improve data collection programs focusing on quahogs, soft-shell clams, and oysters. We should be collecting length-frequency data, catch-per-unit effort, and other standard biological parameters on a regular basis. We should be looking at both juveniles and adults. This would require the addition of three staffers. We should reactivate our hatchery program to have a ready source of seed for problem areas. Additionally we should have a program of hydrographic monitoring so that we could begin drawing some conclusions from our biological data sets.

Questions and Answers

Q. *(Prof. Dennis Nixon, URI) Scott, will there be an overall theme proposal this year from Sea Grant? There had been some discussion about this.*

A. (Dr. Scott Nixon, Sea Grant) No, we will go through a planning exercise in which we will identify a number of areas in which we want particularly to encourage work. We are now beginning the process of making those identifications. Today's conference is part of this in fact. We will accept some individual proposals that may not fall into the identified areas. So the answer is that there will be no one thing that everything has to fit.

Q: *(Mr. John Finneran, shellfisherman) David, do you have direct managerial oversight over Art Ganz?*

A: (Mr. David Borden, DEM) Not directly.

There is another person between us in the chain of command.

Q: *(Finneran) What are the priorities of the division, given the limited funds available? What are your personal goals?*
A: (Borden) First, we should get a clear picture of the quahog stock situation in Narragansett Bay. As I mentioned, we have personnel working on a NMFS data collection program, but unfortunately since they are funding the program, they set the priorities, and unfortunately quahogs are not the priority. There should be an upgrading of the shellfish data collection program. There has been considerable assessment work in coves and small estuaries from Westerly, and along the South Coast and up the bay. The same thing needs to be done in the bay; looking at adults and juveniles, so that when we get into arguments similar to those raised in the diver-digger controversy, we cannot say with scientific certainty that there are demonstrable effects on the stocks.

Q: *(Finneran) What do you plan to do to meet these laudable goals that you outlined?*
A: (Borden) The question is "Where do you get the money?" We would certainly know what to do if we had it. One thing that I would like to mention is that the bulk, if not all of the recent license fee increase that Mr. Carvalho commented about, will be apportioned to the Division of Enforcement. The biological staff will receive little or no benefit from it. It is unfortunate that we will not receive the benefits, but this is a result of DEM priorities.

Q: *(Mr. David Sisson) David, what is the status of the survey that was going to be distributed to most of the license holders?*
A: (Borden) Yes, this is the other side of one of the questions that Mr. Finneran raised. We need to know about the quahog stocks in Narragansett Bay, but we also need basic information about the quahog fishermen and their levels of effort. One of the things that we have been working on cooperatively with the URI Marine Affairs Program is the development of a survey to go out to all licensed fishermen. That questionnaire has been finalized, but it has not been made public. I'm scheduling some meetings with industry leaders to solicit their input and comments on it. It will probably be in September when we actually do the survey. We will be looking at a number of factors, including characterizing gear type, whether they rely on boat trailers and launching ramps, other employment, percentage of time fishing, and so forth.

Q: *(Mr. Tom Noel, bullraker) I rely heavily on conditional area A. During periods of rainfall this area is closed for a period of time. Is there actual testing of the water in that area or is it closed based estimated bacterial loading by rainfall?*
A:(Borden) There are people in the audience that can more directly answer this question, but it is my understanding that the closure is based strictly on the amount of rainfall. There is a monitoring program in which quahogs are collected from sites statewide and analyzed for coliforms by the Department of Health.
A: (Mr. Arthur Ganz, DEM) Just a clarification relative to the monitoring. Conditional area A is checked regularly as part of the whole water quality monitoring scheme that Joe Migliore's people do. Additionally, there are three stations in area A in which quahogs are collected regularly for analysis of the meats. So the triggering mechanism is backed up by good analytical work.

Rhode Island Shellfish Law Enforcement 1987-1991

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Abstract. *The Division of Enforcement within the Rhode Island Department of Environmental Management is charged with the protection of the shellfish resources in Rhode Island waters and preservation of the sanitary quality of Rhode Island shellfish in local and national markets. In addition to enforcement of shellfishing laws and regulations, the division is also responsible for enforcement of hunting and sport fishing regulations, boating safety regulations, and assists the Division of Water Resources in the enforcement of pollution violations among many others. This paper reviews the key activities of the Enforcement Division as they relate to shellfish management.*

Introduction

Scattered along the Rhode Island coast in place names that are often unpronounceable to tourists and state residents alike are testimonies to the importance that shellfishing has held through the centuries. The early native peoples looked to the rich production of Narragansett Bay and the rivers running to the sea for food and bartering materials. Potowomut, "Land of Fires," was so named for the bonfires that the Indians kept burning while they annually made heavy harvests of shellfish in the waters surrounding this sandy peninsula. Apponaug, on the northwest end of Greenwich Bay, was so named for the shell heaps found there.

Since pre-colonial times, the rich resource of bivalves in Rhode Island waters has steadily decreased as man has followed his natural inclination to take and take again. Always, the resource is viewed as unending. As so-called progress and sophistication have carried us through the twentieth century, we have begun to hurt this resource, dealing ever more crippling blows with sewage and chemical pollution, destruction of habitat, and overharvesting. At long last, we have come to recognize that nothing is forever; we **must** effectively manage our shellfish resources if there is to be any fishery left.

Charge of the Enforcement Division

In terms of management of the shellfishery resources, the Division of Enforcement has two key responsibilities. These are the protection of the shellfish resources in Rhode Island waters from illegal over-exploitation, and the protection of the integrity of Rhode Island shellfish in local and national markets by enforcement of shellfish sanitation regulations.

It is the responsibility of the Rhode Island Marine Fishery Council (RIMFC) to promulgate rules and regulations for the management and harvesting of shellfish in Rhode Island waters (see Smith in this volume for discussion of RIMFC). Size limits for each type of shellfish, catch limits by type and area, and regulation of harvest methods and implements have been established to protect the fishery. Rhode Island Conservation Officers protect the shellfish resources of the state through enforcement of these regulations designed to protect the resource.

In their day-to-day involvement with these shellfishery regulations, conservation officers encounter many unforeseen glitches of unworkable regulations, overlapping jurisdictional problems, and public apathy and ignorance. There are a number of examples of problems of this type. For instance, problems have arisen on numerous occasions with Sheffield Cove in Jamestown. Recently expanded pollution closure lines now include the cove, but the *Marine Fisheries Abstract* lists it as a management area, open for shellfishing several weeks before the pollution closure is seasonally lifted. In another instance, Bissel Cove in North Kingstown has presented a problem for officers trying to stem the illegal harvest of undersized shellfish. Once officers noted the prevalence of undersized shellfish in recreational catches, they requested a survey and recommended closing the management area for a longer period. The survey of the cove was conducted and showed 81.6 percent of the shellfish to be undersized. The request to the RIMFC for closure of the area was denied because the members of the council felt that the undersize law addressed the problem. But it is certainly easier for officers to enforce a closure than to check the catches of up to 100 recreational harvesters during an afternoon. Additionally, judges in the district court system have begun to look askance at fines of $300 to $400 for recreational diggers—the minimum fine levied for some of the seizures of undersize shellfish from recreational catches in the Bissel Cove area.

Public ignorance is the most frequently encountered cause of illegal harvesting by recreational diggers. A large percentage of these people do not yet know of the change in size regulations for quahogs and are still measuring them with a ring (the current one-inch hinge width regulation and measuring gauge were instituted in 1987). Posting of closure lines for both management and polluted areas is often nonexistent or left for conservation officers in their spare time. *Marine Fisheries Abstracts* are often not available in easily accessed locations.

In addition to their enforcement duties, officers of the Division of Enforcement provide other valuable services toward managing the shellfishery. For example, they are often the funnel by which information is transmitted to the Division of Fish and Wildlife biologists. The field officer in his daily contacts with commercial and recreational harvesters, sees areas being overfished, receives information of biological problems in the shellstock, recognizes needed additional signing or closures, and encounters the latest trends in harvesting gear.

The enforcement officers serve a very important role in the supervision of the shellfish transplant programs. Transplants are probably the most successful shellfish management tool currently used in Rhode Island. With the potentially available stock found in polluted areas surrounding major harvesting areas, transplants can refurbish and improve thousands of acres of shellfish grounds, if employed to maximum potential. The last paid transplant from Warwick Cove put over 600,000 pounds (7,500 bushels) of quahogs into the Greenwich Bay Management Area in one day. The Warwick Cove source area is annually harvested for transplants—and is one of the most popular areas among illegal harvesters!

Protection of the shellfish resources from illegal harvesting in polluted waters is the second charge of the Division of Enforcement. All of the state's polluted waters are closely monitored by conservation officers for illegal harvesting. Without a strong enforcement program, Rhode Island would not receive certification from the National Shellfish Sanitation Program (NSSP), and interstate sales of Rhode Island shellfish would be prohibited. A yearly inspection of the enforcement program is conducted by the Food and Drug Administration (FDA) regional office in Boston. An inspector spends a day in each of the three enforcement areas of the state with a conservation officer. During the inspection, patrol tactics are monitored, equipment is surveyed, knowledge of the closure areas is noted, and recommendations for upgrading the enforcement program result.

The protection of shellfish sanitary quality in the distribution and marketing channels is also federally mandated by the NSSP. The Rhode Island Department of Health and the Department of Environmental Management have joint responsibility for maintaining state compliance with these regulations. Conservation officers regularly assist by monitoring shippers and dealers.

In addition to enforcing pollution closures and sanitation regulations, officers monitor area postings, reporting missing signs to Division of Water Resources personnel for replacement, but frequently do the actual replacement of signs. Often, officers note pollution sources and report them to Water Resources personnel.

Enforcement Methods and Results

Protection of the shellfish resources is carried out by four basic enforcement approaches. The most basic approach and the backbone of the program is routine patrol. Routine patrol provides visibility, public education, information gathering (both by observation and through contact with informants), and regular inspection of licenses and shellfish. Consistently since 1987, about one third of the license checks conducted by conservation officers has been of shellfish or multipurpose licenses (Table 1). Routine patrols are conducted by boat, vehicle, and on foot. Schedules for conservation officers working in marine areas are based upon low tides and peak harvesting seasons. Frequently, schedules are changed to target problem areas and times.

Table 1

LICENSE CHECKS BY CONSERVATION OFFICERS, 1987 - 1991

Type of license	1987	1988	1989	1990	1991
Resident Shellfish	4,430	4,107	4,266	5,321	4,246
Nonres. Shellfish	1,055	624	807	564	628
Multipurpose	891	496	992	1,078	1,187
# Total licenses	6,376	5,227	6,065	6,963	6,061
# Boats boarded	3,063	2,998	3,146	3,133	3,657
Total # of licenses checked by officers during year (all types)	19,267	19,743	22,194	21,467	22,490

The second enforcement approach is participation in the supervision of transplants and management area openings. During transplants, conservation officers closely monitor the movement of shellstock from polluted areas to temporarily closed cleansing areas. The winter openings of the Greenwich Bay Management Area and the Bristol transplant bed are supervised by officers afloat and ashore to ensure that catch and size limits are strictly followed.

The third enforcement approach is the regular inspection of shellfish dealers. Over the last ten years, the Department of Environmental Management has conducted a shellfish inspection program using civilian inspectors. Overall, this has **not** been a success. Often, inspectors had limited knowledge as to the workings of the shellfish industry. Indeed, some inspectors had never seen quahogs before! At the present time, dealer inspections are conducted by enforcement officers. This is a valuable information-gathering process, as well as a check on the legal postharvest handling of the shellfish.

Improper handling of shellstock at the dealer-shipper level is one of the major causes of substandard shellfish at the consumer level. Examples encountered in the last five years by enforcement officers working both within the state and on the road with out-of-state National Marine Fisheries Service (NMFS) agents have included:

1. A shipment of littleneck quahogs picked up from a Rhode Island dealer and delivered within eight hours to a restaurant in northern New Jersey. When checked for undersized shellfish, they were slimy to the touch and had a very unpleasant smell.

2. Upon opening a tractor-trailer at a commercial vehicle checkpoint on Route 95, bags of shellfish packed into the trailer last were checked for temperature. Although everything in the truck

was close to freezing, these bags registered 78°F. This was over 25°F greater than the legal high temperature allowed by the FDA for shipping shellstock. The truck, when stopped, was less than one-half hour away from its pickup point for this shellfish, showing that it was coming from an unrefrigerated storage plant.

3. Soft-shell clams were shipped in an open pickup truck into southern Rhode Island from Maryland in August. The bags were not iced, nor in a refrigeration unit, but lay exposed to the sun and any contaminants falling on them.

4. Cages of surf clams were checked in August at a Rhode Island dealer who cuts them for soup. These cages came from New York and were stored in the open, without refrigeration. When touched, the necks would not retract at all. Temperatures that day were in excess of 90°F.

5. A Rhode Island dealer had a motorcycle torn down in his cooler for a lengthy period of time while his shellstock sat on the floor in his shop.

6. Finally, every truck checked at a commercial vehicle checkpoint on the Massachusetts Turnpike was found to be in violation of FDA regulations for sanitary shipping of shellstock. Included in the list of violations were the lack of pallets for shellstock or channeling of floors for drainage, mixing together in the same container various kinds of fish and shellfish, and packing shellstock on the bottom. One truck looked as if it had rolled over, with its contents tumbled together haphazardly.

The final enforcement approach is the use of a variety of special operations. In the past five years, Rhode Island has taken the lead in developing innovative enforcement programs. These special operations have included plainclothes investigations, special sting operations, and interjurisdictional cooperation, especially when interstate commerce is a factor. Officers have conducted a series of plainclothes operations offering shellfish for sale to unlicensed shellfish buyers, and selling shellfish to licensed buyers as unlicensed diggers, in attempts to identify purchasers who flaunt DEM regulations on shellfish buying. In conjunction with a poaching sting operation, enforcement officers have utilized the U.S. Fish and Wildlife Service's Cessna 185 float plane for night flights over problem pollution areas to look for illegal harvesting activity. With the small size of Rhode Island, it is possible to combine the flights for deer jacking (spotlighting the eyes of deer to temporarily blind and stun them, making them easier to shoot) with surveys of problem pollution areas.

Joint operations have been developed with Massachusetts Environmental Police Officers, Connecticut Conservation Officers, NMFS Agents, and agents of the Rhode Island Department of Health. These have included stakeouts, routine border patrols, market checks, airport checks, interstate surveillance of shellfish shipments, and seizures in other states. An agreement with Massachusetts allowed the development of an interstate task force to address problems in the Mount Hope Bay and the Fall River area, where shellfish was being harvested from heavily polluted areas and shipped to Rhode Island dealers. With the cooperation of Massachusetts and Rhode Island officers, as well as agents of the NMFS and the U.S. Coast Guard, a number of arrests were made in Massachusetts. At the other end of the state, joint patrols of Little Narragansett Bay and Sandy Point have been conducted since 1989 when Connecticut conservation officers were first charged with enforcement of pollution laws. Additionally, Rhode Island conservation officers have accompanied NMFS agents in making checks at T.F. Greene, Logan, Bradley, JFK, and LaGuardia airports. With their enforcement powers, NMFS agents can actually stop the departure of flights until their freight cargo has been inspected.

In the past few years, Rhode Island conservation officers have become more involved with the enforcement of surf clam regulations in cooperation with NMFS agents. One dealer in 1989 was cutting surf clams for use in soup. He was found to be using clams harvested illegally in New York and Massachusetts. Additionally, he never kept the required records and never removed cage tags or sent them to the NMFS surf clam program. The discovery of another surf clam infraction in 1992 involved a cooperative effort with officers from the New York Department of Environmental Conservation. New York embargoed surf clams taken illegally from a highly polluted section of New York harbor. A harvester broke the embargo and shipped the clams to Rhode Island, where they were found at a local dealer. Officers found that although this dealer normally cuts the clams for food use, he is allowed by the Rhode Island Department of Health to cut polluted clams for bait. The only stipulation is that he cannot do both on the same day. There is no supervision of where the end product goes!

Interstate surveillance of shellfish shipments has proved to be a very effective tool in securing dealer compliance with undersized shellfish regulations. From 1987 through 1989, officers and agents followed a number of shellfish shipments to Massachusetts, New York, and New Jersey, inspecting the shellfish when the truck reached its destination. Inspections were made at the Fulton Fish Market in New York, in northern New Jersey, at the Boston Fish Pier, and in Rome, New York. Almost all of these inspections resulted in charges against Rhode Island dealers by both Rhode Island and New York or Massachusetts enforcement officers, forfeiture of the shellstock, and Lacey Act violations at the federal level.

The last of the special operations is the inspection of trucks at commercial vehicle checkpoints. In conjunction with NMFS agents and Massachusetts or Rhode Island State Police truck squads, checkpoints were set up along the Massachusetts Turnpike and on routes 1, 108, 24, 95, and 146 in Rhode Island. Between 1987 and 1989, hundreds of trucks were stopped and their cargoes inspected (Table 2)

In addition to checking the trucks of many dealers, inspections were made of numerous common carriers, offering the opportunity to check the shipments of several dealers at one time. If violations were found, the dealers were cited, as the carrier could not be held responsible unless he had purchased some of the shellfish himself for resale.

One result of this work with NMFS agents and officers from other states is that a network of contacts has been established. In one case, New York officers seized a large quantity of undersized quahogs at a Long Island dealer and notified us in Rhode Island that they were shipped from here. Rhode Island officers were then able to drive to Long Island, bring back the illegal shellfish, and charge the dealer at this end.

Tools for Enforcement of Shellfish Laws and Regulations

The Division of Enforcement is able to meet the challenge of protecting the shellfish resources in Rhode Island with the use of several tools and aids. The first aid, and by far the most important, is the dedication and tireless effort of the men and women who wear the badge. Rhode Island is divided into three patrol areas, each including a significant portion of the shellfish resources. Each area is patrolled by eight or nine conservation officers, who are supervised by a sergeant and a lieutenant. At the present time, one area lacks a sergeant, and one area has a sergeant in the position of acting lieutenant. These few officers provide the daytime and nighttime monitoring of harvesting activity and dealer inspections in addition to their other duties (Table 3).

Among the most important tools of enforcement are the penalties associated with the rules—regulations and statute laws that allow the officers to protect the resource. As previously discussed, the RIMFC promulgates rules and regulations for the establishment of management areas, sizes and catch limits, and harvesting methods. The penalty for violations of these regulations is up to $500 and/or up to 30 days in jail. Statute law governs the licensing of harvesters and dealers and the establishment of polluted areas with penalties for harvesting in them. Areas that are not certified for the taking of shellfish are legally called polluted areas, and the penalties for taking shellfish from them are up to

Table 2
DEALERS CHECKED IN 1989

Dealer	Check	Dealer	Check
American Mussel Harvesters	CVC, PC	Mar-Lee	CVC
Anchor Seafood	CVC	Met Fisheries Inc.	CVC
Anthony's Seafood	PC	Mitchell Shellfish	CVC, PC
Aquidneck Lobster.	CVC, PC	Morgan's Transfer	CVC
Atlantic Lobster	CVC	Northeast Atlantic Seafood	CVC, PC
Atlantic Lobstermen's Coop	CVC	NESBRO	CVC, PC
Atlantic Wholesale Lobster & Fish Co..	CVC	Ocean Fresh Seafood	CVC
Atwood Brothers	CVC	Ocean State Seafood	PC
Bay Shellfish.	CVC, PC	Ocean Venture	CVC
Bayview Shellfish	CVC, PC	Paiva Shellfish	CVC, PC
Beach Shellfish	CVC, PC	Parascandola Brothers	PC
Blue Gold Mussel Farms.	CVC	Paul's	CVC
Boston Lobster Company	CVC	Plymouth Fish Market	CVC
Bucks Harbor Shellfish	CVC	Point Judith Fishermen's Coop	CVC, PC
Carter's Seafood	CVC, PC	Point Judith Lobster	CVC, PC
Champlin's	CVC, PC	Rathbone's	MC
Channel	CVC	Reliable Shellfish	CVC, PC
Chipperfield Brothers	CVC, PC	Rocky Neck Seafood	CVC
Clipper Seafood	CVC, PC	Roger's Transfer	CVC
Connecticut Shellfish	CVC	Seaboard Express.	CVC
D-Fillet	CVC	Seacoast Transport	CVC
East Coast Lobster	CVC, PC	Seafood Express	CVC
E.M. Montiero	CVC	Seafoods of Maine	CVC
Estrella Seafood	CVC, PC	Seafresh U.S.A.	CVC
Foley Fish Company	CVC	Seair	CVC
Fox Seafood	CVC	Seaside Fish Company	MC
Frank Rideout	CVC	Seaview	CVC
Fulton Fish Company	CVC	Seaview Fillet Company	CVC
Galilean Seafood	CVC	South Pier Fish Company	CVC, PC
Gallomore and Sons	CVC	S.T.I.	CVC
Gilbert's Seafood	CVC, PC	Stonebridge Seafood	CVC, PC
Global Seafood	CVC	Tallman and Mack	PC
Gloucester Sea Cap	CVC	Tichon Seafood	CVC
Greenwich Bay Clam Company	CVC, PC	Thomas Scalford Seafood	CVC
Handrigan's Lobster	CVC, PC	Tiverton Shellfish	CVC, PC
Herb's Shellfish	CVC, PC	Top Quality Shellfish	CVC, PC
J & L	CVC, PC	Town Dock Fish Company	CVC, PC
J.L. Mallowes & Sons	CVC	Tucker Seafood	MC
Kaelbel Seafood	CVC	Warwick Cove Shellfish	CVC, PC
Knickerbocker Corp	CVC	W.E. Pray Trucking	CVC
Lobsters U.S.A.	CVC, PC	Wickford Shellfish	CVC, PC
M & N Seafood	CVC	Zwolinski Shellfish	CVC, PC
Manchester Seafood	PC		

Key:
CVC - checked at commercial vehicle checkpoint
MC - market check conducted with NMFS agent
PC - port check: inspection of cutting facilities or wholesale/retail operation

Table 3

DUTIES OF RHODE ISLAND CONSERVATION OFFICERS

1) enforcement of laws pertaining to:

shellfish	hunting
pollution	freshwater fishing
mgmt. area regs.	lobsters
marine finfish	park regulations
forestry	littering
boating	hunter safety
migratory birds	endangered plants

2) response to nuisance animal complaints
3) response to roadkill deer reports
4) response to coastal and wetlands complaints
5) response to oil spill and hazardous waste complaints
6) response to stranded marine mammal reports
7) assistance to park rangers, as needed
8) officers are also:
   a) deputy agents of the National Marine Fisheries Service
   b) deputy agents of the U.S. Fish and Wildlife Service
9) other activities include:
   a) investigation of exotic pets and preliminary inspection of facilities prior to issuance of propagation permits.
   b) providing boat transportation on an as-needed basis to other divisions and departments of state government
   c) search and rescue operations on land and water.
   d) investigation of all hunting accidents
   e) prosecution of all subjects arrested by enforcement officers.

$500 and/or up to one year in jail for the first offense. The penalty is greatly increased for the second offense, becoming a felony with a penalty of up to $2000 and/or up to four years in jail. In addition to these penalties, any boats, motors, and equipment used in the violation may be forfeited to the state. Shellfishing at night, either in polluted or open water is also a felony.

An excellent enforcement tool has proven to be the administrative hearing, which is an action against a license. Findings against a license may include the revocation or suspension of the license and monetary fines.

The right to inspect boats, vessels, and vehicles used or suspected of being used in the taking or transporting of shellfish is granted to enforcement officers in Title 20, Chapter 8.1, Section 9 of the General Laws of the State of Rhode Island. A condition of being licensed to harvest shellfish is the granting of inspection rights for boats, implements, vehicles, and structures used for harvesting, keeping, or storage of shellfish.

Physical aids to successful enforcement include a variety of surveillance tools. For routine use, officers are issued binoculars and are currently using Steiner or Swarovski optics.[1] For night work, the division uses a night vision scope, purchased over a decade ago. Recently, through the generosity of Swarovski Optics, the latest in night vision equipment was made available for use by conservation officers on a limited basis. Officers have employed the U.S. Coast Guard's forward looking infrared camera (FLIR) in several operations with great success. In a joint operation with Massachusetts, an entire illegal harvesting operation was preserved on videotape for the edification of judge and jury. Officers have also successfully employed the inexpensive "bionic ear" for acoustic surveillance. Probably the most memorable use of the "bionic ear" was the night when plainclothes officers listened to regular reports of "all clear" from a lookout for a digging operation in polluted waters. The lookout, hidden in a woodpile near the officers with the ear, had allowed six officers in plainclothes to sneak into the marina he was watching. The ear is highly successful in locating subjects "shortsticking" (using a short-handled bullrake at wading depths) in more remote and darker areas. During windy weather, however, this is not a usable item.

The actual apprehension of violators very often depends on a well-maintained fleet of pursuit boats. The purchase of an Alison

[1] Use of trade names does not imply endorsement by the Division of Enforcement, the state of Rhode Island, or any agency of the federal government.

high-speed racing boat has given officers the ability to outrun anything used by the diggers, but the construction of this boat does not allow any ramming or high-speed boarding. For plain-clothes work, the boat has been highly successful.

In the past five years, fewer boats have been seized, as the emphasis on pollution harvesting has shifted from boat diggers to "shortstickers." In some areas where abandoned buildings and large wooded areas offer cover for the offenders, officers have employed the use of dogs. The Adult Correctional Institution's SWAT team has welcomed the opportunity to give their dogs training in extended searches for fleeing felons. Local police departments have made their dogs available to look for items hidden by violators.

Global Economy of Seafood and New Enforcement Challenges

Since the mid-1980s, new patterns have appeared in shellfish law enforcement in Rhode Island. With the major influx of Southeast Asians into New England, not only is there an entirely new group of violators working in polluted waters, but the enforcement officer must have extended knowledge of shellfish species that are not native to this area.

As previously discussed, the emphasis of harvesting in pollution has changed from subjects working from boats to hand gatherers and "shortstickers." The problems that have arisen with the Southeast Asian community stem from the fact that they are often from traditional fishing communities; thus extremely efficient in their harvest methods and very non-selective in their choice of harvest. In addition, "pollution" is not in their vocabulary, as all of our waters are much cleaner than those in their homeland. To explain pollution is difficult; and unfortunately, communication problems are common. Since the children of the household usually have the best command of English, they are usually the individuals asked to translate for the other members of the group. In itself, this is a violation of social custom, as the head of the household is the proper person to be approached first. The largest number of problems with Southeast Asians shellfishing in polluted waters has been during the summer months. International "No Shellfishing" signs have been posted without much success. The most heavily fished polluted areas have been Conimicut Point in the Providence River, Greenwich Cove, Mill Cove in Wickford, and Narrow River at Sprague and Middle Bridges. Groups from the Boston area have been encountered, who were harvesting shellfish from polluted waters for sale at ethnic markets.

A second problem for the enforcement officer is the appearance of unfamiliar species in local ethnic markets. The Rhode Island Department of Health recently called in conservation officers after finding large quantities of what appeared to be extremely small quahogs in several Asian markets in the Providence area. Careful study of these clams revealed them to be *Corbicula fluminea*, a freshwater clam native to Asia that was introduced into the United States, and is adapting extremely well to a variety of growing conditions. Further investigation revealed that the source was Florida, where they were being grown in uncertified fresh water and being shipped by a dealer who was not certified to ship interstate. As a result of this investigation, conservation officers presented a program for operators of the Asian markets in the Providence area. In this program, emphasis was placed on the handling of shellfish and fish, size limits, and tagging responsibilities. Several other species of clams were found during market checks, including *Anadara granosa* that had been shipped in from Malaysia. All of these are illegal to import, as the National Shellfish Sanitation Program does not recognize any area in Southeast Asia as having certified growing areas.

Conclusions

Joint cooperation among state and federal agencies is probably the most notable change in shellfish law enforcement over the past few years. With the introduction of more far-flung markets, it becomes imperative that the Rhode Island officers become more knowledgeable about how the market works. No longer can the officer be content with watching the digger in his skiff working on the bay. Market trends, shipping routes, even population changes affect the daily work of the officer. Today, Rhode Island officers have developed contacts as far away as California. A Rhode Island gauge is in use at the San Francisco International Airport to check Rhode Island littlenecks coming in on freight flights. Documentation of illegal shellfish has been obtained from several other states, and cases have been successfully prosecuted as a result of these out-of-state contacts.

It is only through the preservation of superior shellfish products that Rhode Island will remain at the forefront of quahog production in the United States. This is the key goal of Rhode Island Conservation Officers, but unfortunately, budget constraints are making this goal harder and harder to achieve. For some 30 officers to be given the supervision of a multimillion-dollar industry on a part-time basis as a result of other demands on officer patrol time is almost ludicrous.

Questions and Answers

Q. *(Mr. Peter Canis, shellfish diver) You mentioned a number of problems with Rhode Island shellfish dealers. Is this unique to Rhode Island? Do other states have similar problems with their dealers?*
A. (Sgt. Anne Holst, DEM Enforcement) There were shellfish coming out of Maryland that were an obvious violation of Maryland law. All of these violations were violations of FDA rules, which override the states, but the problem is to check these things. We have been able to educate the Rhode Island commercial truck squad so that they keep an eye on things for us. What happens with the health departments or state police truck squads in other states, I cannot say, but in Massachusetts as I reported in the paper, all trucks stopped on the Massachusetts Turnpike during our joint operation were in violation. Most of the problems with poor quality shellfish in the markets can be traced directly to poor dealer handling.

Q. *(name inaudible, shellfisherman) I rarely hear about people that have had penalties for possession of undersized shellfish. What is happening with them?*
A. (Holst) One of the reasons that you don't hear much about these types of things is that the press is usually in court at the time of the arraignment, or they would go to the court clerk and get information about the people arraigned. Most offenders will plead not guilty and go to pre-trial conference, where they will do some pre-trial bargaining and so forth. Usually, the press does not follow through on pre-trial conference actions. So the public does not really see the follow-up actions. People are prosecuted, fined, and licenses are revoked if there is an administrative action. One of the problems at the Division of Enforcement is that we really do not get publicity on the things we do. There are people out there who have no idea about what we do.

Q. *(Mr. Chris Wilkins, Narragansett) You said that thirty officers on a part-time basis was ludicrous. What do you feel that the optimum number of officers should be?*
A. (Holst) I have not thought it through based on the size of the industry. I said part-time because of the many other fish, game, and other laws and regulations we enforce (Listed in Table 3).

Q. *(Mr. John Finneran, shellfisherman) Given tan officer's large number of responsibilities what would you estimate the percentage of time that is devoted to shellfish-related enforcement?*
A. (Holst) During times of the year of peak harvesting, I would say easily 70 percent.

Q. *(Finneran) What about a yearly average?*
A. (Holst) I don't believe I can answer that.

Q. *(Finneran) A second question. You mentioned that enforcement officers now enter shellfish sales establishments. Is there a clear policy about this? Are they going in as administrative agents or police inspectors?*
A. (Holst) We must inspect administratively.

Q. *(Finneran) How are these administrative inspections followed up?*

A. (Holst) There are shellfish inspection reports on each establishment that is entered.

Q. *(Canis) Is it true that the license fee increases will be going to enforcement?*
A. (Holst) I don't know anything about fee increases or finances. I'll find out when you do.

A Legal History of Shellfish Regulation in Rhode Island

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Abstract. *The legal status of shellfisheries and shellfish as a common property resource in Rhode Island is examined. Fisheries in Rhode Island were important enough in the colonial era that they merited special mention in the King Charles Charter of 1646. Such provisions were subsequently included in the Rhode Island State Constitution of 1843. Laws enacted during the 19th century such as the 1844 Oyster Act allowing for aquaculture leases by the state are outlined. A series of court rulings and state supreme court decisions defining the limits of the common property fishery resources are reviewed.*

Virtually every shellfisherman in Rhode Island is aware of the fact that our state's fisheries were important enough in the colonial era to merit special recognition in the King Charles Charter and subsequently in the Rhode Island State Constitution, adopted in 1843. This paper will trace the origins of those provisions and will review the most significant decisions of the Rhode Island Supreme Court which have interpreted them.

The Colony of Rhode Island and Providence Plantations was founded in 1636 by Roger Williams. Unlike other colonies settled after the grant of a colonial charter, Rhode Island was first populated by disaffected settlers from those colonies and then sought official recognition. Roger Williams sold some of his newly acquired real estate to finance a trip to London to seek recognition for the developing colony. In 1644, he returned with a brief "charter of civil incorporation" which created a colony named "Providence Plantations, in the Narragansett Bay in New England." Upon restoration of the crown in 1646, King Charles II replaced it with a far more detailed royal charter.

The King Charles Charter was best known for its remarkable dedication to freedom of religion, a key issue for many early Rhode Islanders who had been asked to leave other colonies because of their religious beliefs. It is better known to those involved in fisheries for its explicit delineation of the rights of fishing and navigation. The Charter specified that:

> Our Express Will and Pleasure is, and We do by these Presents for Us our Heirs and Successors, ordain and Appoint, that these Presents shall not in any manner hinder any of our Loving Subjects whatsoever from using and exercising the Trade of Fishing upon the Coast of New England in America; But that they, and every, or any of them shall have full and free power and liberty to Continue and use the Trade of Fishing upon the said Coasts in any of the Seas thereunto adjoining, or any Armes of the Seas, or Salt Water, Rivers and Creeks when they have been accustomed to Fish.

What did it mean to have "full and free power and liberty" to continue fishing? In the context of the time, it seems clear that this was simply a statement that marine fisheries were to be treated as a common property resource, unlike the generally prevailing rule on land that game was the property of the landowner (the King).

Upon independence, there was some question as to the extent to which colonial law and practice would be recognized by the new United States. With regard to submerged lands and their resources, this question was not resolved until 1842 when the U.S. Supreme Court decided the case of Martin v. Lessee of Waddell. The Court held that:

> when the revolution took place the people of each state became themselves sovereign; and in that character hold the absolute right to all their navigable waters and the soils under them for their own common use, subject only to the rights since surrendered by the Constitution to the general government. 41 U.S. (16 Pet.) 367 (1842)

Thus the common property theme was recognized by the federal government with the stipulation that it was the responsibility of each state to manage its own resources.

Remarkably, the state of Rhode Island continued to use the King Charles Charter as an "unofficial" state constitution until the following year, 1843. Reluctance to adopt a state constitution may have been related to the state's legendary antipathy towards the subject: Rhode Island was the last state to adopt the U.S. Constitution, and did so (by a close vote) only because of tremendous political and economic pressure from the other states. However, the new state constitution was quick to reiterate the special status of the state's fisheries:

> the people shall continue to enjoy and freely exercise all the rights of fishery, and the privileges of the shore, to which they have been heretofore entitled under the charter and usages of this state. But no new right is intended to be granted, nor any existing right impaired, by this declaration. R.I. Const. Art. I, Sec. 17.

"All the rights of fishery" is a term the Rhode Island Supreme Court has been trying to interpret ever since.

The conventional wisdom frequently heard on the waterfront supports the assertion that this constitutional right to the fishery severely limits the power of the state to regulate how the fishery is carried out. The following cases will demonstrate that this could not be further from the truth.

Just one year after the new Constitution was adopted, the Rhode Island General Assembly passed the Oyster Act of 1844. This was essentially the state's first aquaculture law, establishing a board of commissioners for shellfisheries who had authority to grant oyster leases in the bay. The new leasing program was quickly challenged in a series of cases decided in 1850, 1853, and 1855 which upheld the power of the General Assembly to legislate on the subject.

The first case to review the constitutionality of the new law was State v. Cozzens, 2 R.I. 561 (1850). Cozzens had been convicted of violating the oyster law for stealing oysters from a private leased bed. He was fined the then substantial sum of $40. He appealed to the Rhode Island Supreme Court, alleging that the oyster law violated Art.I, Sec. 17 of the state constitution. The court held that the constitutional provision was intended to be carried into effect by legislative regulation, the object of which would be to secure to all the people the right of fishery. Since they found that the leasing law encouraged individuals to plant and cultivate oysters, this produced the public benefit of a more abundant supply and thus satisfied the constitutional intent.

Another criminal appeal was heard in the case of State v. Sutton, 2 R.I. 434 (1853). In that case, Sutton was arrested for taking quahogs within leased oyster grounds. The Supreme Court held that where a portion of the public waters are leased for a private oyster fishery, no one, unless authorized by the owner, has a right thereon for the purpose of taking quahogs.

The final case in this first round of challenges to the oyster law was State v. Medbury, 3 R.I. 138 (1855). Medbury, a resident of Massachusetts, was charged with taking ten bushels of oysters from Narragansett Bay. He argued that the residency requirement in the oyster law was in violation of both the King Charles Charter and the Rhode Island Constitution. The court found that neither document conferred any new rights for a non-resident to fish in Rhode Island waters and denied his appeal. In an interesting bit of dicta, (legal commentary unrelated to the court's holding) the court stated that the right of fishery granted in the charter "related to the cod fishery, and not to the oyster fishery." They asserted that the former might require "wharves, stages, and workhouses," "for the salting, drying and keeping" of the fish "to be taken or gotten upon the coast," while the latter would not.

The next case which attempted to make use of Art. I, Sec. 17 was Clark v. City of Providence, 16 R.I. 337 (1888). A review of this case is particularly interesting in light of recent hearings on the impact of the public trust doctrine on the state's formerly submerged lands. The complainants sought an injunction to stop the filling of the Providence Cove on the grounds that their rights of fishery would be thereby extinguished. A smaller version of that cove will soon become a reality when it is recreated as part of the Capitol Center Project. However, in 1888 the forces of "progress" dictated that the cove be filled. The complainants alleged that since they were accustomed to fishing and clamming in the cove, under Sec. 17 they were entitled to fish in the same manner forever, and that therefore any act of the General Assembly which authorized the filling of the cove must be unconstitutional. However, the court found that "these rights of clamming and fishing are enjoyed in subordination to the paramount power of the General Assembly to regulate and modify, and to some extent at least, to extinguish them."

One of the most detailed reviews of the state's power to regulate fishing can be found in the case of Payne & Butler v. Providence Gas Co., 31 R.I. 295 (1910). Although the case principally concerned pollutants released by the gas company into the river which fouled an oyster bed, the court devoted a significant amount of attention to the powers of the General Assembly. They pointed out that prior to the adoption of the state constitution, the legislature had full authority to grant exclusive rights of fishery in the public waters of the state. In at least two instances, in 1822 and 1827, they did; the General Assembly made exclusive grants of oyster banks. The court found that those grants remained valid because of the second sentence in Sec. 17: "no new right is intended to be granted, nor any existing right impaired, by this declaration." No greater privileges were reserved to the people than they already had, and no powers or rights of the General Assembly were thereby abridged.

The court went on to give a sweeping statement of the General Assembly's authority:

> The whole subject of fisheries...is under the fostering care of the General Assembly...They may even prohibit free fishing for a time...as in their judgment it is for the best interest of the state to do so. They may withhold from the public use such natural oyster beds, clam beds, scallop beds or other fish beds as they may deem desirable...generally they have complete dominion over fisheries. We find no limitation, in the constitution, of the power of the General Assembly to legislate in this regard, and they may delegate the administration of their regulations to such officers or boards as they see fit.

The final sentence of the quote is significant in that it specifically authorizes the same level of responsibility to the current trustee of fisheries management in Rhode Island, the Marine Fisheries Council.

That same year, a related case arose regarding the oyster fishery of Point Judith Pond. In State v. Nelson, 31 R.I. 264 (1910), the defendant Nelson was arrested for taking a peck of oysters from the ground leased to George Griffin by the Town of South Kingstown. Nelson argued that the 1901 law which allowed the Towns of South Kingstown and Narragansett to lease the bottom of the pond (in exchange for the towns' willingness to open and maintain the breachway) was a violation of Art.I, Sec.17. He maintained that this was an unlawful delegation of legislative power since it benefited the towns rather than the people of the state and the towns did not reserve any part of the pond for a free and common oyster fishery. The court found, however, that this was a valid delegation of legislative power and that there was nothing wrong with the town's effort to lease the pond to recoup their expenses in opening and maintaining the breachway.

Another challenge to the state's one year residency requirement was heard in State v.

Kofines, 33 R.I. 211 (1911). This was a case involving the lobster fishery; Kofines argued that the residency requirement was a violation of Art. I, Sec. 17. The court held, once again, that the licensing statute was a valid use of the police power of the state and did not violate the state constitution. In support of its holding, the court spoke persuasively on the need for conservation measures:

> Without protection from the rapacity of man, lobsters must inevitably become scarcer, and consequently dearer. This has been the costly experience of all countries where the experiment has been tried. The natural tendency to kill the goose that lays the golden egg is always exhibited when the opportunity is afforded. And when anyone, attempting to stay the unsparing hand of the despoiler, suggests that something should be saved for posterity he is likely to receive this interrogative reply: Why should we care for posterity, what has it ever done for us? After us, the deluge.

Despite all of the previous cases discussing the General Assembly's power to regulate fisheries, the issue surfaced once again in the case of Windsor v. Coggeshall, 54 R.I. 38 (1933). In that case, a fish trap operator argued that he was protected by Art. I Sec. 17 and did not need a license to place his trap in the bay. The Supreme Court, obviously getting impatient with yet another appeal on exactly the same issue, stated:

> The situation in which the respondents find themselves in respect to their position as fishermen appears to be due to a stubborn adherence to their belief that the General Assembly has not the power to regulate, limit or restrain fishing in the publicwaters of the State. That this belief is groundless is quite evident from the cases heretofore cited which confirm in no uncertain terms the power in the General Assembly which the respondents challenge.

The last time Art. I Sec. 17 was reviewed by the Supreme Court was in 1958, when the General Assembly asked the court to give an advisory ruling on the constitutionality of a proposed statute. The legislature asked if they could pass a law which would prevent commercial fishermen from landing striped bass. The Court found that the power to limit fishing was quite clear from previous cases; however, they also held that if only commercial fishermen were so restricted, the law would be discriminatory and invalid. They found that the Constitution "gives the benefits of fishery to all the people in equal measure." Opinion to the Senate, 87 R.I. 37 (1958).

In conclusion, the power of the General Assembly is quite clear: as long as a statute is not discriminatory, it may comprehensively regulate fishing without any fear of violating the Rhode Island Constitution.

Questions and Answers

Q. *(Mr. Robert Rheault, shellfish aquaculturist) Most of our neighboring states manage shellfish on a town-by-town basis, and there seems to be much more money available for shellfish management. For example, some towns have funds for shellfish management in excess of $700,000 per year and purchase more seed than the whole state of Rhode Island. Do you think that the state may have "shot itself in the foot" by dealing with shellfish management on a state basis rather than a town-by-town basis?*

A. (Prof. Dennis Nixon, URI) To some extent the example that I gave of Narragansett and South Kingstown was one in which the legislature gave the responsibility of managing Point Judith Pond to the towns, as far as oyster leases. Management by towns is possible, but I think that the small size of the state makes it a manageable unit. If you take a look at the examples of Massachusetts and New York, they are quite different in that they were looking at shellfish propagation over a long period of time. Because of Article 1, Section 17 here in Rhode Island, there has been a dynamic between leased grounds and open fisheries. This has hindered a larger planning program. The issue is a programmatic one, and with new, innovative leadership in DEM Fisheries, I hope to see the types of programs you allude to.

Management of Marine Fisheries through the Rhode Island Marine Fisheries Council

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Abstract. *The Rhode Island Marine Fisheries Council (RIMFC) is responsible for the promulgation of rules and regulations for the management of capture fisheries in the waters of the state of Rhode Island. Several examples of fishery management issues from RIMFC and the New England Regional Fisheries Council are discussed, including offshore groundfish, striped bass, winter flounder and quahog fisheries. Successful management of fisheries stocks relies heavily on developing appropriate regulations with the cooperation of both the commercial and recreational fishing communities. Cooperation and negotiation between groups is an important ingredient of success. (Editorial note: This paper is an edited version of the transcripts of Mr. Smith's oral presentation at the conference).*

Introduction

To introduce myself to those who do not know me, I am a full-time commercial fisherman. I have been involved with the Rhode Island Marine Fisheries Council (RIMFC) since its inception in 1976, and have served nine years on the New England Fisheries Management Council. I think that because of these experiences the conference steering committee has invited me to share some ideas with you. Perhaps some of the following will be helpful to you if you want to bring an issue to the Rhode Island, regional, or national fisheries councils.

I think that the most important thing individuals and organizations must understand about the council or legislative process is that there must be negotiation. You will not always win if you demand that your way is the only way of doing things. I really want to emphasize this from the beginning, before I give some examples. If you can learn to negotiate, you can come out on top most of the time. You may lose a few insignificant skirmishes, but in the long haul, you will win the larger battle. Often the other fellow has some very good ideas, so be willing to listen. You may not agree with his ideas, but to win in the long run, your negotiated agreements must improve the status of the fisheries resources.

Examples of Confrontation and Negotiation

The first example of conflict without negotiation is groundfish. Most of you who have been following this story in the newspapers know that the offshore groundfish stocks are not in very good shape. The New England Fisheries Council has been trying to set up a management plan recognizing that about a dozen species are caught at the same time. How do you deal with one species that may not be plentiful, when there are other species that are plentiful and you catch both at the same time? This is a difficult problem to tackle, so people get disappointed and angry. Different groups start to look at the issue as "we are right and they are wrong." What the New England Fisheries Council is trying to do is to implement a plan to improve the status of the fishery resource. One thing that must be understood, whether you work through the council system or legislatively, is that you cannot directly manage the fish, you can only manage the people. The fish are constrained by their natural abilities to reproduce, grow, and survive. The councils must manage fisheries by managing people through regulations. And regulations need to be enforced.

It is difficult to have regulations with weak enforcement, as Anne Holst (this volume) has told us. One key problem is that the National Marine Fisheries Service (NMFS) has even fewer enforcement officers than the state of Rhode Island. There are only 26 NMFS enforcement personnel from Canada to Florida, and they don't even have a boat. Any successful fishery management plan must have the full cooperation of industry, so people like myself in industry and on the council must convince all of the industry to believe in the value of the management tool. But this takes time—too much time for certain groups. So, what has happened in this case of the offshore ground fishery? A group known as the Conservation Law Foundation (CLF) said that they thought that the Council was neglecting its responsibilities of managing the fishery and that CLF had a better way of doing it. They then proceeded to get a court injunction against the council that mandated that the fishery must be managed by the council, and in a specific time period. We are now a year and a half past the time all of this started, and we are no further along in managing the fisheries than we were at the beginning. In fact, I think we have severely digressed, all because we got into a situation of one group against the other. The Council got disappointed, and the Foundation got disappointed. The saddest thing about this is that nothing has been done for the fishery resource. Everything has stopped and moved in another direction because of the pending court case. This very sad situation could have been avoided if there had been negotiation.

As another example of confrontation without negotiation, RIMFC became very involved in the management of the striped bass fishery. Commercial fishermen, rod and reelers, and net fishermen for many years were the dominant groups in the fishery. As time went on, more and more recreational rod and reel fishermen entered the fishery as the price of the fish increased. This created a situation in which one user group was fighting with another. Arguments were flying about such as "the way I catch them is right, the way you catch them is wrong." The groups were at loggerheads—no negotiation. The result was that the fishery was completely closed by RIMFC—no sales. Two things then happened regarding the fishery. The first was that everybody expected that the closure would bring back the fishery. To some degree this was true, but at the same time there were three successive good year classes that came through. We had very high numbers of striped bass after two or three years of closure. Second and more importantly, the price was taken off the head of the fish, so there was no incentive for fishermen to cheat. The people were managed, allowing for natural recovery of the stocks.

Complete closure of the offshore ground fisheries would **not** be the answer, as it was for the striped bass fisheries. The key difference between the two fisheries is that in the groundfisheries, thousands of people are involved. There are huge investments in gear and shoreside facilities. Closure would be an economic disaster for coastal communities. The striped bass fishery closure put a few people out of business for a time, but there was not a major economic impact on the community-at-large.

The recent controversy over winter flounder is worth noting. Winter flounder are caught in Narragansett Bay, the coastal ponds, and out to the 30-fathom depth at sea. They range quite extensively and migrate. People in Rhode Island said that the stock was in bad shape. Fisheries scientists with DEM suggested that we do something about the winter flounder problem. There were a number of recommendations that followed, as well as a number of arguments. The final circumstance was a situation of very poor negotiations. One group wanted to negotiate, the other did not. What happened was truly amazing. The fishery in the state of Rhode Island was closed to all user groups. Nobody won.

Unfortunately the species is in Rhode Island waters for just a few months out of the year. Winter flounder are now caught as they migrate out to the open offshore fishery, while the people in Rhode Island coastal communities suffer, because forty percent of the fish once were caught by recreational rod and reelers. Additionally, a number of inshore commercial fishermen were affected by the ban. According to NMFS statistics, 60,000 pounds of fish were caught annually. But, the fish **were** caught offshore, often by out-of-state boats.

This situation, like many others, was caused because individuals chose not to listen to the biologists and refused to negotiate a reasonable solution. When negotiation does take place, often measures to limit the catch are introduced, but at least the fishery remains.

These examples can be applied to the quahog fishery. The issue of the divers versus diggers came before RIMFC not too long ago. The decision by the council to continue to allow diving as a means for harvesting quahogs was not the one that a lot of people wanted. The key reason for the confrontation was the unwillingness of most fishermen to negotiate. Members of the fisheries council, and especially the legislature, are not experts on every matter relating to fisheries. Nine times out of ten, the petitioners know more about the problem than the council or legislature. The regulatory bodies do not need to be misled or misinformed, just because one noisy group believes that it is right. A strategy of dishonesty just will not work; it will be discovered and your credibility will be lost. Worst of all, this course of action does nothing to improve the quahog resource. The only outcome is that people are angry with one another. Taking fisheries issues to the legislature is not appropriate and is a huge risk, because legislators are certainly not the experts. In fact, they created the council because they recognized their lack of expertise and did not want to deal directly with fisheries management issues.

Need of Fishermen to Consider Unpopular Management Tools

In the opinion of many people, anyone can take part in the free and common fisheries of Rhode Island, and expect that the resources will somehow always be there. My experiences on the Marine Fisheries Council have made it clear to me that this is the farthest thing from the truth. In the estuaries of Rhode Island, we have always had to restrict the amount of catch to be taken. There are simply too many people and not enough of the resource. Overharvesting is the problem. What can be done about this? Well, so far with the free and common fishery, we reduce the amount of catch that can be taken per day. This is an answer, and it does solve the problem—for the time being. But this cannot go on forever.

If we look at an extreme example, there are fisheries on the west coast that are open for only six hours per year. Fishermen prepare all year and spend thousands to get out there during the open season. Is this what we want for Rhode Island fisheries? I don't think so, and I don't believe that many others would either, but how do we avoid this? A number of people have suggested limited entry. It may be unpopular, but it is a solution.

Difficult decisions must be made. As Professor Dennis Nixon (this volume) has pointed out, a real "free and common" fishery was possible in Rhode Island over a hundred years ago. Yet there are probably more people living in South County now than lived in the whole state back then. Our recreational catch limits are now down to a half a peck a day for clams, oysters, and quahogs. And most people do not even know how much that is, so they'll take as much as they can if nobody is around. Needless to say, shallow areas, especially in the salt ponds, are seriously overfished. It is conceivable that, given enough fishermen, the same thing could happen in deeper waters. What then should be done?

Last month, the diver-digger controversy erupted, packing the meeting room. All were present for one reason, the well-being of the quahog resource, but there were many fishermen who were unwilling to negotiate, and then ended up disappointed with the outcome. People must start talking. If limited entry is undesirable, then propose something else. I don't care what the solution is and I don't think anybody else does, as long as the resource is the priority.

Questions and Answers

Q. *(name not stated, shellfisherman) In terms of management of the stocks, if you look at graphs which show the catch of quahogs in Rhode Island, there was a very large harvest around 1955, and then we saw it tail right down. When we see these high harvests, it might be correct to say that we limit harvesting while the catch is still good, rather than waiting for the stocks to deplete to next to nothing and before the alarms are sounded. You can see problems developing.*

During 1953-54 in the Buttonwoods-Nausauket area, there was a tremendous set of quahogs. One day I drove down there to see what looked like rocks in a breakwater, but as I got closer it turned out to be hundreds of shellfishermen. Reports were that after the first week, 30,000 bushels of quahogs (approximately 2.4 million pounds) were taken. When you took one bite with the tongs, you got 200 animals. Prices went from ten cents a pound to four. Reports were that people were buying quahogs at four cents a pound, planting them out on Cape Cod and then harvesting them for years. The area was cleaned out in short order; you couldn't get much out of there after about seven days of the intense harvest. In very low dead tide, you could go down and make five or seven dollars. The point is that management of the resource should have begun while the resource was still there. Why isn't this done?

A. (Mr. Robert Smith) I must say that I was there, when I was 18 years old. With a hand rake I dug 18 bushels in three hours. I agree with you. This is a good example of when to manage a resource. Closure would not have been wise, but limiting the harvest probably would have been good for the fishery, stretching out the harvest for months or even a few weeks. These limits are not always a winner. If the limits are not followed by good year-classes in subsequent years the fishery would be depleted nonetheless. In your example, there were just too many people harvesting. A similar thing happened when the upper Narragansett Bay opened. There were 4,000 people fishing that year, and you could make $300-$400 a day, maybe more.

I disagree with your idea that quahog harvests can be evened out. Even if you severely restrict the fishery, there will be peaks and valleys because of periodic strong year classes. I think that management can assure that the peaks don't go so high, and the valleys don't go so low as in the Buttonwoods and Upper Narragansett Bay examples.

Q. *(Mr. John Finneran, shellfisherman) In fact, the Marine Fisheries Council and the industry, by cooperating and negotiating, did a good job the third time around to smooth out the catch curve you were referring to. We opened the Upper Narragansett Bay three times, 1981, 1984, and 1986 before the current conditional opening system was in place. The first time, we had it open one day a week from sunrise to sunset. At that time, I remember seeing "mountains" of quahogs in every dealer's shop often as high as the rafters of the building. There were clearly problems with the product spoiling in the dealer's shops because of their inability to handle the volume. The next time around, we opened the fishery three days a week, four hours a day, and the problem was not quite as bad, but still bad. The price was terrible, and the dealers would not buy on any day of the week except for Tuesdays. The last time around, we finally got our act together. We opened the fishery five days a week, two hours a day from 6:00-8:00 a.m.. We made it a little more difficult to take part in the fishery. The price remained stable, and everybody who took part in the fishery made some money. Most importantly, we did not sell our resources down the road for somebody else to get the gravy. We finally did something right.*

I wish to make one comment about the key drawback to limited entry. If a property right vests in a license, in other words if you can sell that license, you have created an artificial property. The worst example of this is the spiny lobster fishery in South Australia, where a license has a value of $150,000. You basically create an estate for someone who is lucky enough to be in the fishery at the right time. Professor Nixon mentioned that the intent of the sovereign was to allow the resource to exist as a common *food resource. That is really what it is about in this state; the greatest benefit for the greatest number of Rhode Islanders. I'm a commercial fisherman, I'm not looking to get rich selling my commercial fishing license so that I can retire leisurely. I do agree that we must manage the resources more wisely because the cheese is getting smaller and smaller, and the mice are getting thinner and thinner.*

A. (Smith) That is why I did not emphasize limited entry; I just mentioned it. There are many ways to do fisheries management, and that is just one.

Aspects of the Biology of the Northern Quahog, *Mercenaria mercenaria*, with Emphasis on Growth and Survival during Early Life History

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Abstract. *Key features of the biology of* Mercenaria mercenaria *are reviewed with emphasis on early life history processes. Predatory mortality during juvenile stages of the northern quahog is identified as a primary factor controlling recruitment of natural populations. Predation rates are shown to be strongly modulated both by substrate preference and prey-size selectivity of major predators (crabs and carnivorous gastropods). Smaller xanthid crabs prefer heterogeneous substrates (gravel and shell bottoms), and consume quahogs at a higher rate in these substrates, whereas larger, portunid crabs prefer and forage most effectively in homogeneous substrates. In contrast to predictions of optimal foraging theory, even larger crabs preferentially consume smaller quahogs, when a wide range of prey sizes is available, thus increasing predation pressure on smaller quahog size classes.*

Under field conditions, at near-optimum temperatures, juvenile M. mercenaria *exhibit mean shell growth rates of 0.8 mm week^{-1} (maximum = 1 mm wk^{-1}). Native populations along the east coast exhibit comparatively lower and higher than average lifetime growth rates at the species' northern (Prince Edward Island, Canada) and southern (Florida) distributional limits, respectively. These extremes correlate with the length of the growing season, which is strongly temperature-dependent. Thus, the time to attain legal market-size ranges from 1.9 to $\geq$ 6 years and averages three to four years in the mid-portion of the northern quahog's latitudinal ranges (Massachusetts to Virginia). Up to a two- to three-fold variation in growth rates is typically observed within a single estuary. Three toxic/noxious algal species are identified as potentially harmful to* M. mercenaria *under bloom conditions: the chrysophyte* Aureococcus anophagefferens, *the chlorophyte* Nannochloris atomus, *and the dinoflagellate* Alexandrium fundyense. *Management implications and suggested fruitful directions for future research are discussed throughout the text.*

Introduction

The biology of northern quahogs, *Mercenaria mercenaria*, has been the subject of several earlier (e.g. Belding, 1931) and more recent literature reviews (Pratt et al., 1992; Rice and Pechenik, 1992). Therefore this paper does not attempt an exhaustive review, but rather, will highlight some salient features of this species' life history which are of significance in managing wild stocks. Processes operating during early life history stages (Figure 1) are emphasized, because recruitment success into the fishery appears to be largely predetermined during the clams' first one to two years of life (Malinowski, 1985; Wallace, 1991). Poorly understood aspects of the species' biology will also be stressed, in order to suggest avenues for future research.

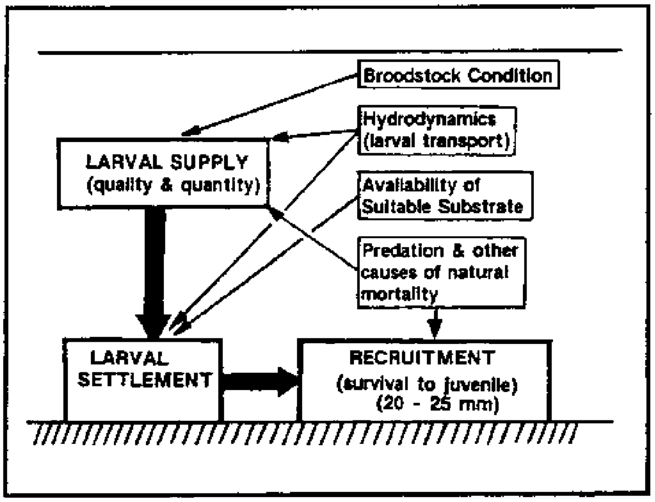

Figure 1. Schematic diagram of major factors controlling Mercenaria mercenaria *recruitment to a size (shell length of 20-25 mm) when hard clams attain size refuge from many of their common predators. See text for discussion.*

Reproduction

Mercenaria mercenaria is a relatively slow-growing, long-lived, dioecious bivalve, characterized by iteroparity (multiple reproductions over its lifespan), high fecundities, production of planktotrophic larvae that typically remain in the plankton for one to two weeks (Carriker, 1961), and high juvenile relative to adult survival (Malinowski and Whitlach, 1988). Important life history characteristics of this species are summarized in Table 1. Aging techniques rely on the presence of annual growth checks in the shell, which are typically produced during the winter in the northern and central portion of the northern quahog's geographic range, and in the summer and early fall in southeastern states (North Carolina, Georgia, and Florida) (Fritz and Haven, 1983; Grizzle and Lutz, 1988; and references therein). Longevity estimates for the species range widely between 23 and 46 years because of the difficulty in aging older specimens, which show crowding of growth rings and numerous spurious growth checks. Maximum size ranges between 110-111 mm in shell length (Rice et al., 1989; Jones et al., 1989) and 135 mm (Walker and Tenore, 1984). A long lifespan, and the coexistence of multiple year classes, will tend to buffer hard clam populations from sudden population crashes caused by sporadic recruitment failure.

Fecundity, as determined by repeated spawning induction of mature individuals in the laboratory, is positively correlated with body size, but highly variable among individuals of the same size (Table 1). *M. mercenaria* shows no evidence of reproductive senility, or decline in reproductive output or gamete viability with age/size (Bricelj and Malouf, 1980), since older clams produce gametes at a level predicted by the power curve relating gonad mass to body size in younger individuals (isometric growth) (Peterson, 1986). Bricelj and Malouf (1980) showed that mature eggs spawned at one time by a single female are characterized by a bimodal size-frequency distribution, with modal peaks at 67 and 81 µm in diameter (range = ca. 50 to 97 µm). This was confirmed by Gallager and Mann (1986), who found that quahog eggs separated into three distinct bands following density gradient centrifugation. The significance of this wide range in egg sizes has not been determined. Since egg size in *M. mercenaria* is known to be positively correlated with egg lipid content (Gallager and Mann, 1986), eggs of different sizes may be characterized by different development times (Clarke, 1982) or differential viability. Thus Kraeuter et al. (1982) found that smaller eggs (< 35 µm) had significantly lower survival than eggs > 44 µm.

Spawning of quahog populations is less synchronous and starts earlier in the year with decreasing latitude (Table 3.3 in Eversole, 1989). The length of the spawning season and the frequency of peak spawning periods also tend to increase with decreasing latitude. A single, annual spawning peak, occurring in the summer, is characteristic of northern and mid-Atlantic waters (e.g. Connecticut, New York, and Delaware), whereas two spawning peaks (in the spring and fall) occur in North and South Carolina (reviewed by Eversole, 1989), and a third winter spawning may occur in Georgia (Heffernan et al., 1989) and in Florida (Hesselman et al., 1989). Quahogs may retain a relatively high condition index after spawning (Ansell et al., 1964; Keck et al., 1975), and consequently do not experience the large fluctuations in meat quality and marketability

Table 1

Life history attributes of *Mercenaria mercenaria*

			Source:
Longevity (years)		40	Jones et al., 1989
		46	Peterson, 1986
		36	Lutz & Haskin, 1985
		23	Walker & Tenore, 1984
Age at first sexual maturity (yrs.)		1	Belding, 1931
Length at first sexual maturity (mm)		22-26	Eversole et al. 1980
		33	Bricelj & Malouf, 1980
		37	
Mean diameter of spawned eggs (μm)		67-81	Bricelj & Malouf, 1980
		81-82	Knaub & Eversole, 1988
Fecundity ($x\ 10^6$ eggs $clam^{-1}$):	Mean	Maximum	
Sublegal	1.6	2.4	
[a]Littlenecks	2.8	7.9	Bricelj & Malouf, 1980
[b]Cherrystones	7.1	16.8	
[c]Chowders	6.3	16.2	
Cherrystones &	8.6	29.9	Calculated from Ansell, 1967
Chowders	24.6	37.3	Calc. from Davis & Chanley, 1956
Littlenecks	1.9	3.3	Knaub & Eversole, 1988

Commercial size classes from Greene (1978):
[a] $48.0 \leq L \leq 70.5$; $25.4 \leq T \leq 36.1$
[b] $70.5 < L \leq 80.2$; $36.1 < T \leq 40.8$
[c] $L > 80.2$; $T > 40.8$, where L = shell length and T = thickness, in mm.

associated with changes in the reproductive cycle which are typically observed in oysters, *Crassostrea* spp. (e.g. Purdue et al., 1981).

Settlement of quahog larvae is highly gregarious, and is stimulated by the presence of conspecifics (e.g. 3 mm juveniles) or other clam species such as *Gemma gemma*, which often occurs at high densities in *Mercenaria* habitat (Ahn, 1990). This attraction appears to be chemically mediated (Keck et al., 1974; Ahn, 1990). In the field, larval settlement and/or retention of postlarvae may be enhanced in shell-covered sediment, which could provide a suitable attachment substrate and/or refuge from predators (Carriker, 1961), but this effect has not been rigorously tested under field or laboratory conditions. Flume studies show that selection capabilities of quahog larvae for a suitable settlement substrate (i.e. preference for sand vs. mud) are affected by flow conditions (Butman et al., 1988), but the relevance of this finding to field conditions has not been demonstrated. Studies of settlement success and post-settlement survival of quahogs have been hindered primarily by the difficulty in efficiently segregating postlarvae from sediment grains of comparable size. Differential settlement was successfully used by Ahn (1990) in small-scale experiments, but may not be practical for large-scale sampling of a patchy natural environment.

Interactions between adult, benthic populations, through suspension-feeding activity or reworking and destabilization of sediments, and quahog larvae are poorly understood. Kurkowski (1981) demonstrated that adult quahogs can readily consume young veliger larvae < 120 μm in laboratory experiments, and that larvae do not survive entrapment in pseudofeces. A negative interaction between adult *Mercenaria* stocks and settlement was also suggested by Rice et al. (1989), who documented much higher densities of juvenile quahogs in areas of Narragansett Bay, Rhode Island, with low adult densities.

Successful metamorphosis and post-settlement recruitment of hatchery-produced quahog larvae is known to be influenced by egg and larval quality, as measured by their lipid content (Gallager et al., 1986; Gallager and Mann, 1986). These authors found that survival of quahog and oyster larvae to the pediveliger stage was invariably poor when egg lipid levels were low (< 18% of the ash-free dry weight), but that high egg lipid content could result in both high and low survival. A similar relationship was described between larval lipid content and survival through metamorphosis (Gallager et al., 1986). These results indicate that lipid content alone is not always a reliable predictor of gamete quality and larval survival. It also remains to be determined whether naturally occurring egg and larval populations commonly experience lipid levels below the minimum threshold which was established as prerequisite for larval survival in the laboratory.

Natural Mortality: Predation

Predation is often considered the most significant source of natural mortality, and thereby the dominant factor controlling recruitment success of naturally occurring bivalves, including *Mercenaria mercenaria* (e.g. Virnstein, 1977; Malinowski, 1985). Vulnerability to predation is known to be strongly size-dependent, with smallest quahogs (< ca. 20 mm in shell length) suffering greatest mortalities (MacKenzie, 1977; Malinowski, 1985). Furthermore, modeling efforts by Malinowski and Whitlach (1988) demonstrated that population growth rates of quahogs were two to four orders of magnitude more sensitive to changes in juvenile survivorship, than to those in adult survival or fecundity. These authors therefore suggested that stock enhancement measures would be most effective when directed towards enhancing juvenile survival (e.g. through predator control). In this context, Peterson (1990) recently argued convincingly for the need to apply experimental data on size selectivity and habitat preference of bivalve predators to fishery management and resource enhancement efforts.

Effect of Prey Size

Newly settled clams are expected to be highly vulnerable to predation because they are asiphonate and must feed at the sediment-water interface. Information on predation of early post-settlement stages is extremely limited, however, and largely qualitative (reviewed by Gibbons and Blogoslawski, 1989). Losses during later, juvenile stages are better documented, but have rarely been determined by sampling of natural populations because quahogs < 20 mm in length are inefficiently captured by most commonly used sampling gear, e.g. quahog shell buckets. MacKenzie (1977), however, was able to provide strong evidence of high predatory mortalities at smaller sizes in Great South Bay, New York and Horseshoe Cove, New Jersey, by determining the relative proportion of dead and live quahogs collected with a diver-operated hydraulic suction dredge. He also used distinctive shell markings to attribute deaths to specific predator groups (various gastropods, crabs, and starfish). This approach, when used in commercially exploited areas, is obviously only reliable to determine natural mortality rates of quahogs below legal harvestable size. It also tends to underestimate the number of dead quahogs, because crabs often break shells, especially of smaller prey, to irretrievable fragments. Evidence of greater predation pressure on smaller sizes is therefore mostly generated from field plantings of quahogs of varying sizes (e.g. Malinowski, 1985; Flagg and Malouf, 1983; Peterson, 1990).

Crabs, carnivorous gastropods, and starfish are the three most important groups of predators of quahogs, although finfish (e.g. rays) are known to be significant predators south of Delaware Bay (Kraeuter and Castagna, 1980). *M. mercenaria* attains complete size refuge from oyster drills, and most crabs, including spider crabs, rock crabs, green crabs, and mud crabs (*Dyspanopeus sayi)* at a shell length $\geq$ 30 mm (Figure 1). Quahogs < 40 mm remain vulnerable to two of the larger crabs species, the mud crab *Panoepus herbstii* and blue crab, *Callinectes sapidus,* which attain maximum sizes of ca. 62 mm and 227 mm in carapace width (CW) respectively (Williams, 1984). Susceptibility to predation is inversely related to quahog size because both the number of potential predators (Figure 2), and the number of prey consumed by any given predator size class (e.g. Peterson, 1990) decline with increasing prey size.

Burrowing, predatory gastropods such as whelks and moon snails are the most important predators of adult quahogs > 40 mm in shell length (Figure 1). Gastropods (including oyster drills) are highly specialized predators that feed almost exclusively on bivalves, and leave distinct markings on their shells. However, they are relatively slow moving and thus cannot rapidly invade an area following natural (e.g. salinity disturbance) or man-induced eradication. Wide dispersal is further limited by the lack of a free-swimming early developmental stage, except in the case of moon snails. Gastropods also exhibit long prey handling times, and consumption rates for quahogs that are typically two to three orders of magnitude lower than those of crabs [e.g. $\leq$ 1 quahog week^{-1} for whelks and moon snails (Carriker, 1951; Greene, 1978)]. Whelks preferentially feed on larger quahogs (> 40 mm), and both whelks and moon snails show preference for thin-shelled bivalves, when alternate prey is available (Carriker, 1951). Nevertheless, whelks are known to be major predators of adult *Mercenaria* in North Carolina (Peterson, 1982; Irlandi and Peterson, 1991), and can account for up to 13 percent annual losses of the quahog population in Great South Bay, New York (Greene, 1978). Starfish can only prey on large quahogs in aggregation (Doering, 1981), and are more effective predators of epifaunal than infaunal bivalves (e.g. oysters, mussels, and scallops).

Due to their motility, high predation rates, and high relative abundance, crabs are deemed the most serious predators of smaller quahogs. They are generally able to consume quahogs of shell lengths up to 30 percent of their CW, although *Panopeus herbstii*, which feeds on quahogs up to 65 percent of its CW, provides an exception to this rule of thumb (MacKenzie, 1977; Whetstone and Eversole, 1981; Gibbons and Blogoslawski, 1989). The high vulnerability to predation of quahogs <20-25 mm in length is aggravated by the fact that even larger crabs, that are not mechanically constrained to feed on small prey, select smaller quahogs when a wide size range is available. For example, large blue crabs (> 125 mm in CW) preferentially prey on 10-25 mm *M. mercenaria,* when offered quahogs ranging in size from 5 to 35 mm, both in the presence and absence of sediment (Peterson, 1990). Their consumption rates (number of prey eaten per unit time) for 30-35 mm quahogs are 5 times lower than those for 10-15 mm quahogs. A similar preference for smaller quahogs was shown for the large mud crab, *Panopeus herbstii* (Whetstone and Eversole, 1981), although energy intake (tissue weight of quahogs consumed per unit time), was maximized at larger sizes.

Selection for smaller prey appears to be a general phenomenon among crustaceans

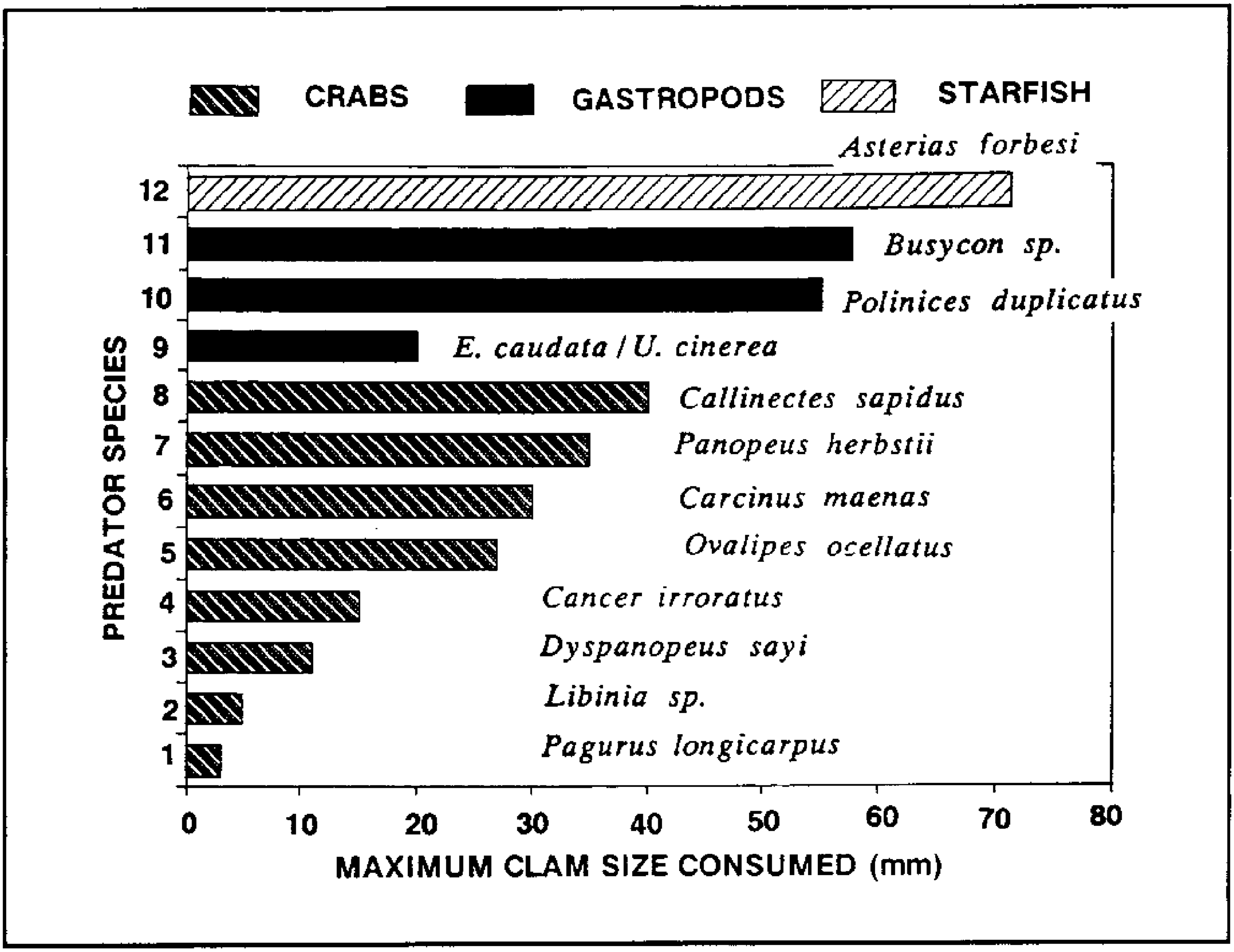

Figure 2. Maximum size (shell length in mm) of hard clams consumed by twelve common predators of Mercenaria mercenaria *in east coast estuaries.*

Sources:

P. longicarpus *(hermit crab)*	*Gibbons, 1984*
Libinia sp. *(spider crab)*	*Gibbons & Blogoslawski, 1989*
D. (Neopanope) sayi *(mud crab)*	*Carriker, 1961; Gibbons, 1984*
C. irroratus *(rock crab)*	*MacKenzie, 1977*
O. ocellatus *(calico crab)*	*Gibbons & Blogoslawski, 1989*
C. maenas *(green crab)*	*MacPhail et al. 1955 & Taxiarchis, 1955 in Gibbons & Blogoslawski, 1989*
P. herbstii *(mud crab)*	*Whetstone & Eversole, 1981*
C. sapidus *(blue crab)*	*Arnold, 1984*
Eupleura caudata & Urosalpinx cinerea *(oyster drills)*	*MacKenzie, 1977*
P. duplicatus *(moon snail)*	*Carriker, 1951; Greene, 1978*
Busycon canaliculatum *(whelk)*	*Carriker, 1951; Greene, 1978*
Asterias forbesi	*Doering, 1981*

(primarily crabs) feeding on hard-shelled mollusks, and occurs even when larger prey are more profitable in terms of energy yield per unit time (Juanes, 1992). This discrepancy between empirical data and classical optimal foraging theory, which predicts preference for prey that maximize the predators' net energy gain, may be related to greater claw damage and fitness costs associated with handling of larger prey (Juanes and Hartwick, 1990).

Effect of Substrate Type

Characterization of the predator assemblage at a given site, and an understanding of the effects of environmental factors (e.g. temperature and substrate type) on feeding rates of key predator species are important in explaining and predicting site-specific differences in population abundance of quahogs, and in implementing resource enhancement management strategies (e.g. habitat manipulation). The effects of sediment type on quahog predatory mortalities have only been studied in the laboratory or small-scale field trials; their outcome depends to a large extent on the species composition, abundance, size structure, and substrate preference of existing predators.

Seagrasses were shown to enhance survival of infaunal prey that can burrow beneath the root-rhyzome mat, such as quahogs, by reducing the foraging effectiveness of whelks (Peterson, 1982). Whelks are also generally absent from shell-covered bottoms, which inhibit their burrowing activity (WAPORA, 1981). Crabs typically show highest predation rates in their preferred substrates. This generalization will be illustrated below for two major groups of quahog predators, the large swimming crabs (*Portunidae*), such as blue crabs (*Callinectes sapidus*) and calico crabs (*Ovalipes ocellatus*), and for the smaller mud crabs (*Xanthidae*). The former prefer homogeneous substrates (sand or mud/sand combinations) to crushed shell or gravel (20 to 50 mm in diameter) (Figure 3A). Given an equal density of quahogs among substrates, they also prey most heavily in their preferred substrate (Figure 3B).

Reduced foraging efficiency of *O. ocellatus* in gravel was related to increased searching time and handling of non-prey items in this substrate (Sponaugle and Lawton, 1990). This behavioral response provides the basis for the recommended use of gravel or crushed stone aggregate in quahog growout sites in southeastern states such as Virginia, where blue crabs are prevalent (Castagna and Kraeuter, 1977). Abundance and therefore predation intensity by large, highly mobile portunid crabs (e.g. blue crabs) is expected to be temporally much more variable, especially in areas that are at the limit of their distributional range, than that of mud crabs, which form less mobile, gregarious populations that persist from year to year.

Mud crabs are often the numerically dominant crabs in east coast estuaries. *Dyspanopeus sayi* is most abundant north of Delaware Bay, attaining densities of up to 100 crabs m^{-2} (WAPORA, 1981), whereas *Eurypanopeus depressus* and *Panopeus herbstii* are prevalent in Chesapeake Bay and the Carolinas respectively (Day, 1987). Field surveys reveal that the three species are found at highest densities in heterogeneous substrates (gravel, or bottoms with shell, eelgrass or *Spartina* cover) (WAPORA, 1981;

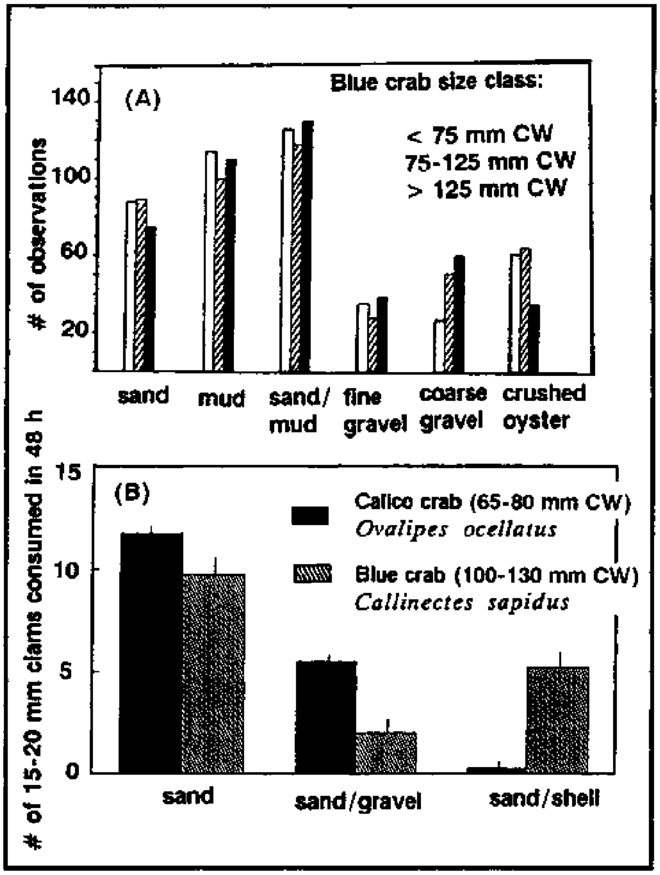

***Figure 3.** (A) Results of blue crab (*Callinectes sapidus*) substrate preference tests, in which the location of a crab with respect to sediment type was determined in a series of laboratory paired (2-choice) comparisons (drawn from Arnold, 1984).*

(B) Predation rate (mean ± standard error) of blue crabs and calico crabs on Mercenaria mercenaria *in various substrates, determined in the laboratory (drawn from Sponaugle & Lawton, 1990) (see sources for further details).*

Day and Lawton, 1988). In agreement with field data, and in contrast to the larger portunid crabs, laboratory trials show that mud crabs (*D. sayi, E. depressus,* and *P. herbstii*) prefer heterogeneous substrates, especially crushed shell, to sand or mud (Day, 1987). Predation rates of *D. sayi* on juvenile quahogs were found to be significantly greater in small (<17 mm diameter) or large (>30 mm) gravel than in sand (Day, 1987), thereby lending support to the observation that substrate preference and predation pressure are positively correlated, and illustrating that habitat structural complexity is not always associated with a reduction in foraging efficiency. Flagg and Malouf (1983) also found that survival of field-planted juvenile quahogs in areas where mud crabs were abundant, was inversely correlated with gravel size ranging between 6 and 32 mm in diameter.

This preference for substrates with a complex topography appears to be related to the mud crabs' small adult size (e.g. *D. sayi* attains only 28 mm in CW), and thus requirement for refuge from top predators (bottom-feeding fish). Consumption of juvenile quahogs by *D. sayi*, for example, is strongly inhibited by increased predatory risk in the presence of toadfish, *Opsanus tau* (Day, 1987). Introduction of this fish species has therefore been suggested as a method of biological control of predation in quahog growout sites (Gibbons and Castagna, 1985).

Effect of Prey Density

A strong, predator-mediated, negative correlation between population density and survivorship of *M. mercenaria* has been demonstrated during juvenile but not adult stages (Malinowski, 1985). Average seasonal survivorship in eastern Long Island was four times greater at a density of 100 juvenile quahogs m^{-2} than at 1200 quahogs m^{-2}. In this study, quahog density had a greater effect in explaining juvenile survival at two sites where crustaceans were the dominant predators, than all other combined variables tested (quahog size, time of year, and location). Predation during juvenile stages was thus attributed a dominant role in maintaining the low densities characteristic of quahog populations.

Low density may thus provide infaunal prey populations with a mechanism for persistence even when subject to intense predation (Eggleston et al., 1992). Sponaugle and Lawton (1990) suggested that juvenile quahogs achieve a relative refuge from predation by calico crabs at low densities, in heterogeneous (sand/shell) substrate, but not in sand. In contrast, Peterson (1982) found no low density refuge, over the range seven to 28 quahogs m^{-2}, for adult quahogs preyed upon by whelks. Thus refuge value at low densities may be predator- and habitat-specific.

Growth

The time required for seed clams to achieve size refuge from most predators will be effectively determined by their growth rate. Growth data for clams < one year old, sampled from natural populations, may be biased by size-selective predation or sampling efficiency, and are thus more readily derived from land-based culture systems or field enclosures that exclude predators. Growth rates of seed clams reared in the laboratory under optimal temperature and food conditions average about 0.58 mm week (Table 2.12 in Malouf and Bricelj, 1989). Even higher growth rates, of up to one mm wk^{-1} can be realized with natural seston at near-optimum temperatures (17 to 28^{o}C) (Table 2). However, lower values (e.g. 0.45 to 0.62 mm $week^{-1}$ are typically obtained when averaged over the entire growing season (e.g. Eldridge et al., 1979).

Table 3 lists some of the factors which have been shown to significantly influence growth of quahogs (see Rice and Pechenik, 1992 for a more extensive review). Temperature and sediment type are two of the environmental variables most frequently correlated with growth of *M. mercenaria*. Growth is generally greater in coarse-grained (sand or silty sand) than in fine-grained sediments. However, the effects of substrate type *per se* cannot be readily decoupled from the effects of flow velocity, and the quality and quantity of the overlying seston. Growth rate is consistently reduced at high suspended

Table 2

Growth rates of juvenile *Mercenaria mercenaria* exposed to natural seston (L_o and L_f = initial and final shell length in mm). Maximum (subtidal and density-independent) growth rates were selected where several conditions were tested. Growth rates were determined in enclosures in the natural environment unless otherwise noted.

Site;Period	Shell Length (L_o - L_f)	Temp. (°C)	Growth Rate(mm/wk)	Source
Napeague Harbor, NY; July-Aug.	10.3 - 14.2	22 - 28	0.96	Bricelj & Borrero,unpubl.
Great South Bay, NY; Oct.-Nov. (raceways)	10.5 - 15.4	27	0.54	Bricelj,unpubl.
Fishers Island, NY; Aug. (land-based upwellers)	4.6 - 5.7	22	1.05	Appelmans, 1989
Shinnecock Bay*, NY; July-Oct.	7.9 - 15.4	-	0.62	Flagg & Malouf, 1983
Folly River, SC; Feb.-Aug.	3.9 - 16.9	8 - 32	0.48	Hadley & Manzi, 1984
May (raceways)		21 - 26	1.11[a]	
Clark Sound,* SC; May-Dec.	13.0 - 26.9	-	0.45	Eldridge et al., 1979
Wassaw Sound*, GA (intertidal)	6.1 - 28.3	-	1.08	Walker, 1984
Alligator Harbor; FL; April	5.4 - 9.0	17 - 26	0.84	Menzel, 1963
		Mean =	0.83	

[a] Maximum seasonal growth rate.
* Clams grown in substrate.

sediment loads (≥ 23 to 44 mg dry weight l^{-1}), whether these result from bioturbation (Murphy, 1985), or physical disturbance (wave action) (Turner and Miller, 1991).

Studies of the effects of seagrass habitat relative to unvegetated substrate on growth of *Mercenaria mercenaria* (reviewed in Table 3) have yielded conflicting results which may be related to site-specific differences in the flow regime, food concentrations, and structure of submerged aquatic vegetation. Positive effects have been attributed to increased near-bottom food supply to the benthos through enhanced particle settlement (Peterson et al., 1984), and resuspension or *in situ* production of benthic or epiphytic algae within the seagrass bed (Judge et al., in press), reduced siphon nipping activity by finfish (Coen and Heck, 1991), enhanced

Table 3.

Factors influencing growth of *Mercenaria mercenaria* (TOM = total organic matter; L_o and L_f = initial and final shell length). Positive or negative effects on growth are indicated, as well as the magnitude of growth inhibition, where appropriate.

Variable	Effect	Magnitude	Source
Sediment type (% silt-clay or TOM)	Sand > Mud	24%	(1)
	Sand > Mud	≤36%	(2)
	Sand > Mud	≤ 8%	(3)
Suspended Sediments	(-)	16% at 44 mgDW l^{-1}	(4)
	(-)	38% at 23 mgDW l^{-1}	(5)
	(-)	38% at 193 mgDW l^{-1}	(6)
Seston Flux	Max. growth at intermediate levels		(3,7)
Phytoplankton Concentration	(+) Diatoms<15 µm	-	(2)
	(+) Chlorophyll *a*	-	(8)
Presence of Seagrass	(-)	-	(9,12)
	(+)	-	(10,11,12)
	no effect		(12)
Biological disturbance: siphon nipping	(-)	≤25%	(13)
	(-)	-	(11)
Temperature	Range for (+) growth = 9-31°C Optimum = 20-25°C		(2,14,15)
Population Density	(-)	18% (80 clams m^{-2}; L_o = 5.8 cm)*	(12)
	(-)	22% (190 clams m^{-2}; L_f=6.2cm)*	(16)
	(-)	≤19% (1159 clams m^{-2}; L_o=1.3cm,* L_f=4.6-5.7cm)*	(17)
	(-)	33% (3027 clams m^{-2} L_o=1.7,L_f=3.3cm)*	(18)

Sources: (1) Pratt, 1953; (2) Pratt & Campbell, 1956; (3) Grizzle & Morin, 1989; (4) Bricelj et al., 1984a; (5) Murphy, 1985; (6) Turner & Miller; (7) Grizzle & Lutz, 1989; (8) Evjen, 1985; (9) Kerswill, 1949; (10) Peterson et al., 1984; (11) Irlandi & Peterson, 1991; (12) Peterson & Beal, 1989; (13) Coen & Heck, 1991; (14) Ansell, 1968; (15) Laing et al., 1987; (16) Rice et al., 1989; (17) Eldridge et al., 1979;
(18) Walker,1984.

* Population density parameters include average length data.

sediment stability and reduced sediment resuspension (postulated by Irlandi and Peterson,1991). Adverse effects may result from a reduction in horizontal seston flux (the product of seston concentration and current velocity) due to baffling of currents within the seagrass canopy (Irlandi and Peterson, 1991 and references in Table 3).

Differences in growth rate of *M. mercenaria* along the east coast of North America were described by Ansell (1968), who found no clear latitudinal pattern or correlation of growth rates with temperature in comparing populations between Massachusetts and Florida. Reduced growth occurs, however, near the species' northern distributional limit (Prince Edward Island, Canada), where lower temperatures result in a shorter growing season, and quahogs require six years or more to attain legal market size. The highest growth rates (time to market size = 2.2 years) have been recently reported for populations in Florida, where they are attributed to continued growth during the winter, and thus lengthening of the annual growing season at this latitude (Jones et al., 1990). These results were substantiated by Arnold et al. (1991) who noted that the mean ω growth parameter (the product of k and asymptotic size in the von Bertalanffy growth equation) was twice as high in the Indian River, Florida, than in Narragansett Bay, Rhode Island. Therefore *M. mercenaria* can achieve growth rates approaching those of faster growing clam species such as *Spisula solidissima* (surf clams) and *Mya arenaria* (softshell clams) (Fig. 2.5 in Malouf and Bricelj, 1989) only in the southern portion of its geographic range.

Table 4 compares growth rates of *M. mercenaria* populations, as reflected in the time required to attain legal market size. Ansell's (1968) data are extended or replaced where more current information is available. Minimum legal size is here assumed to be 25.4 mm in shell thickness, (the New York state limit), corresponding to a shell length of 48 mm based on morphometrics of quahog populations in Great South Bay (Greene, 1978), although the ratio of length to thickness may vary somewhat between locations. Populations between Maine and Georgia grow at comparable rates, typically requiring 3.0 to 4.4 years to attain market size (Table 4). Differences in growth rate among sites within an estuary are often greater than those among latitudes over a broader geographic scale [e.g. two-fold variation in Great South Bay (Greene, 1978), three-fold variation in Cape Lookout, North Carolina (Peterson and Beal, 1989), and 1.7- to two-fold variation in the ω parameter in the Indian River, Florida (Arnold et al., 1991) and Narragansett Bay, Rhode Island (Jones et al., 1989) respectively].

Population density of quahogs is generally not a significant factor influencing growth rates of natural populations (e.g. Malinowski, 1985). Density-dependent growth inhibition, generally only occurs during growout of cultured clams planted at densities two to three orders of magnitude greater than those found in nature (Table 3). Stunting of adult clams was found, however, in uncertified waters in Greenwich Cove, Narragansett Bay, at unusually high natural densities of 190 clams m^{-2} (Rice et al., 1989). Similarly, reduction in the condition index of adult clams occurred at experimental densities of 203 clams m^{-2} (Malinowski, 1985).

Bulk measures of food quantity or phytoplankton biomass (chlorophyll *a* concentration) may not necessarily provide a good predictor of bivalve growth, except under conditions of food limitation, which are not typically encountered in shallow, eutrophic estuaries. Thus, during virtually monospecific blooms of noxious (unpalatable, toxic, or indigestible) algae, bivalve populations may exhibit severe growth depression which may not be reflected in low or abnormal chlorophyll levels (e.g. Cosper et al., 1987). Correlations between food availability and growth can be improved by incorporating relevant measures of food quality(e.g. biomass of phytoplankton species known to support bivalve growth) (Pratt and Campbell, 1956).

Effect of Noxious Algal Blooms

Algal species which may adversely affect quahog populations under bloom conditions include: the chlorophyte *Nannochloris atomus*,

Table 4.

Average time (in years) to attain legal market size [= 48 mm in shell length (see text)] of *Mercenaria mercenaria* natural populations along the species' latitudinal range, from north to south. Range is shown between brackets; unless indicated, time to market size is calculated from fitted von Bertalanffy, Gompertz or logarithmic growth equations.

Time (yrs.)	Location	Source
6.0	Prince Edward Island, Canada	Fig. 5 in Ansell, 1968
4.4	Maine	Fig. 5 in Ansell, 1968
3.2	Monomoy Point, Massachusetts	Fig. 5 in Ansell, 1968
4.0 (3.0 - 4.8)	Narragansett Bay, Rhode Island	[1]Jones et al., 1989
3.5 (3.0 - 4.0) (2.5 - 5.0)	Great South Bay, New York	Appendix 4 in Buckner, 1984 Greene, 1978
3.0 4.3 (3.8 - 4.6)	Barnegat Bay, New Jersey	[1]Kennish and Loveland, 1980 From Table 5 in Kennish, 1980
4.4	York River, Virginia	From Fig. 3 in Loesch and Haven, 1973
2.4	Core Sound, NC	[2]Peterson et al., 1983
3.0 - 4.0	Wassaw Sound, Georgia (intertidal)	Walker and Tenore, 1984
2.0	Kings Bay, southern GA	[3]Jones et al., 1990
2.2 - 2.3 2.1 (1.9 - 2.5)	Indian River, Atlantic coast of Florida	[3]Jones et al., 1990 Arnold et al., 1991
2.6	Gulf Coast, Florida	Fig. 5 in Ansell, 1968

1. Shell height (H) converted to length using an H/L ratio = 0.933;
2. Assuming that age in years = number of annual bands;
3. Using a H/L conversion factor = 0.91.

the chrysophyte *Aureococcus anophagefferens*, and the dinoflagellate *Alexandrium fundyense*, the causative agents of "green," "brown," and "red" tides respectively. The first two species are picoplanktonic algae (circa 2 μm in diameter), which, due to their small size, are expected to be poorly retained by the clams' feeding apparatus. [Particle retention efficiency in *M. mercenaria* decreases steeply with decreasing particle size below a size of about four mm (Riisgård, 1988)].

Summer blooms of *N. atomus* were documented in Long Island's southern bays in the 1950's (reviewed by Ryther, 1989). Laboratory studies subsequently demonstrated that monospecific cultures of this alga do not support growth of quahogs in either larval (Tiu et al., 1989) or juvenile stages (Bass et al., 1990), and cause growth inhibition when combined with other algae of high nutritional value. Lack of growth on a monospecific diet of *N. atomus* was attributed to the quahogs' short gut retention and low absorption efficiency of ingested organics for this alga (Bricelj et al., 1984b).

Aureococcus anophagefferens first occurred in Narragansett Bay (Sieburth et al., 1988) and in eastern and southern Long Island bays in 1985 (Cosper et al., 1987), and has reappeared in New York waters in past years. This alga causes severe inhibition of quahog filtration rates (Tracey, 1988), and inhibition of ciliary beat in gill tissue excised from quahogs (Gainey and Shumway, 1991). The mechanism of this alga's toxigenic action is not yet clearly understood. Preliminary data suggest that although quahogs are less sensitive to the effects of *A. anophagefferens* than mussels, *Mytilus edulis*, they may still experience growth reduction at even moderate field concentrations of *A. anophagefferens* (1.1×10^8 to 3.2×10^8 cells liter^{-1}) (Bricelj and Borrero, unpublished data).

Finally, *Alexandrium fundyense* and related species are responsible for the accumulation of paralytic shellfish poisoning (PSP) neurotoxins in suspension-feeding bivalves. *Mercenaria mercenaria* was found to accumulate low levels of PSP toxins during New England red tide outbreaks in 1972, when other similarly exposed bivalve species became highly toxic, presumably because blooms of highly toxic forms of this dinoflagellate elicit feeding depression and shell closure in this species (Twarog and Yamaguchi, 1974). Laboratory toxification experiments show, however, that *M. mercenaria* is capable of acquiring high levels of PSP toxins (2 to 3 orders of magnitude above the regulatory level for shellfish closures), when exposed to a Long Island, low-toxicity strain of *A. fundyense*, or a New England, high-toxicity dinoflagellate strain in combination with non-toxic phytoplankton (Bricelj et al., 1991). In conclusion, although the effects of blooms of these three algal species on naturally occurring quahog populations have not yet been determined, the experimental evidence indicates that they are at least capable of causing severe growth reduction, and could potentially cause mortalities of some life history stages under prolonged exposure.

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Questions and Answers

Q. *(Mr. George DeBlois, shellfisherman) Have there been any studies to show how many spawners are needed to effectively repopulate an area, given predation, fishing, and other factors?*

A. (Dr. Monica Bricelj, SUNY-Stony Brook) There has been some interest in trying to determine the minimum amount of stock necessary to sustain recruitment into the fishery. I know that there was a plan to do this kind of study in New Jersey, but I don't know if the plan was actually carried out. There is no published information at this time about minimum required broodstock, but there is some indirect evidence that might be considered. In the Great South Bay of Long Island, there has been a steady decline of the adult population. In spite of this, there has been no noticeable effect on the abundance of sublegal-sized clams (new recruits) between 1986 and 1989 in eastern Great South Bay, where survey data are available. Fishing has not appeared to lower the adult population below the critical minimum required to sustain recruitment. A decrease in the number of sublegal clams has been observed, however, in the last few years (1990 through 1992).

In terms of quahog growth, most studies have shown that the density of quahogs is not too important in limiting growth. In most areas, densities are somewhere between two to 15 animals per square meter. Generally it is rather rare to find natural populations of quahogs in densities of hundreds per square meter. Greenwich Cove is one of the exceptional areas with very high adult densities. In these very high densities, lower growth or stunting has been shown. Density may have a major affect on recruitment, but this needs further study.

Q. *(DeBlois) I have read that cherrystones produce many more eggs than the smaller littlenecks. Is there any evidence of a cessation of egg production as quahogs age?*
A. (Bricelj) There is no evidence for this reproductive senecence in quahogs. Scallops are the only group of bivalves that I am aware of that have a reduction of gamete production with age. There is one important thing to be aware of. The studies which have shown that chowder quahogs are the most fecund are based upon laboratory examination of the number of gametes produced during induced spawning. We do not know how this reflects what is going on in the real world, in the sense that "How often do chowders spawn in nature?" But from the laboratory spawning experiments, there is no difference in the viability of eggs from littlenecks or chowders.

Q. *(Prof. Dennis Nixon, URI) One of our objectives is increasing the stock, and my question is about predator control. About a hundred years ago there used to be a statute in Rhode Island that set a bounty on starfish, because of their recognized impact on shellfish populations. Do you believe that attempts at predator control in an open fishery such as in Narragansett Bay could be of any value?*
A. (Bricelj) Well, Clyde MacKenzie of the National Marine Fisheries Service has suggested just this in the past, but people have balked at programs that would clear large areas such as the Great South Bay of predators. Economically it is not a very feasible solution. Perhaps in the context of smaller-scale areas, enhancement programs might work. Some type of habitat manipulation might be undertaken when we know which predator is most troublesome and what features of the substrate or other characteristics are important. Predator control is certainly important in nursery and growout phases of aquaculture. Predator control in open fisheries has not been tested except for MacKenzie's work back in the mid-1970s. He did some predator eradication in relatively small plots and showed that there was a positive response, but there has been little further testing of this in the field. Eradication needs to be tested on a variety of scales to show just where it is effective. Eradication measures may be more effective at controlling moon snails or whelks, because they move slowly into an area. If you have highly motile predators such as blue crabs, it is doubtful that any eradication measures would work because they can come into an area so quickly. In brief, I think that any kind of eradication program must address predator type and scale.

Q. *(Mr. John Finneran, shellfisherman) Is there any evidence showing that some sediments are more conducive to larval settlement than others? In other words, are there sediments that have a "better flavor" to settling larvae?*
A. (Bricelj) Yes, there have been some laboratory studies on this. Keck and co-workers showed that if you treat sediment with "clam juice," you will get an attractant response and increased larval settlement. This is a similar result to the data I presented which showed that juvenile clams exhibit an attractant response. It must be a chemosensory response, because sediments that were "pretreated" by placement of clams that were subsequently removed, also enhanced settlement. Physical factors may also play a role, since additions of gravel or clean clamshell to the sediment also increased settlement in this study.

Q. *(Finneran) Are there any inorganics that might act as an attractant? I have noted that there are often large quahog assemblages in sediments that are high in coal ash.*
A. (Bricelj) No, but one of the possible explanations for areas of high abundance in Great South Bay, might be the presence of shell fragments that modify the bottom topography making the area better for larval settlement and survival of juveniles. There has been no testing of this though. This is very difficult work. With oysters it is relatively easy, because they settle on hard surfaces like shells. Postset quahogs are in the size range of sediment particles, so nobody really wants to do this kind of tedious work. This kind of work is not intractable though, just difficult. One of the key things I want to

emphasize is that we need many more studies on the early life history stages of quahogs rather than adults. Year-class strength is being determined by post-larval and juvenile survival. These stages need more research attention.

Overview of Quahog Management Studies in Narragansett Bay, 1946 to 1992[1]

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Abstract. *There have been a considerable number of studies on quahog populations in Narragansett Bay that have provided valuable information for fisheries managers. Additionally, there have been a few socio-economic studies that have characterized the labor force in the quahog fishery and have provided information pertinent to levels of fishing effort. Most ecological studies have focused on the population structure and standing crop densities of quahogs in Narragansett Bay. The age and growth rates of quahogs in different parts of Narragansett Bay are well known, but there is a dearth of information about the patterns of quahog recruitment. As with most fisheries that require little capital requirements, the levels of fishing effort in Narragansett Bay are known to increase or decrease with relative ease as conditions in the fishery or the general economy change. It is recommended that available socioeconomic data about the fishery be updated, and that studies be undertaken to assess the relative impacts of currently used fishing gear.*

Introduction

It has been recognized by fisheries managers that a number of factors describing a fishery stock must be determined before one can begin to make any rational predictions about what levels of fishing effort are desirable for maintenance of a sustainable fishery (e.g. Royce, 1984). In simple terms, the inputs to a fishery stock are the recruitment of new individuals into the fishery and growth of individuals previously recruited into the fishery (Figure 1). Likewise, the factors which tend to reduce the size of fishery stocks are natural mortality of the stocks and the fishing mortality—a combination of the fishing catch plus associated mortality due to damage by gear etc. These basic principles of dynamic fishery stock models have been most frequently used for the management of finfish stocks, but with care can be applied to bivalve molluscan fisheries (Caddy, 1989).

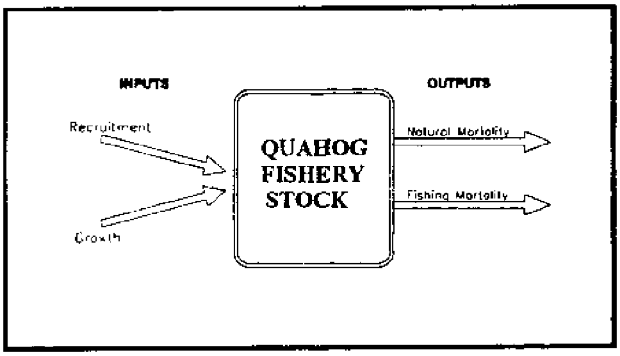

Figure 1. The four key factors that determine quahog stock size.

One key aspect that distinguishes assessment of bivalve fisheries, such as the quahog fishery of Narragansett Bay, from assessment of finfisheries is that one is dealing with a sessile population of juveniles and adults. Additionally, quahogs and other bivalves are highly fecund, so that parental stock size is considered less important for recruitment than is available space, suitable conditions for settlement, and postsettlement predation loss prior to recruitment into the fishery (Hancock, 1973; Kassner and Malouf, 1982; Malinowski and Whitlatch 1988; Malinowski, this volume). The end result of the various physical and biological factors determining quahog distribution is that fishery recruits are found in patches or clumps (e.g. Kassner et al., 1991). As a consequence of the patchiness in distribution of quahogs, special care must be taken to design appropriate sampling protocols that utilize appropriate statistical methods (e.g. Saila and Gaucher, 1966; Gardefors and Orrhage, 1968; Ludwig and Reynolds, 1988; Murawski and Serchuk, 1989). Techniques that may be appropriate for the sampling of quahogs in Narragansett Bay include transect or quadrat methodologies in coves and inlets (e.g. Rice et al., 1989) or stratified random sampling methods over wider areas (e.g. Russell, 1972; Murawski and Serchuk, 1989).

Recognizing that the sampling and statistical methods for quahogs may be different from those used for finfish stock assessments, it is the aim of this paper to outline key studies related to shellfish stock assessment that have been carried out in Narragansett Bay over the last 45 years, and to provide some insights into the areas where data is lacking. It should be noted that a recent report has been prepared that outlines in greater detail many of the studies covered in this paper (Pratt et al., 1992).

Quahog Age and Growth

One of the key factors of interest in quahog stock assessment is the rate at which quahogs grow. There have been a number of studies since the 1950s that have investigated the growth rate of quahogs. Pratt (1953) estimated the growth of quahogs by measuring changes in the length-frequency distributions of experimental populations (quahogs planted into bottom enclosures) over time. Using a protocol of marking quahogs at various stations around Narragansett Bay and measuring their growth after recapture, Pratt

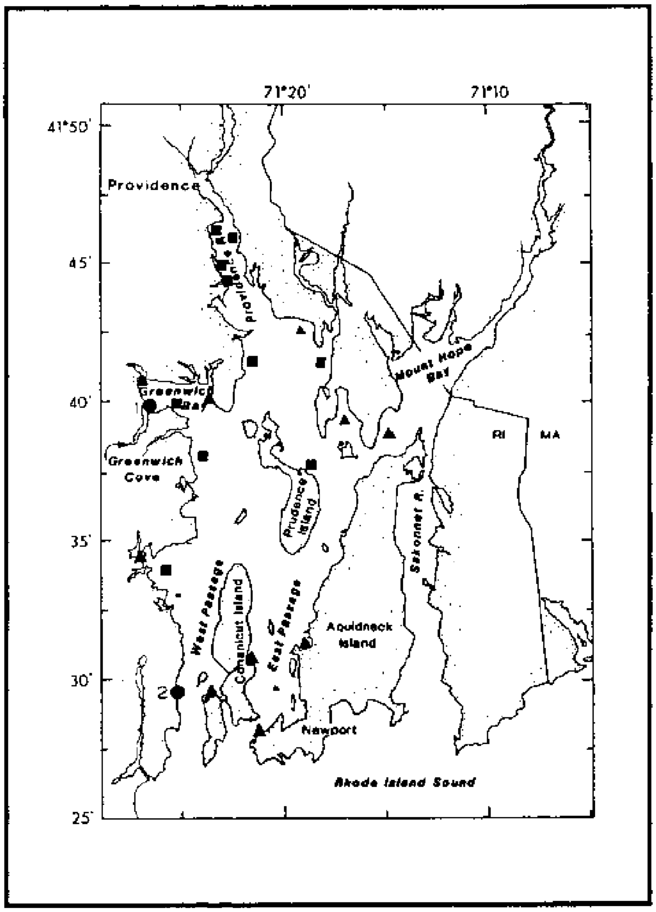

Figure 2. Locations of stations in Narragansett Bay from which quahogs were sampled for studies of growth rate. Triangles: Pratt and Campbell (1956); Squares: Jones et al. (1989); Circles: Rice et al. (1989).

and Campbell (1956) were able to collect very detailed information about the growth of quahogs from a number of locations around Narragansett Bay (Figure 2).

More recent studies have used the technique of sclerochronology (the assessment of age by quantification of periodic increments in the shell) for determining the age of quahogs (e.g. Rhoads and Panella, 1970; Kennish, 1980). Use of sclerochronology allows for the identification of individual year classes, which is otherwise difficult because quahogs are spawning throughout the summer and individual growth rates are highly variable.

By quantifying annual growth rings of quahogs from 10 stations in Narragansett Bay (Figure 3), Jones et al. (1989) were able to give a very detailed description of quahog growth as related to average annual water temperatures. One of their main findings is

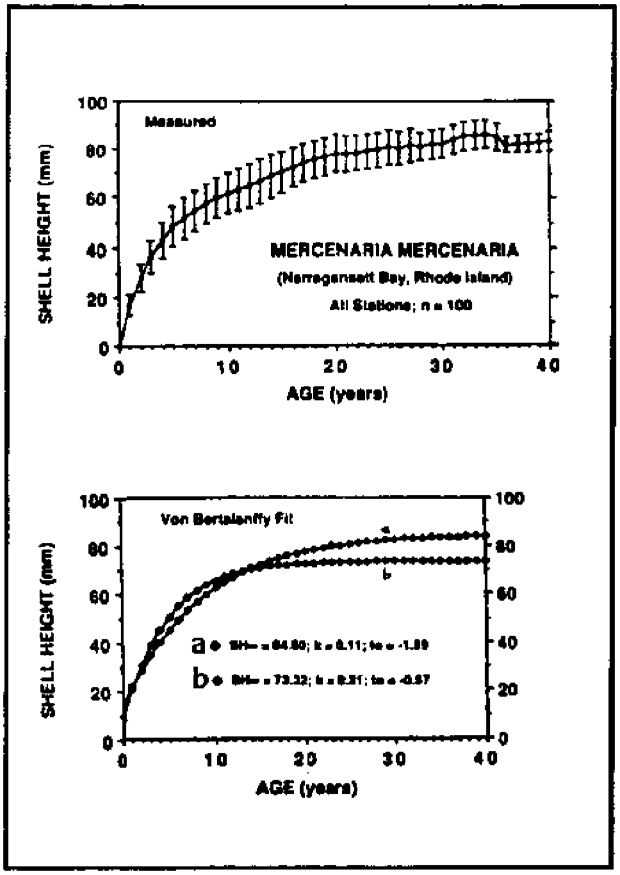

Figure 3. Growth curves for quahogs from Narragansett Bay based on 100 individuals from 10 stations. The top graph represents average size-at-age measurements ± 1 SD for each year of growth. The bottom graph represents modeled growth based on the von Bertalanffy equation. Curve fitting followed two approaches (a) fitting one curve to the averaged shell-at-age measurements on the top graph, and (b) fitting a separate curve to each of the 100 quahogs and averaging the resultant von Bertalanffy growth parameters (Jones et al. 1989).

that quahog growth is best described by the von Bertalanffy negative exponential growth function (Figure 3). Jones et al. (1989) used shell height (SH)—umbo to ventral valve margin measurement—as their standard measurement. Their average von Bertalanffy growth parameters from the 10 Narragansett Bay stations were:

$$SH_{\infty} = 73.32 \text{ mm (valve height)}$$
$$k = 0.21$$
$$\text{and } t_0 = -0.57$$

Although there are differences in the growth rates of quahogs from various sites in Narragansett Bay, the average quahog reaches minimum legal size (25.4 mm, 1 inch wide) by the end of its third growing season, and remains in the littleneck size category (25.4 to 38 mm wide) for four years after recruitment into the fishery. A recent comparison of growth data collected by Pratt and Campbell (1956) and the data of Jones et al. (1989) showed that although the methods were different and the studies were 33 years apart, the average growth rates of quahogs in Narragansett Bay were quite similar (Pratt et al., 1992). Additionally, a study done in North Carolina has validated the annual periodicity of bands in quahogs by use of a mark-and-recapture study (Peterson et al., 1983). Rice et al. (1989) also used sclerochronology to determine the growth rates of quahogs in dense adult assemblages in Greenwich Cove and West Passage (Figure 2). They found that quahogs in very dense assemblages grow at considerably lower rates than quahogs in less dense assemblages typified by the other growth studies. See Rice and Pechenik (1992) for a review of factors that may affect the growth of quahogs.

Spawning and Recruitment

The spawning of quahogs is known to be temperature dependent, and appears to be triggered as water temperatures approach 20° C (Loosanoff, 1937). Details of quahog fecundity and spawning are provided by Bricelj (this volume). A study based on plankton net tows in Narragansett Bay from 1950-1952 showed that the maximum numbers of quahog larvae in the water column were found during the summer months June to August (Landers, 1954). Since the larval period of quahogs can last approximately two weeks (Loosanoff et al., 1951), it is most probable that tidal currents and wind-generated surface waves can effectively disperse quahog larvae throughout Narragansett Bay (Wood and Hargis, 1971; Andrews, 1983). Thus, there need not be a necessity for a close proximity of broodstock to increase the level larval settlement and subsequent recruitment into the fishery.

Successful recruitment of quahogs is highly dependent on postsettlement survival of juveniles rather than absolute numbers of spawners producing gametes (Hancock, 1973; Malinowski and Whitlatch, 1988; Malinowski, this volume). Kassner and Malouf (1982) evaluated the practice of augmenting the numbers of broodstock in the Great South Bay, Long Island and found that there was no significant increase in quahog recruitment. Indeed, MacKenzie (1979) urged that the most effective means for increasing quahog recruitment is to protect juvenile quahogs from predation losses.

There have been few studies carried out in Narragansett Bay in which the rates of quahog recruitment have been determined. Juvenile quahogs have been quantified in some benthic surveys (e.g. Pratt, 1977), but these studies were not followed up to determine the rates at which postset juveniles reach legally fishable size. There have been two studies aimed at investigating the effects of fishing gear on the recruitment of quahogs. The first of these studies compared the relative impact of power dredging versus bullraking on the recruitment of quahogs (Glude and Landers, 1953). In the study area chosen for this study, there was little settlement or recruitment in control and test areas. Likewise, in a recent study by Sparsis and DeAlteris (details in this volume) designed to test the effects of bottom cultivation on the settlement and recruitment of quahogs, little settlement or recruitment of quahogs was noted in their test or control plots. The failure to find settlement and recruitment of quahogs in these studies during 1949-1950 and 1990-1991 suggests that there may be some paucity of quahog recruitment in some areas of Narragansett Bay. In another area of Narragansett Bay—Greenwich Bay, which is known to be one of the most productive areas for the quahog fishery—benthic studies suggest that there is annual recruitment of quahogs (Stickney and Stringer, 1957; Rice et al., 1989).

Assessments of Standing Stocks of Quahog

There have been a number of studies in the last 40 years aimed at mapping the location of quahog stocks and providing estimates of standing stock densities, but most have been confined to coves, inlets, and small portions of Narragansett Bay. A survey by Pratt (1953) carried out in 1949-1950 included 123 stations in Narragansett Bay, but the data were not mapped. The first Narragansett Bay-wide study that mapped the distribution of quahogs was based on a dredge survey between 1956 and 1957, undertaken in response to calls for the construction of mid-Bay hurricane barriers (Stringer, 1959). In this study, nearly 2,800 samples were taken on a 900-foot grid. Although the data from this study (Figure 4) were collected 35 years ago, the quahog distributions roughly approximate the general position of known stocks today. The last Narragansett Bay-wide study of quahog distributions was conducted jointly by the U.S. Environmental Protection Agency and the R.I. Division of Fish and Wildlife (1974). Maps of shellfish distribution were made, but there was no information provided as to stock abundance. The reason why large-scale surveys of quahog populations have been carried out only on an occasional basis is that these studies tend to be quite expensive.

Most quahog population studies have focused on coves or other subsections of Narragansett Bay. Quahog population studies were carried out by grab sampling in Greenwich Bay from 1951-1957 by the U.S. Fish and Wildlife Service and the R.I. Division of Fish and Game (Stickney and Stringer, 1957). At that time, maximum densities of quahogs were found in mixed sand and silt bottoms near the mouth of Greenwich Cove and near Mary's Creek (Figure 5). For a comparison, divers in 1988 using quadrat sampling methods found an average density of 190 quahogs/m^2 at the mouth of Greenwich Cove (Rice et al., 1989). Quantitative stock surveys have been carried

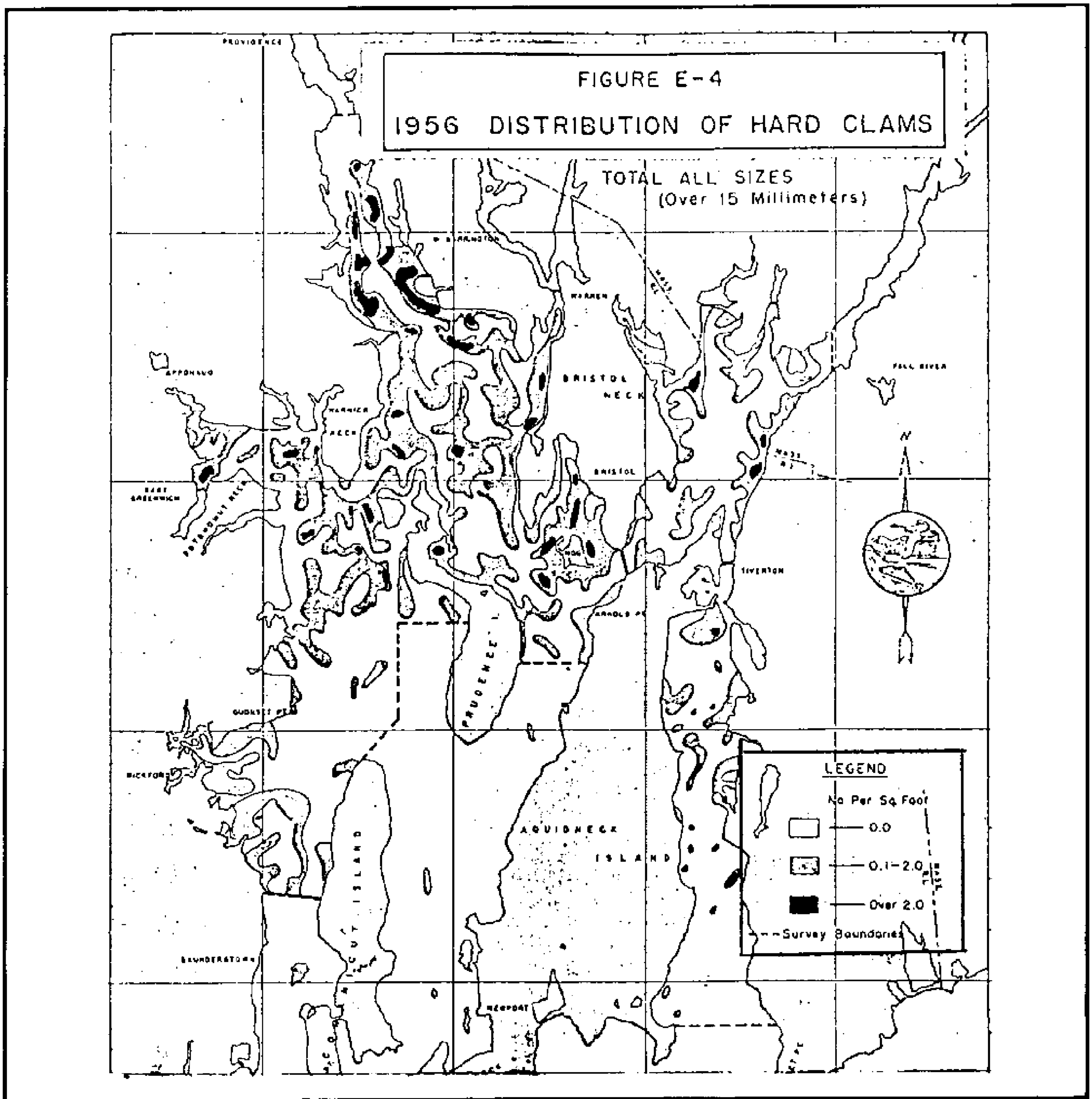

Figure 4. Distribution of quahogs in Narragansett Bay from a quantitative survey 1955-1956 (Stringer, 1959).

out in the closed areas of Providence River and the Upper Bay in 1956, 1965, 1976, and 1985 (Stringer, 1959; Campbell, n.d.; Canario and Kovach, 1965a; Saila et al., 1967; Sisson, 1977; Pratt et al., 1987). In each of these studies, the population of quahogs in these areas was dominated by the presence of large adults, which typifies the population structure of quahogs in areas that have been closed to shellfishing for a long time (Figure 6).

In comparison to the numerous published studies which have focused on stocks in areas closed to shellfishing, there have been relatively few published studies on shellfish stocks in the areas of Narragansett Bay open to shellfishing. In addition to the previously cited Narragansett Bay-wide studies, Russell (1972) surveyed quahog populations in the West Passage of Narragansett Bay using dredge sampling techniques. A number of R.I. Department of Environmental

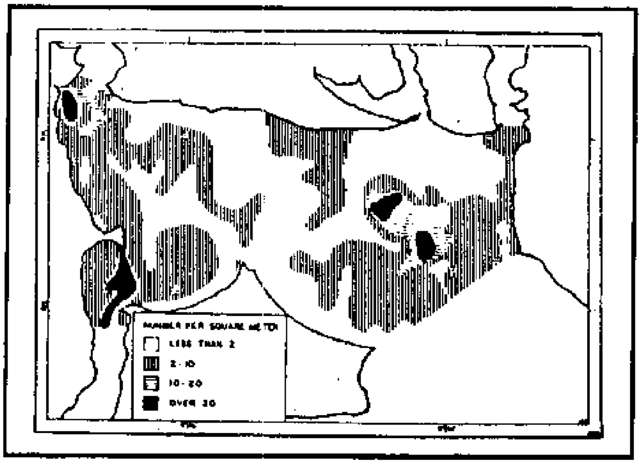

Figure 5. Distribution of quahogs over 25 mm long in Greenwich Bay during 1952. Data were gathered from 226 stations using a 0.46 m² grab sampler and a 12 mm mesh sieve (Stickney and Stringer, 1957).

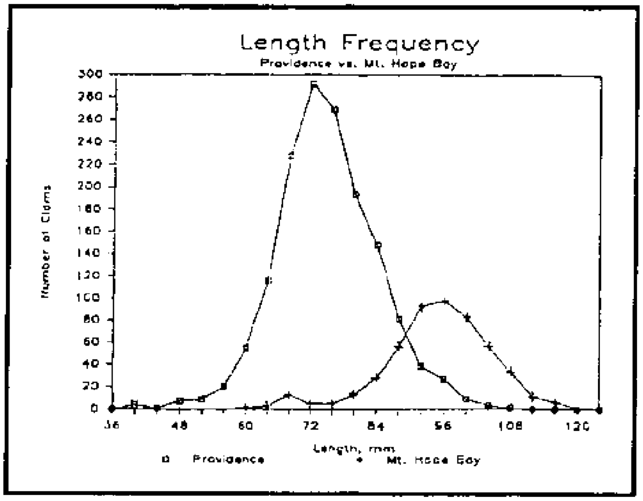

Figure 6. Overall length-frequency distribution of quahogs in the Providence River and Mount Hope Bay. Both areas are closed to shellfishing. Quahogs were collected November 1985 (Pratt et al., 1987).

Management (R.I.D.E.M.)-sponsored studies are documented in the R.I. Division of Fish and Wildlife Leaflet Series. These R.I.D.E.M. surveys include the northern portion of Greenwich Bay (Campbell, 1959a); the Potowomut River (Campbell, 1959b); the Kickamuit River (Campbell 1959c; Canario, 1963); and the East Passage (Canario and Kovach, 1965b). In general, the population structure of quahogs in actively fished areas of Narragansett Bay differs from closed areas in that the fished areas have a predominance of younger, smaller quahogs. This distinction is best illustrated in a comparison study between actively fished and closed areas in Greenwich

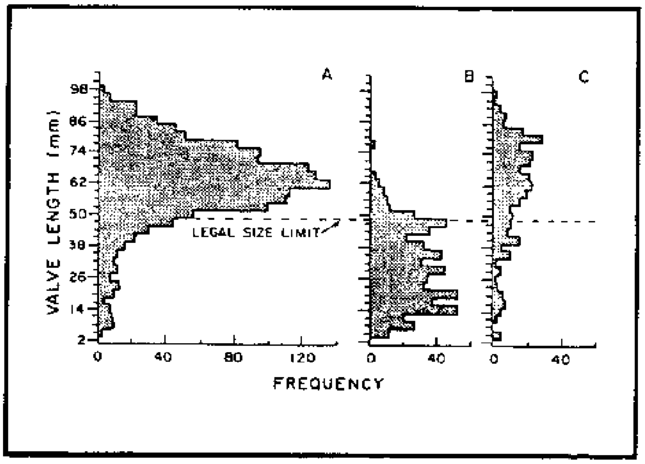

Figure 7. Quahogs were collected by divers from 30 quadrats (0.25 m²) in each of three sites in Narragansett Bay. The sites are: (A) Greenwich Cove, (B) Greenwich Bay, and (C) South Ferry, West Passage. Histograms represent total numbers of quahogs in size classes of 3 mm increments. The indicated valve lengths are size class midpoints. The dashed line represents the Rhode Island legal size limit for quahogs that is a one-inch hinge width, which corresponds to a 48 mm valve length (Rice et al., 1989)

Bay and West Passage (Figure 7) (Rice et al., 1989).

Estimates of Natural Mortality

The first of the factors which remove individuals from quahog stocks is natural mortality. Natural mortality includes losses due to predation and diseases. It is known that pre-recruit juvenile quahogs are highly susceptible to predation losses. However, once quahog reach the size at which they recruit into the fishery, they are relatively resistant to most predators (e.g.. Whetstone and Eversole, 1978; MacKenzie, 1979; Boulding and Hay, 1984).

Caddy (1989) outlines a method for estimating the natural mortality of bivalves by successively sampling the number of dead shells (paired valves) present in closed areas in relation to the number of live animals present. In the various studies of stock abundance in closed areas of Narragansett Bay, there has been no quantitative data collected as the levels of natural mortality in those areas. It is likely that natural mortality is relatively higher in quahogs in excess of 85 mm valve length because of their reduced ability to reburrow (Rice et al., 1989). There may be periodic increases in natural mortality of quahogs corresponding with cyclic fluctuations of starfish (*Asterias forbesii*) populations in Narragansett Bay (Pratt et al., 1992).

Estimates of Mortality Caused by Fishing

Estimates of the mortality of quahogs caused by fishing can be made by using estimates of standing crop abundances of quahogs and the number of quahogs caught. This method of estimating fishing mortality is highly dependent upon knowledge of the selectivity of the harvest gear. Using a "rocking chair" dredge, with catch efficiencies known for various substrate types, Russell (1972) estimated the fishing mortality of quahogs in the West Passage during one season of the commercial dredge fishery. During the dredge season, the standing crop of quahogs in his study area declined from 18,148 ± 5,704 bu to 7,235 ± 2,167 bu (1 bu = approximately 80 pounds or 31.5 kg). Breakage is important to consider as it may be a source of bias in fishing mortality estimates if catch alone is the sole basis of these estimates. One study in Narragansett Bay compared the effects of harvesting gear and handling on the breakage of quahogs (Glude and Landers, 1953). Broken quahogs caught in a "rocking chair" dredge ranged from 0.7% to 1.2% of the total catch. In rocky sediments, 2.9% of the remaining quahogs were found broken on the bottom, but in sand/silt areas, 1.0% of the remaining quahogs were found to be broken. There was no evidence of breakage of quahogs <60 mm valve length by the dredge, and there was no evidence that the dredge smothered quahogs by covering them with sediments. There was essentially no damage to quahogs directly by bullrakes, but handling of quahogs by bullrakers aboard the boat caused some breakage—0.1% to 0.3% of the total landed.

Estimates of Fishing Effort and Fishing Intensity

The number of fishermen in the quahog fishery and the average catch per fisherman are important data which can be useful for estimating fishing effort. The National Marine Fisheries Service (NMFS) makes annual estimates of the numbers of shellfishermen in Rhode Island. Based on the number of licenses issued and the number of boats registered to shellfishermen, NMFS estimates there to be between 1,000 and 1,300 full-time shellfishermen in recent years. This estimate is considerably higher than the estimate of 700-800 full-time shellfishermen currently used by Rhode Island Department of Environmental Management fisheries scientists (see Pratt et al., 1992 for discussion of estimation methods).

There have been two surveys of shellfishermen to gather data about the levels of fishing effort among shellfishermen. Holmsen (1966) and Holmsen and Horsley (1981) conducted mail surveys of all shellfish license holders and made estimates of the numbers of those deriving different proportions of their income from quahogging (Table 1).

TABLE 1

(Holmsen and Horsley, 1981)

	1962-1963		1978-1979	
Proportion of Income	**#**	**%**	**#**	**%**
none	139	17	113	11
less than 20%	359	44	297	29
about 25%	81	10	114	11
about 50%	65	8	135	13
about 75%	33	4	31	3
over 90%	138	17	338	33
Totals	**815**	**100%**	**1,028**	**100%**

The proportion of fishermen obtaining at least 75% of their income from quahogging increased from 21% to 36% in these two surveys. Holmsen (1966) also found an increase in full-time fishermen from the mid-1950s to 1961, indicating a trend of professionalization during periods of inclining as well as decreasing landings. One key conclusion of Holmsen's surveys is that one of the main characteristics of the Rhode Island quahog fishery is the relative ease of increasing or decreasing fishing effort as conditions change in the fishery or the general economy.

At present, the three commercial methods of quahogging in Rhode Island waters are with the use of tongs, bullrakes, and by commercial diving. Commercial diving has increased in importance as a method of quahog harvesting since the 1981 study of Holmsen and Horsley, so there is little information about the amount of fishing effort attributable to divers. Boyd (1991) provides an excellent historical overview of tonging and bullraking in Narragansett Bay. Over the years since the late 1940s, there has been a gradual shift in the use of gear from a predominance of tongs to a predominance of bullrakes.

The location of tong and bullrake fishing effort was mapped intermittently between June 1955 and August 1960 (Campbell and Dalpe 1960; Campbell, 1961). Maps generated by this project (Figure 8) showed that the major fishing effort was confined to the middle and upper Narragansett Bay, with tong fishermen confined to the shallower near-shore areas.

By use of a mail-survey questionnaire, Holmsen and Horsley (1981) showed similarly that most of the fishing effort was confined to the middle and upper Narragansett Bay (Figure 9). There is little published information about the location of fishing effort by shellfish divers.

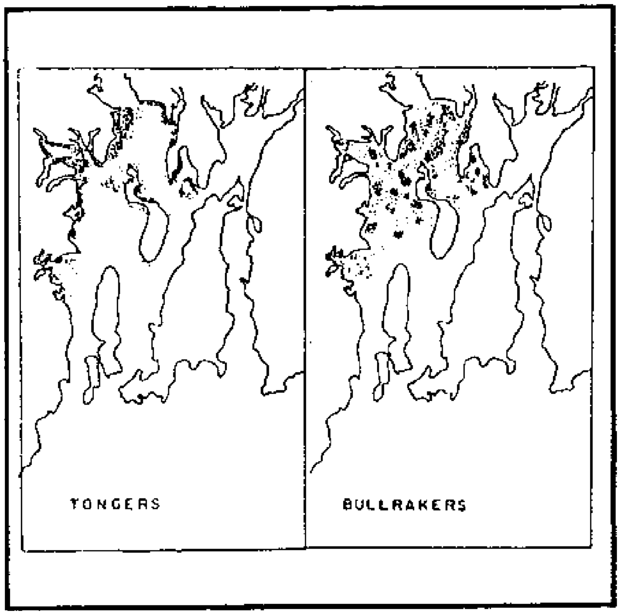

Figure 8. Location of tong and bullrake fishermen in Narragansett Bay recorded between September 1959 and August 1960 (Campbell, 1961).

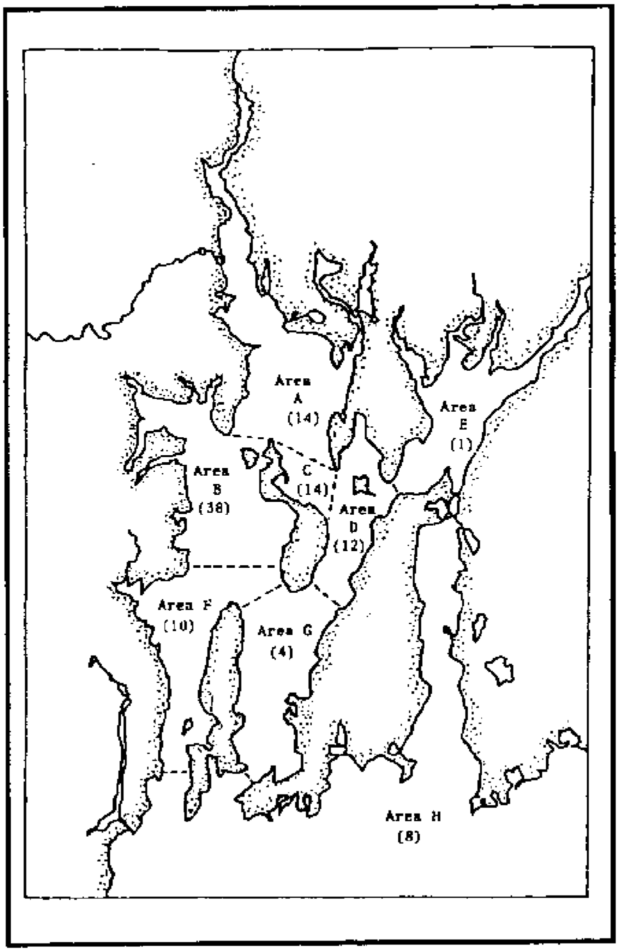

Figure 9. Percent of quahogging effort in selected areas of Narragansett Bay (Holmsen and Horsley, 1981).

Relative Gear Efficiencies and Environmental Impacts

There has been only one study in Narragansett Bay that compares the relative impacts and efficiencies of different gear types (Glude and Landers, 1953). In this study carried out in 3-acre plots, the efficiency ratios for the bullrake and dredge were determined. The bullrakes used were able to most efficiently retain quahogs greater than 55 mm valve length, but some quahogs 35 to 55 mm in valve length were able to be retained. The dredge was able to most efficiently retain quahogs above 70 mm in valve length. There were no significant differences in the physical or biological composition of raked or dredged bottoms, but both had fewer living forms than the unfished control area. These authors concluded that there was no biological basis for prohibiting either bullraking or dredging.

A recent study on the environmental impact of bottom cultivation and removal of adult quahogs on the set and recruitment of quahogs was recently concluded (Sparsis et al., this volume). They found that after three months there were no significant differences in the physical, chemical, and biological parameters between fished, cultivated, and control plots because of high environmental variability.

Conclusions and Recommendations

There have been a considerable number of studies since 1946 focusing on the biology and fishery of quahogs in Narragansett Bay. The information base about the growth rates of quahogs in Narragansett Bay seems to be quite good. There appears to be a shortage of information about quahog recruitment. Some studies appear to indicate that there is a paucity of recruitment into some areas, yet there appears to be annual recruitment into other areas, particularly Greenwich Bay and upper Narragansett Bay. A systematic study of quahog recruitment patterns throughout Narragansett Bay is warranted. Estimates of fishing effort and fishing mortality in areas throughout Narragansett Bay are lacking, and much of the information that is available is now 10 years out-of-date. It is recommended that a socio-economic study similar to that of Holmsen and Horsley (1981) be undertaken in order to update the fishing effort information. Additionally, given the current mix of harvest technologies, a study of the relative harvest efficiencies of tongs, bullrakes, and hand collecting by commercial divers is recommended. In conclusion, there is a great wealth of information available to fisheries managers about quahogs in Narragansett Bay. It is hoped that this review will provide a starting point for the assessment of where we have been in terms of the fisheries management studies, and that it will be useful in planning management strategies for Rhode Island's most important fishery resource.

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Questions and Answers

Q. (Mr. John Finneran, shellfisherman) In the Glude and Landers study, were divers used to determine what was left and what was broken on the bottom?

A. (Dr. Michael Rice, URI) No, the Glude and Landers (1953) study used a large grab sampler that brought up intact sediments and quahogs after the dredging or bullraking treatments. Grab sampling can be used effectively for sampling because everything is brought up—juveniles, adults, etc. One possible problem with grab sampling is that care must be taken to avoid biases in breakage estimates, because some breakage will occur as the sampler hits bottom. Subsamples from the center of the grab sample are representative of intact sediments. Grab sampling was used during the surveys of the 1950s and the Saila et al. (1965) study. More recent studies have used divers for sampling. Diving appears to be best for sampling juveniles and determining population structure without gear bias. Indeed, the best way to calibrate sampling gear such as dredges, tongs, and rakes is by diver sampling.

Q. (Mr. George DeBlois, shellfisherman) You mentioned the Kassner and Malouf (1982) spawner transplant study in Great South Bay. What was the time frame of that study?

A. (Rice) Jeff Kassner, one of the people who did that work is in the audience. Perhaps he could answer that for you .

A. (Mr. Jeffrey Kassner, Brookhaven, New York) What that study did was to look at the spawning cycle of hard clams in the Great South Bay that was performed over a two-year spawning period. The underlying principal behind the spawner transplant was that broodstock were brought in from more northern, colder waters and had a retarded gametogenic cycle. The idea was to exploit the retarded cycle to extend the spawning period after the native stock had ceased spawning. What we found is that the natural spawning variability was so high that bringing in clams did not affect the recruitment. Additionally, bringing in 400 to 500 bushels did not make much difference when compared to the natural spawning stocks. Now the idea of spawner transplants evolved into the idea of spawner sanctuaries. If you then know the likely hydrographic larval dispersal patterns, you can strategically place your spawner stock for settlement in preselected areas.

Q. (Mr. Edgar Thompson) Are there any recent studies on the effects of pollution on quahogs? An example might be the effects of heavy metals on quahogs. There are a number of organizations such as Save The Bay that are committed to cleaning up the Bay, and I want to know if there has been some headway.

A. (Rice) There are a considerable number of studies on this. In the first quahog conference we held in 1990, Ms. Katrina Kipp of the Environmental Protection Agency and the Narragansett Bay Project gave a very excellent review of studies of Narragansett Bay in which quahogs were analyzed for heavy metals, various organic pollutants, and pesticides. She outlined the risk assessment program in which the health risk to people eating Narragansett Bay quahogs was compared to other common health risks. In general, Narragansett Bay quahogs carried a rather low-risk value to the consuming public. Sheldon Pratt from here at GSO had one study that looked at quahog populations in the Providence River, and the adults are alive and well. One interesting study that came out of the National Marine Fisheries Service shellfish lab in Milford, Connecticut showed that heavy metal pollutants are much more toxic to bivalve larvae than they are to adults. It is possible that shellfisheries in polluted areas might be damaged by reducing recruitment rather than by the outright killing of adults.

Q. (Johnson) In a nutshell, do you believe that we are moving forward or backward.
A. (Rice) Well, I think we're probably moving forward. Improvements in upper Narragansett Bay water quality due to the improvements by the Narragansett Bay Commission to the combined sewer overflow system are a positive step forward. Shellfish openings (albeit not all the time) in the conditional areas suggest some improvement. The next thing in line, however, is the nonpoint source pollution problem. This is a much more expensive problem, and technically a harder nut to crack.

Q. (Mr. David Borden, DEM) You have summarized where there is knowledge and where there is need for more work. Can you give me some sense of priority on what studies you think are most important?
A. (Rice) As it so happens, we have a full panel discussion this afternoon, with your question as our topic. So, please stay tuned.

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Effects of Bottom Cultivation on Quahogs and Other Bottom Invertebrates in Narragansett Bay

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Abstract. *The effects of mechanical disturbance of estuarine sediments on the population structure of quahogs and other infauna was studied. Nine contiguous circular study plots with a 10 m radius were established in approximately 3.5 m of water in the West Passage of Narragansett Bay. Preliminary sediment and infaunal samples were taken as a baseline. The infaunal assemblages were typical of the West Passage. Numerically dominant species were nematodes, capitellids, spionids, oligochaetes, and the amphipod* Ampelisca abdita. *Quahogs,* Mercenaria mercenaria, *were in low abundance (3.6 animals/m²) and averaged 85 mm in valve length. After preliminary sampling, three plots were harvested using a hydraulic bullrake, an additional three plots were cultivated (sham harvested using the hydraulic bullrake with an open basket to leave quahogs on the bottom), and three plots were left untreated as control areas. The thorough, one-time sediment disturbance did not significantly alter sediment grain-size characteristics, TOC, or water content. No statistically significant differences in infaunal communities were noted after the hydraulic disturbance. The magnitude of effects of bottom cultivation were much less than natural spatial and seasonal variability in the study plots.*

Introduction

The mechanical and/or hydraulic disturbance of sediments, hereafter referred to as bottom cultivation, occurs during the harvesting of quahogs, *Mercenaria mercenaria.* It has been a long-held belief among shellfishermen that the action of bottom cultivation increases the set and recruitment of bivalves (Meade, 1906; Belding, 1931). More recently, this claim was supported by MacKenzie, (1979) who hypothesized that "...hydraulically jetting the bottom to improve grain sizes..." would increase setting densities. A number of studies (Hancock, 1973; Rice et al. 1989; Walker, 1989) support this theory by showing that populations of bivalves in actively fished areas are dominated by smaller, younger individuals.

The mechanism for the apparent enhancement of shellfish set and recruitment in response to bottom cultivation is poorly understood. There are two possible explanations. The first explanation is that large adult quahogs may preempt the settlement of larvae, thus adult removal may enhance larval set. For example, Kurkowski (1981) showed in laboratory experiments that adult quahogs can filter quahog larvae from the water column. Secondly, the physical turnover of sediments may improve the bottom in some way that will enhance set. Substrate chemistry and morphology, food availability, loss of post set animals to predation, proximity of suitable and available substrata, disease, and water currents are commonly accepted as limiting factors in faunal distribution (Petersen, 1913; Sanders, 1958; Butman, 1987; Kassner, 1988; Mann, 1988). It can therefore be assumed that changes in any of these factors, caused by cultivation, may affect benthic communities present and the set and survival of benthic animals in cultivated areas.

The purpose of this study is to determine, under controlled conditions, if bottom cultivation can enhance the settlement of quahogs and their subsequent recruitment to the fishery. The effects of bottom cultivation on various sediment parameters will be determined, and the distinction between the effects of sediment disturbance and adult bivalve removal will be studied.

Materials and Methods

Sediment samples were collected in summer 1989, winter and summer 1990, and winter 1991 from the Wickford area in Narragansett Bay, Rhode Island (Figure 1). The study area is characterized by depths of 2.5 to 3.5 m at low tide with sediments that are described as sand and silty sand (McMaster, 1960). Currents in the study area do not exceed 0.1 m/s (Spaulding and Swanson, 1984). The sediments of this area are dominated by members of the tube-dwelling amphipod *Ampelisca*, which is true of much of the West Passage of Narragansett Bay, Quonset Point, and Greenwich Bay (Olsen et al., 1980). The area is typical of areas with low shellfishing pressure, having a unimodal size/frequency distribution of adult quahogs, lacking in juveniles, described by Rice et al. (1989).

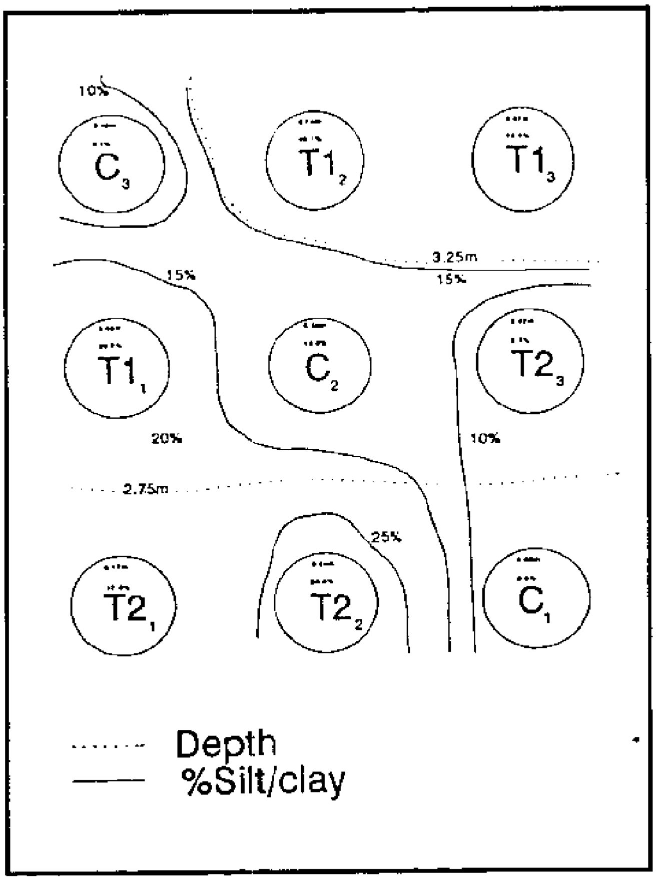

Figure 1. Station layout, depth and silt/clay contours

Duplicate sediment cores were taken at ten randomly predetermined positions from each of nine circular sampling stations of a 10 m radius. The sampling stations were marked by buoys and were used as three replicates for each of the two treatments and a control. Sediment cores were collected by scuba divers with hand-held corers. The corers used were made from 7.62 cm internal diameter 16 cm long polyvinyl chloride tubes capped on both sides with removable soft plastic caps.

The duplicate sediment cores allowed one core to be used for geological sediment analyses while the other was used for obtaining biological data. Cores intended for biological analysis were prepared by addition of a 10 percent solution of borate buffered formalin, stained with Rose Bengal. The fixed samples were washed through a 0.5 mm mesh sieve. Retained animals were counted and identified to the lowest possible taxon. Other cores were used for measurements of water content, pH, total organic carbon (TOC), and sand/silt-clay content.

Concurrent with the sediment sampling in January 1990, adult bivalve abundance was estimated using ten randomly assigned 0.25 m^2 quadrat samples taken from each of the nine stations. The sediment within each quadrat sample was removed down to 18 cm, and wet sieved through a 3 mm mesh bag. All bivalves retained in the bag were counted and their valve lengths measured.

The cultivation process took place in May 1990 using a commercially used bull rake modified with an attached water-jet manifold. The water-jet manifold allowed water from a water pump to be jetted into the sediments, liquefying them (Figure 2). Part of the pressurized water was diverted to spray directly into the basket to prevent mud clogging and to wash the catch. A "Pacer" 5 H.P. pump, capable of delivering 10 L/s, was used.

Three of nine stations were randomly chosen as controls, three for cultivation and three for cultivation and removal of quahogs. The rake was, in each case, lowered over the bow of a 5.2 m Boston Whaler bridled to the buoy in the center of the station to be treated. The boat was then put in reverse, at a speed of 0.5 m/s, dragging the rake, while water was pumped through the manifold into the sediments. In stations where removal of bivalves was required, the rake was periodically brought up and emptied. All the bivalves removed were identified, counted, and measured. After the three cultivation and removal replicates were treated, part of the basket of the rake was removed to allow escapement of quahogs for the second treatment. Cultivation was continued for two hours at each station. The effects of the cultivation were visually evaluated by a scuba diver.

The speed of the boat during treatment, 0.5 m/s, multiplied by treatment duration, 2 hours, and the width of the rake, 60 cm, gives us an estimate of 2160 m^2, area covered, during the process. Considering that each station cultivated occupies an area of 314 m^2, the dredge covered the whole area approximately seven times.

In September 1991 the sampling procedure was repeated. Quadrat samples were again taken by divers to determine the efficiency of the removal procedure. The fourth and final sampling was performed in January 1991.

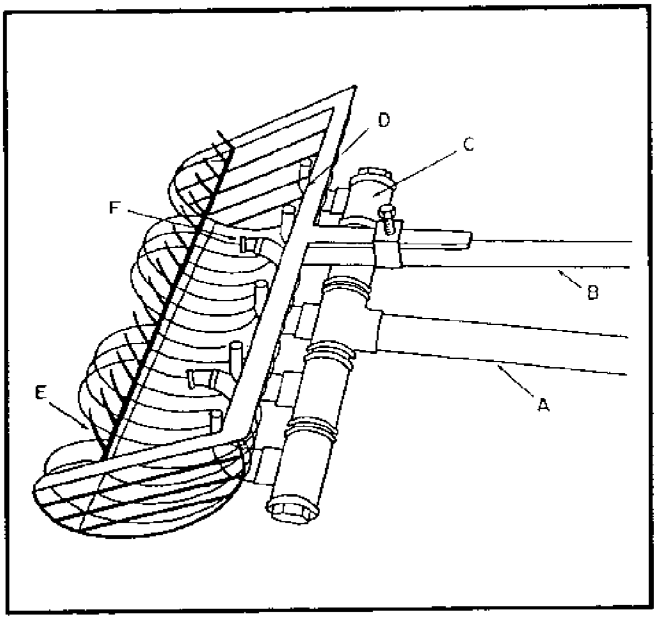

Figure 2. Hydraulic bull rake specifications

The valve length/frequency distribution of the clams removed was compared with that of the clams taken during the quadrat sampling to determine if the clams removed were representative of the population present. The Kolmogorov-Smirnov non-parametric test was used to test this hypothesis (Sokal and Rohlf, 1969). A two-way analysis of variance (ANOVA) was performed on abundances before and after bivalve removal to determine the effectiveness of the treatment.

To determine the effects of the two treatments on sediment chemistry and morphology, sediment data were examined using four two-way analyses of variance using the method of unweighted means. The two variables used in the two-way analysis of variance were treatment and season and the four parameters were pH, sand/silt-clay content, total organic carbon, and moisture content. A one-way analysis of variance using only season as a variable was also performed, using only the three control stations in each sampling. The seasonal effects on sediments and a comparison of the magnitude of the seasonal, versus treatment effects could thus be determined (Table 1). The Duncan multiple range test was used for the multiple comparison procedures in both the one-way and the two-way ANOVAs (Dowdy and Wearden, 1983).

Total abundances of animals per square meter were calculated for each group of stations. The resulting data were subsequently used in three two-way ANOVAs to determine if either one of the treatments affected total abundance of quahogs or other infauna.

Results

Diver observations indicated that cultivation formed depressions relative to the surrounding sediments, of up to 50 cm Sediment plumes were observed from the surface during treatment.

Silt-clay content varied considerably between stations even before treatment began. Average silt-clay content values from 8.3 to 26.8 percent before cultivation, and 3.4 - 33.0 percent after cultivation. Silt-clay content was generally lower in the summer and higher in the winter (Figure 3). Sediment TOC and moisture correlated well with silt-clay fluctuations—high moisture, high TOC, and high silt/clay occurring together. The highest value recorded for TOC was in winter 1990 at station T11 with a value of three percent. The minimum value recorded occurred the following summer in station C1 (0.8 percent). TOC values were generally lower in the summer than in the winter (Figure 4). Moisture content varied from 20.1 percent to 35.2 percent and correlated well with TOC levels (Figure 5). Average pH for all stations through all four sampling seasons was 7.2 ± 0.2. Minimum and maximum values recorded were 6.1 and 7.9 respectively.

To determine the effects of seasonal changes on the environmental parameters monitored, four one-way ANOVAs were performed using only control station data from all four sampling periods. No statistically significant change in sediment parameters could be shown in the control stations for any of the variables measured (Table 1). Four two-way ANOVAs were performed to determine the effect of treatment on environmental parameters. All sediment data

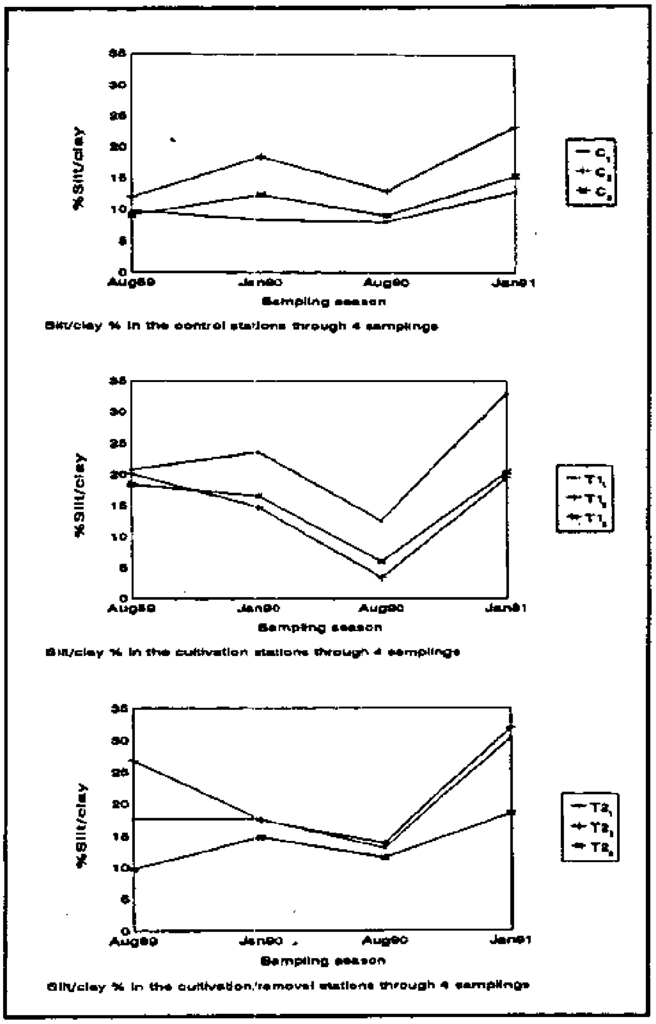

Figure 3. Silt/clay levels

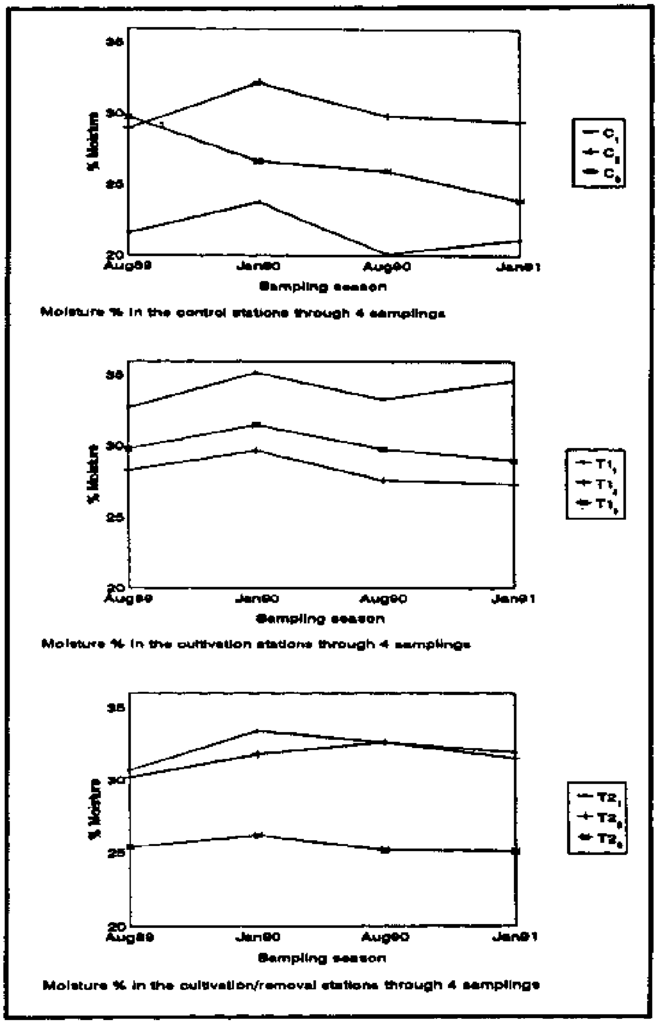

Figure 4. Moisture levels

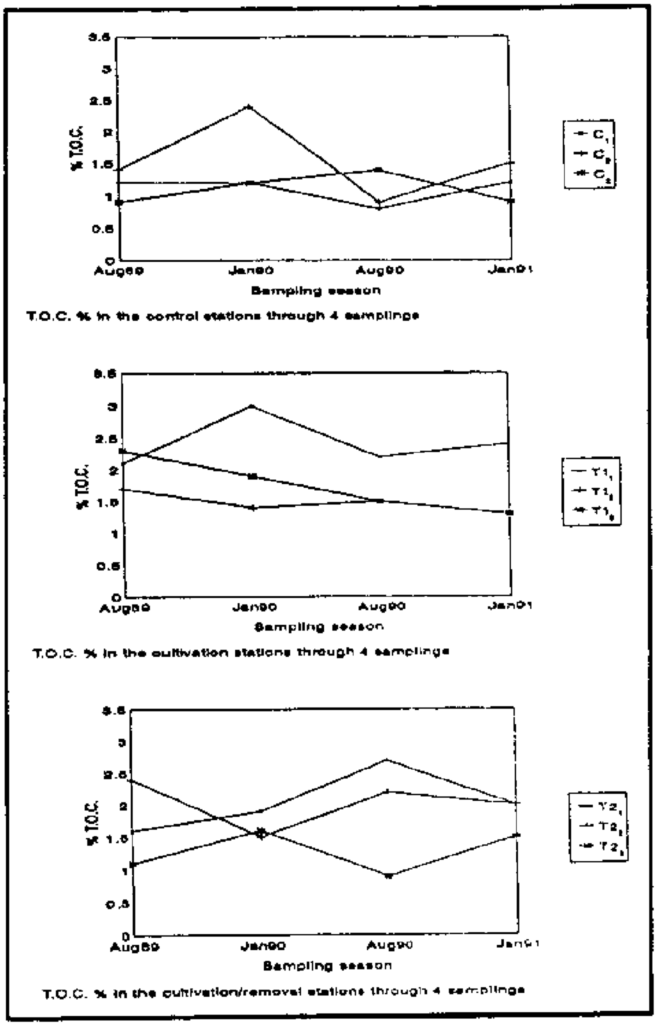

Figure 5. T.O.C. levels

from both treatment and control stations obtained from the last two samplings were used in this analysis. The Duncan Multiple Range Test was performed only where a significant difference was shown in the ANOVAs (Table 1).

Treatment did not significantly affect silt-clay levels. Winter silt-clay content however was twice as high as it was in summer. Mean silt-clay content in control stations was lower than mean silt-clay content in the treatment stations. Levels of silt/clay correspond well with the means for TOC, but there is no significant interaction between season and treatment.

Seasonal levels of TOC were not significantly different. The mean TOC levels for both treatment one and treatment two (1.70 percent and 2.06 percent respectively) were higher than the control stations mean (1.13 percent). The treatment combining both cultivation and removal of large filter feeding bivalves is the only one that can be shown to differ significantly from the control. No interaction between season and treatment can be seen.

Neither season nor treatment significantly affected sediment moisture or pH which remained almost constant throughout the sampling period (Table 1). The means for sediment moisture for the two treatment stations

Table 1

Synopsis of statistical results for sediment analysis

1. One-way analyses of variance to determine seasonal effects on environmental parameters, using only control station data.

Independent variable: Season

Dependent Variable	Result
% Silt/clay	No significant difference
% Moisture	No significant difference
% T.O.C.	No significant difference
pH	No significant difference

2. Two-way analyses of variance to determine effects of treatments on environmental parameters, using only the last two samplings data.

Independent variables: Season, treatment

Dependent Variable	Result
% Silt/clay	Season: Significantly different Treatment: No significant difference
% Moisture	Season: No significant difference Treatment: No significant difference
% T.O.C.	Season: No significant difference Treatment: Cultivation/removal significantly different from control
pH	Season: No significant difference Treatment: No significant difference

were higher than the controls (30.2 percent, 29.8 percent, and 25.1 percent for treatment one, treatment two, and control, respectively). There was no season/treatment interaction.

During initial quadrat sampling to determine bivalve abundances before cultivation, *Mercenaria mercenaria* comprised more than 99 percent of the bivalves captured. The remainder of the bivalves caught during quadrat sampling and with the bull-rake were blood arks (*Anadara ovalis*). Length-frequency histograms of quahogs were constructed for quahogs collected in quadrats or collected by bullrake (Figure 6). The mean length of quahogs in quadrats was 85 mm ± 11 mm (sd), and average abundance was 3.6 ± 5.3 quahogs/m^2 (sd). Quahog distribution was very inhomogeneous, resulting in the high standard deviation in mean abundance. Eighty-one quahogs were taken in ninety 0.25 m^2 quadrat samples. There were no significant differences among stations. Length distribution was unimodal and no animals smaller than 52 mm were caught. The largest animal present in the sampling was 109 mm in length. The D statistic calculated for the Kolmogorov-Smirnov non-parametric test, for the two length/frequency distributions is D=0.11 < Da=0.16. It therefore can be assumed that the two distributions are the same for an α=0.05 and that both the divers and the rake are sampling the same population (Sokal and Rohlf, 1969).

During the cultivation and removal process, 680 adult quahogs were taken at station 1, 609 at station 2, and 309 at station 4. Abundance in the cultivation/removal stations was reduced from 0.967 to 0.533 animals per quadrat sample. The two-way analysis of variance on abundances of *M. mercenaria* in before and after cultivation and treated/non-treated stations showed no significant differences, although the bullrake passed over the treatment area seven times (Figure 7). The lack of significant differences in the mean abundance before and after removal can most likely be

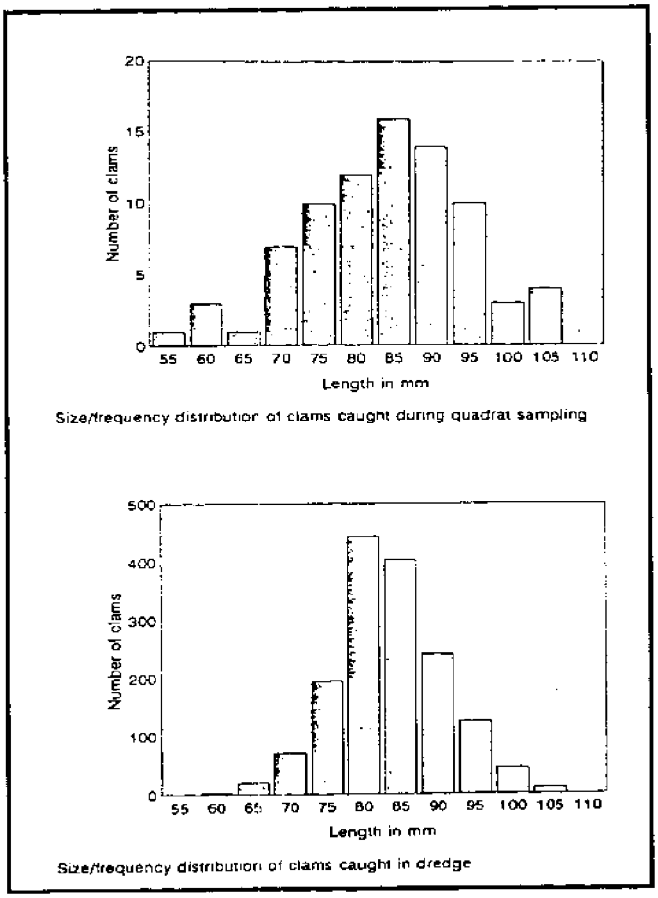

Figure 6. Size-frequency distribution of quahogs retrieved during quadrat sampling and cultivation

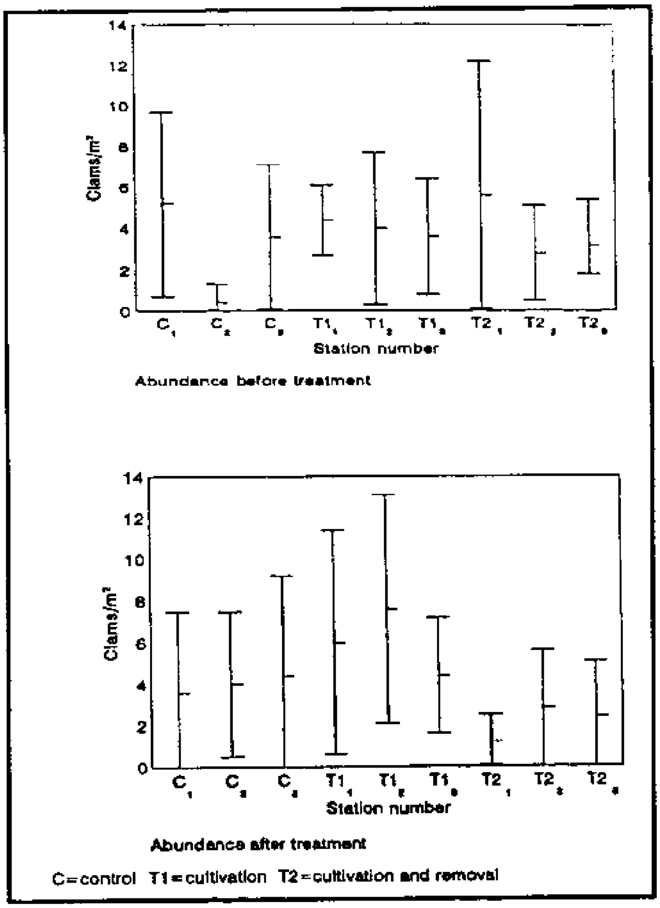

Figure 7. Quahog abundances before and after "removal" treatment

Table 2

Groups of species and species abundances (abundance/100 cm^2) for Summer 1989

	T21	T22	C1	T23	C2	T11	C3	T12	T13
SPIONIDAE	272	226	593	436	107	94	116	83	125
CAPITELLIDA	1040	848	1307	1568	482	600	412	502	894
CHAETOPTERIDAE	44	26	138	48	0	0	57	24	11
GLYCERIDAE	7	11	13	24	7	7	48	13	11
LUMBRINARIDAE	4	0	0	0	0	0	35	13	0
MALDANIDAE	48	37	26	64	31	37	50	48	103
NEPHTIDAE	4	0	0	0	0	0	0	9	0
NEREIDAE	26	2	2	2	18	2	2	4	20
ORBINIDAE	18	2	0	0	0	4	0	2	2
PHYLLODOCIDAE	2	2	9	24	18	2	20	22	24
POLYNOIDAE	4	0	0	2	0	0	0	0	0
SABELLIDAE	4	0	0	2	0	0	0	0	2
SERPULIDAE	0	0	0	0	0	0	0	0	0
TEREBELLIDAE	4	0	0	2	0	0	0	0	2
EXOGONINAE	0	0	2	0	0	0	0	0	0
FLABELLIGERIDAE	0	0	2	0	0	0	0	0	0
PARAONIDAE	2	0	0	0	0	0	2	0	0
ARABELIDAE	18	9	2	26	2	0	0	0	0
SPINTHIRIDAE	2	0	0	0	0	0	0	0	0
OPHELIIDAE	4	0	0	0	0	0	9	0	0
PECTINARIDAE	20	0	2	20	2	20	0	0	0
CIRRATULIDAE	7	0	11	11	0	0	9	0	0
SIGALIONIDAE	0	0	0	0	0	0	0	0	0
GONADIDAE	0	2	0	0	2	2	0	0	4
MAGALLONIDAE	0	0	0	0	0	0	0	0	0
ONUPHIDAE	0	0	0	0	0	0	0	0	0
HESIONIDAE	0	0	0	0	0	2	0	0	0
DORVELLIDAE	0	0	0	0	0	0	2	0	0
OLIGOCHAETA	342	204	247	155	138	193	278	164	350
AMPHIPODA	1040	129	445	653	534	453	405	530	460
DECAPODA	7	2	2	2	4	2	4	2	0
CUMACEA	0	0	0	0	0	0	0	0	0
CEPHALOCARIDA	0	2	0	2	7	9	18	9	2
COPEPODA	2	0	22	13	4	2	2	4	0
OSTRACODA	0	0	0	28	7	4	0	4	4
CIRRIPEDIA	0	0	0	0	0	0	0	0	0
BIVALVIA	64	24	72	105	94	88	35	53	158
GASTROPODA	53	0	66	4	2	15	7	2	4
NEMATODA	4242	2891	4645	6609	1570	3979	2236	2875	2672

Table 3

Groups of species and species abundances (abundance/100 cm^2) for Winter 1990

	T21	T22	C1	T23	C2	T11	C3	T12	T13
SPIONIDAE	904	716	1058	532	1047	773	767	491	177
CAPITELLIDA	2595	1347	3854	6550	3486	1833	2291	1717	3970
CHAETOPTERIDAE	18	11	37	15	7	2	20	13	48
GLYCERIDAE	13	9	26	20	42	11	64	35	42
LUMBRINARIDAE	4	4	11	9	4	4	9	2	7
MALDANIDAE	15	2	11	26	20	9	26	18	81
NEPHTIDAE	0	0	0	0	0	0	0	0	0
NEREIDAE	22	2	4	7	4	2	7	7	2
ORBINIDAE	0	11	2	13	7	24	0	2	0
PHYLLODOCIDDAE	107	88	22	33	48	70	33	35	46
POLYNOIDAE	0	4	0	2	2	0	4	0	2
SABELLIDAE	0	0	2	0	0	0	0	0	0
SERPULIDAE	0	0	0	0	0	0	0	0	0
TEREBELLIDAE	0	0	0	0	0	0	0	0	0
EXOGONINAE	0	0	0	0	0	0	0	4	0
FLABELLIGERIDAE	0	0	0	0	0	0	0	0	0
PARAONIDAE	11	0	0	0	0	0	7	0	0
ARABELIDAE	0	0	4	13	4	0	0	0	0
SPINTHIRIDAE	0	0	0	0	0	0	0	0	0
OPHELIIDAE	0	0	0	0	0	0	0	0	0
PECTINARIDAE	0	4	0	2	2	2	4	0	4
CIRRATULIDAE	0	0	2	0	2	0	2	0	0
SIGALIONIDAE	0	0	0	0	0	0	0	0	0
GONADIDAE	11	11	33	42	55	35	57	28	24
MAGALLONIDAE	0	0	0	0	0	0	0	0	0
ONUPHIDAE	0	0	0	2	0	0	0	0	0
HESIONIDAE	0	0	0	0	0	0	0	0	0
DORVELLIDAE	0	0	0	0	0	0	0	0	0
OLIGOCHAETA	834	429	473	850	160	134	206	300	556
AMPHIPODA	510	107	1001	2065	1826	1209	217	1261	1296
DECAPODA	2	2	9	13	33	2	0	11	24
CUMACEA	0	0	0	0	0	0	0	0	0
CEPHALOCARIDA	0	0	0	0	0	0	0	0	0
COPEPODA	11	7	20	11	4	4	18	11	13
OSTRACODA	0	0	0	112	0	2	7	0	72
CIRRIPEDIA	0	0	0	0	0	0	0	0	0
BIVALVIA	77	37	68	136	105	112	155	85	79
GASTROPODA	24	28	31	15	28	39	24	11	24
NEMATODA	7301	3924	3379	3169	2840	2586	6574	3211	2992

Table 4

Groups of species and species abundances(abundance/100 cm^2) for Summer 1990

	T21	T22	C1	T23	C2	T11	C3	T12	T13
SPIONIDAE	64	18	68	42	28	85	74	46	15
CAPITELLIDA	298	162	14754	12378	17467	2304	10188	1350	5580
CHAETOPTERIDAE	15	2	193	158	169	9	160	90	81
GLYCERIDAE	2	0	31	53	26	2	59	59	35
LUMBRINARIDAE	2	0	2	11	2	0	9	0	2
MALDANIDAE	4	2	105	61	46	9	184	68	50
NEPHTIDAE	0	0	0	0	0	0	0	0	0
NEREIDAE	0	0	0	0	0		0	4	0
ORBINIDAE	9	7	2	0	2	7	0	0	2
PHYLLODOCIDAE	1	2	112	105	120	50	92	131	70
POLYNOIDAE	0	2	0	0	0	0	0	0	0
SABELLIDAE	0	0	0	0	2	0	0	0	0
SERPULIDAE	0	0	0	0	0	0	0	0	0
TEREBELLIDAE	0	0	0	0	0	0	0	0	0
EXOGONINAE	0	0	0	2	0	2	2	2	2
FLABELLIGERIDAE	0	0	0	0	0	0	0	0	0
PARAONIDAE	0	0	0	0	0	0	0	0	0
ARABELIDAE	7	0	0	11	0	0	0	0	0
SPINTHIRIDAE	0	0	0	0	0	0	0	0	0
OPHELIIDAE	0	0	0	0	0	0	0	0	0
PECTINARIDAE	7	2	42	57	68	57	64	57	20
CIRRATULIDAE	0	0	0	0	0	0	4	7	0
SIGALIONIDAE	0	0	0	0	0	0	0	0	0
GONADIDAE	0	0	28	81	48	13	66	59	53
MAGALLONIDAE	0	0	0	0	0	0	0	0	0
ONUPHIDAE	0	0	0	0	0	0	0	0	0
HESIONIDAE	0	0	0	0	0	0	0	0	0
DORVELLIDAE	0	0	0	0	0	0	0	0	0
OLIGOCHAETA	261	278	191	764	287	267	337	333	175
AMPHIPODA	4	7	1351	4465	3351	405	6014	6559	4557
DECAPODA	7	0	4	33	11	0	9	7	46
CUMACEA	0	2	0	2	4	9	0	0	0
CEPHALOCARIDA	0	0	0	0	2	0	2	39	0
COPEPODA	0	0	22	13	9	0	7	11	7
OSTRACODA	0	0	9	127	9	0	4	9	129
CIRRIPEDIA	0	0	0	0	0	0	0	2	0
BIVALVIA	22	0	177	269	77	39	254	188	169
GASTROPODA	22	11	50	53	42	37	39	37	48
NEMATODA	1107	7709	18159	16550	10667	2788	10904	11079	7516

Table 5

Groups of species and species abundances(abundance/100 cm^2) for Winter 1991

	T21	T22	C1	T23	C2	T11	C3	T12	T13
SPIONIDAE	670	1220	819	96	77	223	118	99	15
CAPITELLIDA	3070	5401	21206	8876	8876	6110	2713	11423	10162
CHAETOPTERIDAE	18	2	26	1	11	22	11	0	0
GLYCERIDAE	13	4	20	33	15	11	26	13	20
LUMBRINARIDAE	26	0	7	0	0	4	0	0	7
MALDANIDAE	11	57	42	50	35	26	50	26	59
NEPHTIDAE	0	0	0	0	0	0	0	0	0
NEREIDAE	7	24	7	4	9	28	0	2	4
ORBINIDAE	64	94	20	0	7	22	7	7	4
PHYLLODOCIDAE	239	241	191	158	171	184	101	254	195
POLYNOIDAE	0	0	0	0	0	0	0	0	0
SABELLIDAE	0	0	0	2	0	0	0	0	0
SERPULIDAE	0	0	0	0	0	0	0	0	0
TEREBELLIDAE	0	0	0	0	0	0	0	0	0
EXOGONINAE	0	0	2	4	0	2	0	0	4
FLABELLIGERIDAE	0	0	0	0	0	0	0	0	0
PARAONIDAE	0	0	0	0	0	0	0	0	0
ARABELIDAE	0	0	0	11	2	2	0	0	4
SPINTHIRIDAE	0	0	0	0	0	0	0	0	0
OPHELIIDAE	0	0	0	0	0	0	0	0	0
PECTINARIDAE	4	2	4	11	15	11	4	4	7
CIRRATULIDAE	2	4	11	0	0	0	2	0	0
SIGALIONIDAE	0	0	0	0	0	0	0	0	0
GONADIDAE	11	26	39	37	31	15	35	64	42
MAGALLONIDAE	0	0	0	0	0	0	0	0	0
ONUPHIDAE	0	0	0	0	0	0	0	0	0
HESIONIDAE	0	0	0	0	0	0	0	0	0
DORVELLIDAE	0	0	0	0	0	0	0	0	0
OLIGOCHAETA	377	556	298	344	162	357	158	357	653
AMPHIPODA	2256	3405	5256	8563	5567	3204	5317	6728	5245
DECAPODA	0	4	0	0	7	0	22	4	11
CUMACEA	2	2	7	9	0	7	2	13	9
CEPHALOCARIDA	0	0	0	11	13	4	0	2	2
COPEPODA	0	4	22	488	169	129	2	42	26
OSTRACODA	0	0	26	267	28	2	7	31	254
CIRRIPEDIA	0	0	0	0	0	0	0	0	0
BIVALVIA	37	48	274	221	145	33	162	140	162
GASTROPODA	9	2	48	55	92	28	22	72	55
NEMATODA	3460	3817	4776	4882	4036	3819	1833	3789	2873

attributed to the unusually large confidence intervals due to the extreme patchiness of quahog distribution.

Because it is impossible to demonstrate clearly the effective removal of large filter feeding bivalves, the second treatment for this experiment was not considered in further analyses. All the data from the T2 stations were incorporated with T1 for sediment analysis purposes but were not considered in the biological analysis as the effect of removal is not quantifiable.

By far the most commonly encountered animals were the nematodes with abundances often exceeding 200,000/m^2 and in one sample reaching 527,000/m^2. Capitelids, oligochaetes, and amphipods followed in abundance. More than 95 percent of the amphipods present in samples were *Ampelisca abdita*. Also common were the polychaetes *Streblospio benedicti*, *Polydora* sp., and *Pectinaria gouldii* (Tables 2-5). The bivalve *M. mercenaria* was present in low abundances throughout the sampling (average abundance 7.25/m^2), but in all the 360 cores analyzed, no quahogs larger than 5 mm were found.

The apparent lack of effect of the treatment on the macrobenthic community is reflected in a comparison of the mean abundances for each treatment in the four sampling seasons (Table 6). Although the mean abundances in the cultivation treatment are significantly different in the first and last samplings, the same is true for the three control stations. Moreover, an increase rather than the expected decrease in abundance can be seen in most stations. In the case of stations T21 and T22, however, the sampling immediately after cultivation caused no increase in abundance and amphipod abundances decreased by at least a hundredfold. The same decrease is also true for the capitellids and to a lesser extent the pectinarids and the phyllodocids. By the final sampling, abundances in the two stations were back to near original values.

Table 6

Synopsis of statistical results for biological analysis

Two-way analysis of variance on total abundance of animals per square meter, through all four seasons.

Class	Levels	Values
SEASON	4	SUM89 SUM90 WIN90 WIN91

Cultivation treatment: Summer '89 abundances significally lower than Winter '91

Cultivation and removal: No significant difference

Control: Summer '89 abundances significantly lower than Winter '91

Discussion

The community examined is typical of the *Ampelisca* type found at the mouth of Greenwich Bay and described by Hale (1974). The sediments of the area are silty/sand with total fines ranging from 6.0 to 30.4 percent. In an earlier bay-wide study (Pratt and Bisagni, 1976), seven out of eight stations investigated revealed that the small clam *Mulinia lateralis* was numerically dominant. The average silt/clay content for these stations was 61 percent. In the only station where fines were considerably lower (27 percent) the dominant species was the amphipod *Ampelisca abdita*, which is consistent with the present investigation. In a list compiled from nine studies conducted between 1957 and 1986 by Frithsen (1989), the most abundant species in the mid-Narragansett Bay region were: *Ampelisca abdita, Acteocena canaliculata, Mulinia lateralis, Nucula proxima, Nephtys* *incisa, Yoldia limatula, Nucula annulata, Pitar morrhuana, Leptocheirus pinquis, Tubonilla interrupta, Macoma tenta, Mediomastus ambiseta*, and *Polydora ligni*. Of the thirteen species identified in this list, seven were present —though not necessarily abundant—in the area of study.

The quahog population sampled showed low abundances of very large adults (3.6 animals/m^2 on average with an average length of 85 mm). This is comparable to the population of quahogs studied by Malinowski (this volume). Much like the Malinowski study, low numbers of juvenile quahogs were found, suggesting low recruitment rates. Other areas in Narragansett Bay such as Greenwich Bay may have higher annual recruitment (Rice, this volume).

Diver observations indicated that treatment with the hydraulic dredge produced grooves as deep as 1 meter in certain areas. There is no doubt that the study area was severely disturbed. This level of disturbance might have been expected to damage extensively established communities by burial of the existing animals and destruction of such biogenic structures as amphipod and polychaete tubes. The expected sharp drop in abundance after treatment is not reflected in the data. In fact, the highest abundances recorded, with the exceptions of stations T21 and T22, were recorded after treatment. As unexpected as the apparent quick recovery of the sediments was, it is consistent with the findings of an earlier study in the Narragansett Bay. Glude and Landers (1953) report that no difference could be seen in two areas cultivated by bullrake and by dredge, and a control area, after one to three months from treatment.

The slight increase observed in fine sediments in the treated stations may very well have resulted from the resuspension of the sediments into the water column and the subsequent size grading during redeposition. It would have been expected that by the last winter sampling, currents would have winnowed out the finer sediments giving lower silt/clay values than those obtained in the sampling immediately after cultivation. Exactly the opposite was observed however. The increase in TOC in the treated sites is also difficult to explain. Although TOC is normally associated with finer sediments, the mixing with deeper, and supposedly less TOC-rich sediments should have reduced, not increased, overall values. The trend of increased moisture content in treated stations could not be shown to be statistically significant but it did correspond well with TOC and silt/clay values.

The rapid reestablishment of infaunal communities is of interest. Most of the infauna found in the area, such as the polychaetes and amphipods, have life spans of one or two years with only one or two breeding seasons. It is unlikely that the time between treatment and sampling, which did not exceed four months, would have been enough time for benthic colonies to re-establish themselves. It is far more likely that the treatment was not as destructive to the benthos as expected. It is possible that differential settling allowed the lighter animals to settle last, after the re-suspended sediments had settled, causing them only a minimum amount of damage. In a study in Florida, Bell and Devlin (1983), reported that samples of defaunated sediments were recolonized within 7.5 hours. In that report, a table of nine other similar studies was provided, noting recolonization times. The table includes data from nine studies including McCall's (1977) Long Island Sound study and Commito's (1976) study in North Carolina. In all nine cases, recolonization occurred at times between three hours and 40 minutes and two months. In most studies, defaunated sediment samples used were only a few centimeters in diameter and were placed in control sediments with ambient macrofauna. Animals in adjacent sediments could then quickly migrate into the available new niche. The areas studied in this investigation were much larger and more time would be required for adult macrofauna to migrate into the area. A combination of some survival after cultivation and subsequent rapid recolonization by adults may explain the apparent lack of effect of the cultivation treatment on the macrobenthos.

The infaunal abundance variability observed in the samples is not unusual. Both seasonal and spacial abundances have been shown to vary more than 100 percent from year to year and site to site (Stickney and Stringer, 1951; Rudnick et al., 1985; Frithsen, 1989). The inherent patchiness of benthic communities due to differential recruitment, predation, interactions with preexisting fauna and abiotic variations, may far exceed anthropogenic influence, making it impossible to determine the extent of disturbance.

A positive correlation between disturbance and sediment or animal composition cannot be drawn. The extent of the data collected and the thoroughness of the cultivation process indicate that the apparent inconclusiveness of the study is due to environmental variability, not experimental design. The magnitude of the seasonal changes and the inherent variability of the system appear to be far greater than the anthropogenic effects of mechanical disturbance. Neither the sampling immediately after nor the winter sampling, eight months after treatment, indicated that cultivation significantly affected the macrobenthos or the monitored sediment parameters. Considering the magnitude of the effects of cultivation compared to the magnitude of the seasonal and spatial variation, it is unlikely that a single cultivation will have measurable effect on future macrofaunal settling.

The unsuccessful removal of large filter feeders prevents any conclusions from being drawn as to the second treatment's effects. Studies such as Hancock (1983), Rice et al., (1989), and Walker (1989) report that in actively fished areas adult infaunal bivalve assemblages are less dense and greater numbers of younger year-class animals are present. Such studies have the added advantage of being able to report on areas where continuous disturbance over long periods of time has occurred as opposed to the isolated disturbance event discussed here. The negative results of this one-time disturbance study do not necessarily rule out the possibility that continuous bottom disturbance may enhance the recruitment of quahogs.

Acknowledgments

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Questions and Answers

Q. *(Mr. Gerald Carvalho, RI Watermen's Association) Are there any other data on bottom cultivation, and if so how does your data compare?*

A. (Ms. Maria Sparsis, URI Fisheries) There were a few other studies. Some of these were by dumping dredge spoil, and others were essentially removal of fauna to see how fast recolonization occurred. Recolonization rates, depending on species and location, could vary from a few hours to upwards of eleven years. The size of the study area has a great effect on the recolonization rates. Most defaunation studies have been carried out in small-scale plots. If you have study areas that are in the size range of a square meter, you have the problem of edge effects. Recolonization from adjacent areas occurs in a matter of hours. Larger scale studies are rarer, because of the technical difficulties.

Q. (Carvalho) *Are you satisfied with your conclusion that bottom cultivation has no effect on quahog recruitment? Was your study sufficient enough to be the final word on this matter?*
A. (Sparsis) Final is an awfully final word. We did have some problems, as I stated. I regret that we were not able to get complete information about the effects of bivalve removal. However, I am confident that in this study area of low quahog abundance and low quahog recruitment, our conclusions are valid.

Q. (Carvalho) *Do you think that you might have seen a difference in another area, perhaps a more productive area?*
A. (Sparsis) Yes, different areas will respond differently. For example eel grass areas would be negatively impacted by disturbing the bottom. In our study area there was no vegetation, so there was no effect.

Q. (Dr. Scott Nixon, RI Sea Grant) You never actually measured recruitment, right?
A. (Sparsis) The last sampling we did was in January of 1991. The treatments were in May 1990, so there were several months between the treatment and final sampling. There were about four or five animals per sample core at beginning and end.

Q. *(S. Nixon) What worries me is that judging from the earlier talks today, our knowledge of what factors influence recruitment are in fact not very good. And, the parameters that you use to quantify the disturbance effect are quite coarse, i.e. water content, total organic carbon. These may have very little to do with what the larvae actually see in terms of setting into an area or any post-settlement success they might have. Would it not have been better to choose an area where recruitment was going on?*
A. (Sparsis) The aim was to choose a non-productive area and attempt to change it to improve recruitment.

Q. *(S. Nixon) Did you sample larvae in the area?*
A. (Sparsis) No.

Comment (Mr. Karl Rask, Massachusetts Cooperative Extension) I have done a considerable amount of work on this and have found drastic changes in sediment as a result of the use of hydraulic gear. In Massachusetts, we have seen definite improvement of the bottom and increased sets into many areas. I would say that most of the towns around Cape Cod are using hydraulic gear for set enhancement.

Comment (Dr. Monica Bricelj, SUNY-Stony Brook) I think an explanation for differences may be in the frequency of cultivation. Repeated cultivation may have cumulative effects, whereas a single cultivation may not do much.

Q. (Mr. Neal Perry, shellfish diver) You mentioned that one of the aims of the cultivation is to try to remove fine particles, in your attempt to "improve" the bottom. Higher current velocities would better remove the fine sediments. Did you measure current speed in an attempt to maximize the removal of the fine sediments?
A. (Sparsis) No, we did not have any data as to the time of the tide. But my thought on this is that if you have a current, you are moving the sediment downstream. Depending on the scale, you get the sediments right back again on a returning tide. So, I'm not convinced that would do much.

Comment (Dr. Joseph DeAlteris, URI Fisheries) I just want to clarify something. When we did the cultivation, it was over the period of an entire day. Given the speed of the boat, and area of the bottom, we went over the same area seven times during the cultivation process. The area was thoroughly disturbed. Because of the length of the cultivation process, it spanned an entire flood-ebb cycle. Sediments could be seen as a plume coming up off the bottom and were carried off out of the area. If you had an aerial photo of this, you would see the plume of sediments moving away at one stage of the tide, and returning with the other. The sediments were resuspended and the fines were put into the water column. Now, our working hypothesis is just what you believe Jerry, and we had your papers before we even started the project, Karl. In fact I believed and promoted the technique in the Middle Atlantic region for years. But what we found was quite different from our working hypothesis and our gut feelings.

Q. *(Rask) As I recall from the data presented, there was no difference in sediment-grain size before and after cultivation. How could that possibly be?*
A. (DeAlteris) Because we were suspending fines into the water column. With the hydraulic jets, we were digging up the bottom to depths of 12 to 24 inches. As is panned out, everything just settled back to the bottom. We did not **significantly** (there's the magic word) change the grain-size parameter as expressed as sand/silt percentages. For the kind of work we are doing, I feel reasonably good about this level of precision. In terms of the results and conclusions, I know we disturbed the bottom, and I know we did not see any differences.

Effects of Density on Adult Growth, Survivorship, Fecundity, and Recruitment of Northern Quahogs

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Abstract. *A population study of quahogs near Fishers Island, eastern Long Island Sound, was conducted from June 1982 to July 1983. Quahogs were sampled using a diver-quadrat methodology. Additional manipulative field experiments were performed in which quahogs were placed at varying densities in subtidal plots with 1/4-inch mesh predator exclusion screens. The average density of quahogs was 12.3/m^2. Age determinations suggest that in the past fifteen years, there had been only two significant years of quahog recruitment. Average annual recruitment was approximately 0.21 quahogs/m^2/yr. Growth of quahogs at the study site is extremely slow, but survival of quahogs >35 mm valve length was very high (0.915-0.955). Survival of these quahogs (>35 mm) is independent of density. Evidence suggests that quahogs are extremely long lived and recruitment rates are very low. Thus, sustainable harvest from this Fishers Island population is only 0.5 quahogs/m^2/yr. (Editorial note: This paper is reprinted from S. Malinowski. (1985).* The population ecology of the hard clam, *Mercenaria mercenaria* in eastern Long Island Sound. *PhD Dissertation, University of Connecticut at Avery Point, Groton, CT 112 pp. Dr. Malinowski has granted his permission for its inclusion in these proceedings. Further information about mathematical modeling and quahog management can be found in a subsequent paper: Malinowski, S. and R.B. Whitlatch. (1988). A theoretical evaluation of shellfish resource management.* Journal of Shellfish Research *7:95-100.)*

Introduction

Although there is a growing body of literature that has documented the importance of density-dependent interactions and predation in regulating the distribution and abundance of marine infaunal invertebrates (e.g., Wooden, 1976; Whitlatch, 1980; Brenchley, 1981; Wilson, 1983; and Wooden, 1974; Young et al., 1976; Virnstein, 1977; and Holland et al., 1980), relatively few studies have examined the importance of biological interactions in influencing the distribution and abundance of large, infaunal bivalves despite the fact that these species frequently constitute a large percent of infaunal biomass. Hypothetically, populations of large suspension feeders may be regulated by intraspecific competition for food or space. High population densities may deplete the food resources of overlying water masses to a critical level that results in depressed rates of growth, survivorship and/or fecundity or inhibit recruitment if adults ingest settling larvae (as suggested by Woodin, 1976). On the other hand, intense rates of predation may regulate these populations by maintaining population densities below the carrying capacity of the environment. Peterson and Andre (1980) found evidence of interspecific competition between two large West Coast bivalves and in a study of *Protothaca stamina*, Peterson (1982a) concluded that growth, fecundity, and recruitment were all significantly reduced by increases in adult population density, even at experimental densities that approximated the ambient natural population.

Several studies have documented the importance of intense predation on juvenile age classes in influencing the ultimate abundance of large bivalves (e.g., Carriker, 1959; MacKenzie, 1977; Kelso, 1979; Blundon and Kennedy, 1982; and Flagg and Malouf, 1983), including predator-mediated density-dependent survivorship of juveniles (Boulding and Hay, 1984). It is generally believed that as quahogs (*Mercenaria mercenaria*) grow, their susceptibility to predators is dramatically decreased (Haven and Andrews, 1956; Carriker, 1959; Walne and Dean, 1972; Eldridge et al., 1979; and Whetstone and Eversole, 1981). In manipulative field studies of adult (>30mm) survivorship, Hibbert (1977) found the annual survivorship of large *M. mercenaria* to range from 30-40 percent on an intertidal mud flat in Great Britain, and Peterson (1982b) reported a maximum of 65 percent survivorship over a six month period. In the former study, the primary adult predator was the Herring gull (*Larus argentatus*) while in the latter most mortality was caused by whelks (*Busycon spp.*). In neither of these studies was adult survivorship dependent upon density or size.

Biological interactions (particularly intraspecific ones) can have important resource management implications. For example, if growth, fecundity, or recruitment are limited by high population densities, then maximum sustainable harvests can be enhanced by certain levels of harvesting. In the present study I use a combination of manipulative field experiments and quantitative sampling of an unexploited natural population to examine the effects of adult population density on growth, survivorship, fecundity, and recruitment into the adult age classes in quahog, *M. mercenaria.*

Materials and Methods

This study was conducted in eastern Long Island Sound at West Harbor, Fishers Island, N.Y. (72°00'26" W, 41°16'12" N). The study site is approximately 100 meters from shore where water depth is 2-3 meters MLW and is located midway between an incomplete semicircle of boulders and a sandy beach. There is a relatively coarse sand bottom and patchily distributed eelgrass (*Zostera marina*) bed. Water temperature ranges from 3° C (January - February) to 22° C (August) and salinity ranges from 26-28 ppt. The predominant adult quahog predator at this site is the starfish (*Asterias forbesi*). Whelks (*Busycon spp.*) and moonsnail (*Polinices duplicata*) are also present. A combination of *in situ* manipulative field experiments and quantitative sampling of the resident unexploited population of *M. mercenaria* was conducted from June, 1982 to July, 1983. All field work was done with the aid of scuba. Two separate procedures were used to collect a total of 80 0.33m² samples of the natural population. Thirty samples were obtained using a 58cm x 58cm steel frame to delineate an area from which all sediments were removed with a hand trowel to a depth of approximately 20cm. Sediments were retained in large plastic bags, brought to the surface and washed through a 2mm screen. The remaining samples were obtained using a small, three-pronged garden rake (tines spaced 24mm apart) to locate and remove all quahogs from the area within the steel frame. The latter method efficiently sampled quahogs >30mm. The spatial distribution of samples was determined by establishing eight randomly selected transects within the three-acre area of the study site. Ten samples, spaced 58cm apart, were collected along each transect. The retained quahogs of each quadrat were counted, measured (length, width, height), and aged. Aging consisted of counting the yearly annuli of sectioned shells. Shells were transversely cut with a band saw, the cross sections sanded sequentially with 80 and 220 grit sand paper, and dipped in 10 percent HCl for 10 seconds. Yearly annuli were then counted under a dissecting microscope. This technique is similar to that used by Peterson et al. (1983). Due to the small yearly increments of growth of older quahogs, it was only possible to determine the age of quahogs ≤15 years old with accuracy using this technique.

The manipulative field experiments consisted of planting a variety of densities of adult quahogs (>35mm in length) in 0.33 m^2 plots. Plots were established similar to the techniques of Peterson and Andre (1980). Mesh enclosures (58cm x 58cm x 15cm) consisting of galvanized hardware cloth (1/4" mesh) with a wooden dowel attached to each corner were dug into the sediments until they were flush with the sediment-water interface. All sediments within enclosures were removed to a depth of 15cm and replaced with medium grain size azoic sediments obtained from the adjacent shoreline. Quahogs (36-112mm) were collected from a variety of habitats along the northern shore of Fishers Island and planted in June, 1981 at four densities (4, 11, 27, and 67 quahogs/plot) with three replicates for the two highest densities, four replicates for plots with eleven quahogs, and seven replicates for the lowest density. The highest density represents the maximum number of quahogs, placed shell to shell, that would fit in a quadrat. Care was taken to maintain a consistent size distribution of quahogs between treatments. Prior to planting, all quahogs were measured (length, width, and height) and marked. It was necessary to individually scrub and dry each shell before numbering with a permanent felt-tip marker.

The following summer (mid-July) quahogs were retrieved from the field plots. During the summer, water temperature was carefully monitored and quahogs were removed when water temperature was 21°C (mid-July). At this temperature, it is unlikely that any of the quahogs would have released their gametes (Loosanoff 1937; Carriker 1961). A small number of individuals of the ambient population were inspected and found to be ripe with spawn. Quahogs were counted to determine survivorship and measured and then placed in an autoclave for 15 minutes at 100°C to facilitate opening. Individual displacement volumes of quahog meats were determined volumetrically the same day quahogs were removed from field plots.

Manipulative field experiments were analyzed using one-way analysis of variance (ANOVA) to determine the effect of density on survivorship and analysis of covariance to assess the effect of population density on quahog meat displacement volumes. Survivorship values were transformed prior to analysis, (arcsine ($\sqrt{x}$)), as recommended by Snedcor and Cochran (1980). Ambient population samples were used to indirectly assess the effects of quahog density on successful recruitment into the adult age classes and growth. To determine if aged quahogs ($\leq$15 years old) had a tendency to be found in quadrats of specific densities, I historically reconstructed the densities of individual quadrats during most of the last 15 years (when a year class was represented by >4 quahogs) and used Chi-square analysis to compare the observed distribution of quahogs with respect to density within individual quadrats to the actual frequency of quadrats with a specific quahog density at the times of past settlement. Linear regression analysis was used to compare quahog size with quahog density/quadrat within abundant age classes.

Results

Manipulative Field Experiments

The objectives of the manipulative field experiments were to determine natural survivorship of adult (>35mm) quahogs and assess the effects of population density on individual quahog growth and condition. Annual survivorship of quahogs planted at a variety of densities is presented in Table 1. Survivorship within individual plots ranged from 0.50 to 1.00. Survivorship was not significantly affected by density ($p>0.995$, one-way ANOVA). Of a total of 354 quahogs originally planted, 338 were recovered. A small number (<10) of these quahogs were found close to (within 0.25m) but just outside experimental plots. Of the total quahogs recovered, 324 were alive and 14 were dead. Therefore, overall survivorship ranged from 0.915 to 0.955 dependent upon how many unrecovered quahogs had died. Mortality was independent of quahog size/age since the size distribution of dead quahogs was similar to that of those originally planted. There was no indication of size-specific mortality.

Table 1

Survivorship of adult quahogs at each of four planting densities after one year

Initial Planting Density per $0.33m^2$	Total Number of Quahogs Recovered	Survivorship
4	4	1.000
4	3	0.750
4	4	1.000
4	4	1.000
4	3	0.750
4	4	1.000
4	2	0.500
11	9	0.818
11	10	0.909
11	10	0.909
11	10	0.909
27	25	0.926
27	24	0.889
27	24	0.889
67	63	0.940
67	63	0.940
67	62	0.925
Total	**Total recovered**	**Survivorship**
354	324	0.915

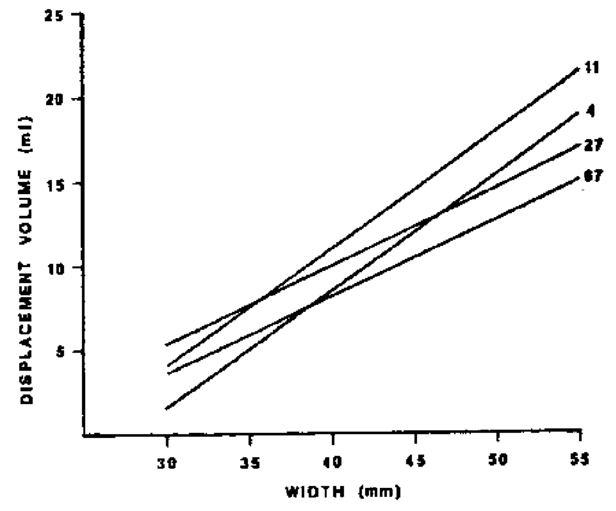

Figure 1. The relationship between quahog width and the displacement volume of individual quahog meats at each of the four experimental densities. Density (quahogs/0.33 m^2) *is designated to the right of each line. All replicates within each treatment have been combined. The lines are best fit lines predicted from linear regression analysis [for each density the regression equations are: 4 - volume = 8.4 + .705 (width - 39.9), 11 - volume = 11.1 + .693(width - 40.1), 27 - volume = 11.0 + .466(width - 42.6), and 67 - volume = 10.0 + .459(width - 43.6)].*

Displacement volume of individual quahog meats was used as a relative measure of quahog condition, and since more than 50 percent of the meat weight of a ripe quahog may be released as gametes (Ansell et al., 1964), it serves as a relative comparison of the potential gamete production of individuals as well. The relationship between size and displacement volume is presented graphically in Figure 1. The elevation of the individual predicted linear regression lines tended to decrease as density increased, with the exception of the lowest density which was between the two intermediate densities. The effect of density on displacement volume was significant ($p<0.01$, analysis of covariance, Table 2). However, further analyses revealed that the effect of density on displacement volume becomes significant only at the highest density since there was no significant difference between the three lowest densities ($p>0.05$, analysis of covariance) while the difference between the three lowest densities combined and the highest density was highly significant ($p<0.005$, analysis of covariance, Table 3).

Growth of quahogs in all treatments was extremely poor. Nearly one half of the total quahogs planted did not grow during the full year, and of those that did grow, only a very small percentage grew at what would be the predicted rate (Figure 2). A combination of the large size of the animals, the poorly documented growth rates of seed quahogs at this site (Steve Malinowski, unpublished data), and stress is believed to be responsible for the low and inconsistent observed growth rates. Subsequent to this study it was learned that growth rates of quahogs can be affected by the past history of handling. Little or no growth during an entire growing season has been documented in two other independent studies (Steve Malinowski, unpublished data and Ed Rhodes, NMFS, Milford, Connecticut, personal communication)

Table 2

Comparison of regression lines of quahog width (maximum distance across umbo) versus quahog meat displacement volume (after autoclave, see text) for four plant-ing densities (per 0.33 m²). Individual replicates within each treatment are combined.

Density	Reg. Coef.	d.f.	Deviation from Regression S.S.	M.S.
4	.705	21	187.9	8.9
11	.693	36	683.2	19.0
27	.466	61	1618.3	26.5
67	459	146	2533.8	17.4
		264	5023.2	19.0
Pooled, W		267	5147.8	19.3
Difference between slope		3	124.7	41.6
Between adjusted means		3	297.8	99.3

For slope, F = 2.18, N.S.
For elevation, F = 5.15, Significant difference (p<.Ol)

Table 3

Comparison of regression lines of quahog width (maximum distance across umbo) versus quahog meat displacement volume (after autoclave, see text) for the three lowest densities (4, 11, and 27 quahogs/ 0.33 m²) combined and the highest density (67 quahogs/0.33 m²). Individual replicates within each treatment are combined.

Density	Reg. Coef.	d.f.	Deviation from Regression S.S.	M.S.
4,11,27	.581	122	2670.3	21.9
67	.459	146	2533.8	17.4
		268	5204.1	19.4
Pooled, W		268	5248.4	19.5
Difference between slope		1	44.2	44.2
Between adjusted means		1	197.4	197.4

For slope, F = 2.28, N.S. (p>0.05)
For elevation, F = 10.12, Significant difference (p<0.005)

and is believed to be the result of stress during handling. During the present study, quahogs were stressed during the numbering procedure (since shells had to be dried before marking) and during the period of time (approximately one month) when quahogs were held in the water column at high densities prior to planting.

Ambient Population Samples

A total of 328 quahogs were collected during the field sampling. The densities of quahogs within individual 0.33 m² samples ranged from 0 to 11 with an average of 4.1 quahogs/quadrat (12.3 quahogs/m²). The frequency distribution of quahogs/quadrat (Figure 3) is skewed to the left with 65 percent of the quadrats having a density of four quahogs or less. The most common density was three quahogs/quadrat (22.5 percent of all samples).

As indicated by the size-frequency distribution (Figure 4), the study site is dominated by large, relatively old quahogs. Only 106 quahogs (32 percent) were 15 years of age or less. The frequency of each age class during the last fifteen years is presented in Figure 5. More than one half (54 percent) of all quahogs fifteen years of age or less were from two age classes. There were representatives of each age class except one (14). Significant recruitment into the adult age classes occurred only twice during the last fifteen years. Adjusting the age class frequencies to reflect the observed annual survivorship (see Figure 5) results in a predicted recruitment into the

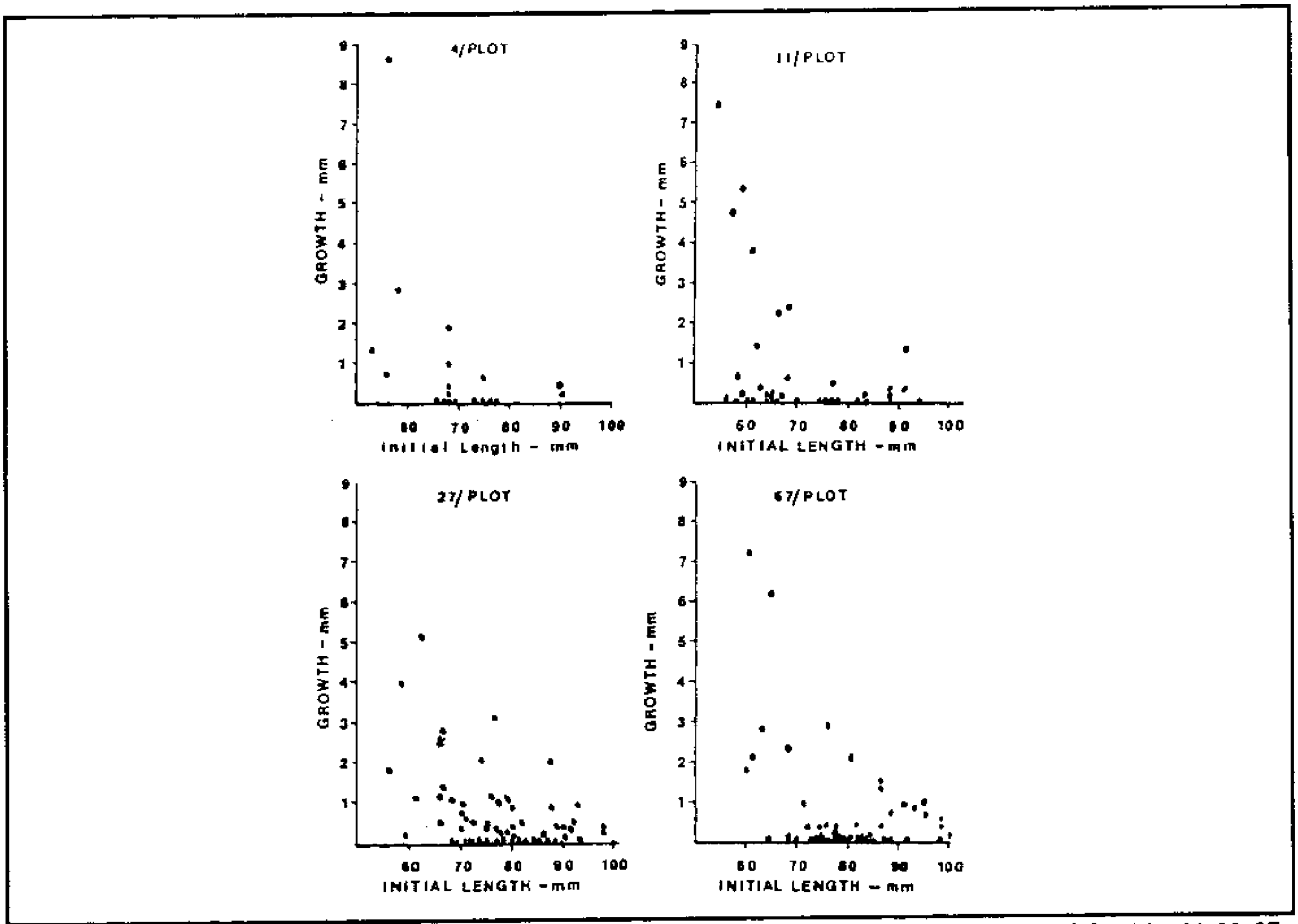

Figure 2. Growth increments versus size (length) for quahogs planted at each of the four experimental densities (4, 11, 27, and 67 quahogs/0.33 m^2). All replicates for the three lowest densities and one replicate for the highest density (67 quahogs/0.33 m^2) are represented.

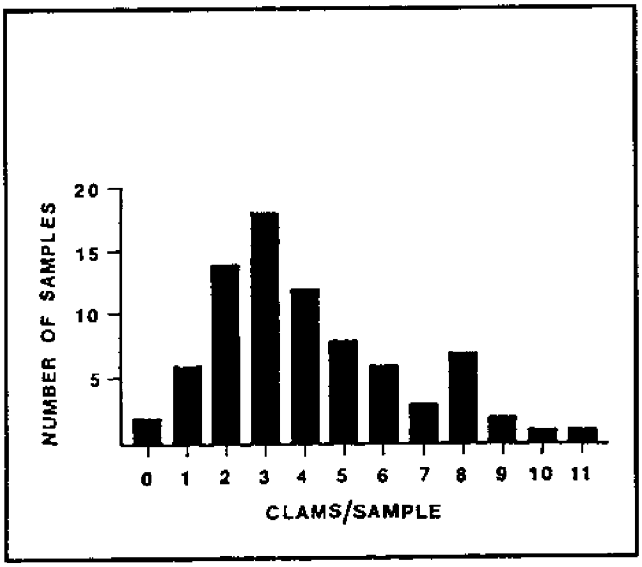

Figure 3. Frequency distribution of the numbers of natural population samples (0.33 m^2) that had specific densities of quahogs at West Harbor, Fishers Island, N.Y. Data for both sampling techniques (see text) have been combined.

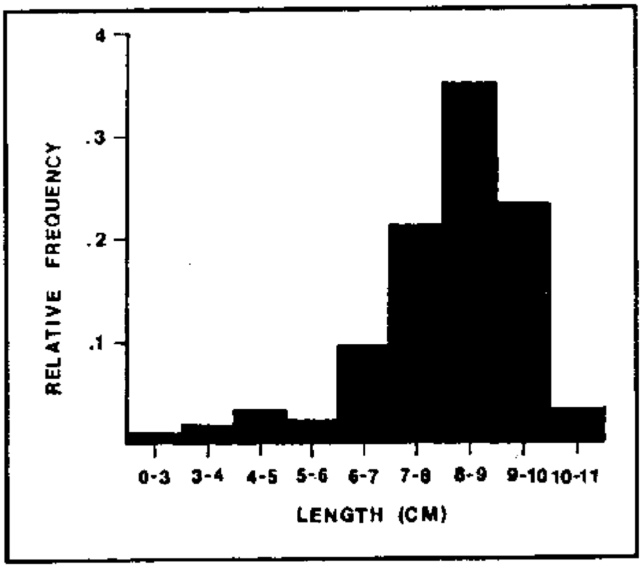

Figure 4. The distribution of all quahogs (n=328) sampled from the natural population at West Harbor, Fishers Island, N.Y. into size classes. Data from both sampling techniques are combined and therefore the smallest size class (0- 3 cm) is underestimated (see text).

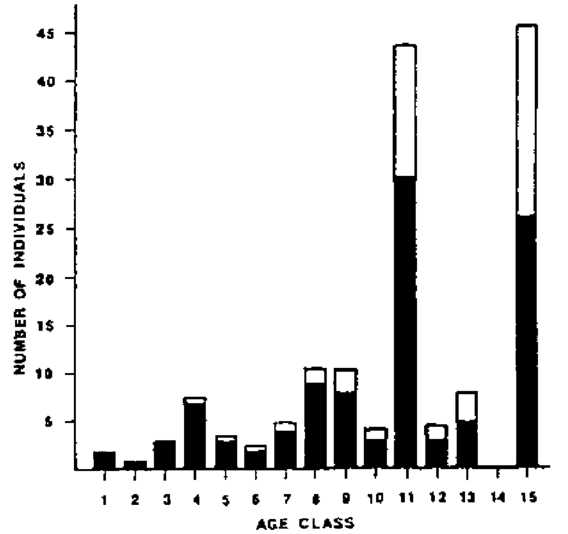

Figure 5. The distribution of all aged quahogs (n=106) from natural population samples collected at West Harbor, Fishers Island, N.Y. into age classes. The shaded area of each bar represents the actual number of quahogs collected while the unshaded area represents the predicted number that would have been observed if adult survivorship were 100 percent instead of 95.5 percent (as predicted from field experiments). Therefore, the unshaded areas are an estimation of the amount of recruitment into the adult age classes that occurred during 12 of the last 15 years.

adult age classes (>3 years of age) of 144.7 quahogs during the last 15 years or an average of 0.151 quahogs/ quadrat/year.

Aged quahogs (those <15 years of age) were used to determine if there was correlational evidence to suggest that either successful recruitment into the adult age classes or quahog growth was affected by small-scale differences in population density. Although the data are correlational, the density of quahogs within individual quadrats did not appear to affect either the probability of successful recruitment into the adult age classes (>3 years of age) or individual quahog growth. Analysis of the spatial distribution of all aged quahogs with respect to the densities of quahogs within individual quadrats revealed that quahogs were distributed randomly since the probability of finding a quahog in a quadrat with a particular density was not significantly different than the relative frequency of quadrats with that density at the time of initial recruitment (p>0.70, Chi-square test, Table 4). Since this analysis is based on individuals that survive to adults, it

Table 4

Chi-square test for the effect of density on the historical patterns of successful recruitment for all age classes (<15 years old) combined from natural population samples. Observed values are the number of aged quahogs that were sampled from quadrats that had a particular density (column 1) at the time of recruitment, Expected values represent the predicted frequency if recruitment were independent of density (e.g., the number of quahogs found in quadrats that had a given density were equal to the relative frequency, among quadrats, of that density). In other words, if 70 percent of the quadrats had a density of 3 quahogs/quadrat and there were a total of 10 quahogs recruited, then the expected value for quadrats with that density would be 7.

Density	Observed (f)	Expected (F)	f-F	X^2
0	4	5.2	-1.2	.28
1	17	17.0	0	0
2	23	21.2	1.8	0.15
3	14	23.6	-9.6	3.91
4	12	11.6	.4	0.01
5	12	7.9	4.1	2.13
6	8	6.5	1.5	.35
7	8	4.6	3.4	2.51
8	5	5.9	-0.9	0.14
9	3	2.0	1.0	0.50
11		0.7	-0.7	0.62
Total	106	106.2	-0.2	10.60*

* No significant difference (P>0.70).

combines all potential density-dependent effects (positive and/or negative) that may occur during the first three years. The two abundant age classes, 11 and 15-year old quahogs (Figure 5), were used to assess the effect of density on growth. Analysis of quahog size versus quadrat density within each age class revealed no significant correlation between quahog density/quadrat and quahog size (r^2 =0.06 and 0.11, p>0.05, linear regression analysis).

Discussion

The analyses of the natural population samples are an indirect assessment of the effects of density on growth and recruitment. The observed average density was within the range of several populations sampled by MacKenzie (1977) and a number of individual quadrats had abundances (7 - 11 quahogs/0.33 m^2) considered "dense" by Carriker (1961). Therefore, with respect to population density, this is likely a typical population. Within the observed range of densities (0-11 quahogs/ 0.33 m^2), I found no evidence of intraspecific competition for either food or space. The manipulative field experiments provide additional evidence of the lack of intraspecific competition. There were no significant effects of density on displacement volumes of quahog meats (relative fecundity) at densities up to 27 quahogs/0.33 m^2. Although displacement volumes were significantly depressed at the highest density (67 quahogs/0.33 m^2), this is an unrealistically high density (it represents the maximum number of quahogs that would fit in a quadrat).

The differences between the results of this study and Peterson's (1982) are dramatic. His results indicate depressed rates of growth and fecundity in treatments where less than three percent of the substrate was occupied by quahogs. In contrast, I see no effect of density on growth (natural population) or fecundity (field experiments) in situations where up to nearly 40 percent of the substrate is occupied by quahogs. Additional support for this result comes from experiments to determine optimal planting densities of *M. mercenaria* in artificial culture operations. Quahogs grow at optimal rates to a size of 25 mm at densities as high as 4300/m^2 (Steve Malinowski, personal observations) and to a size of 50 mm at densities as high as 540/m^2 (Menzel and Simms, 1964; Futch and Torpey, 1966; Castagna and Kraeuter, 1981). At these sizes and densities, quahogs may occupy nearly the entire surface area of the substrate (individual quahogs may actually be forced out of the substrate). While the maximum density of *M. mercenaria* that can be optimally supported per unit space is not unlimited and densities that exceed the carrying capacity of an environment have been documented in isolated circumstances (Glude, 1952; Dow and Wallace, 1951), this species most likely typically exists at densities that are far below the maximum densities sustainable by available food and space.

In agreement with previous studies (Hibbert, 1977 and Peterson, 1982), I found adult survivorship to be independent of size or density. However, survivorship was much higher (91-95 percent) in the present study than previously reported. This is undoubtedly the result of differences in the abundances and species of adult quahog predators. At the present study site, adult quahog predators (starfish and whelks) occur at very low densities (<<l/m^2).

The lack of evidence of intraspecific competition suggests that predation is more important than competition in regulating the population of *M. mercenaria* at the present study site. Whether or not this conclusion also applies to other populations living in different habitats (e.g., small estuaries) remains to be tested. However, assuming it does, the absence of density-dependent processes among adult age classes allows us to describe population growth within a local habitat with the following equation:

$$(N_x)(P) + C = N_{x+1}$$

where N is the number of individuals per quadrat, P is the average annual adult survivorship, C is the average annual recruitment of quahogs into the adult age classes, and x is time (years). The equation describes a function that increases at a decreasing rate with the position of the asymptote dependent upon the values of P and C. It therefore predicts the density of quahogs that may be sustained by combinations of particular values of adult survivorship and successful recruitment into the adult age classes. In addition to the lack of density-dependence among the adult age classes, this equation assumes that C, the number of recruits into the adult population, is independent of current population size. This assumption is supported by the analyses of natural population data and, since *M. mercenaria* has a prolonged planktotrophic larval stage, it is unlikely that larvae recruiting into a local population originate from that same population. This term (C) represents the end result of the combination of all early life history processes (i.e. intensities of larval settlement and juvenile mortality).

Substituting observed rates of adult survivorship (95.5 percent) and average annual recruitment into the adult age classes (0.151 quahogs/ quadrat/year) into the equation results in a predicted density of 3.4 quahogs/quadrat. This is very close to the observed density (4.1 quahogs/ quadrat) since the equation is extremely sensitive to even small changes in P or C. For example, doubling the value of C doubles the predicted density and the predicted density would be exactly equal to the observed if adult survivorship were 96.3 percent instead of 95.5 percent. Since the natural population of West Harbor, Fishers Island, N.Y. is dominated by large, relatively old quahogs, it is tempting to conclude that this is evidence of decreased rates of recruitment during the recent past. However, since *M. mercenaria* is extremely long-lived (Hopkins, 1941 and Peterson, 1983) and has low rates of adult mortality, high abundances of large quahogs may represent an accumulation of over 50 years of recruitment and the seemingly low rates of observed recruitment into the adult age classes during the last fifteen years are adequate to account for the observed population densities.

There were only two pulses of significant recruitment into the adult age classes (1.7 quahogs/m^2/year) during the last fifteen years. However, if these pulses had been the norm instead of the exception, a density of 38 quahogs/m^2 could be sustained. Neglecting these two exceptional years, adult recruitment during the last fifteen years could sustain a population density of 5.1 quahogs/m^2. Therefore, about 41 percent of the observed density can be accounted for by the persistent, but relatively low (0.21 quahogs/ m^2/year) adult recruitment that appears to be the norm. Either the pattern of recruitment during the last fifteen years is atypical, or the population relies on infrequent pulses of recruitment to maintain the observed population density. Pulses of adult recruitment could be the result of abnormally dense larval settlement. However, since there is evidence of predator-mediated density-dependent juvenile survivorship and documentation of reductions in the density of post-set quahogs to undetectable levels within a sampling area over a period of a few weeks following a dense larval settlement (Wende Wiltse, University of Connecticut, personal communication), it is possible that variability in adult recruitment reflects the historical relative abundance of juvenile predators.

The lack of intraspecific density-dependent interactions among adults and the intense predator-mediated density-dependent survivorship among juveniles suggests that the density of populations of *M. mercenaria* in Eastern Long Island Sound are regulated by predators of both the adult and juvenile life stages. Although adult mortality is extremely low relative to juvenile mortality, maximum sustainable density is still very sensitive to adult mortality. For example, the predicted density of quahogs/quadrat in the previous example would have be 13.9 instead of 3.4 if annual adult survivorship were 99 percent instead of 95.5 percent.

The results of this study have important implications with respect to the management of quahog resources. Since I was unable to document density-dependent growth, fecundity, or recruitment, it is not likely that any amount of harvesting will increase the population growth rate of local populations. However, this does not necessarily imply that all amounts of harvesting are detrimental to local populations. Since juvenile survivorship is density-dependent, it is possible to have substantial reductions in the density of larval settlement (resulting from decreases in numbers of spawning quahogs) with no realized reductions in harvestable quahogs. By similar reasoning, reducing the average size and therefore fecundity of quahogs in a population does not necessarily result in future reductions of recruitment into harvestable age classes (as suggested by Bricelj and Malouf, 1978; and McHugh, 1981) and the common practice of adding spawner stocks will not necessarily increase the future number of harvestable quahogs.

It is not surprising that sustained harvesting often results in depleted quahog populations. Since *M. mercenaria* is extremely long-lived, dense unexploited populations may take years to accumulate. There is a dense unexploited population of quahogs at West Harbor even though, on the average, only one quahog/m^2 enters the adult age classes every other year. If this dense population were completely exploited, it would take approximately 100 years for the current densities to be restored. During the initial exploitation of the population, there may be more than 50 year classes available for harvest and yield would be high. However, as the older age classes are removed, only more recent age classes are available for harvest and the maximum sustainable harvest would eventually be only 0.5 quahogs/m^2/year (C in the previous equation).

The maximum sustainable annual harvests of a quahog population can be no greater than the average number of quahogs that enter harvestable size classes annually. Dramatically decreased yields do not necessarily imply "damaged" populations where recruitment into the harvestable age classes has been reduced. Even in situations where recruitment remains constant (and this is likely since it is probable that natural spawner sanctuaries will always exist, i.e. areas that cannot be exploited due to bottom type and/or depth), maximum sustainable harvests of typical populations will probably be less than one quahog/m^2/year. Carriker (1961) stated that 3.6 quahogs/m^2 is a commercially exploitable density. An area that is capable of supporting a sustained fishery of 3.6 quahogs/m^2 /year would have an unexploited density of 80 quahogs/m^2 (if adult survivorship were 95.5 percent). Unexploited populations of such magnitude are rare.

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Aquaculture and Shellfisheries Management in Massachusetts

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Abstract. *Shellfish aquaculture in Massachusetts has grown dramatically in the last few years. For the most part, this is due to the development of a reliable technology for quahog culture, as well as a willingness of towns to provide lease areas. Quahogs are the most important shellfish product grown in the state. Oysters are next in importance, but recent problems with MSX and other oyster diseases have temporarily discouraged the development of new operations. Recent research with disease resistant stocks seems promising, and commercial-scale field grow-out trials using disease resistant oysters are in progress. At this time, there are about 130 shellfish culture operations in Massachusetts, most of them on Cape Cod.*

Management

Shellfish management, and especially aquaculture, in Massachusetts is controlled by the individual towns, with each town having local control over the management of its own fisheries. Massachusetts Marine Fisheries law leaves the specifics of management to local control, as long as the basic underlying laws are observed. Commercial shellfish licenses and aquacultural permits are only granted to town residents, and most towns have different regulations. Recreational licenses are available to both residents and nonresidents. Some towns are in favor of aquaculture, or at least don't prohibit it, while some are not. Towns with an active shellfishery employ a shellfish warden, and in many cases have a shellfish or natural resources department responsible for regulation and management of the resource. Towns may or may not have a shellfish committee.

Although many towns do very little in terms of shellfish management, some are quite active. In such cases, much more can be done than the state ever could hope to accomplish, since there is local input and local involvement. Many towns have also turned to aquacultural methods, in attempts to enhance the natural stocks. This will be the focus of my discussion, since the economic impacts of successful management of the wild stocks are considerable.

Aquaculture permitting

Shellfish lease sites are called "grants", which provide exclusive rights to the area for shellfish production. Specific state laws exist which cover the licensing and operating procedures. To start a new shellfish culture operation may take several months, or longer, depending on the town. Most existing grants average one acre, with only a few larger than five acres.

The applicant must first find a site that has no significant natural shellfish production, as this is a stipulation in state law. The Massachusetts Division of Marine Fisheries surveys the site to determine the level of productivity, and will not approve a site that is already productive. This has prevented many potential conflicts between aquaculturists and shellfishermen, as the grant areas are not naturally productive sites. Further, they can be brought back into productivity by the efforts of the grower.

In addition to a review by the Shellfish Department, the applicant also has to file under the state Wetlands Protection Act, as well as the U.S. Army Corps of Engineers. The "project" is reviewed on environmental grounds, including not only location, but also access, equipment, and methods. Even though the grant can be "licensed" by the selectmen of the city or town, regulatory approval is also needed prior to starting.

Fees at this time are limited to $25 per acre per year. There is some intent on the part of the towns to increase these fees, to perhaps $50 or $100 per acre, as the towns see this as a possible source of revenue. Some towns do not even charge the full $25 per acre, as they feel that the industry present is worthwhile.

Due to the relatively few protected growing areas, and the intense competition for space on the water, suitable lease sites are hard to obtain. Objections from waterfront property owners far exceed any objections from fishermen, who are in a position to understand what is being proposed, where it will be, and what it will actually mean to the fishery and the environment. Much of the more sheltered area along the coast is prime shellfish habitat to start, and this further limits the potential for expansion.

Technology

If you look at the existing technology, in terms of how it is being used in the private sector, there are several systems for growing shellfish (especially quahogs) that work. This is why the industry has recently expanded, as growers can see first hand the methodology and the success rate. When this technology is translated to the town level, in order for it to be effective, the same principles need to be used. However, this is not always the case, and tremendous amounts of money have been lost to "local aquaculture for stock enhancement" programs that did not adhere to proven methods. A quick look at the problems within the industry itself may be helpful.

The entire quahog industry at this time relies upon the hatchery production of seed. Shellfish can be spawned in a hatchery, and (more or less) standard methods exist for culturing algae to feed larvae and juveniles. The point being that there is a supply of seed available for commercial field grow-out, being produced by a number of different hatcheries up and down the coast. This supply has increased as the number of growers has increased.

In most cases, the number one problem to the grower is predation. Growers get around this by excluding the predator: using a variety of cages, nets, and other protective gear. There is no practical way to remove predators from the grant sites; the only other option available is to operate on a large enough scale that can absorb major predation losses while still being profitable. In almost all cases, growers protect their crop until market, since this level of protection has proven itself to be cost effective. Many towns have broadcast seed in a variety of locations, and I believe that the actual return of this practice to the commercial shellfishing industry is low. Further, it is not as cost effective as longer-term protection from predators, even when there is a significant return to the commercial fishery. Local management, and especially stock enhancement, should be viewed with some sense of cost/benefit because there are so many options available. In the last three or four years, budgets have been cut drastically, and there are limited funds that are directed towards any propagation effort, if there still is one.

In any case, first-year seed is planted in some type of nursery system, usually a raised box or cage equipped with a liner that will hold sand. The small seed grows inside the cage, in a few inches of sand, enclosed by mesh, for the first summer. After one summer, seed is then planted in the bottom, and covered with a larger mesh protective netting. Although a small percentage of the stock may be marketable after two seasons on a good site, the crop is harvested some time during the third season. Slow growers require four seasons; some sites are unsuitable because of such a slow growth rate. Hatchery oyster seed is also grown for one season in some type of nursery system, usually floating. Some areas also receive natural sets, but this is limited to only a few towns. Oysters can be held in captivity until market, but problems with the enormous amounts of gear required limit this practice. Bottom culture is the most successful method, even in spite of known predation losses. Disease is the primary limiting factor at this time.

Most commercial hatcheries providing quahog seed at this time are using a specific strain known as *Mercenaria mercenaria notata*. This differs slightly from the wild stock, in that the shells have a noticeable brown striped pattern. Note that this is the same species, is not a hybrid, and is naturally found in the wild population. This strain was selected because of the shell markings, which identify the product as being aquacultured. Not only is this a benefit to growers in marketing the product, but towns also can identify shellfish that were part of the propagation effort. In addition, the use of the *notata* strain has shown that there is a significant recruitment from the adult shellfish on the grants, as *notata* clams have been found in areas where there have been no seeding programs.

Whether the propagation efforts are targeted at the commercial level, or focused more on recreational shellfishing varies with the population of the towns and the extent of commercial activity. Regardless of the aquaculture intent of the town, much more can be done with habitat improvements and utilizing the shellfish growing in closed areas for transplant. Certain areas consistently catch good natural sets. These should not only be used, but should be cultivated as seed producing areas. In many cases, increased cultivation can increase the productivity of these areas, especially if done with setting and survival in mind (instead of an indirect possible benefit from harvesting adults). In addition, they can be managed scientifically, especially if in a closure area. Many Massachusetts towns are paying over $10 per bushel for contaminated stock: spending several thousand dollars per year in a put-and-take type program. At the same time, shellfish from within town could be transplanted for about the same amount. This would provide not only a better product, but more productive seed producing areas, and also some control over managing the resources locally.

Status

In terms of aquaculture, the industry continues to grow at a slow rate. Regulatory constraints are without a doubt a major impediment to increased growth, and in some cases have completely prevented new operations. In most cases, this is not a conflicting situation with the existing commercial shellfisheries, since one of the stipulations for the aquacultural license is that the area is nonproductive to start with. The conflicts that do occur generally are a result of waterfront property owners that are not in favor of any activities on the water, often including commercial fishing. Many commercial fishermen have obtained shellfish leases, and work their beds while still being active in the fisheries. Benefits include a reliable product supply control over product price and quality, a high quality product from approved clean waters, as well as a renewable income using proven methods.

Commercial shellfishing in many parts of Massachusetts has declined, as water quality closures continue to reduce the area available for shellfishing. The price for the product is also not stable, and is presently down. Market demands for a product with a better perceived quality have helped the aquaculture grower, as the aquaculturist can guarantee where the shellfish are from (the lease areas, which are in state approved clean waters), can maintain a consistent supply, and can ensure the highest quality by shipping to order. The aquacultured quahog, for example, is also a noticeably different product to the consumer, providing product recognition. Significant price differences exist between cultured and wild stock shellfish for these reasons, and should continue to help the aquaculture producer.

Questions and Answers

Q. *(Mr. Robert Rheault, SPATCO Ltd.) Karl, how many people are making a living off the aquaculture leases you talked about?*
A. (Mr. Karl Rask, Massachusetts Cooperative Extension) As a rule, an acre site, if fully usable, is sufficient for one or two people. Most of the leases in Massachusetts are two acres or less.

Q. *(Mr. Gerald Carvalho, R.I. Watermen's Association) Have you calculated a break-even price for production, in terms of price per quahog?*
A. (Rask) Right now, at 16 cents per clam, it works, but marginally, since it depends on the survival rate. Some of the markets are over 30 cents per clam.

Q. *(Carvalho) Do you foresee a reduction in the 16 cent per clam break-even figure?*
A. (Rask) Yes, I do foresee a reduction in production costs, and I also foresee an increase in wholesale price for aquaculture quahogs. We are pushing the fact that we can have the product in 24 hours and are sure of the source. This helps out the marketing considerably.

Q. *(Carvalho) Right now you are competing against anywhere from 8 to 14 cent wild harvest quahogs. Right?*
A. (Rask) That's right, and the 16 cent aquaculture clams are selling. But this is a small group of producers, relatively speaking. In total, I would estimate that about 10% of the quahogs sold in Massachusetts are aquaculture products.

Q. *(Mr. John Finneran, shellfisherman) At what density are quahogs planted?*
A. (Rask) They are planted at about 50 per square foot and you can harvest out 40 per square foot. This is not an average harvest but what is possible.

Q. *(Finneran) Do you have any estimates of mortality percentages?*
A. (Rask) Yes. It depends on who's doing it, but you can get 85% to 90% survival from seed clams for some people, and down to around 25% for other people, if they're lucky. We have 135 leases, and many people are new. It takes a few years for people to identify what is going on in their sites.
Q. *(Mr. Chris Wilkins) Narragansett) How long do leases run, and how much are the licensing fees?*
A. (Rask) The leases are administered by the towns, and the license fees are up to $25 per acre per year. There is some talk about fee increases to $50, but the added revenue would be insignificant to the towns and possibly a burden to the guy who might have a few acres. The leases are for 10 or 15 years and renewable. To keep continuity, leases can be renewed two to three years prior to the expiration. Some towns see aquaculture as an economic development opportunity where there is not much else to fall back on. For example, our fisheries are not able to support as many fishermen as they used to. In other towns, there are vocal groups of waterfront property owners who are opposed to aquaculture. In these places, you may have only one lease in town, or none.

Q. *(DeBlois) Do you have the opportunity to play the market?*
A. (Rask) Yes. Prices are high on Fourth of July, Labor Day and others, and the product is there the whole time, ready for harvest.

Q. *(Dr. Monica Bricelj, SUNY-Stony Brook) What is the background of people engaged in aquaculture?*

A. (Rask) They are mostly commercial shellfishermen. It is a portion of their income. They may be lobstering or quahogging too. Most people do other things, because once you have the clams planted, you don't have to be there 10 hours a day.

Research Priorities for Quahog Management: Transcripts of a Panel Discussion

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Joseph DeAlteris

I would like to thank you all for coming to this, our last session of the conference. This session, from my point of view, is the most valuable part of the conference. What we want to do is respond to the comments that were made by Drs. Miller and Nixon this morning in terms of setting research priorities. This will help us at Sea Grant and the Agricultural Experiment Station to develop plans of action for development of proposals. One thing that I want to stress is that we look forward to everybody's interest and cooperation in terms of working with us. I would like to see a module in the next round of Sea Grant proposals that will cover quahog biology, management, policy, socio-economic patterns, etc. So, I urge your input during this process.

To start off, our panelists have a few initial comments. We will start off with Mr. Neal Perry.

Neal Perry

We have heard quite a bit about the quahog resource and ways to enhance the resource. I think that the driving force for change in our fishery may very well be the collapse of the fishery. I don't think that the typical fisherman who goes out to make a day's pay thinks about this too much, as long as that day's pay is there. I don't think that most shellfishermen are aware that there is no longer a true Rhode Island shellfish industry. It *is* in reality an East Coast shellfish industry. There have been considerable changes in the last five years that are continuing. There is aquaculture up and down the coast in competing states that is growing. As you have heard from Karl Rask, aquaculture of quahogs is going on in Massachusetts. It is also growing in importance in South Carolina and Florida. The South Carolina producers claim that their production will capture 10 percent of the national market this year. In addition, there is depuration. A company in New York was just approved for operation, and 3,000 acres of previously closed areas are now available for harvest to supply the depuration plant. The competitive nature of the national quahog industry must be recognized here in Rhode Island or we will face ruin.

I think that we can head off local market collapse by increasing competitiveness by properly managing effort and resources. Many of these things were discussed already today. Limited entry was mentioned by Bob Smith, and John Finneran spoke of putting a value on licenses. There are several fisheries on the west coast in which licenses are limited, and they are controlled on the basis of allowable biomass to be fished. The new entry licenses are non-transferable and issued by lottery, to avoid the problem of creating artificial property. This system would be one that would deal with management of effort.

To manage resources, we must begin to look at recruitment. We have the on and off again transplant programs in Greenwich Bay and other areas. These should continue, but we should look at the use of hydraulic dredges similar to Rask's work, to see if we can improve recruitment in known productive areas that are full of adults. We saw that the Sparsis-DeAlteris hydraulic dredge study did not increase recruitment, but it deserves repeating in the more productive closed areas. The costs for such a study are quite small compared to their potential benefits. This can be done by the public sector.

Either the public or private sector could pursue hatcheries for enhancement of resources such as soft-shell clams and scallops. In time, hatcheries may be useful for quahogs in especially heavily impacted areas. You only require a small area for hatcheries, but more importantly, bivalve nursery areas are needed that require more area. As we have seen in the various presentations, predation losses of juvenile shellfish are high. So the best way to enhance fisheries is to protect the juveniles until they get to a predator-resistant size. Perhaps the past Sea Grant-funded study that showed that marinas can be used as nursery areas can be investigated further. Another management may be rotating closures. We have the beginnings of a rotating closure system now. The Greenwich Bay Management Area is only open during winter, and we have Conditional Area A that opens only when it does not rain very much. Both of these areas have a very high yield when they are open. Other areas for rotational closure might be explored. We could also look into depuration plants or "natural" depuration. In Connecticut, fishermen can take mildly polluted quahogs for depuration. In New Jersey, there are set-aside plots for individual fishermen who will harvest mildly polluted quahogs for relay on their plots in certified water.

I want to reiterate that I think that we now need to become innovative in our ways of thinking about the quahog fishery. Our industry is in a crisis.

George DeBlois

Much of what I have to present has been put together by me, but it is supported by the Rhode Island Shellfishermen's Association. I agree with Neal Perry that our industry is in jeopardy and we must deal with problems now. Methods to manage the fishery that have been unpopular in the past must be considered now and in the future.

Our organization has a few concerns. The first concern is the Sakonnet River. In the early 1970s, the northern end of the Sakonnet River was a very productive quahogging area. There used to be quahoggers who traveled all the way from Warwick Cove all the way into the Sakonnet River, because of the abundant fishable stocks. Another area of concern to us is the East Passage area, along the northeast shore of

Prudence Island from Providence Point to Popasquash Point down to mid-Prudence Island. This area also used to be highly productive back in the 1970s. For some unknown reason, these areas have become very depleted. On any given day, only a few boats can be seen in the East Passage of Sakonnet River areas. These areas are of concern to us because they offer sheltered harvest areas during the windy seasons of early spring and late fall. What we would like the University of Rhode Island and the Sea Grant organization to address is what we might call a "jump-start" program for these areas. What we have in mind is transplanting to reseed the areas.

I propose a massive spring transplanting program into these areas to be carried out in three successive years, with adequate closure times to allow reproduction and spatfall to occur. If successful, fishing in these areas would take pressure off areas that are currently heavily fished. I hope that Dr. Rice and other researchers at the university would consider this plan.

Now, I listened intently to the discussion of the Kassner and Malouf (1982) study and began to worry that it may not work, but the conditions in the Great South Bay and our areas may be sufficiently different to make a try worthwhile. Additionally, I was very impressed by the presentation of the studies on quahog biology by Dr. Monica Bricelj. I now know a great deal more about the species than I did before today.

Q. *(unidentified shellfisherman) What do you mean by productivity? Do you mean the difference between high priced littlenecks and low priced chowders? The Sakonnet is loaded with chowders, but the price is low so nobody fishes there.*

A. (DeBlois) We don't have control over quahog prices. What we do have control over is perhaps enhancing the resource. These areas have not produced a viable set of littlenecks in a very long time.

Comment (unidentified shellfisherman) But the scientific data seems to show that in areas where there are large number of chowders, recruitment of littlenecks is hindered by lack of space. People still don't fish there because of the low price for chowders.

A. (DeBlois) Maybe I don't go to the right places, but every time I go there, I don't catch that many "bigs."

Moderator's comment (DeAlteris) I think that this type of thing calls for another bay-wide standing crop-stock assessment study. This type of argument between fishermen about where the stocks are and where they are not can go on forever. This may be a prelude for many things that need to be done. We need the answer to the question, "What does the resource look like today?" With that you can make a decision as to whether you need spawning areas or that sort of thing.

Q. (Mr. Peter Canis, shellfish diver) George, how do you plan to transport these quahogs to these two areas, by dredge boat or by individual quahoggers?

A. (DeBlois) It would have to be coordinated between the university and DEM. There is sufficient source stock in Mount Hope Bay and Bristol Harbor.

Moderator's comment (DeAlteris) I think that the question—"Would you support the use of dredge boats for moving shellstock from polluted areas into the transplant beds?"—was more to the point.

A. (DeBlois) Yes, I would support dredging for this purpose.

Q. *(unidentified) Are you referring to the entire Sakonnet River or just a portion for a t rial transplant?*

A. (DeBlois) The area I refer to is at the northern end of the Sakonnet River. I worked the are as recently as a year and a half ago. I fished regularly in this same area during the 1970s when littlenecks were plentiful. This should be studied by university researchers. Why haven't the littlenecks returned?

Moderator's comment (DeAlteris) Let's move on to the next panelist. We can return to questions later.

Gerald Carvalho

Some of the questions that Neal has raised and George has raised lead directly into some of the questions that I will raise. It is said that the reason for the recent poor prices for quahogs has been because of the bad publicity that we have been receiving in the last couple of years. The economy is down, and a combination of that with the bad publicity has created a depressed market.

Beyond this, many problems in the industry are self-inflicted. We are still selling Rhode Island quahogs in used Texas onion bags. This is not the best way to market our product. In my opinion, Rhode Island produces the best quality hardshell clam in the whole world. I challenge anybody from any state or any country to bring their clam and put it up against the Rhode Island littleneck in an unbiased contest to see which one tastes best. We have the product, but what we don't have is the marketing program. We don't have a program where we sell the best product, and get the best price for them. I would like to see the university study the feasibility of creating a marketing board. In other areas, for example the California orange growers, there are marketing boards. This is done to make the best possible returns on investment. The Rhode Island quahogs, 90 percent of which are shipped out of state, are simply dumped on the market, fetching prices at whatever the market will bear. We will continue getting the lowest price that people are willing to pay as long as we continue dumping the product on the market. I think that we can make some serious changes in the marketing of our product.

Neal raised the issue of aquaculture. Some say that next year aquaculture will capture 10 percent of the market. I think we need a study by the university to find out how much of a threat aquaculture really is. Do we have a contingency plan? If aquaculture captures 10 percent this year, an extra 10 percent the year after that, and another 10 percent the year following, then the Rhode Island shellfish industry will be in serious trouble. We will not be able to compete as we have competed over the last 20 or 30 years. The game will change radically. It will be the free and common Rhode Island fishery against the strength of aquaculture. Do we have a contingency plan? How are we going to deal with that type of competition, or are we going to fall by the wayside? We need an objective evaluation of potential threats.

Another thing that the university might look at is how we have addressed the shellfisheries in the past. We have looked at it in many instances from an environmental standpoint (i.e. How do we grow it? How do we limit harvest? Do we have a transplant?). In fact the hundreds of independent fishermen are small businessmen. There is a profit. Nobody would go out to be a fishermen if he could not make a profit at doing it. We need to look at the people in this industry as small businessmen, not just as people who go out to gather what nature has dumped. We need to change our perspective. Things are changing, and we have to change with it.

Anne Holst

The Division of Enforcement is obviously not in the business of setting up management programs. However, the most important thing that I can say on the behalf of the division is that if there are management programs, they must be feasible for officers to enforce. I think the key problem with both Enforcement and Fish and Wildlife is that we are practically pulling rabbits out of hats. We do not have adequate resources in either division to give you quahoggers adequate enforcement or research. It will be up to the industry to **demand** better from the state.

Q. (Mr. John Finneran, shellfisherman) Sergeant Holst, how much more manpower would you suggest is necessary to assure that enforcement regains its high standards as set in the past?

A. (Holst) Well from listening to some of the management suggestions from the panel, more enforcement will be needed if these suggestions are acted on and plans are to be carried forward. For example, depuration in Connecticut was mentioned. Connecticut tries a form of depuration, and Massachusetts has depuration. I know firsthand some of the things that go on in Connecticut, because we have assisted when polluted shellfish is taken from the Pawcatuck River. When I was involved, there was absolutely no control over where the shellfish went, whether it went to the relay areas or onto a truck directly to market. Problems in Massachusetts were highlighted in a film called *The Great Clam Scam* by a television station in Boston. It was an exposé on what was happening on the clam flats around Boston and how polluted product was getting directly to market. There is no way that the thirty enforcement people we have now could monitor a depuration program effectively, unless the depuration is done by one person, and harvesting is carried out by using one dredge boat.

Comment (Mr. Neal Perry, panelist) The New York depuration has built into it a provision for self-funding by industry for payment of enforcement personnel. Self funding by industry is a viable course of action if there is a collective will.

A. (Holst) As it goes now, there is no way we could do that type of thing. The number of extra enforcement officers needed would depend on the type of management program, but to do today's job, we could use another 20 people. Even if it was not 20 conservation officers. If we were able to hand off such things as nuisance animal complaints to animal control officers, or the handling of roadkill animals to an appropriate civilian person, we would be better able to focus on shellfish issues.

Q. *(Finneran) Do you think that specialization of tasks in the division might be helpful, such as a dedicated animal control person, or a dedicated inland fisheries person?*
A. (Holst) Well, there are basic problems with having specialized enforcement personnel. There are provisions in our union contract that exclude this, but civilian animal control officers are an option.

Q. *(Ms. Kathleen Castro, University of Rhode Island Fisheries) This morning you mentioned that education of the general public and specific groups such as the Southeast Asians is a problem. Do you think that an educational program by the university with multilingual printed materials could be helpful to enforcement officers?*

A. (Holst) Yes, I think so. We had a very successful education program for operators of Asian markets in the Providence area in cooperation with the Rhode Island Health Department, in which translators were available. Interagency education programs are quite welcome.

Jeffrey Willis

There is one research topic that the Coastal Resources Management Council staff asked me to present today. This would be an update of the shellfish atlas that basically shows where the shellfish resources are. This was mentioned earlier in this panel discussion, and we need it for many of our coastal management decisions. At the CRMC, we must make decisions, but there is no fishery expertise *per se*. We must rely on the DEM Division of Fish and Wildlife and the Fisheries Council. Likewise, aquaculture permitting is one of our responsibilities and we must rely on outside expertise of DEM staff for input.

Another area that CRMC has become involved in are the harbor management plans of coastal towns. We will ask the towns to locate their shellfish resources so that mooring fields and other activities minimally impinge on shellfisheries. Additionally, knowledge of shellfish resource location is important in our Special Area Management Planning process; for example we utilize Art Ganz's expertise to identify shellfish resources in the Pawcatuck River area. So, for these reasons, the CRMC staff highly recommend a comprehensive mapping of shellfish resources in Rhode Island waters.

Arthur Ganz

I envision two things. First are research opportunities, research needs, and some of the luxury items that the University of Rhode Island can provide in terms of resources. But right now we have a more immediate problem—David Borden has said it, Anne Holst has said it, and I'm going to say it again. The Department of Environmental Management is the natural resources agency of the state. We are underfunded and understaffed. With the cutbacks that have taken place over the last year, things are even worse. Our resources are in a more critical condition now than ever before. With this economic recession, more and more people are forced to take to the water to make a living. The Department of Health has a few representatives here in the audience. The Health Department is responsible for market and restaurant checks as part of the shellfish sanitation program and total food safety program. Cuts in the Health Department make it so that they are now operating below the bare bones. Functions of the state Departments of Health and Environmental Management cannot be taken over by the university. Adequate funding is needed for agencies to do their *grass roots* jobs.

In terms of my function in DEM, I am the person who is essentially the resource manager for the shellfish industry. I approach things from two broad directions—from the point of view of protecting the resource and from the point of view of serving industry needs. More recently, my efforts have been in the area of addressing industry's needs. This effort has been a need-to-know, reactive, brushfire fighting process. When these things come up, they place long-range planning and worthwhile projects such as the shellfish atlas on the back burner. I have been working on the shellfish atlas for five years, but it takes a back seat to such issues as the diver-digger controversy.

In terms of resource status, we do some surveys in critical areas. We can address resource issues on an area-by-area basis. If we talk about resources in small areas such as Mill Gut or Bissel's Cove, we can do that in a day or two. Larger areas such as the Pawcatuck River or the coastal ponds are an entire summer's work. The large abyss of Narragansett Bay is just too big to be managed with the current DEM Fish & Wildlife staff.

Another direction we go in is stock enhancement programs. We do transplants when funding is available. These provide huge economic returns to the state. Like Jeff Kassner, we do stock enhancement activities such as maintenance of "spawner sanctuaries" in two of our coastal salt ponds; one has worked well and the other has been a miserable failure. We have all sorts of stocking programs, such as an oyster seeding project and a scallop seeding project. For about 10 years, we operated our own shellfish hatchery, but now there is no money or staff, so the facility just sits there. The expertise is there, all we need is the money.

We do set up shellfish management areas. There are 15 of these areas around the state in which catch limits and/or catch seasons are modified. These are successful for the most part. With more resources, we could do more.

To meet the needs of industry, my most valuable tool is the Quahog Committee, that is a sub-committee of the Rhode Island Marine Fisheries Council. At meetings, we have a dialog between the agency and industry. This has been going on for about ten years now. Bob Smith, in his presentation earlier today, said that the key to fishery management is negotiation. I cannot agree more and we try to work toward this ideal at the Quahog Committee meetings. Very rarely do people who go to the Quahog Committee or the Marine Fisheries Council with ears closed and mouth open get anything accomplished.

Q. *(Ms. Victoria Langley, Narragansett Times) Many of the license and fee increases have been ostensibly dedicated to many of the purposes you have outlined. Where should additional funds come from to allow your plans to go forward?*

A. (Ganz) In a sense, proper funding is a matter of priorities.

Q. *(Langley) Whose priorities? The legislature's? Agencies'? Taxpayers'? Industry's?*

A. (Ganz) All of the above. The people at the grass roots level are the ones who are actually doing the job. The biologist in the field must have equipment to do the job. But with the shortage of funds in the state, decisions must be made between loss of personnel and project funding. Project funding takes a lower priority.

Shellfish projects are funded 100 percent by the state. There plenty of federal grant opportunities available for finfish, because they are migratory and can cross state boundaries. All of the DEM Fish and Wildlife personnel are at least partially funded in their research efforts except for one, me. Shellfish management is seen by federal agencies as purely a state or local matter. We have heard that in Massachusetts, the towns set aside money for shellfish management. Shellfish management at the local level offers the advantage of being able to dedicate funds without having them filter through a huge bureaucratic system. But the geography of Narragansett Bay precludes a town by town management system.

Comment (Mr. Gerald Carvalho, panelist) I would like to make a comment. The state must set its priorities on how it will spend its money. The DEM budget increased by almost $4 million this year, yet a license fee increase was found to be necessary to survive—or so Arthur was told. Our license fees are now double what they are in neighboring states, and we still cannot do the job right. I don't think that more money from the fishermen is the answer. I think that good leadership is the answer. I think that setting better priorities is the answer.

While a town, such as Nantucket can spend $181,000 on a $1.3 million shellfish industry, our state in the last two years could not come up with $20,000 for transplants. The state didn't come up with it because it was thought to be unimportant. It is important to support all of the social programs that help to make you popular and get you elected to office. It is nice to help all of the people in need, such as provide transportation for the handicapped, and all of these noble things. Societies that do things like this have to be very wealthy. They must produce something. If you do not produce anything, you cannot afford all of these luxuries.

What the leadership of the state does not realize is that if they do not take steps to make their businesses more productive, there is no tax money to fund all of these noble endeavors. The leadership does not spend money on endeavors that actually **make** money for the state of Rhode Island. Ninety percent of our product is shipped out of state and money comes in to feed the machine. The state has its priorities screwed up. When they have the goose that lays the golden egg, they look at the egg with awe and grab it to divide among themselves. And when the pieces get smaller, instead of putting a few eggs aside to produce more geese and more golden eggs, they grab the goose by the neck and squeeze it. They say that these fishermen have to pay more—that's how we'll get the job done. In fact, shellfish are a state resource and the fishermen provide a service by harvesting the product. You don't get more product by beating up the guy who provides the service. You in fact go to the owner of the product, the sovereign, the people. When you police the resource, you are not policing it just for the fishermen, you are policing it for the owners of the resource. It is a state responsibility. The state can recognize its potential and capitalize on it, or it can fail to. I believe that in the last two years especially, the state has failed.

Moderator's comment (DeAlteris) Thank you, Jerry.

Michael Rice

In terms of research priorities, I see two major areas, and these closely follow my presentation earlier today that sought to identify holes in the research data base. The first area is what I would consider socioeconomic studies. These would follow closely the Holmsen (1966) and Holmsen and Horsley (1981) studies. We need information on numbers of tongers, numbers of rakers, and numbers of divers. The estimates we currently have are practically pulled right out of a hat. These numbers will change with the status of the economy. We know now that with the bad economy, numbers of shellfishermen are high, but we do not know how high is high. We don't know average catch. We don't know what an average bullraker takes, and we don't know what an average diver takes. We have a lot of suppositions and we have a lot of speculation, but we don't have any hard data.

The second group of items in the socioeconomic area would be marketing studies. This is very important. Jerry mentioned the marketing of oranges in California. Closer to home, in terms of location and product, Maine has made a very good effort at marketing their lobsters. They even have a lobster on their license plate. Objectively, Maine lobsters are not any different than anybody else's lobsters, but to the general public when people think lobsters they think Maine...Maine-lobsters, lobsters-Maine. This could be done for the Rhode Island quahog. I think that a very high priority would be for our resource economics, marketing, and anthropology people to study the markets and to help in the strengthening of industry organizations so that fisherman-directed marketing can develop.

In terms of biology, we definitely need estimates of recruitment rates in areas throughout Rhode Island. We have seen evidence that there are areas that may go years without a set followed by a good year class, but in other areas there appears to be annual recruitment. For example there has been an active quahog fishery in Greenwich Bay continuously since before the 1920s. Fairly easily, we can get some estimates of natural mortality of quahogs in the bay. This all leads to the big question, and Steve Malinowski ended his presentation with it, "Just what is the maximum sustainable yield (MSY)?" I suspect that the MSY in Narragansett Bay will be higher than the areas in Long Island Sound that Steve spoke of, but we really don't have a quantitative answer. Once we have the answer to the MSY question and the catch effort quantification, we will be able to answer in a very rational way whether or not the current 12-bushel limits are sufficient to protect the resource.

Q. *(John Finneran, shellfisherman) You mentioned maximum sustainable yield. Could there be a cost-benefit analysis on programs designed to increase MSY by enhancing stock?*

A. (Rice) This would be part and parcel of studies dependent upon our understanding of what recruitment rates actually are. We cannot begin to make comparisons unless we have a starting point.

Comment (name not stated, shellfisherman) Figures from 1955 and 1985 are around 5 million pounds maximum sustainable yield. It seems to me that if you go out and cannot make money, you have surpassed maximum sustainable yield. That is where we are now. There have been a whole series of technological improvements in tongs and bullrakes that make for better access to unfished stocks. We are now running out of stocks to fish. We have gone along this pathway for so long that the resource is stressed. It is a variable resource and harvestable amounts change. In some of the talks today, it is suggested that predation on juveniles is a major factor controlling recruitment. I would suggest studies on some sort of biological or mechanical predator control to increase recruitment. As it is now, I'm sure we have exceeded maximum sustainable yield. This is based on a historical perspective; I cannot catch what I used to on the bay.

A. (Rice) Points well taken, but the five million pound figures are not in fact maximum sustainable yields, but actual landing weights. These were not sustainable, because landings dropped in later years.

Comment (Colonel Edgar Thompson) I want to commend the university for making the effort to get the information from those who have it to those who sorely need it. On the other hand I think that a great deal more must be done in this field. I think that the university could be a good "running block" to take the information from the little guy who has it but is afraid that he will be labeled either a law breaker or an amateur ignoramus who is trying to pass the word about something he knows about quahogs.

There is a great deal that the university can do to educate the public. Television may be an excellent medium. For example, if there is something good being done in terms of clam culture in Charlestown, the university might bring this to the attention of the public in general via the appropriate media outlet. Such a system would be a two-way flow of information with feedback to the university. We have many talented "lay people" out there, and I think that the university should tap this resource.

Comment. (name not stated, shellfisherman) I find it refreshing that after a very tough winter, a group of people from different careers and backgrounds can get together to calmly discuss the pressing problems of the shellfish industry. Robert Smith spoke of the key word—negotiation. We need to sit down and chat about problems.

Along the lines of education, I find it rather frustrating that now that the license fees have increased to $200, you only get to see the charts out in the hall. Pamphlets and information about pollution closure areas are not readily available at the point of purchase of the license. Sometimes they are not available anywhere during major portions of the year. Another problem that has been alluded to before is that if you chat with conservation officers about specific laws or regulations or closure areas, there are frequent inconsistencies. I really feel that DEM Enforcement could do a better job of getting information out. I feel bad about some of the stories about what some of the Southeast Asian community members are doing, but a greater education effort is required. The gentleman before me spoke of "amateur ignoramuses." I know recently that people have been laid off from Direktor Shipyards or Electric Boat Company and have turned to shellfishing to put food on the table. I've seen people out in management areas during days or times when they were not supposed to be there. They often do not even have a good idea how to use tongs or a bullrake. It would be a shame if these poor guys got busted for doing this. Losing their gear and boat on top of the rest of their problems is really unfair. An education program for these newcomers is needed. In the name of fairness, education is important.

To Jeff Willis of CRMC, I would like to say that we have heard a great deal today about aquaculture. I have heard horror stories about time delays in the permitting process for everything from dock refurbishing to adding an extra room on a house in the coastal zone. If we have all of these time delays, aquaculture is not going to happen in Rhode Island. CRMC will not be able to change rapidly enough to meet industry needs. Are you aware of these things? Things must be done in a rational, timely manner. People can't wait to pay their bills as the process grinds through the system. People should perhaps have "trial permits" to speed things along. I hear horror stories about the CRMC aquaculture permitting.

A. (Mr. Jeff Willis, panelist, CRMC) Many of the past delays are unfortunate, but we have been working to improve the system. We split up our staff into teams of biologists and policy people for maximum efficiency. We have four teams, so that should speed up the process. We have recently had a major staff training program in which we have looked at all of the regulations in an effort to establish a uniform application policy. This does not specifically answer your aquaculture question, but it does get at a process that should be helpful in the future. We do want to work with aquaculture as it develops in Rhode Island.

A. (Mr. Arthur Ganz, panelist, DEM Fish and Wildlife) I would like to address the question about education. The centralized Education and Information office of DEM has been eliminated. The Division of Water Resources and the Division of Fish and Wildlife must assume the responsibility for education without a concomitant increase in support or resources. This is the key reason that although information exists, it is often very difficult to find.

Comment (Mr. Keith Griffith) It seems to me that this discussion of funding boils down to politics. This gets down to marketing. Unless the politicians see the importance of the industry, nothing will be forthcoming. We as fishermen might do something as simple as having a bumper sticker that says "Eat More Quahogs, They're Good for You." It sounds silly, but it increases awareness of our product. Everyone is aware of Idaho potatoes or California raisins. Why not Rhode Island quahogs? We need to work on increasing the awareness of politicians. But, unfortunately in this state, politicians will not see the importance of something unless they can get their fingers into the pie.

Moderator's comment (DeAlteris) I have worked for a number of years in Virginia. There, there was just about as much disorganization in terms of the industry. Yet they were able to come together enough to create a Virginia Seafood Council, that was not just a group of marketers or buyers, but an appendage of the Virginia Marine Resources Commission (much like our DEM Fish and Wildlife). Their entire purpose was the marketing of Virginia seafood products. It was formed by the impetus of industry. Fishermen insisted that license fees and taxes on catch be directed toward funding the Seafood Council. We have seen so many money problems here in Rhode Island. I would hazard a guess that if the industry came together and spoke in unison, things would get done. As difficult as it may be, the industry, speaking in unison, could say something like, "We have done a marketing study and aquaculture is a threat, we need to consider depuration." Whatever is agreed on does not matter, but a unified voice is important. There are plenty of models out there to emulate. A unified industry can finance plans by self-tax on fishery sales. Virginia, for example, has a very good program for depurating James River clams. This has been going on for 20 years, now they are using cage depuration in clean waters. This is done by a few buyers, but one could argue whether or not that would work here. In any case, you must come up with some plans, and workable plans come only by consensus and a unified voice.