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SUFFOLK COUNTY'S HARD CLAM INDUSTRY: AN OVERVIEW AND AN ANALYSIS OF MANAGEMENT ALTERNATIVES

A Report of a Study
by the
Coastal Ocean Science and Management Alternatives
(COSMA) Program

of the

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COSMA: An Overview

The Coastal Ocean Science and Management Alternatives (COSMA) Program was initiated by the Marine Sciences Research Center in 1982 with support from the William H. Donner Foundation. The goal of COSMA is to improve coastal management. COSMA concentrates on two different kinds of activities: on developing new and more effective ways of using scientific and technical information in environmental decision making, and on analyzing important coastal problems of regional, national, or international scope by bringing together scholars from different disciplines and from different institutions.

COSMA is a vehicle to bring together scholars to respond effectively to problems of coastal marine environments which result from society's uses of those environments. The Program is not intended to provide a home for scholars to select problems that interest them. The problems will be used to "select" the problem solvers rather than the reverse which is the way most academic institutions operate. To succeed, the Program must attain and sustain a good match between the problems and the problem solvers. This can be done only if there is great flexibility in the selection of problem solvers. The structure of COSMA ensures the potential to match problem solvers with problems. The most pressing environmental problems are interdisciplinary, and can be resolved only by teams of specialists working within their own disciplines but in close and carefully orchestrated coordination.

Several criteria are used in selecting problems for study through COSMA. Problems must be related to the coastal marine environment. They must be important problems whose solutions are truly interdisciplinary. The prospects should be good that the problems will be tractable with the resources in talent, time, and money that are available to the Program. Not all important problems are tractable. There will be no shortage of appropriate problems. The difficulty will be in selecting among them.

Once a problem has been chosen and the problem solvers selected, the next step will be to identify the full range of plausible alternative ways of dealing with it. Then a rigorous assessment will be made of the environmental, economic, socio-political and public health effects associated with each alternative. After this analysis is completed, the results will be cast in forms appropriate for decision making; forms that facilitate comparison of the advantages and disadvantages of each of the alternatives and selection of the most appropriate alternative.

MAJOR FINDINGS

HISTORY AND CURRENT STATUS OF THE HARD CLAM FISHERIES IN SUFFOLK COUNTY

- Hard clamming as a major industry has developed relatively recently in Great South Bay (GSB).
  Justification: Until the 1930s the oyster industry was the major shellfishery in GSB. Environmental changes in the Bay caused oyster stocks to decline while hard clam (*Mercenaria mercenaria*) stocks increased.

- Many current management practices and attitudes can be traced to the oyster fishery.
  Justification: The restriction of harvesting to hand operated equipment and the planting of adult brood stock both began in the oyster industry in the 19th century. The present attitude of baymen toward leasing can be traced to the 1890s when the fishery was dominated by a small number of large lease holders.

- Maximum hard clam harvest from GSB occurred in 1976. Since then landings and stocks have decreased.

- During the period 1975-80, the hard clam resource in Great South Bay was overfished, i.e., harvested at a rate that exceeded recruitment.
  Justification: It has been shown that for the period 1975-80, harvesting mortality exceeded natural recruitment.

- Possible reasons for the decline in hard clam abundance include: over-fishing, removal of clams from uncertified areas, harvest of seed clams, increase in Bay salinity, deteriorating water quality, and reduced reproductive success.

- Hard clam harvest from Suffolk County's north shore bays and from the Peconic Bays is low relative to Great South Bay, but at its peak (1961-63) Huntington Bay provided nearly half of New York's total hard clam landings.

- Of Suffolk County's north shore bays, Huntington Bay supports by far the largest hard clam fishery. Landings from north shore bays are far below their peak values but provide an important contribution to total Suffolk County hard clam landings.

- The decline in harvest from Huntington Bay is due to a combination of factors including, but not necessarily limited to, large-scale harvest of seed clams in the early 1960s and increases in the area closed to shellfishing.

Justification: Recollections of baymen from the period and newspaper accounts indicate that large, illegal harvests of seed clams did take place in the early 1960s. Total closed area in Huntington Bay has increased since 1960 and some of the new closures were in very productive areas.

- Hard clam density in the Peconics is much lower than the average density in GSB.
  Justification: New York State Department of Environmental Conservation (DEC) surveys show hard clam densities as high as 1.6 clams/m^2 in only a few areas of the Peconics. Buckner's (1984) report shows an average density of 5 clams/m^2 in certified areas of Islip waters.

- Hard clam production in Shinnecock Bay at present is low relative to that of Great South Bay.

- Prior to 1938 there was no hard clam fishery in Shinnecock Bay because salinity was too low as a result of the lack of an inlet between Shinnecock Bay and the Atlantic Ocean.

- The status of Moriches Inlet and runoff of wastes from duck farms have been major factors influencing hard clam production in Moriches Bay, although there never has been a major hard clam fishery there.
  Justification: During periods when the Inlet was closed (prior to 1931 and from 1951 to 1953) poor flushing allowed duck wastes to build up in the Bay. This led to the closure of large areas to shellfishing and poor quality of the clams even in open areas.

- The limited hard clam production in Moriches Bay, at present, may be the result of a lack of setting rather than in inability of the Bay to support growth of hard clams.
  Justification: Turner (1983) found that the growth rate of hard clams is greater in Moriches Bay than in GSB. Carter has hypothesized that the residence time in most of Moriches Bay is less than the length of the planktonic larval stage of hard clams (see Spawner Sanctuaries, this volume). The coves in Moriches Bay may have sufficient residence time, but their clam stocks are depleted.

THE NEED FOR ACTION

- o Any over-all fishery management program that does not maintain a healthy resource is a failure.
  Justification: If management programs do not ensure that stocks are maintained at levels which can sustain the harvests taken, the resource will decline, landings will fall, and the number of baymen who can expect to make a reasonable living will decrease.

- o Without changes in existing management practices, it is unlikely that the hard clam fishery will recover and be stabilized.
  Justification: Under present circumstances the clam harvest, in the long run will continue to decline. The decline will not be regular because setting will vary due to natural conditions. Since the industry is capable of exploiting a new set as soon as it reaches legal size occasional large sets will not contribute to a sustained population.

- o Present regulations on hard clam harvesting have not restricted the total harvest to a level the resource can support.
  Justification: New York State production of hard clams, most of which come from Suffolk County, dropped from 9 million pounds of meats in 1977 to less than 3 million pounds in 1984

- o Some mechanism is needed to control harvest if overfishing is to be prevented.

- o Water body-wide management would make sense from economic and ecological points of view.

- o Certain controls on the hard clam fishery are required even without any concern for the future of the fishery.
  Justification: To ensure compliance with Federal regulation of interstate shipment of shellfish, an adequate enforcement program is required to prevent harvest from uncertified areas.

- o Development of vacant and agricultural land coupled with population increases in Suffolk County projected for the next 35 years will place additional stress on the environment which could have ramifications for the County's shellfish resources.
  Justification: The impacts of development on water quality could affect adversely spawning, survival, and growth of hard clams. The number of potential recreational and commercial harvesters will increase. The acreage closed to shellfishing in the County is likely to increase over the long-term, but it is not known by how much.

ASSESSMENT OF HARD CLAM MANAGEMENT ALTERNATIVES

Limited Entry and Limited Catch

- Sustainable yield is defined to be the level of harvest that the stock can support over an extended period. Reliable estimates of the sustainable yields of hard clams are unavailable for any of Suffolk County's bays. Only for the Town of Islip is such an estimate available.
  Justification: Estimates of sustainable yields have been made for Great South Bay but the information upon which they are based is inadequate for that purpose. Stock assessments carried out by the Town of Islip offer an empirical basis for determining sustainable yields for that Town's waters.

- Restricting the number of participants in the fishery (limited entry) and setting total catch quotas are two management measures that have not been used, but which could be used to control total catch of hard clams in Suffolk County waters.

- Implementation of any management strategies which would limit entry to the hard clam fishery would be controversial and would require courageous action by decision makers. Any limited entry program would require effective enforcement which would be costly.
  Justification: The prevailing sentiment among baymen is to oppose any attempt at limited entry. These baymen are a persuasive and politically powerful group. Additional problems would result from the increased enforcement costs if a limited entry program were instituted.

- Individual towns could institute limited entry programs for hard clam fisheries in town waters by themselves or in cooperation with the State Department of Environmental Conservation. In either case, the question of issuing permits to harvest other species of shellfish would have to be resolved.

- A system of transferable quotas is one of a variety of mechanisms that could be used to control the total harvest and apportion it among harvesters.

- The existing minimum legal size limit should be enforced. However, since this size restriction does not ensure that clams will reach their full spawning potential, the addition of a maximum legal size should be considered to enhance reproductive capacity.
  Justification: Small clams must be protected from harvesting to ensure that they reach reproductive age. An upper limit on the size would further enhance the

reproductive capacity of the resource because cherrystones and chowders produce many more eggs than smaller clams.

Selective Closure

- o There are four basic selective closure strategies: (1) closing areas until most small clams reach harvestable size; (2) closing areas after some prescribed optimum yield has been reached; (3) closing areas until the harvestable population reaches some minimum threshold level, and (4) closing nearshore areas to ensure a winter grounds for harvest during inclement weather.

- o The choice among selective closure alternatives will depend upon the goal of the management plan. Selected closure can be used alone or in combination with other management alternatives.

- o All types of selective closure need to be combined with population assessments as an integral part of the management program.
  Justification: Population surveys must be conducted prior to closing to determine stock size plus recruitment and mortality rates. Additional (annual) surveys are needed to monitor the rate at which stock rebuilds. Even closures to maintain winter harvest grounds require stock assessment for proper management, since the area must have an existing stock of harvestable density.

- o To be optimally effective, selective closure should be combined with some type of program of limited entry, limited catch, or both.
  Justification: Maintenance of some minimum stock size in an area may be necessary for successful recruitment. If this is true, then limited harvest needs to be implemented during the period when an area is open. Limited catch might also be implemented to prevent overharvesting of areas which remain open, and to prevent uncontrolled harvest on newly reopened areas.

Spawner Sanctuary

- o The spawner sanctuary concept is a refinement of the spawner transplant program. A spawner sanctuary is an area stocked with large, fecund hard clams to enhance fertilization of eggs, and which is located so that it will enhance the set of sanctuary produced larvae in preselected areas which are capable of sustaining good growth and high densities.

- o The recent development of numerical (computer) models to simulate the flow fields of coastal embayments makes it possible to select sites for establishment of spawner sanctuaries which will supply larvae to preselected target areas with an accuracy not previously possible.

- The evaluation of the spawner sanctuary management alternative should be based on its contributions to standing stocks in, or harvests from, the target areas over a period of at least five years.
  Justification: Once stocked, and if poaching is not excessive, the original brood stock should remain fecund for five years, on the average (based on current knowledge of survivorship and fecundity), during which it should contribute to standing stocks.

- It is unlikely that any of the north shore bays is a good candidate for spawner sanctuaries, although information needed for a rigorous assessment is not available.
  Justification: The large tidal exchange between the north shore bays and Long Island Sound, relative to the volumes of these bays, indicates that the residence time of water is probably 7-8 days rather than the 20+ days needed for establishment of an effective sanctuary. Residence times of these bays could be determined with dye release studies.

- Shinnecock and Moriches Bays probably are more appropriate for establishment of spawner sanctuaries than the north shore bays, but less suitable than Great South Bay.
  Justification: Because the residence times of water of Moriches and Shinnecock Bays are greater than those of north shore bays, the former are more suitable for establishment of spawner sanctuaries than the latter. Moriches and Shinnecock Bay are somewhat less appropriate for establishment of spawner sanctuaries than Great South Bay because they are smaller and have shorter residence times. A suitable model and data base exist to evaluate the potential of Moriches Bay for spawner sanctuaries and might also be used to evaluate Shinnecock Bay because the two bays are similar.

Seed Planting

- Seed planting programs are popular among baymen and most town officials as a hard clam management alternative.

- Although seed planting may not be practical as a method for producing a substantial increase in the number of clams available for harvest, it may be useful in enhancing and maintaining recreational fisheries in small areas, and under certain conditions, in rehabilitating stocks for commercial harvest in selected and restricted areas.
  Justification: If specific criteria are met, seed planting could be used to rehabilitate an area in which stocks have been reduced below harvestable density. Such an area should have--in addition to reduced stocks--a combination of biological and physical

factors which make successful recruitment infrequent, and characteristics which permit a survival rate of at least 10% from 25 mm to littleneck size.

- It is very unlikely that seed planting programs of the scale now carried out can contribute in any significant way to total harvest. Typical town seeding programs would have to be increased by at least ten-fold, and perhaps by as much as one hundred-fold, to make a significant contribution to total harvest.
  Justification: Total annual hard clam harvest for a town on Great South Bay is currently about 100,000 bushels. A typical town seed planting program would plant about 2 million seed clams at 25 mm. Even if 100% of the seed planted were harvested as littlenecks, the town's annual harvest would be increased by only 4%. A more realistic survival rate would be 15% which would result in an increase in landings of less than 1%.

- A rigorous assessment has never been made, for any relatively large-scale town program, of the survival of planted seed clams and their overall contribution to harvestable stocks.

- Seed planting should be evaluated rigorously as a hard clam management alternative. The evaluation must include three primary criteria: the effectiveness in achieving the goals of the program, the scale of the program, and the costs of the program.

<u>Predator Control</u>

- Potential predators of hard clams are many, and vary with the size of clams. The life stages most vulnerable to predation in nature are post-set clams up to about 25 mm in length. If clams in nature are to be protected against predators, the life stage to concentrate on is early post-set clams between 4 and 25 mm in length.
  Justification: Larval and early post-set clams up to about 4 mm cannot be protected economically in the field. Once clams reach about 25 mm length they usually are much less vulnerable to predation.

- The environment may be manipulated to enhance hard clam production either by making conditions more favorable for the hard clam or less favorable for its predators.

- Five general methods of hard clam predator control in the wild fishery have been identified: (1) chemical methods, (2) gravel or shell (aggregate), (3) mechanical methods to collect predators, (4) fences, and (5) ecological approaches.

- Protection of clams in relatively small areas against predators may be feasible using available methods, but protection over large areas is not practical at present. Relatively little is known about hard clam predator controls. It would be useful to obtain the information necessary to rank predators in terms of their importance on a water body-wide basis, and to understand how their importance varies under different environmental conditions.

Justification: The primary reason for considering predator control is that predation may be the most important factor controlling recruitment, although not the only one. Conditions under which predator control is not feasible or cost-effective should be known. Effective predator control will require a knowledge of each predator's life cycle, and of key or limiting factors that control predator distribution and abundance. Size-specific predation rates also should be known.

- Unless predation can be controlled, it is unlikely that other management approaches will be effective in increasing and sustaining enhanced stocks and catches of clams in the Peconics estuarine system. Predator control is necessary but may not be sufficient to enhance the resource in this area.

  Justification: Density of hard clams in Great South Bay appears to be about ten times that in the Peconics. There are more whelks and starfish in the Peconics then in Great South Bay. The lower abundance of clams is assumed to be related to the greater abundance of large predators.

Mariculture

- Mariculture is the manipulation of all or part of the life cycle of a marine organism to enhance its production. Mariculture may be public or private in its orientation. The goal of public mariculture is to enhance natural stocks in a public fishery in a cost effective way. The goal of private mariculture is to turn a profit. Public mariculture to enhance stocks of hard clams for the catch fishery is encouraged by baymen and is facilitated by town, county and State governments. The development of private mariculture is discouraged by baymen and impeded by existing attitudes and regulations.

- The practices of private and public mariculture are not mutually exclusive. Public mariculture activities rely upon private mariculturists, on Long Island and elsewhere, for seed clams to augment natural stocks.

- Private mariculture is not a management alternative for rehabilitating and sustaining the wild harvest, but may play an important role in the future of hard clam production and in preservation of the traditional lifestyle of baymen.

- Private mariculture requires the allocation and exclusive use of segments of the sea floor. If publicly-held lands are allocated, private mariculture will compete with public sector users.

- The development of private mariculture on Long Island will require guaranteed long-term access to underwater lands and/or overlying waters.

  Justification: Successful private mariculture requires guaranteed long-term access to underwater lands through sales, leases, or other mechanisms to justify the initial investment required for a private mariculture venture.

- Development of private mariculture will require a change in attitudes by government and public alike and the implementation of management plans which allocate specific areas of the marine environment among competing uses.

  Justification: The development of new private mariculture ventures in Suffolk County's coastal zone is limited by the ability of the culturist to acquire ownership, lease, or guaranteed access to coastal waters and underwater lands suitable for the enterprise. Lack of action by State and local governments and negative attitudes toward mariculture on the part of commercial fishermen, recreational boaters, and shoreline residents have tended to discourage potential mariculture developers.

- The economic viability of hard clam culture on Long Island has not been demonstrated convincingly.

- The economic outlook for private mariculture hinges on the development of technical advances which improve growth and survival during growout, and recovery at harvest.

  Justification: The profitability of hard clam mariculture primarily depends upon the cost of seed clams and the recovery of market size clams. At the current retail price for littlenecks, 15-20% of the planted seed must be recovered after 2-3 years of growout just to cover the costs of seed production. Higher rates of survival to harvest must be achieved to cover all costs and provide a profit, yet documented estimates of survival to 50 mm rarely exceed 15% and often are less than 1%.

  Development and maintenance of effective mariculture programs--public and private--will require substantial and sustained research and development efforts comparable to those provided to the agriculture industry through agriculture experiment stations.

LITERATURE CITED

Turner, E.J. 1983. Effects of a storm-induced breach on *Mercenaria mercenaria* in Moriches Bay. M.S. Thesis, Marine Sciences Research Center, State University of New York at Stony Brook, 77 pp.

A SELECTION OF MANAGEMENT ALTERNATIVES

FOR INDIVIDUAL WATER BODIES

INTRODUCTION

The primary goal of this report is to provide a technical assessment of the full range of plausible management alternatives which could be used individually, or in various combinations, to revitalize and stabilize Suffolk County's hard clam industry. This industry could take a variety of forms. We have concentrated our efforts on one part of the industry, the commercial wild fishery, and have touched only relatively lightly on the recreational hard clam fishery and on the potential for the development of a hard clam mariculture industry. Our analysis has been restricted largely to a consideration of the technical and scientific aspects of the various management alternatives. We have assessed the scientific evidence to determine the extent to which these management alternatives could contribute to the revitalization and stabilization of Suffolk County's hard clam fishery, if they were applied. We have given only cursory attention to the very important socio-cultural factors which must be considered in determining which alternatives should be applied.

This choice was deliberate. Our objective has been to provide the best technical assessment we could. We have not attempted to set societal goals as to what kind of hard clam industry is most desirable, or most appropriate, for Suffolk County. That was not our task; had it been, a quite different working group would have been required. Few of the present members are qualified to express expert opinions on such matters. As Lewis Thomas (1980) points out "There are some things about which it is not true to say that every man has a right to his own opinion." The opinions expressed in this report on technical matters, however, should be given proper consideration. They carry the force of knowledge and were arrived at only after considerable deliberation. As knowledge increases, the choices may change. The likelihood of selecting the best--most appropriate and effective--management strategies could be increased by conducting studies designed to fill important data and information needs outlined elsewhere in this report.

In the development of a comprehensive management plan, which is to be accomplished in Phase II of this study, the technical analysis will have to be combined with a socio-economic analysis and presented in the context of societal objectives and goals for Suffolk County's hard clam industry. The technical analysis provides the basis for selecting management strategies to maximize the likelihood of achieving those goals once selected.

In this section, we present for individual water bodies in Suffolk County a list of those management strategies which, based on our technical analyses, we believe in the aggregate would be most likely to be successful in maximizing, on a continuing basis, the yield of hard clams from that water body. The reason for selecting the goal of Maximum Sustainable Yield for management is that one must choose some goal and by maximizing the sustainable yield of hard clams, one maximizes the number of possible choices of societal objectives and goals which are attainable for a hard clam industry. While some management strategies are common to programs for all water bodies, other are not.

An integral part of any management program should be a mechanism to provide an on-going evaluation of the effectiveness of the over-all program and the extent to which each individual management component contributes to the success (effectiveness) of the over-all program. Such evaluation is required for the programs outlined on the following pages.

GREAT SOUTH BAY

- Conduct stock assessments throughout the Bay designed to provide reliable information on the population dynamics of the resource.
- Establish spawner sanctuaries free of the constraints of town boundaries.
- Develop a plan of alternate openings and closing of harvest grounds to limit total harvest and to spread the harvest out over the year.
- Establish a maximum legal size and retain, or increase, the present minimum legal size to ensure maximum protection of the spawning stock.
- Enhance the enforcement of hard clam laws by increasing patrols and by intensifying the prosecution of violators.
- Utilize clams in uncertified areas as a renewable resource for maintaining the spawning stock.
- Set aside a small percentage of the Bay (<10%) for controlled culture and harvest of hard clams and other species by individuals or groups.
- Encourage the formation of baymen's cooperatives to increase economic returns to baymen.
- Monitor salinity over the long-term at a small number of stations at key locations throughout the Bay to establish long-term trends which may provide insights into how changes in salinity affect standing stocks of hard clams.
- Take steps to ensure that there is no further alteration in water quality which could decrease standing stocks of hard clams or increase the areas closed to harvesting.

- Conduct a research program to determine if the standing stock of hard clams is limited significantly by predation. If it is, determine whether, or not, it is possible to effectively control predation and if so, where, by what means, and at what cost.

- Conduct stock assessment throughout the Bay to provide reliable information on the population dynamics of the resource.

- Establish a maximum legal size and retain or increase the present minimum legal size to ensure maximum protection of spawning stock.

- Enhance the enforcement of hard clam laws by increasing patrols and by intensifying the prosecution of violators.

- Utilize clams in uncertified areas as a renewable resource for maintenance of spawning stock.

- Encourage the formation of baymen's cooperatives.

- Evaluate land use decisions on the basis of their potential impacts on water quality and living marine resources.

- Set aside an appropriate percentage of the Bay for controlled culture and harvest of hard clams and other species by individuals and groups. If predation limits stocks and can be controlled, an appropriate percentage might be 10% of the total area. If predation can not be controlled effectively, the percentage should be increased.

- Evaluate the impact of improvements in sewage treatment and disposal on certification of shellfish growing areas.

- Take steps to ensure that there is no further alteration in water quality which could decrease standing stocks of living marine resources or increase areas closed to harvesting.

The Peconic estuarine system contains highly variable environments, especially within the many small embayments along the margins. The efficacy of the recommended plan will change from place to place and the components of the plan will need to be evaluated separately, and in different combinations, for the various sub-environments. The strategies listed are for a commercial wild fishery. Other strategies would be selected to create and sustain a localized resource to support a recreational fishery.

MORICHES AND SHINNECOCK BAYS

- Conduct a research program to determine if the resource is limited significantly by predation, or by natural physical factors which limit setting of hard clams within the bay. If the answer to either of these questions is yes and if the factors affecting predation and/or setting cannot be controlled effectively at acceptable cost, the area allocated to mariculture should be increased above the nominal 10% recommended for Great South Bay.

- Conduct stock assessments throughout the Bay to provide reliable information on the population dynamics of the resource.

- Establish a maximum legal size and retain or increase the present minimum legal size to ensure maximum protection of the spawning stock.

- Enhance the enforcement of hard clam laws by increasing patrols and by intensifying the prosecution of violators.

- Utilize clams in uncertified areas as a renewable resource for maintenance of spawning stock. (This applies only to Moriches Bay since there are not substantial closed areas in Shinnecock Bay.)

- Encourage the formation of baymen's cooperatives.

- Evaluate land use decisions on the basis of their potential impacts on water quality and living marine resources.

- Evaluate proposals for modification and stablization of inlets on the basis of their potential impacts on water quality and living marine resources.

- Evaluate the potential of these Bays for the establishment of spawner sanctuaries.

- Monitor salinity over the long-term at a small number of stations at key locations throughout the Bays to establish long-term trends which may provide insight into how changes in salinity affect standing stocks of hard clams.

NORTH SHORE BAYS: (HUNTINGTON BAY, SMITHTOWN BAY, PORT JEFFERSON HARBOR, MT. SINAI HARBOR)

- Conduct a research program to determine if the resource is limited significantly by natural physical factors which limit setting of hard clams within these Bays. If it is and if the factors affecting setting cannot be effectively controlled at acceptable cost, the areas allocated to mariculture should be increased above the nominal 10%.

- Conduct stock assessments throughout the Bay designed to provide reliable information on the population dynamics of the resource.

- Establish a maximum legal size and retain, or increase, the present minimum legal size to ensure maximum protection of the spawning stock.

- Enhance the enforcement of hard clam laws by increasing patrols and by intensifying the prosecution of violators.

- Utilize the clams in areas which are uncertified as a renewable resource for maintenance of spawning stock.

- Encourage the formation of baymen's cooperatives.

- Evaluate the potential of these Bays for the establishment of spawner sanctuaries.

- Develop a plan of alternate openings and closings of harvest grounds to limit total harvest and spread the harvest out over the year. (This strategy probably should be limited to Huntington Bay.)

- Evaluate the impact of improvements in sewage treatment and disposal on certification of shellfish growing areas.

- Evaluate land use decisions on the basis of their potential impacts on water quality and living marine resources.

TABLE II-1

A SUMMARY OF MANAGEMENT STRATEGIES
FOR INDIVIDUAL BAYS

Hard Clam Management Strategies	Great South Bay	Peconic Bay System (a)	Moriches and Shinnecock Bays	North Shore Bays (b)
o Conduct stock assessments throughout the bay(s) designed to provide reliable information on the population dynamics of the resource.	X	X	X	X
o Establish spawner sanctuaries free of the constraints of town boundaries.	X			
o Evaluate the potential of the bay(s) for the establishment of spawner sanctuaries.			X	X
o Develop a plan of alternate openings and closings of harvest grounds to limit total harvest and to spread the harvest out over the year.	X			X (c)
o Establish a maximum legal size and retain, or increase, the present minimum legal size to ensure maximum protection of the spawning stock.	X	X	X	X
o Enhance the enforcement of hard clam laws by increasing patrols and by intensifying the prosecution of violators.	X	X	X	X
o Utilize clams in uncertified areas as a renewable resource for maintenance of spawning stock	X	X	X (d)	X

TABLE II-1 (continued)

Hard Clam Management Strategies	Great South Bay	Peconic Bay System (a)	Moriches and Shinnecock Bays	North Shore Bays
o Monitor salinity over the long-term at a small number of stations at key locations throughout the bay(s) to establish long-term trends which may provide insight into how changes in salinity affect standing stocks of hard clams.	X		X	
o Evaluate proposals for modification and stabilization of inlets on the basis of their potential impacts on water quality and living marine resources.			X	
o Encourage the formation of baymen's cooperatives to increase economic returns to baymen.	X	X	X	X
o Take steps to ensure that there is no further alteration in water quality which could decrease standing stocks of hard clams or increase the areas closed to harvesting.	X	X	X	X
o Evaluate the impact of improvements in sewage treatment and disposal on certification of shellfish growing areas.		X		X
o Evaluate land use decisions on the basis of their potential impacts on water quality and living marine resources.		X	X	X

TABLE II-1 (continued)

Hard Clam Management Strategies	Great South Bay	Peconic Bay System (a)	Moriches and Shinnecock Bays	North Shore Bays (b)
o Conduct a research program to determine if the standing stock of hard clams is limited significantly by predation. If it is, determine whether or not it is possible to effectively control predation and if so, where, by what means, and at what cost.		X	X	
o Conduct a research program to determine if the hard clam resource is restricted significantly by natural physical factors, which limit setting of clams in the bay(s). If it is, determine whether or not it is possible to effectively control these factors, and if so, where, by what means, and at what cost.			X	X
o Set aside an appropriate percentage of bay(s) area for controlled culture and harvest of hard clams and other species by individuals or groups.	< 10%	10% - if resource is limited by predation, which can be effectively controlled at acceptable cost.	10% - if resource is not limited by physical factors or predation. >10% - if resource is limited by physical fac-	10% - if resource is not limited by physical factors. >10% - if resource is limited by physical factors, which

TABLE II-1 (continued)

Hard Clam Management Strategies	Great South Bay	Peconic Bay System (a)	Moriches and Shinnecock Bays	North Shore Bays (b)
		>10% - if resource is limited by predation, which cannot be effectively controlled at acceptable cost.	tors or predation, either of which cannot be effectively controlled at acceptable cost.	cannot be effectively controlled at acceptable cost.

(a) The Peconic estuarine system contains highly variable environments, especially within the many small embayments along the margins. The efficacy of the recommended plan will change from place to place and the components of the plan will need to be evaluated separately, and in different combinations, for the various sub-environments. The strategies listed are for a commercial wild fishery. Other strategies would be selected to create and sustain a localized resource to support a recreational fishery.

(b) North Shore Bays includes Huntington Bay, Smithtown Bay, Port Jefferson Harbor and Mt. Sinai Harbor.

(c) This strategy probably should be limited to Huntington Bay.

(d) This strategy applies only to Moriches Bay, since only a small proportion of Shinnecock Bay is closed to shellfishing.

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INFORMATION PRIORITIES

BACKGROUND

Significant improvements in the efficiency and effectiveness of management of Suffolk County's hard clam industry will come only through knowledge; through the utilization of existing knowledge and the development of new knowledge--new information. In a professional context information often is used as a synonym for knowledge, at least for selected knowledge. Information differs from data, from facts, in that it connotes structure or orderliness, especially of the kind that makes possible the formulation and transmission of a meaningful message. While existing information has not been utilized fully in selecting and implementing management strategies, new information is required. According to P.D. Medewar's (1984) Law of Conservation of Information "No process of logical reasoning--no mere act of computer-programmable operation--can enlarge the information content of the axioms and premises or observation statements from which it proceeds." Since information is the refined product of research, additional research is needed to significantly improve our ability to rehabilitate and to sustain--to manage--Suffolk County's hard clam industry.

The information gaps listed below are those which we believe should be given the highest priority. The criterion for selection is the potential contribution each could make to improved management for each dollar invested. In some cases, constriction or closure of these information gaps requires additional research; other cases do not. The individual items are not ranked.

SOME IMPORTANT INFORMATION GAPS WHICH CAN BE FILLED WITHOUT ADDITIONAL RESEARCH

- Evaluation of existing information is needed to select an appropriate maximum legal size, and a re-evaluation of the present minimum size is needed to provide further protection for the spawning stock (This evaluation should include social and economic, as well as biological considerations).

- A rigorous evaluation is needed of the options available for allocating public bay bottom to mariculture and the potential returns to the region of such allocation.

SOME IMPORTANT INFORMATION GAPS
WHICH CANNOT BE FILLED WITHOUT ADDITIONAL RESEARCH

- Stock assessments are needed which will provide reliable estimates of sustainable yields for Great South Bay and possibly other Suffolk County waterbodies.

- Research is needed to improve the knowledge of predator/prey relationships for hard clam populations in Suffolk County waters. These studies should include, but not necessarily be limited to, the effect of predation on hard clam recruitment, and life histories of major predators.

- Research is needed to improve methods of predator control.

- Research is needed to determine if there is a minimum density of adult clams necessary to encourage set of larvae in an area.

- Research is needed to assess the effects of disturbance and modification of the bay bottom on hard clam sets and survival.

- Research is needed on hard clam mariculture in the nursery and growout phases to improve the ability of nursery systems to produce large seed clams and to increase survival during growout.

- A rigorous evaluation of a large scale seeding program is needed to assess the survival rate of planted seed clams and their overall contribution to recruitment and standing stock.

- A rigorous evaluation is needed of one or more spawner sanctuaries to assess their overall contribution to recruitment and to standing stocks.

- Research is needed to determine the effects of salinity changes and long-term salinity trends on the hard clam resource.

- Research is needed to evaluate the suitability of Moriches and Shinnecock Bays (using an existing model) for the establishment of spawner sanctuaries.

- Research (using a dye release) is needed to evaluate one, or more, north shore bays to determine their potential for establishment of spawner sanctuaries.

- Research is needed to identify the relationships among population growth, land use, marine water quality, and living marine resources.

- Research is needed on toxic and pathogenic agents and substances, which may occur in hard clams as a result of marine pollution, and the threat they pose to public health.

- Research is needed to provide detailed socio-cultural information on the fishermen and the fishing industry for use in devising and implementing appropriate management programs.

- Research is needed which will lead to the development of an information system for the hard clam industry which would include biological, economical, social, cultural, and environmental information.

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THE HARD CLAM FISHERY

AN OVERVIEW OF ITS PAST, ITS PRESENT CONDITION, AND ITS PROSPECTS FOR THE FUTURE

Brief History of New York Hard Clam Fishery

Prior to World War II hard clams were of secondary importance to oysters in New York. In the early days they were looked upon, for the most part, as a standby food for hard times, a food not in keeping with American culture and affluence. Even before World War II this began to change. Following a brief and rather sharp rise in prices during the later War years, and then an equally abrupt fall, hard clam landings and prices in New York began to rise rapidly in the early 1950s (Figure IV-1). The peak of landings was reached in 1947, when more than 10 million pounds of meats were landed. Landings fell off thereafter until in 1954 only about 2.5 million pounds were produced. They began to rise again as good sets were experienced in Great South Bay, and rose to a secondary maximum in 1976 of about nine million pounds of meats. Prices rose also, as clams became more popular, so that by 1976 the price had risen to about $1.18 per pound from a low of about $0.45 per pound in 1948 (prices expressed in standard dollars with 1967 = 100 as a base). Since 1976, production has fallen off rather steadily, so that by 1984 only about 2.7 million pounds of meats were landed.

Prices continued to rise until 1980, but thereafter, despite the substantial drop in production, prices fell. This was probably caused partially by competition from other states, but also was due to a drop in consumer confidence caused by a pollution scare in 1982 and early 1983. From the peak in 1947 to the low in 1984, hard clams have declined to about one-third of their former level, while prices have risen from about $0.45 to about $1.62 per pound (in standard dollars) at their peak in 1980.

The relative importance of landings from different areas has changed over time. In the early days many hard clams came from Raritan Bay and nearshore waters of the western end of Long Island. Some time between 1904 and 1921 the supply of hard clams available for harvest around the western end of Long Island dropped sharply, and Suffolk County became the source of 80 percent, or more, of the total harvest of hard clams in New York. The precise time of the change is not certain, because statistics were not recorded every year before 1929. The north shore of Long Island was quite productive for a while, and in 1962 and 1963 the north shore and the Peconic Bays together yielded over 2 million pounds of meats. Landings from these areas dropped off sharply soon after, and Great South Bay became the major supplier.

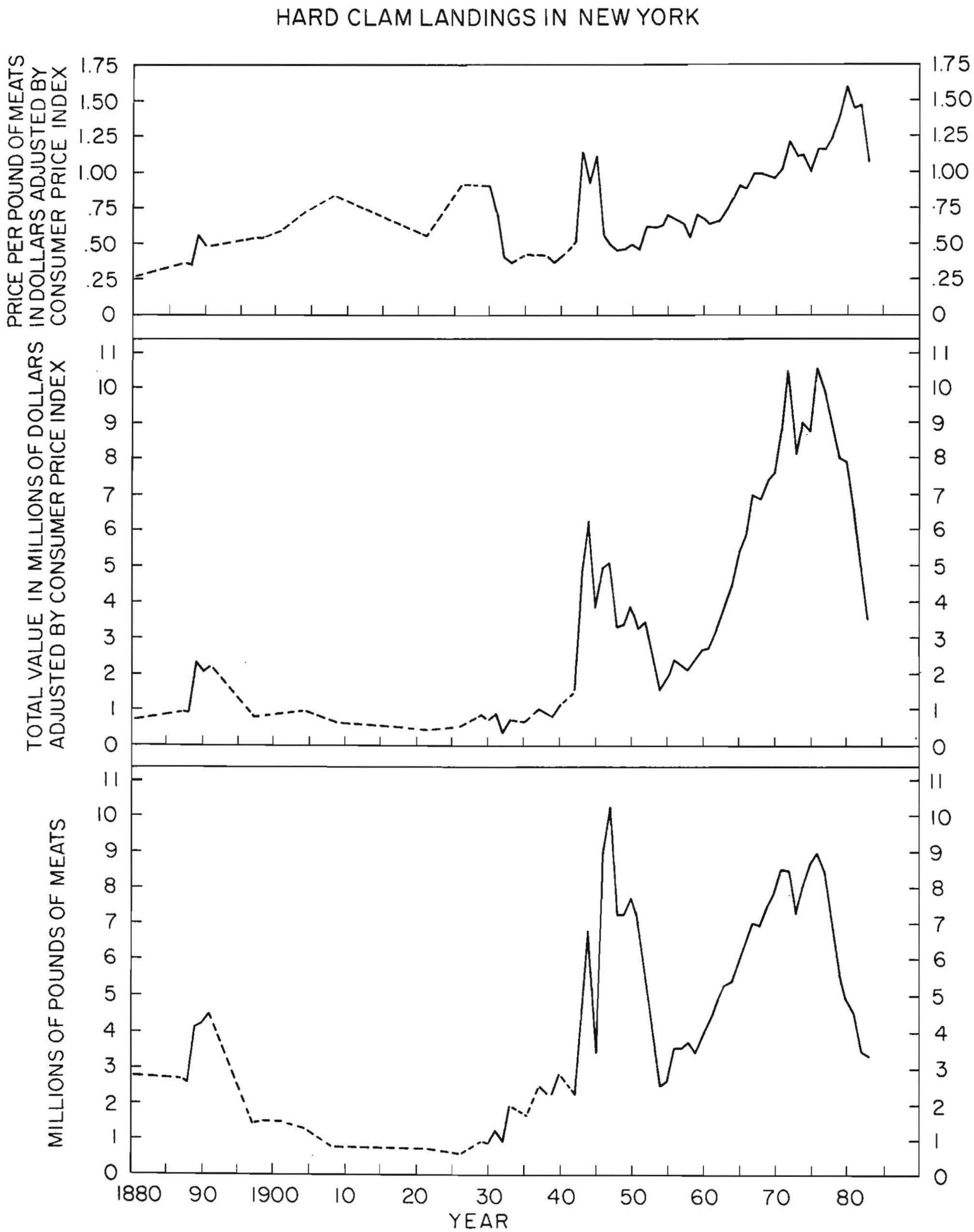

Figure IV-1. New York State annual hard clam landings and value.

PRESENT CONDITION OF THE FISHERY

Overharvesting of the Resource

There is a justifiable need for concern about the fishery. Not only have total landings in New York dropped to about one-quarter of their maximum, but the total value of the resource harvested has dropped even further (Figure IV-1), from a maximum of about $10.6 million in 1976 (1967 dollars - about $18.1 million in 1976 dollars) to a low of about $3.1 million in 1984 (in 1967 dollars; about $9.4 million in 1984 dollars). This was caused partly by the drop in landings, and perhaps also by competition from elsewhere. It apparently was enhanced by a perceived loss in the quality of New York clams attributed to degradation of water quality. The unit price continued to rise at an even higher rate after the peak in landings was reached in 1976, but after 1980 further degradation in the reputation of New York's clams associate with the effects of water pollution and increased competition from imported clams caused the unit price to drop even though landings dropped also. There is little doubt that the drop in landings was caused at least partly by overfishing.

Buckner (1984) showed that between 1978 and 1979 in Islip waters of Great South Bay, mortality of adult clams caused by harvesting was four times the mortality from natural causes in uncertified and in certified areas. That the intensity of fishing had increased during this period in areas leased to private operators was shown by a reduction in the proportion of large clams and a corresponding increase in the proportion of small clams. In the certified areas the relative proportions of littlenecks, cherrystones, and chowder clams were stable from one year to the next, demonstrating that there had been little change in harvesting intensity. Intense fishing in certified and leased areas was clearly demonstrated by the average harvest mortality of 43 percent in certified areas and 63 percent in leased areas. Differences in survivorship rates between those based on natural mortality and those based on total mortality also indicated that the stocks of clams were being reduced at an alarming rate, clearly in excess of net natural reproduction. The intense rate of harvesting resulted in a 54 percent decline in reported landings between 1979 and 1982.

Using the 1978 density of clams in Bay Shore Cove (26.4 clams per square meter) as an estimate of maximum population size in an uncertified area, it can be seen that certified areas, with an average of only 5.1 clams per square meter, and leased areas, with an average of only 3.1 clams per square meter, had been seriously reduced in stock. These reductions were accompanied by a decrease in catch. Since a substantial amount of illegal harvesting takes place in the uncertified areas (Becker 1983), it is clear that the estimated percentages of maximum population size in certified and leased areas are conservative, and therefore actually substantially lower than actual expected maximum concentrations.

Further evidence of overfishing (Buckner 1984) was obtained from observations of changes in age structure of the fished stocks. Decreased average size of clams in the population throughout the fishery demonstrated a decrease in average longevity. This might, however, mean only heavy fishing and not necessarily overfishing. However, survivorship curves obtained in this study were characteristic of an overfished population, for decreased survival of older clams was not compensated for by increased survival of younger clams. Clearly, the symptoms associated with an overfished stock were evident in the size and age composition of clams in the Great South Bay fishery.

Water Quality Problems

From time to time, outbreaks of several types of bacterial and viral enteric diseases such as typhoid, gastroenteritis and infectious hepatitis, sometimes referred to by the vague term food poisoning, have been attributed to consumption of raw shellfish. Major outbreaks have occurred in the New York and New Jersey regions in 1924-26, 1961, 1964, and most recently in 1982-83. Occurrences have been sporadic, and may not always be reported. Violations of shellfish sanitary control regulations are frequent. It has been reported that up to 50 percent of clam diggers may work in uncertified waters at times (Mirchel 1980). Buckner (1984) has estimated the quantities of clams harvested from uncertified areas to be significant. Human disease outbreaks will continue, and the future of the industry may depend in part on the need for greater accountability and quality control. At present, enforcement of harvesting regulations relies largely upon the integrity of diggers, but traditionally it has been to the diggers' advantage economically, at least in the short term, to exploit the clam resource illegally by digging in uncertified waters. The chances of a particular digger being caught, or receiving a large penalty if caught, have been small. The potential for outbreaks of bacterial and viral enteric diseases attributed to the consumption of raw hard clams probably will increase as the population of Long Island increases, and as the populations of clams in certified areas decreases. Not all outbreaks have been positively traced to clams harvested from Great South Bay or other areas on Long Island, but if consumer confidence is affected, and the price of clams drops, it does not matter very much whether Long Island is directly implicated or not.

Declining Economic Value

The declining economic value of the hard clam fishery has been substantial since its peak in 1976. It has dropped in real dollars (1967 base) from about $10.6 million in 1976 to about $3.1 million in 1984 (Figure IV-1). This decline may continue, and is unlikely to rise very much, unless some way to control poaching of clams from beds closed by poor water quality is found. Poaching is likely to increase if stocks on certified grounds continue to remain low from overfishing. New York's share of the hard clam market has declined in recent years, and this probably has had some effect upon prices paid. Moreover, as has already been said, the fear of consumers caused by pollution scares, real or imagined, can affect the price adversely, also.

PROSPECTS FOR THE FUTURE

Continued Environmental Pressure

Pressure on the coastal marine environment is likely to continue as Long Island's population continues to grow. Some areas may be close to saturation now, but others still have room for growth. Increased discharges of sewage, treated or otherwise; increased industrial wastes; and increased pollution from non-point sources are bound to lead to decreased water quality, especially at the eastern end of Long Island. This will tend to increase the area of coastal waters uncertified for harvesting of shellfish. The result will be increased harvesting from uncertified areas as the areas open to shellfishing shrink, and probably more frequent outbreaks of disease attributed to consumption of raw shellfish. This may further erode public confidence in clams, causing prices to decrease further, and make it increasingly difficult for baymen to make a decent living.

Increased Fishing Pressure

Increased fishing pressure in certified areas will, unless checked in one way or another, lead to further declines in standing stock, again reducing the chances for baymen to make a living. Some baymen undoubtedly will drop out of the fishery, but continued attrition is likely to hold the stocks down to low levels. The future is not bright for the hard clam industry in Suffolk County unless significant steps are taken promptly to correct the major problems. The management alternatives for rehabilitation and sustaining the hard clam fishery are the focus of this report.

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HISTORIES OF SUFFOLK COUNTY'S HARD CLAM FISHERIES

THE GREAT SOUTH BAY HARD CLAM FISHERY
A HISTORICAL PERSPECTIVE[1]

Introduction

Great South Bay and the shellfish industry it supports have a rich and complex history. Over the decades, both have undergone great change. A historical perspective can, therefore, be useful in understanding and interpreting present Bay conditions. In addition, a knowledge of past events can reveal relationships that become evident only through the passage of time and can also aid in present decision making.

The history of the shellfishery can be presented in a number of ways. The most common is to present events chronologically. A more interesting and instructive approach is to think of the shellfishery as the end product of three interacting systems: the Bay and the shellfish; the baymen; and the ownership/management regime. All three continuously interact, although the relative importance of each varies over time. This review traces the recent history of the Great South Bay hard clam fishery by focusing on these interactions.

It should be noted at the outset that hard clamming as a major industry is a rather recent phenomenon. From colonial times up until the 1930s, the oyster dominated the Bay's shellfishery. Thereafter, the emphasis shifted to the hard clam as the oyster declined in abundance while the hard clam population rose. This shift was caused by environmental changes, shifting consumer preferences, the pollution of oyster seed areas, and changes in the workforce.

THE RELATIONSHIP BETWEEN OYSTERING AND CLAMMING

The hard clam fishery did not become economically important until the collapse of the Bay's oyster stocks in the early 1930s. During the oyster years, hard clams apparently flourished in the Bay but the oyster was the focus of attention. Hard clams were harvested commercially but on a part-time basis in summer when the oyster fishery was closed.

The oyster industry in many ways precluded growth of the hard clam fishery (Kellogg 1901). The rapid expansion of the acreage devoted to oyster culture in the late 1800s reduced the area available for the taking of hard clams--some of the most productive hard clam grounds were on leased bay bottom. At the same time, the labor intensive practices of the oyster fishery limited the amount of effort

[1]This section is based upon a chapter in a book being prepared by Jeffrey Kassner.

that could be devoted to clamming. Finally, the hard clam was considered to be inferior as food to the oyster.

Even though the oyster industry was essentially incompatible with hard clamming, oystering has had a major influence on the hard clam fishery. This is caused largely by the similarity in harvesting technology and marketing which made it relatively easy for an oysterman to become a hard clammer. In so doing, many aspects of the oyster fishery were transferred to, and absorbed by the hard clam fishery. Many current hard clam management practices originated in the oyster industry. For example, the planting of oysters to serve as brood stock was undertaken in the 1890s while the restricting of harvesting to hand operated equipment dates back to the 1860s.

Many attitudes of present day baymen can be traced to events that took place during the oyster fishery years. Perhaps the most notable is the present anti-leasing sentiment among baymen who fear that if leasing is permitted, even on a limited basis, the Bay will be taken over by large companies. In the 1890s when leasing was practiced, the bay was largely controlled by the leasing interests who also controlled the shellfish markets.

HARD CLAMS AND THE BAY

The Early Hard Clam Fishery

Little is recorded about the hard clam fishery prior to 1880. Hard clams were harvested and must have been of some importance as evidenced by laws concerning hard clamming enacted by the Towns of Islip, Brookhaven, and Babylon (formerly Huntington). In 1789, for example, Brookhaven passed a resolution establishing a fee of two pence for every hundred clams harvested and taken out of the Town.

According to Mather (1887), from 1840 to 1880, the range of the hard clam within Great South Bay was slowly extending eastward and by 1880, the center of the fishery was located slightly east of Sayville. A good day's harvest was considered to be 1,000 clams (about 3 bushels) which sold for $2 per bushel. Production was estimated at 150,000 bushels a year.

In 1900, in testimony give by baymen in the trial that led to the partitioning of Great South Bay east of Nicolls Point between the Town of Brookhaven and the Smith heirs, it was reported that the best clamming was on the bottom leased for oyster culture. It was claimed that on some leased bottom, a person could harvest 10 to 12 bushels of hard clams in a day. It was claimed that oyster leases were taken, in some cases, to secure the hard clams on the leased grounds.

Even during the oyster years hard clams often assumed considerable importance. In the winter of 1924-25, for example, a typhoid epidemic was traced to oysters harvested from Great South Bay resulting in the near total closure of the oyster fishery. Men laid off by the oyster companies supported themselves by digging clams in Great South Bay (New York Times, February 20, 1925).

The Modern Hard Clam Fishery

There is a dearth of historical quantitative information on the abundance of hard clams. It was not until 1974 that Islip Town began a quantitative assessment of hard clam resources in their waters. Babylon adopted a similar program several years later, but Brookhaven has yet to initiate a stock assessment program. The New York State Department of Environmental Conservation (DEC) began a program of assessing clam stocks at a number of index stations located throughout the Bay in 1978.

A relative estimate of abundance is available from hard clam landings which are available for the Towns of Babylon, Islip and Brookhaven from 1946 to the present. This information is presented in Figure V-1. If landings data are combined with other historical accounts, one can obtain a relatively good picture of changes in hard clam abundance, together with the factors that may have affected clam abundance. The modern hard clam fishery began in 1931 when Moriches Inlet opened, setting off a chain of events that altered the fishery. The most important was the increase in salinity that enabled the oyster drill to expand its range eastward onto the oyster setting grounds. Good oyster sets become infrequent and the oyster fishery declined rapidly. Fortunately, the new environmental conditions that were detrimental to the oyster, proved agreeable to the hard clam. Before the opening of Moriches Inlet, hard clams were not found in any abundance east of Cherry Grove (Van Popering and Glancy 1947). The increased salinity, which permitted the eastward expansion of the oyster drill, also permitted the hard clam to expand into the eastern Bay.

Other changes occurred in the Bay in the early 1930s which are said to have increased hard clam production. The opening of the intracoastal waterway in the western Bay increased salinity off Babylon and Bayshore, tripling the productive clamming area (Tiller *et al.* 1952). Beginning in 1931, eelgrass began to disappear and by 1932, 99% of the eelgrass had disappeared (Wilson and Brenowitz 1966). As a result, circulation was enhanced and more areas were opened up for clam production (Tiller *et al.* 1952).

In 1938, a major hurricane struck the south shore of Long Island. The storm caused considerable damage to the Island and also smothered thousands of bushels of oysters in Great South Bay (Suffolk County News, December 16, 1938). The storm also may have killed many shellfish predators--a thriving blue crab fishery was wiped out

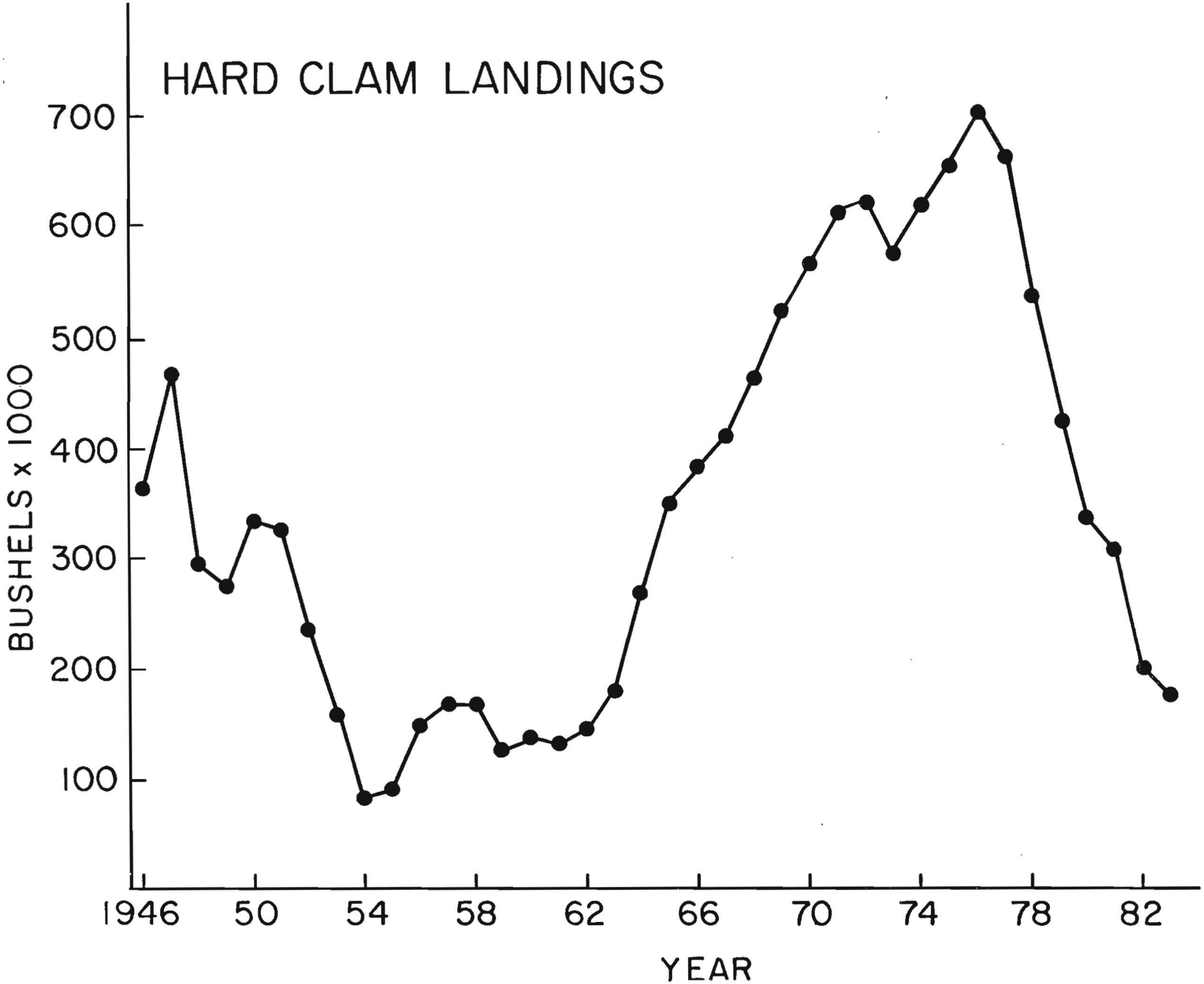

Figure V - 1
Hard Clam landings from Great South Bay (Suffolk County)

(A. Hoek, Baymen Oral History Group, Suffolk County Marine Museums, Personal Communication). The reduction in predators may have been responsible, in part, for a heavy set of hard clams in 1941 (Tiller *et al.* 1952). Another heavy set occurred in 1943 (New York State Conservation Department 1946).

Beginning in the late 1940s, blooms of a small species of phytoplankton that become known as "small forms" appeared in the Bay. The small forms clogged the gills of hard clams and oysters, although oysters were affected to a much greater extent than clams, inhibiting feeding such that the meats of the shellfish were of poor quality and not acceptable in the market. This led to a series of environmental studies of the Bay by the Woods Hole Oceanographic Institution beginning in 1950.

Initially, it was thought that a reduction in the exchange of water between Great South Bay and the Atlantic Ocean through Fire Island Inlet was the cause of the blooms. It was shown, however, that the blooms originated in Moriches Bay where they thrived on the wastes discharged by duck farms into Moriches Bay. The blooms were subsequently transported through Narrow Bay into Great South Bay. The restriction in flow through Moriches Inlet in the late 1940s and its ultimate closure in 1951 exacerbated the problem because when there is no inlet into Moriches Bay, there is a net flow from Moriches Bay into Great South Bay (the opposite occurs when there is an inlet into Moriches Bay).

By 1953, persistent blooms of small forms had caused the quality of hard clams to decline to such an extent that they were no longer accepted by New York City markets (Patchogue Advance, July 8, 1954). The threatened extinction of the Great South Bay's shellfish industry from small forms was a major force behind the dredging to reopen Moriches Inlet in 1953.

Algal blooms occurred in the western part of Great South Bay in 1958 and 1960 (Sayville 1962). In Babylon waters, blooms of Irish linen (*Chartomorpha linum*) were so dense in 1957 and 1958 that they interfered with navigation (New York State Conservation Department 1958). Algal blooms, attributed to excess phosphate and nitrate from domestic wastes, continued through the early 1960s. A study of the problem completed in 1962 called for the construction of sewers in southwestern Suffolk to control Bay pollution (Babylon Beacon, July 5, 1962).

Because clams stocks in the Bay were depressed through the 1950s and early 1960s many baymen either gave up shellfishing or shifted their activities to the north shore, particularly to Huntington Bay. When the Huntington Bay hard clam fishery collapsed in 1964, many of the baymen returned to Great South Bay which had experienced several good sets in the early 1960s (Losee 1983) and landings began to rise. These sets have been attributed to low concentrations of predators brought about by the severe winter of 1961 (J. Kranski, Blue Points Company, Personal Communication) and to the blooms of small forms (G. Vanderborgh, Vanderborgh Associates, Personal Communication).

According to Mercer (1968), the "small form" returned to the Bay in 1965. Oysters and clams experienced black gills and thin meats characteristic of the worst years between 1947 and 1952. Although the condition of hard clam meats deteriorated, they were still marketable and their abundance was largely unaffected.

The increasing numbers of baymen working on the Bay in the 1960s threatened the continued viability of the resource. By 1967, there was a significant harvest of seed (Losee 1983). In the early 1970s, there was an increase in poaching in uncertified areas because density of clams was high there. At the same time, the drought of the late 1960s, according to Lane (1975), increased mortality of clam larvae and reduced the spawning rates of adult clams so that by the early 1970s, the harvest of 4 to 6 year old clams, which would have been spawned during the drought period, had decreased dramatically.

Early signs of overfishing appeared in the mid 1970s (Buckner 1983). In 1974 average daily catch was about 3 bushels per bayman. By 1980, average daily catch declined from 3 bushels to 1.75 bushels per bayman.

Maximum hard clam production in Great South Bay occurred in 1976 when nearly 750,000 bushels were harvested. Landings have declined subsequently because stock abundance declined which has, in turn, led to a decrease in fishing effort. There is a perception among Baymen that sets have declined in the last ten years.

There is no agreement as to the cause of the decline of the hard clam population. While overfishing no doubt played a significant role, other factors may have contributed to the lack of sets. The following have been suggested as contributing factors:

1. The dredging of Yellow Bar. In 1970, a sand bar located inside Fire Island Inlet, known locally as Yellow Bar, was removed. The removal of this bar is said to have changed circulation patterns within the Bay and increased the salinity leading to an increase in the invasion of hard clam predators.

2. Hard clam removal from uncertified areas. Many baymen feel that the uncertified areas, which have had high population densities, contribute to standing stocks in certified areas by providing a good supply of larvae. During the 1970s a combination of poaching and government-sponsored transplants removed much of the shellstock from these areas and today, the abundance of hard clams in uncertified areas is only slightly greater than in the certified areas (Buckner 1983). This decrease in abundance is said to have reduced spawning potential.

3. Illegal harvesting of seed clams. Although there are no quantitative estimates, it is likely that substantial numbers of seed clams were taken illegally from the Bay beginning in the early 1970s. In 1977, 31 persons and three companies were indicted on stealing millions

of seed clams from the Bay (New York Times, June 10, 1977). It was alleged that $60,000 worth of seed clams were taken in 1975 and $65,000 worth of seed were taken between January 1976 and June 1977. The charges were later dismissed on technical grounds.

4. Increase in Bay salinity. It is commonly held that there has been a long-term increase in the salinity of the Bay (Hollman and Thatcher 1979), and that this increase has enabled many of the hard clam's predators to expand their range and abundance in the Bay. There is some evidence though to suggest that there has not been a significant salinity increase (see, "Salinity and Great South Bay", this volume).

5. Changes in Moriches Inlet. Historically, Moriches Inlet has had a major impact on Great South Bay, particularly the eastern portion. The Inlet has undergone dramatic natural and man-induced changes over the past 33 years (Kassner and Black 1982). Most recently, in early 1980 the inlet was eroded to a width of over 3,000 feet before it was artificially narrowed to 600 feet in 1981. The exact relationships between changes in the geometry of Moriches Inlet and conditions in Great South Bay have not been documented.

6. Failure of clams to spawn. According to the Blue Points Company (E. Usinger, Blue Points Company, Personal Communication), there has not been a successful spawning of hard clams in the Bay for the past several years. This observation has not been verified by others.

It is, of course, possible that the decline in the hard clam population may be a stage in a cyclical pattern of hard clam abundance. There is, unfortunately, an inadequate understanding of the natural fluctuations in hard clam abundance and the causes of such fluctuations.

THE BAYMEN AND THE HARD CLAM

Baymen are an important political force and perhaps the major determinant of hard clam abundance. They also have played a significant role in shellfish management activities. Although the relationship between baymen and management has received little attention, the baymen have had a significant impact.

Baymen as a Political Force

Baymen have a long tradition of political involvement in the management of the Bay. They are perceived as an important political force and often have been extremely vocal in their opinions. Local governments see the baymen as a major constituency and in many instances are of the opinion that the "baymen know what is best." While any number of events can be used to illustrate the baymen as a political force, two stand out in particular--the "Peanut Clam Debate" in the Town of Islip in 1931 and the Bay leasing controversy, also in Islip.

The "Peanut Clam Debate" began in 1931 when Islip Town, as a means of conserving its hard clam resource, passed an ordinance prohibiting the taking of small (less than 1 inch in thickness), or "peanut" clams. Shortly after the minimum size ordinance was passed, a group of baymen with a different viewpoint went before the Islip Town Board arguing that the taking of small clams should be permitted since "there will always be peanut clams as long as there is a set" (Suffolk County News, August 14, 1931). The Town Board acceded to the baymen and rescinded the minimum size ordinance that had been in effect for less than 70 days. The baymen's demand appears to have been to based more on economics than management; a bayman could make $4 a barrel for large clams but $35 to $40 a day harvesting peanut clams (Suffolk County News, August 14, 1931).

For reasons unknown, in July 1938 the Community Baymen's Association requested Islip Town to adopt a 1 inch minimum size for hard clams. Shippers and some independent baymen who sold the small clams to the shippers for transplanting, opposed the size limit arguing that it was "unnecessary, unenforceable, and unfair" (Suffolk County News, October 14, 1938). As a compromise, a minimum size of three-quarters of an inch was set. It was not until the 1940s that the present 1 inch minimum size was established by New York State.

The one issue that has generated more controversy over the years than any other is the leasing of bay bottom to private individuals for mariculture. Although baymen attempted to have the practice terminated as early as the late 1800s, they were not totally successful (in the Town of Islip) until 1977, when Islip Town refused to renew leases it had been granting since before the turn of the century. After it had lain dormant for a number of years, baymen raised the leasing issue again in late 1957. It began when baymen sought to prohibit the use of hydraulic dredges on leased grounds. The fight against hydraulic dredging soon shifted to the validity of the leases; the baymen arguing that they were illegal since the leases were not advertised when last renewed in 1952. The matter soon ended up in the State Supreme Court which in 1959 upheld the validity of the leases (Suffolk County News, March 12, 1959).

The Islip leases were up for renewal in 1967 and the Islip Town Board again was confronted with the conflicting demands of the lessees and the baymen. The Board was advised by counsel that the leases, because their wording was faulty, had to be renewed. The Board, however, was able to persuade the lease holders to give up 200 acres in the western Bay and to modify the boundaries of the leased plots to consolidate them and simplify their description.

The Islip leases were up for renewal again in 1977. In 1974 though, the Islip Town Supervisor indicated that he was in favor of eliminating leases and opening the ground up to the public (Newsday, June 9, 1974). When the leases came up for renewal, they were not renewed although the bottom was not given up by the lease holders until 1982 because of their five-year option to renew.

The Baymen as Predators

The amount of clams harvested by an individual bayman is difficult to determine because baymen tend to be secretive about their catch. The number of clams harvested often is given by baymen in terms of a "good day's catch." In the early 1950s, it was said to have been 10 bushels (Patchogue Advance, May 4, 1954). By 1979, it was 2 bushels of littlenecks (Kelpin 1981) and in 1984, a good day's catch was considered to be a bushel.

The harvesting of clams is restricted by law to hand-operated devices, mostly long handled rakes or tongs. A 1977 survey of commercial shellfish permit applicants (Fox 1980) revealed that there were three times as many tongers as rakers in Babylon while in Islip and Brookhaven there were three times as many rakers as tongers.

It is worth noting that tongs were used almost exclusively in the Bay until the early 1960s. It was not until the baymen shifted from Huntington Harbor, where rakes were favored, to Great South Bay following the collapse of Huntington Harbor's shellfish resource that rakes became commonplace on the Bay.

Baymen say that the introduction of the rake revolutionized the shellfish industry. Although the comparative harvesting capabilities of the two types of gear have not been examined, it appears that the use of rakes enabled a greater portion of the Bay to be harvested. Rakers can work in bottom types where tongs are ineffective and rakes can also be used in deeper water. Rakes also can be used profitably in areas of lower clam density because more area can be harvested with rakes per unit time than with tongs. Finally, the efficiency of a rake is determined in large part by its design, which is easily modified, while the efficiency of tongs is determined by the skill of the operator. Consequently, part of the increased landings in the late 1960s and early 1970s can be attributed to a change in harvesting technology.

MANAGEMENT AND THE HARD CLAM

Hard clam management activities have been undertaken almost since the beginning of the fishery. Many of the early management activities were derived from the oyster fishery and were undertaken only when the need arose. The DEC, as well as the towns, periodically oversaw hard clam management activities but it was not until the mid 1970s, when the Towns of Islip, Babylon, and Brookhaven established specific bay management divisions, that ongoing hard clam management programs began.

A wide variety of activities have been undertaken to manage the hard clam resources of the Great South Bay. Four management activities--relays, seed planting, spawner programs, and growing area certification--are described in the following section because they are historically important.

Relay Programs

Relaying is the harvesting of shellfish from uncertified waters and replanting in certified waters. After depurating for approximately 21 days it is assumed that the transplanted shellfish will have purged themselves of bacterial contamination, and, as a result, be safe for human consumption. Transplants can be done either within the same waterbody or between two different water bodies.

The first relay in Great South Bay appears to have been undertaken in 1939 (New York State Conservation Department 1939) when clams were taken from the Nissequoque River, sold to private growers and planted in Great South Bay. In 1942, clams were taken from lower New York Bay and planted in Great South Bay (New York State Conservation Department 1942). During the ensuing years many relay operations have been undertaken by New York State and by various towns.

In 1964, New York established a Shellfish Transportation Fund to support transplanting of shellfish from uncertified to certified waters (New York State Conservation Department 1965). The program had two goals:

(1) to reduce the high concentrations of shellfish in the restricted areas which were being poached and, therefore, posed a risk to public health, and

(2) to make available shellfish stocks that could not otherwise be harvested.

In 1964, a relay took place of approximately 2,200 bushels of clams from Hempstead Harbor to the Great South Bay (New York State Conservation Department 1965).

In 1973, relay operations became eligible for 50 percent reimbursement through Public Law 88-309 (Hendrickson 1975). Relays within Great South Bay were undertaken on an annual basis by Babylon, Brookhaven, and Islip until 1979. A combination of reduced stock sizes in the uncertified areas which increased the per bushel harvesting cost, and the development of an anti-relaying sentiment by baymen led to the termination of the program.

Seed Planting

Seed planting is the release of juvenile shellfish into the Bay to increase stock size and ultimately, the harvest. The seed may come from other natural shellfish producing areas or may be produced by a hatchery. Planting of seed hard clams was undertaken privately in New York as early as 1909 (Belding 1912), although the first seed clam planting on public lands in the Great South Bay did not occur until 1956 when 5,000 juveniles were planted (New York State Conservation Department 1957). Information on the source of seed, planting techniques, and survival, is not available.

Seed clam planting in Great South Bay began anew in 1975 when the Town of Islip purchased and planted 100,000 seed clams (Buckner 1983). Babylon and Brookhaven initiated seed clam programs in 1978. All three towns have continued to plant seed clams although questions remain about the costs of seed planting programs and the contribution they can make to the harvest.

Spawner Clam Programs

All spawner clam programs involve the planting of adult hard clams with the objective of increasing the spawning potential in the Bay by either increasing the number of larvae produced or by prolonging the spawning season. There are three basic types of spawner programs:

(1) Spawner transplant: The planting of gametogenically ripe clams from northern waters after the native clams have spawned to extend the spawning season thereby increasing the chances of larvae being present under suitable conditions for survival and growth.

(2) Spawner sanctuary: The planting of mature clams in a selected location to target larvae to a particular area.

(3) Genetic enhancement: The introduction of clams from areas outside the Bay to increase the gene pool within the Bay which could lead to a larger and stronger clam.

There have been no rigorous studies to document the contributions of the various spawner programs to clam stocks. The first spawner clam program appears to have been undertaken by the Town of Islip in 1938. In that year, the Islip Town Board spent $1,000 to obtain clams from out-of-state (Suffolk County News, May 6, 1938). Since 1938, the planting of spawner clams from outside the Bay has been undertaken periodically by Babylon, Brookhaven, and Islip.

In 1955, adult clams were planted in a "sanctuary" established by the Town of Babylon (New York State Conservation Department 1957). An additional 20,000 clams were planted in 1956, and 400 bushels were added in 1957. Hydrographic studies done after the planting showed that the set could be expected east of the sanctuary (New York State Conservation Department 1958). The sanctuary project was discontinued in 1958.

The practice of planting of clams from northern waters after the native clams have spawned appears to have begun about 1963 (S.A. Hendrickson, NYSDEC, Personal Communication). The origins of this program are not known but the practice was continued well into the 1970s. The locations for planting were selected by those conducting the program on the basis of where they thought the clams would do best. The decisions were made by baymen until Bay management agencies were established.

Recent improvements in our understanding of the circulation in Great South Bay and the development of computer models which show expected larval transport within the Bay have permitted the implementation of spawner sanctuaries. Spawner sanctuaries can now be located to target the larvae they produce to preselected locations. Both Brookhaven and Islip used the model to locate sanctuaries within their waters in 1983. The two towns anticipate maintaining and enlarging their respective sanctuaries (see, "Spawner Sanctuaries", this volume).

Growing Area Certification

Shellfish taken from sewage contaminated waters were suspected of causing human illness as early as 1903. In 1909, the predecessor agency of the Food and Drug Administration made it unlawful to ship sewage contaminated oysters in interstate commerce. It was not until 1925, following a typhoid epidemic traced to sewage contaminated oysters, that the sanitary evaluation of growing areas became mandated.

In May 1925 New York State adopted legislation that placed all shellfish grounds in the State under the Supervisor of Marine Fisheries and hired two shellfish inspectors to patrol growing areas.

The Supervisor was required to issue certificates of inspections of growing areas and to certify them to be in good sanitary condition (Brooklyn Daily Eagle, August 24, 1925).

In 1929, Great South Bay was considered to be unpolluted and acceptable for shellfishing except within a quarter mile of the mouths of the creeks at Patchogue, Bayshore, and Babylon (J. Redman, New York State Conservation Department, Personal Communication). There is little evidence to indicate that contamination in growing areas, either in area affected or in public concern, was much of a problem through the 1960s.

In 1970, 2,495 acres of the nearly 60,000 acres in Great South Bay were closed to shellfishing (J. Redman, New York State Department of Environmental Conservation, Personal Communication). By 1976, the closed areas had increased to 3,870 acres (New York State Department of Environmental Conservation unpublished 1984). Contamination of growing areas was becoming a major concern. Baymen expressed concern that if the trend continued the entire Bay would be closed to shellfishing. Public officials were concerned about the increase in poaching activities in contaminated areas.

In 1977, the closure of bay bottom became a cause celebre leading to the so-called "Clam War." In January, poaching in the uncertified areas off Islip and Babylon had reached critical levels and forced the State DEC to initiate a major crackdown. At the same time, the State threatened to close nearly 1,400 acres off Babylon (Newsday, January 9, 1977). The threat united baymen and caused the Town of Babylon to revive a lawsuit it had started in 1975 in which it was joined by the towns of Islip, Huntingon, and Brookhaven challenging the validity of the coliform standard (Newsday, January 26, 1977). The State moved to close the area off Babylon in May 1977 although it did designate 1,100 acres in Babylon as conditional shellfishing areas. The four towns, led by Babylon, responded by filing a lawsuit challenging the coliform standard, as a way of blocking the closure. The towns were able to stop the closure and the matter was litigated through July. The State's action was subsequently upheld with the ruling that the coliform standard was valid and that the State had acted properly (Newsday, September 27, 1977).

Decertification of additional areas of Great South Bay (particularly Patchogue Bay) continues to be a concern to the hard clam fishery. Outbreaks of gastroenteritus in recent years have been traced to the consumption of contaminated clams. Although none of the outbreaks has been traced to clams originating in Great South Bay, the unfavorable publicity has adversely affected the Bay's shellfishery.

CONCLUSION

Great South Bay and its shellfishery are, by their nature, ever-changing. Clam abundances rise and fall in response to a number of factors: environmental, socio-political and administrative. Because the relationships among the factors are not constant and are poorly understood, effective management is difficult.

In the past, each peak in landings has been followed by a decline only to have abundance rebound several years later. There is concern now that the recent precipitous declines portend a bleak future for the shellfishery. The number of baymen is greatly diminished, public confidence in the purity of the shellfish has been shaken, the industry is dominated by production from outside New York and there is the possibility that the environment of the Bay, either from natural processes or human activities, has shifted away from conditions optimum for hard clam production. Increasing demands are being put on management agencies to restore the Bay to its former productivity and some steps are being taken. It is to early to tell if these measures will be successful.

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THE HISTORY OF THE HARD CLAM FISHERY OF MORICHES BAY AND SHINNECOCK BAY

INTRODUCTION

Moriches Bay and Shinnecock Bay are shallow bar-built bays located on the south shore of Long Island. Moriches and Shinnecock Bays are similar in size, shape, and hydrography and each has a direct connection, via a tidal inlet, to the Atlantic Ocean. The western two-thirds of Moriches Bay lies within the Town of Brookhaven while the eastern third and all of Shinnecock Bay are under the jurisdiction of the Town of Southampton.

Hard clams are found in Moriches and Shinnecock Bays, but stocks are small. Although they are distinct water bodies, Moriches and Shinnecock Bays are treated as a single harvesting area in landings statistics. Since 1959 landings have ranged from a low of 18,883 bushels in 1964 to a high of 49,080 bushels in 1972. In 1983, 20,494 bushels were harvested (F. Blossom, National Marine Fisheries Service, Patchogue, New York, Personal Communication).

The hard clam fishery of Shinnecock and Moriches Bays is poorly documented, owing in part to their small production relative to other areas. However, both Bays have undergone dramatic change during this century which, even though quantification is not possible, have no doubt affected the abundance of hard clams. Thus, the history of the hard clam fisheries can be inferred, in part, from the history of Moriches and Shinnecock Bays.

MORICHES BAY

Description of Moriches Bay

The surface area of Moriches Bay proper is 13.6 square miles. It is approximately 9.4 miles long and has widths up to 2.5 miles (Figure VI-1). Moriches Bay is relatively shallow, particularly along the south shore, and in the vicinity of Moriches Inlet; about 42 percent of the bay is less than 3 feet deep (U.S. Army Corps of Engineers 1975a). The Long Island Intracoastal Waterway traverses the Bay from east-to-west and has as authorized depth of 6 feet at the mean low water.

The north shore of the Bay has four major promontories. One, Tuthill Point, which projects southward from the mainland north of Moriches Inlet, nearly joins with extensive shoals adjacent to the inlet. Approximately equal areas of the Bay are located on either side of Tuthill Point (U.S. Army Corps of Engineers 1975a).

There are 15 streams flowing into the Bay. The principal ones are Beaverdam Creek, East River, Forge River, Speonk River, Terrell River, Tuthill Creek, and Sealuck Creek (Pagenkopf and Bigham 1977).

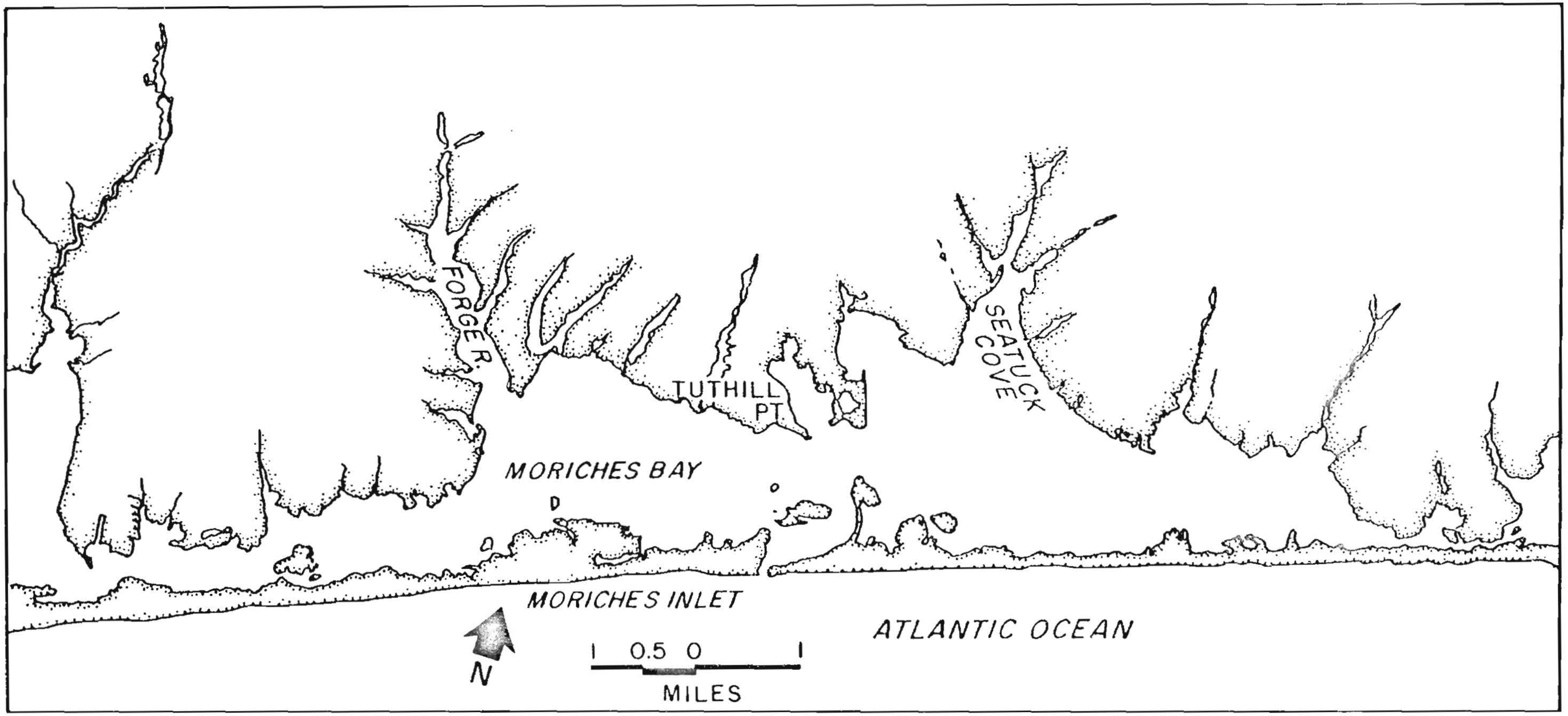


Figure VI - 6

Locator map of Moriches Bay

The total area draining into the Bay is about 47 square miles (U.S. Army Corps of Engineers 1975a).

At the west end of Moriches Bay, and considered a part of the Bay, is Narrow Bay. Narrow Bay is 3 miles long with widths up to 0.75 miles. Narrow Bay enters the east end of Great South Bay and there is thus a flow of water between Moriches and Great South Bay, the direction and volume depending upon the condition of Moriches Inlet.

The morphology of Moriches Inlet has a significant impact upon the hydrography of Moriches Bay. Tidal range, salinity, and water quality have all varied considerably during the recent past due to the opening, closing, dredging and stabilization of Moriches Inlet.

Hydrographic information on Moriches Bay is limited. The salinity in the vicinity of Moriches Inlet is 29 $^{o}/oo$ and decreases to the east and west of the Inlet. The mean tide range as of November 1975 as measured at the East Moriches Coast Guard Station was 1.9 feet (Pagenkopf and Bigham 1977). The mean tidal prism has been estimated by Jarret (1976) to be 8.46×10^8 ft.^{3}.

History of Moriches Bay

Two major events have affected the shellfishery of Moriches Bay: the opening, closing and stabilization of Moriches Inlet; and the development of a duck farming industry along the tributaries of the Bay beginning at the turn of the century. These two factors have together determined water quality in the Bay, particularly the opening and closing of the Bay to shellfish harvesting.

The morphology of Moriches Inlet, which has been variable over the years, controls the tidal exchange in Moriches Bay. Moriches Inlet is highly dynamic and its recent history can be divided into 5 periods (Kassner and Black 1982):

(1) prior to 1931 (both Moriches Inlet and Shinnecock Inlet closed);

(2) 1931 to 1938 (Moriches open, Shinnecock closed);

(3) 1938 to 1951 (both inlets open);

(4) 1951 to 1953 (Moriches closed, Shinnecock open) and

(5) 1953 to present (both inlets open).

Shinnecock Inlet is important to Moriches Inlet because there is a connection between Shinnecock Bay and Moriches Bay. In addition to natural changes in the shape of Moriches Inlet, the inlet has been modified by a number of dredging and stabilization projects (Table VI-1). Change in inlet morphology is given in Table VI-2.

Table VI-1

Stabilization Activities at Moriches Inlet
(from U.S. Army Corps of Engineers, 1983)

Date	Project	Agency
1931	Channel through inner bar, 10 ft. deep, 150 ft. wide, 1,600 ft. long	East Moriches Improvement Assoc.
1935	Channel from inlet to Long Island Intracoastal Waterway	Suffolk County
1938	Brush barriers and hydraulic fill placed at Westhampton Beach, NY	Suffolk County
1947	Stone revetment 790 ft. long on west side of inlet	N.Y. State, Suffolk County, Town of Brookhaven
1952-1954	Construction of east jetty 846 ft. long, construction of west jetty 1,461 ft. long, channel 10 ft. deep, 200 ft. wide, 700 ft. long at the inlet, and hydraulic fill with beach grass placed east of inlet	N.Y. State, Suffolk County, Town of Brookhaven, N.Y. State, Suffolk County
1958	Channel, 10 ft. deep, 200 ft. wide, from the inlet to the Long Island Intracoastal Waterway	Suffolk County
1963	Widen 1958 channel to 300 ft. wide, from the inlet to the Long Island Intracoastal Waterway	Suffolk County
1966	Channel, 12 ft. deep, 300 ft. wide through shoal northwest of inlet	Suffolk County
1969	Channel, 10 ft. deep, 300 ft. wide from the inlet to the Long Island Intracoastal waterway (follows 1958 channel)	Suffolk County
1973	Dredge shoals along 1958 channel	Suffolk County
1978	Dredge along 1958 channel for maintenance purposes	Suffolk County
1981	Construct stone revetment on east side of inlet along 1980 breach Materials were placed along the east and west Moriches Bay shorelines	N.Y. State

Table VI-2

Changes in the morphology of Moriches Inlet
(from U.S. Army Corps of Engineers, 1983)

MORICHES INLET THROAT CROSS-SECTIONAL AND HYDRAULIC CHANGES
(1955-1981)

Date of Survey	A Cross-sectional Area below MSL (sq.ft.)*	R Hydraulic Radius (ft.)	$D_{av.}$ Average Channel Depth (ft.msl)**
Dec. 1955	5,000	6.5	6.5
June 1965	5,760	7.1	7.2
May 1968	10,080	13.4	13.5
July 1974	12,500	17.0	17.1
Dec. 1974	11,520	15.4	15.6
April 1978	11,980	16.0	16.1
Jan. 1980 – March 1981		Breach occurred	
March/April 1981	10,230	13.5	14.2
Aug. 1981	11,420	14.9	15.0

* Minimum cross-sectional area measured along lines across the inlet throat approximately perpendicular to the direction of flow.

** $D_{av.}$ = A/T. where T = top width of the channel, A= Cross-sectional Area

Moriches Inlet controls the flow of water between Moriches Bay and Great South Bay and between Moriches Bay and Shinnecock Bay. When Moriches Inlet is open and the tide flooding, water flows westerly from Moriches Bay into the Great South Bay and from Moriches Bay into Shinnecock Bay (U.S. Army Corps of Engineers 1975a). Over each tidal cycle, there is a net westward flow through Narrow Bay and Quantuck Canal (Suffolk County Planning Department 1982).

Salinity in Moriches Bay is strongly influenced by the condition of Moriches Inlet. In 1907, when Moriches Inlet was closed, salinity ranged from 9.5 to $10.5^{o}/oo$ (Whipple 1912). Following the opening of the inlet in 1931, salinities in both Moriches Bay and eastern Great South Bay rose. In 1950, the salinity was about $25^{o}/oo$ (Woods Hole Oceanographic Institution 1951). Following closure of the inlet, in 1951, salinity fell between 8 and $10^{o}/oo$ (Redfield 1952).

Salinity rose in the Bay following the reopening of Moriches Inlet in 1953. Shortly after the reopening, the inlet began to shoal. By 1956 salinity had dropped by $3^{o}/oo$ compared to 1954 (Figure VI-2). Moriches Inlet has since been dredged many times. The salinity distribution in 1977, the most recent available, is given in Figure VI-3.

The duck farming industry began on Long Island in the 1880s (Suffolk County Planning Department 1982). Many of the farms were located along the tidal creeks, coves and tributaries bordering Moriches Bay. The duck farming operations were run in such a way that nearly all the wastes from the farms eventually entered the water body upon which the farms were located. The duck farms, as a result, released large quantities of nitrogen, phosphorus, coliform bacteria and organic matter. It was estimated that the 4 million ducks raised in 1952 released 2.7 million pounds of nitrogen and 0.8 million pounds of phosphorus (Redfield 1952). The pollution problem was exacerbated because the wastes were discharged into poorly flushed tributaries.

In 1938, it was recognized that unless some methods were implemented to reduce duck farm discharges, substantial areas of Moriches Bay would have to be closed to shellfishing. In the 1950s, it was determined that the wastes originating from the duck farms were responsible for the large blooms of phytoplankton known as "small forms." These species had a deleterious impact on the shellfish of Moriches Bay, and because they were exported to Great South Bay via Narrow Bay, also on Great South Bay shellfish.

In 1951, New York State initiated steps to control discharges from duck farms (New York State Conservation Department 1956). However, it was not until 1955 that the Federal Water Pollution Control Board required duck farmers to desist from polluting adjacent water (New York State Conservation Department 1956). Construction of treatment facilities began the following year. In 1965 New York State required that primary treatment facilities be built by 1968 (Suffolk County Planning Department 1982).

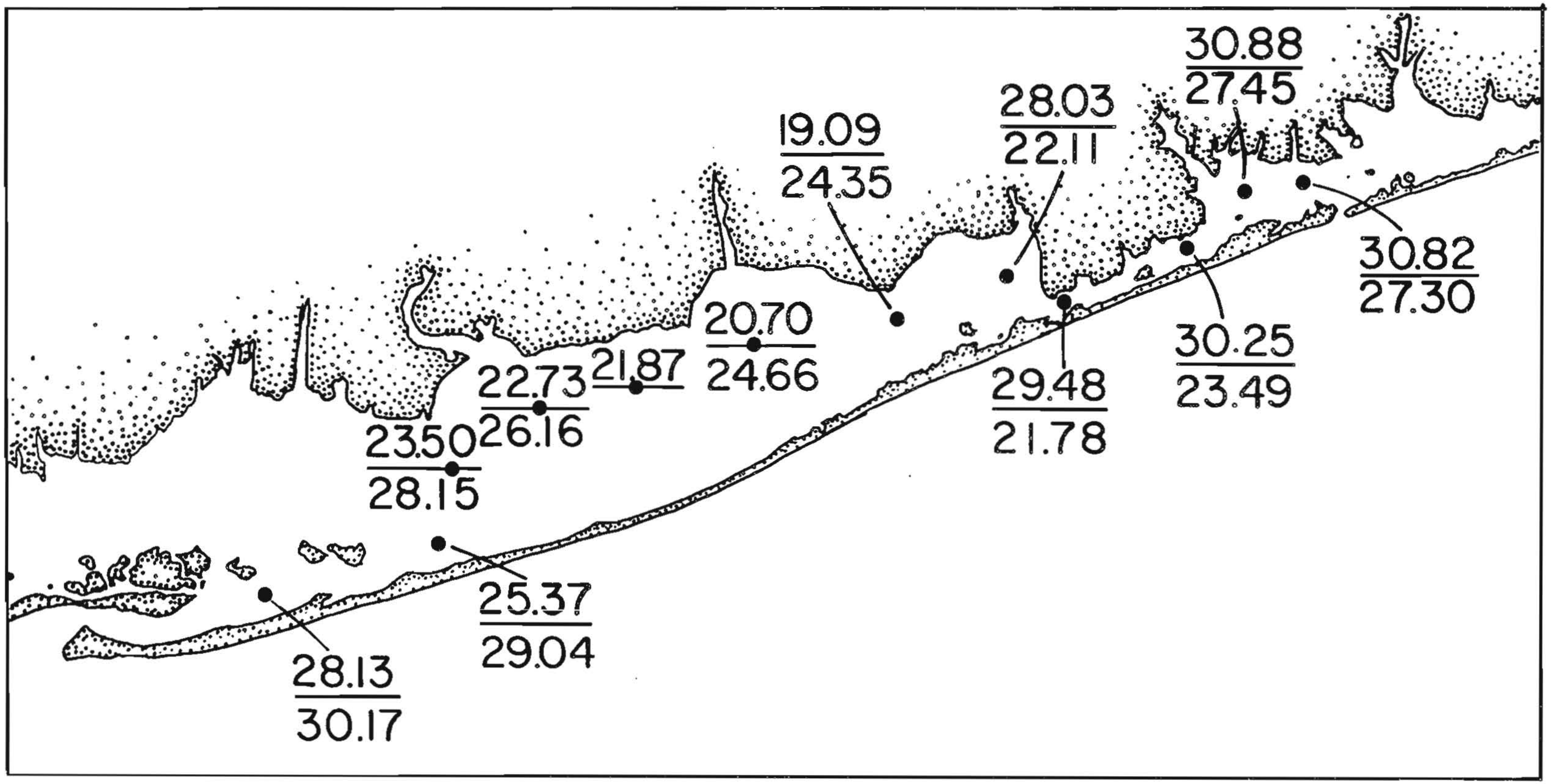


Figure VI - 2

Salinity distribution in eastern Great South Bay and western Moriches

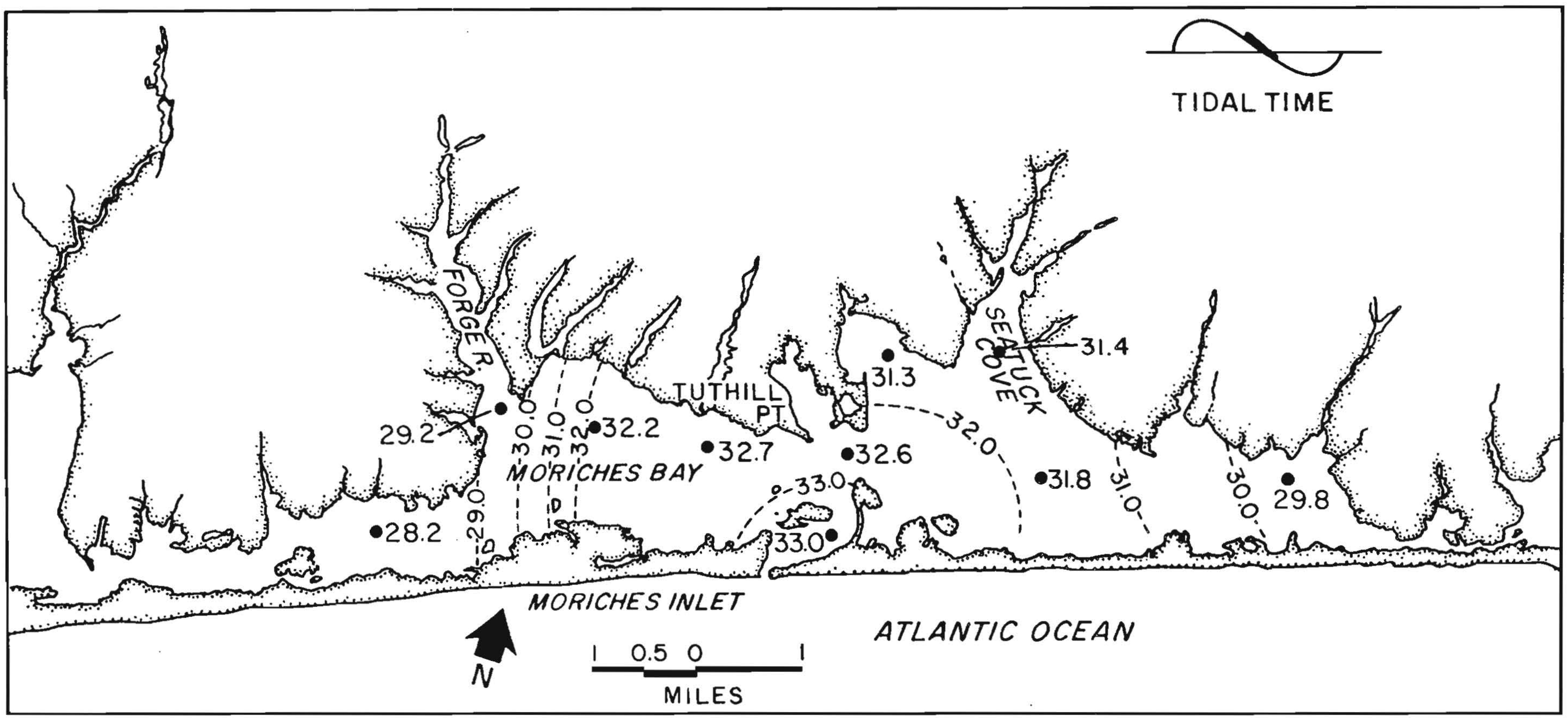


Figure VI - 3
Salinity in Moriches Bay on March 21, 1977

The impact of the pollution from the duck farms was intensified in the 1950s by the shoaling and eventual closure of Moriches Inlet. The reduced flushing ability of the inlet increased the residence time in Moriches Bay and, when the inlet closed in 1951, there was a net export of water to Great South Bay. The reduction in water quality threatened the future of Great South Bay's shellfish industry and this fear was one of the factors that brought about the reopening of Moriches Inlet in 1953.

Duck farming operations peaked in the late 1950s and early 1960s. Today there are less than 14 farms (Suffolk County Planning Department 1982) and most waste discharges have been stopped. One legacy of the industry still remains--the duck farms were responsible for deposition of large volumes of organic sludge on the bottoms of many of the tributaries of Moriches Bay. In 1968, it was estimated that over 7 million cubic yards of duck sludge deposits were in Moriches Bay tributaries. In the early 1970s Suffolk County dredged many of the tributaries removing over a half million cubic yards of duck sludge (Pagenkopf and Bigham 1977).

HISTORY OF HARD CLAM FISHERY IN MORICHES BAY

Moriches Bay has an area of slightly less than 11,000 acres. Even relatively small closures can include a significant fraction of the Bay. As early as 1908, half of Moriches Bay was closed to shellfishing, presumably caused by duck farms (Suffolk County Planning Department 1982). In 1938, duck farm pollution was responsible for closing 2,656 acres in Moriches Bay (New York State Conservation Department 1939), a time when Moriches Inlet was open.

Sometime prior to 1952, and perhaps as early as 1938, the State Conservation Department adopted a policy of opening portions of the closed areas in winter (November to April). This was possible because the duck farms ceased production in the winter months, resulting in an improvement in water quality. This policy was discontinued in 1968.

The area and acreage closed to shellfishing has varied considerably since 1962. The major change has been the distance of the closure line from shore. The closure never extended past the mid point of the Bay; the area adjacent to the barrier beach has never been closed while the coves have rarely been open (see "History of Uncertified Areas, 1965-1984," this volume).

In 1977, the New York State Department of Environmental Conservation instituted a program of conditional openings in Moriches Bay. Under this program, selected areas were open to shellfishing, provided there had not been 0.25 inches or more of rain in any of the preceding seven days. This program was terminated in 1982 because water quality no longer improved during periods of no, or low, rainfall.

Information on stock size of the hard clams in the Bay is relatively scarce. Prior to the opening of Moriches Inlet in 1931, salinities were too low for scallops, hard clams, or soft clams. Curiously, there was an active blue crab fishery before the opening of the inlet which dates back to at least 1880 (Mather 1887).

Following the opening of Moriches Inlet, salinity rose in Moriches Bay. In a qualitative study undertaken in 1938, Townes (1939) reported that oysters and soft clams were "common to abundant."

Following the reopening of Moriches Inlet in 1953, salinities in the Bay rose and the increase in tidal exchange flushed out much of the duck farm waste. It was reported that in 1955 there was excellent production of soft and hard clams (New York State Conservation Department 1956).

In 1962, the United State Department of Interior prepared a map (Figure VI-4) showing the distribution of shellfish resources in Moriches Bay (U.S. Army Corps of Engineers 1975b). No information is given about the methodologies employed in constructing the map. A similar but undated map, prepared by the New York State Conservation Department (Figure VI-5) was presented at a public hearing sponsored by the Federal Water Pollution Control Administration in 1966 (Wallace 1966). There are no recent maps of stock distribution.

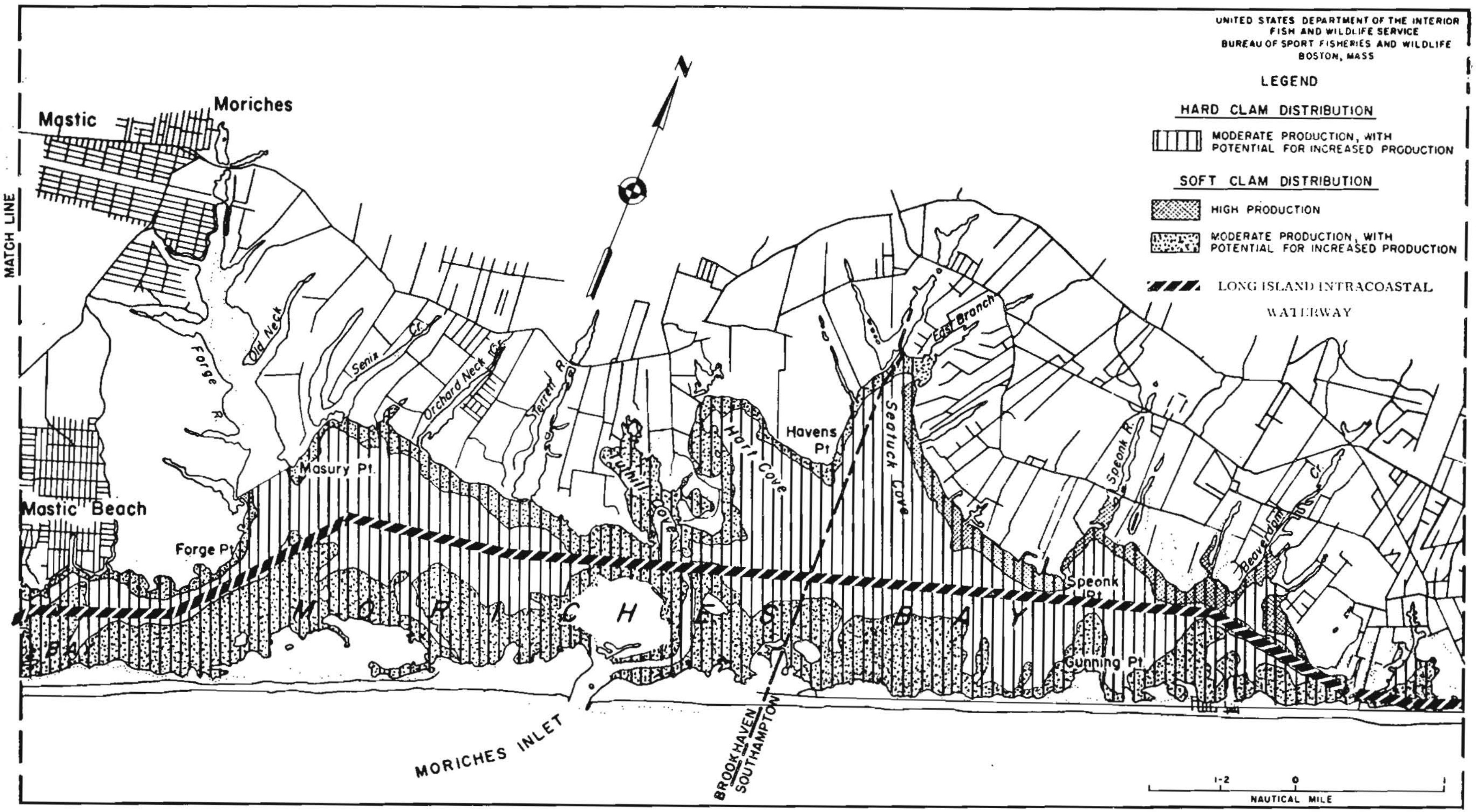
According to Turner (1983), the growth rate of hard clams in Moriches Bay is faster than clams inhabiting Great South Bay. This suggests that Moriches Bay can support hard clams and that the lack of production may be due to the lack of setting. Moriches Bay has a large tidal exchange relative to its volume and its residence time may be less than the planktonic larval stage of the hard clam, although this has not been precisely determined (see "Spawner Sanctuaries," this volume).

Hard clam production is very low in Moriches Bay. There is some recreational harvesting adjacent to the barrier beach. At the time of the first conditional opening in 1977, the coves did have a sizeable hard clam population comprised of cherrystones and chowders. These areas currently are depleted.

SHINNECOCK BAY

Description of Shinnecock Bay

Shinnecock Bay has a surface area of 14.5 square miles with a width up to 2.9 miles (U.S. Army Corps of Engineers 1975a). The Bay is effectively divided in two parts by Ponquogue Point which extends southward toward the barrier beach, constricting the width to 1,200


UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
BOSTON, MASS
LEGEND
HARD CLAM DISTRIBUTION
MODERATE PRODUCTION, WITH POTENTIAL FOR INCREASED PRODUCTION
SOFT CLAM DISTRIBUTION
HIGH PRODUCTION
MODERATE PRODUCTION, WITH POTENTIAL FOR INCREASED PRODUCTION
LONG ISLAND INTRACOASTAL WATERWAY
MATCH LINE
Mastic
Moriches
Mastic Beach
Forge Pt.
Masury Pt.
Forge R.
Old Neck
Senix Cr.
Orchard Neck Cr.
Terrell R.
Hart Cove
Havens Pt.
Seatuck Cove
East Branch
Speonk R.
Beaverdam Cr.
Speonk Pt.
Gunning Pt.
M O R I C H E S B A Y
MORICHES INLET
BROOKHAVEN
SOUTHAMPTON
N
1/2 0 1
NAUTICAL MILE

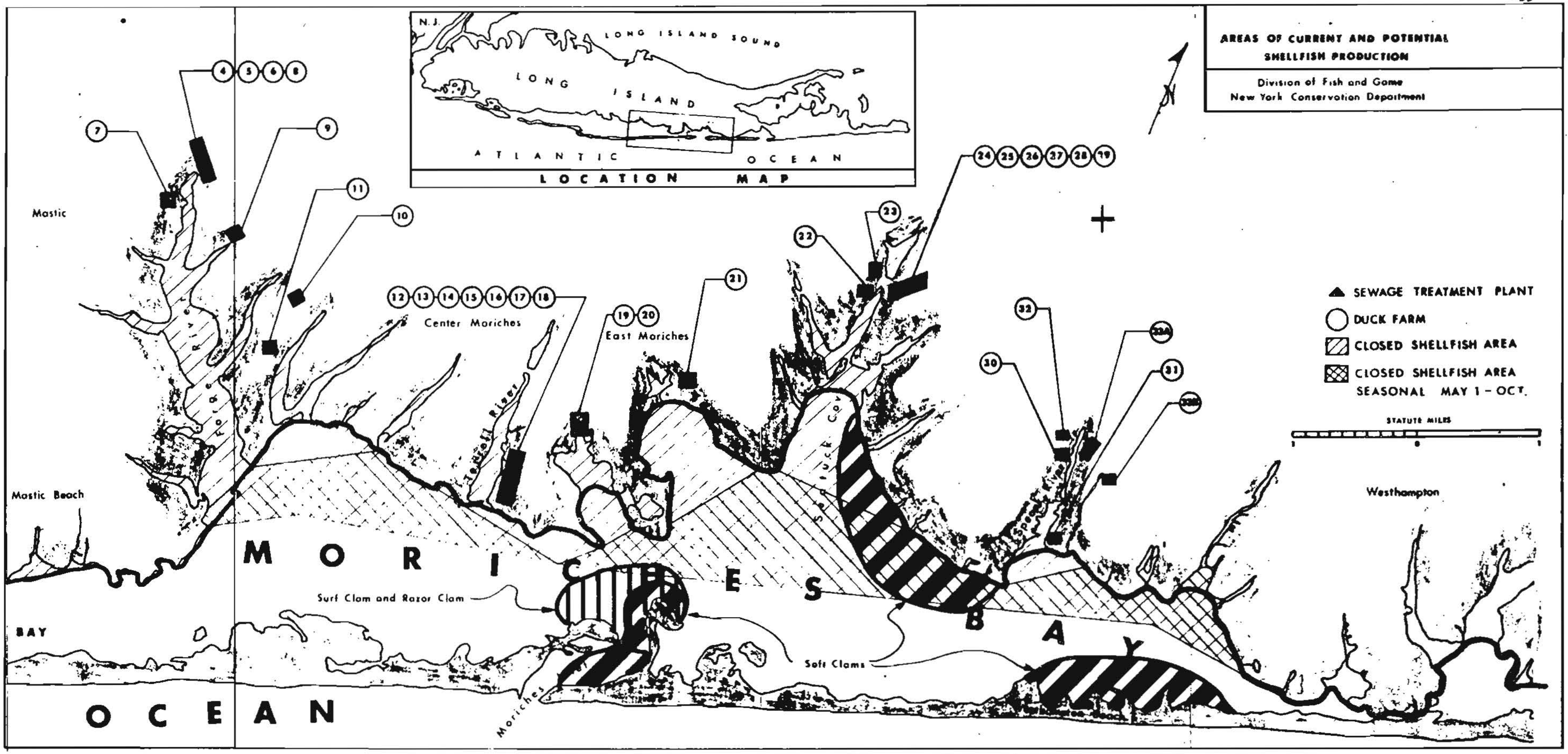


Figure VI - 5
Shellfish production in Moriches Bay.

feet. Approximately 56 percent of the Bay lies east of Ponquogue Point (Figure VI-6).

The two halves of Shinnecock Bay are considered distinct water bodies by local baymen (H. Berglin, Southampton Baymen's Association, Personal Communication) and are dissimilar hydrographically. The eastern half is connected to Peconic Bay by Shinnecock Canal and Shinnecock Inlet is located in the center of the eastern basin. The western half is connected to Moriches Bay via Quantuck Canal, Quantuck Bay and Quoque Canal.

The average depth of Shinnecock Bay is 5 feet at mean low water (U.S. Army Corps of Engineers 1975a). The maximum depth in the eastern section is 12 feet while in the western section it is 7 feet. Marshes and shallow flats cover 42 percent of the Bay area.

The hydrography of Shinnecock Bay is poorly documented. The salinity distribution was studied in April 1977 and is presented in Figure VI-7. In 1955, following completion of the jetties at the inlet and with an inlet cross sectional area at mid-tide of 5,520 square feet, the average flood tide volume through Shinnecock Inlet was 290 million cubic feet, and at ebb 339 million cubic feet (U.S. Army Corps of Engineers 1975a).

History of Shinnecock Bay

The major factor affecting Shinnecock Bay has been Shinnecock Inlet. There was an inlet into Shinnecock Bay prior to 1891 but from 1891 to 1938 there was no inlet between Shinnecock Bay and the Atlantic Ocean (Kassner and Black 1983). Salinity was very low during these years and, as a result, Shinnecock Bay was not a productive shellfish area. To increase salinity and shellfish production, Shinnecock Canal was improved in 1898. Several attempts also were made to artificially open an inlet, again to increase Bay salinities, prior to the opening of the present Inlet by the hurricane of 1938.

Shinnecock Inlet has been open continuously since 1938, although it has been modified by numerous stabilization efforts (Kassner and Black 1983). In 1951, a channel 9 feet deep and 100 feet long was dredged through the inlet. Stone jetties have been constructed on both banks of the Inlet since then.

History of Shinnecock Bay's Hard Clam Fishery

The history of the hard clam fishery in Shinnecock Bay is poorly documented. This is a result of two factors: the low production from the Bay and the fact that baymen are more diversified there than in other areas.

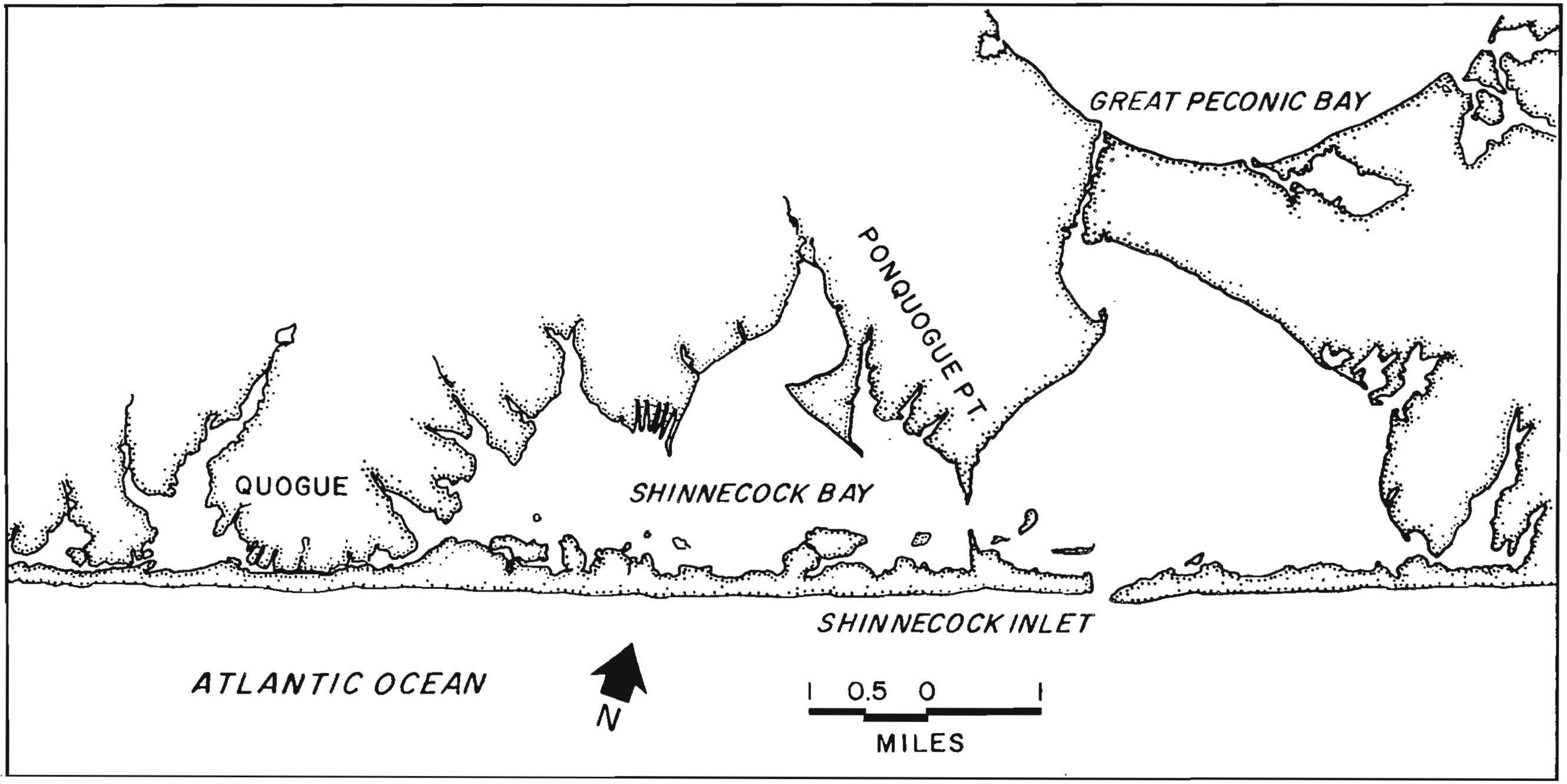
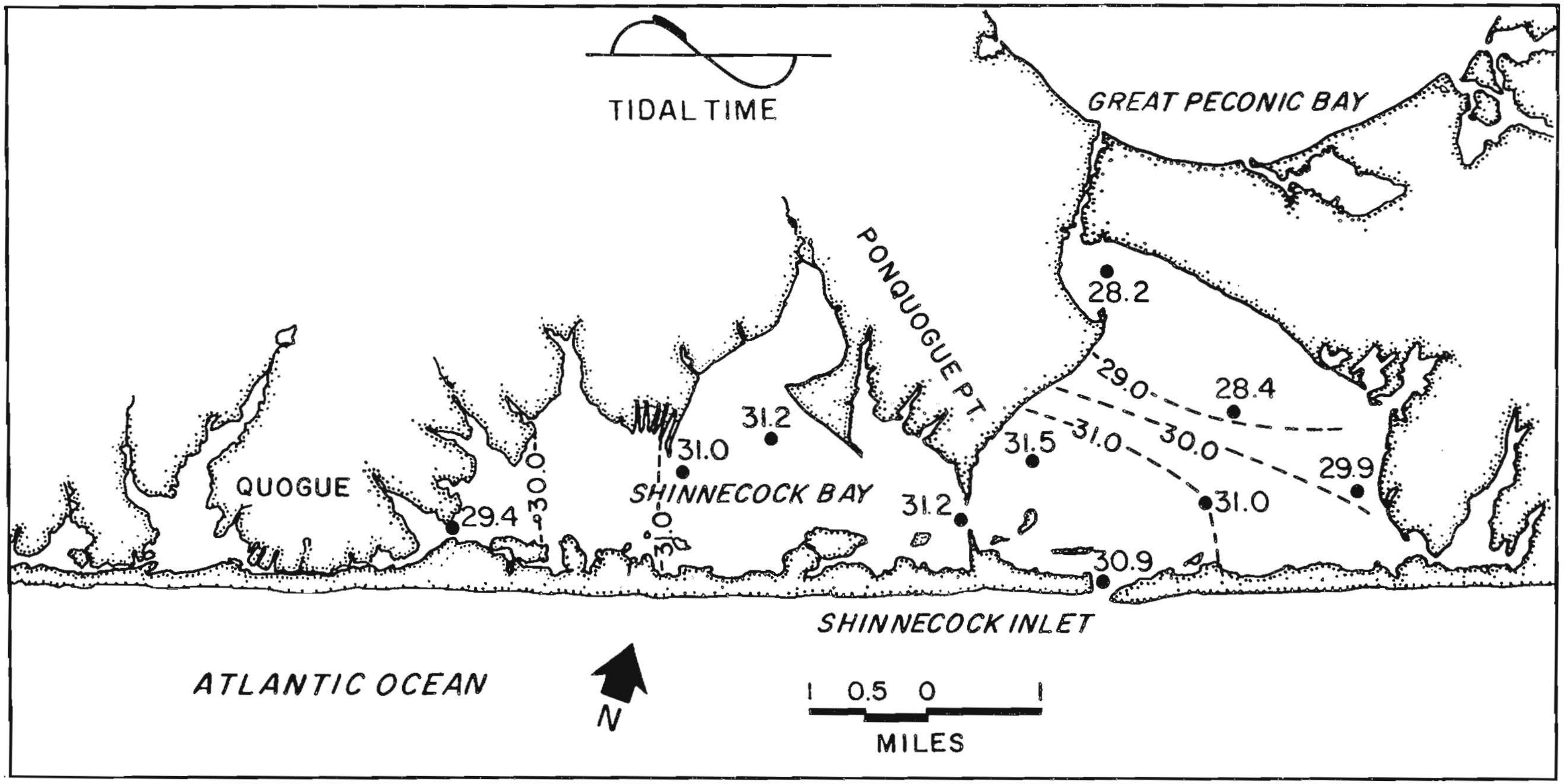


Figure VI - 6
Locator map of Shinnecock Bay


TIDAL TIME
GREAT PECONIC BAY
PONQUOGUE PT.
QUOGUE
SHINNECOCK BAY
SHINNECOCK INLET
ATLANTIC OCEAN
N
1 0.5 0 1
MILES
28.2
29.0
28.4
31.2
31.0
31.5
31.0
30.0
29.9
29.4
30.0
31.0
31.2
31.0
30.9

Hard clams were not found in any abundance in Shinnecock Bay prior in the opening of Shinnecock Inlet (H. Berglin, Southampton Baymen's Association, Personal Communication). According to Berglin, there was a good set of clams either in 1942 or 1943. Sets occurred about every 5 years there after but there have been no sets of any consequence in about 10 years.

Historically, the western half of Shinnecock Bay has been more productive than the eastern half (H. Berglin, Personal Communication, Southampton Baymen's Association). Five years ago, a good days catch was 2 to 3 bushels of littlenecks. Today it is a bushel. Nearly every area of the Bay now has impoverished stocks of hard clams.

Water quality is not a problem for the hard clam industry in Shinnecock Bay. Of the Bay's 9,170 acres, only 220 are currently closed to shellfishing. There has been no change in the area closed to shellfishing since 1970.

REPORTED LANDINGS FOR MORICHES AND SHINNECOCK

Hard clam harvests for Moriches and Shinnecock Bays are reported by Township. Since two-thirds of Moriches Bay is in Brookhaven and the remaining one-third and all of Shinnecock Bay is in Southampton, it is not possible to obtain landings for each area separately. Historical landings by township and the two water bodies together is given in Table VI-3.

No historical estimates of the fishing effort for either Bay can be made. Harvesters licensed by both towns can work in other waters of their respective towns. There is no reciprocal shellfishing agreement between Southampton and Brookhaven as there is between adjacent towns on Great South Bay.

Table VI-3

Landings (bushels) and Value (dollars) of Hard Clams taken From Moriches and Shinnecock Bay

	Brookhaven		Southampton		Total	
Year	Landings	Value	Landings	Value	Landings	Value
1983	9,055	378,895	11,439	512,983	20,494	891,878
1982	14,906	732,313	10,045	424,133	24,951	1,257,456
1981						
1980						
1979	4,400	168,934	23,303	725,804	27,703	894,738
1978	3,260	79,208	20,121	618,493	23,381	697,701
1977	4,453	112,852	22,384	572,873	26,837	685,725
1976	3,929	93,093	38,768	367,559	42,697	460,652
1975	12,798	255,453	13,374	267,053	26,172	520,506
1974	11,210	227,406	14,629	305,291	25,839	532,697
1973	6,762	126,180	17,450	326,976	24,212	453,156
1972	13,418	260,663	25,662	657,003	49,080	917,666
1971	3,890	59,011	36,718	542,503	40,608	601,514
1970	5,899	76,249	37,662	487,943	43,561	564,192
1969	No Landings Reported		33,615	425,966	33,615	425,966
1968	No Landings Reported		39,643	486,269	39,643	486,269
1967	2,410	29,710	28,747	356,110	31,157	385,820
1966	2,025	23,600	24,751	270,497	26,776	294,097
1965						
1964					18,883	
1963					25,150	
1962					21,000	
1961					21,325	
1960					20,000	
1959						

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HISTORY OF THE PECONICS AND NORTH SHORE HARD CLAM FISHERIES

INTRODUCTION

In recent years the hard clam fisheries of Long Island's north shore and the Peconic Bays have been greatly overshadowed by the Great South Bay (GSB) fishery. Although hard clam landings in the former areas have been low, relative to peak production in GSB, they have provided an important contribution to total New York landings.

Historically, the north shore bays and the Peconics have been important areas for oyster production; and in the Peconics scallops have been a major resource as well. However, there seems to have been an important north shore hard clam fishery even when the oyster industry was at, or near, its peak. According to Mather (1887) about 86,000 bushels of hard clams were taken (commercially) in 1880 from Huntington Bay, Stony Brook Harbor, and Port Jefferson Harbor (including Conscience Bay). In the same year about 20,000 bushels of hard clams were harvested in Peconics and Gardiners Bays.

NORTH SHORE FISHERY

The four embayments on Suffolk County's north shore in which clamming takes place are Huntington Bay, Stony Brook Harbor, Port Jefferson Harbor, and Mt. Sinai Harbor. All are relatively small coastal indentations partially cut off from Long Island Sound by baymouth bars (Gross *et al.* 1972). Stony Brook Harbor continues to be the location of most of the clamming activity in Smithtown. At present, Huntington Bay supports by far the largest hard clam fishery on Suffolk County's north shore.

Huntington Bay

Huntington Bay lies just east of the Nassau-Suffolk border and can be divided into two parts: Huntington Bay, which opens directly to the Sound, and Northport Bay which opens into Huntington Bay. These bays contain three extensively developed harbors: Huntington, Centerport, and Northport, and two relatively undeveloped harbors; Lloyd and Duck Island. Huntington Bay will be used here to refer to the entire Huntington-Northport Bay complex (Figure VII-1). Figure VII-1 also shows the salinity distribution for Huntington Bay. These data are means of six samples taken at each station during the spring and summer of 1978.

Shellfishing, at a subsistence level by local residents, has been an important activity in Huntington Bay since the area was first settled. The commercial shellfishing industry began to develop in the

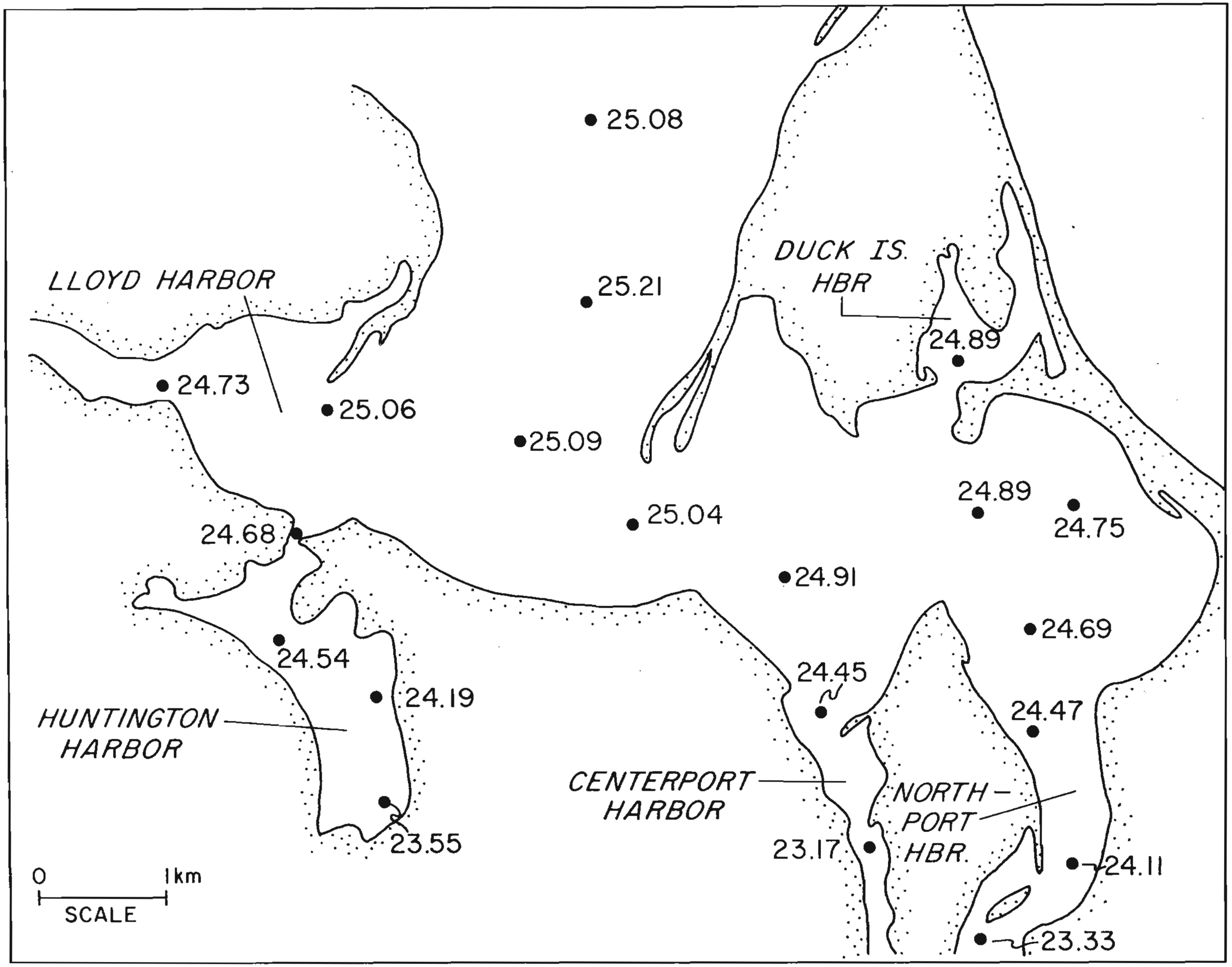

25.08
LLOYD HARBOR
25.21
DUCK IS. HBR
24.89
24.73
25.06
25.09
24.89
24.75
25.04
24.68
24.91
24.69
24.54
24.45
24.19
24.47
HUNTINGTON HARBOR
CENTERPORT HARBOR
NORTH-PORT HBR.
23.55
23.17
24.11
23.33
0
1km
SCALE

Figure VII - 1

nineteenth century. Oysters were the primary catch but clams and scallops also were taken by commercial fishermen (Kavenagh 1980). Ingersoll (1884) mentions that hard clams from the Little Neck area were of very high reputation and in great demand when oysters were out of season. Leasing of oyster beds by the Huntington Town trustees was begun in 1875 but the issuing of leases ended in 1883 as a result of pressure by voters (Kavenagh 1980). Long Island Oyster Farms presently leases 1740 acres stemming from the renewal, in 1976, of leases originally issued during the 1880s. Sometime during the first half of the twentieth century clams began to replace oysters as the major shellfish resource in Huntington Bay. Oystering began to decline toward the end of the nineteenth century, apparently as a result of overharvesting and a major starfish invasion (Kavenagh 1980). By 1946 [the first year for which New York State Department of Environmental Conservation (DEC) statistics are available], hard clam landings were about ten times greater than oyster landings. Oysters did, however, continue to be an important crop at least into the 1950s (DEC 1984 unpub. data).

Reported hard clam landings from Huntington Bay peaked at over 167,000 bushels in 1962 and landings exceeded 100,000 bushels each year from 1961 to 1963 (Figure VII-2). During this period Huntington Bay accounted for nearly half of the total New York hard clam landings (DEC 1984 unpub. data). After 1964 the hard clam catch in Huntington Bay declined dramatically and stabilized at 10,000 - 20,000 bushels annually, climbing slightly since 1980 (Figure VII-2).

There is a scarcity of well documented information on the rise and decline of the clam fishery in Huntington Bay. Some evidence exists of large scale harvesting of undersized clams during this period including the personal recollections of baymen and newspaper accounts of arrests for possession of sublegal size hard clams. In March 1962 the Town of Huntington shellfish code was changed to required clammers to carry a size gauge. This measure was apparently supported by the Huntington Baymen's Association. The increasing development of Huntington Bay and the surrounding area was probably also a major factor in declining harvests. During the late nineteenth and early twentieth centuries the Huntington area experienced substantial activity in the development of its shoreline areas and increased pleasure boat traffic in the harbors (Kavenagh 1980). This, in turn, produced a degradation of water quality and an increase in the total area closed to shellfishing.

Most likely, the depletion of hard clams in Huntington Bay can be traced to a combination of overfishing (including removal of seed clams) and deteriorating water quality. Stocks may have been reduced by overharvesting to a point at which their ability to produce a successful set was severely limited. Reduced water quality served to further decrease the chances of a good set of clams. The slight increases in hard clam landings in 1975 and again in 1982 and 1983 indicate that successful recruitment may still take place, but at infrequent intervals. The number of baymen, or potential baymen, now in the area is such that when a substantial set does occur it can be exploited as soon as it reaches legal size (D. Relyea, F.M. Flower and Sons, Personal Communication).

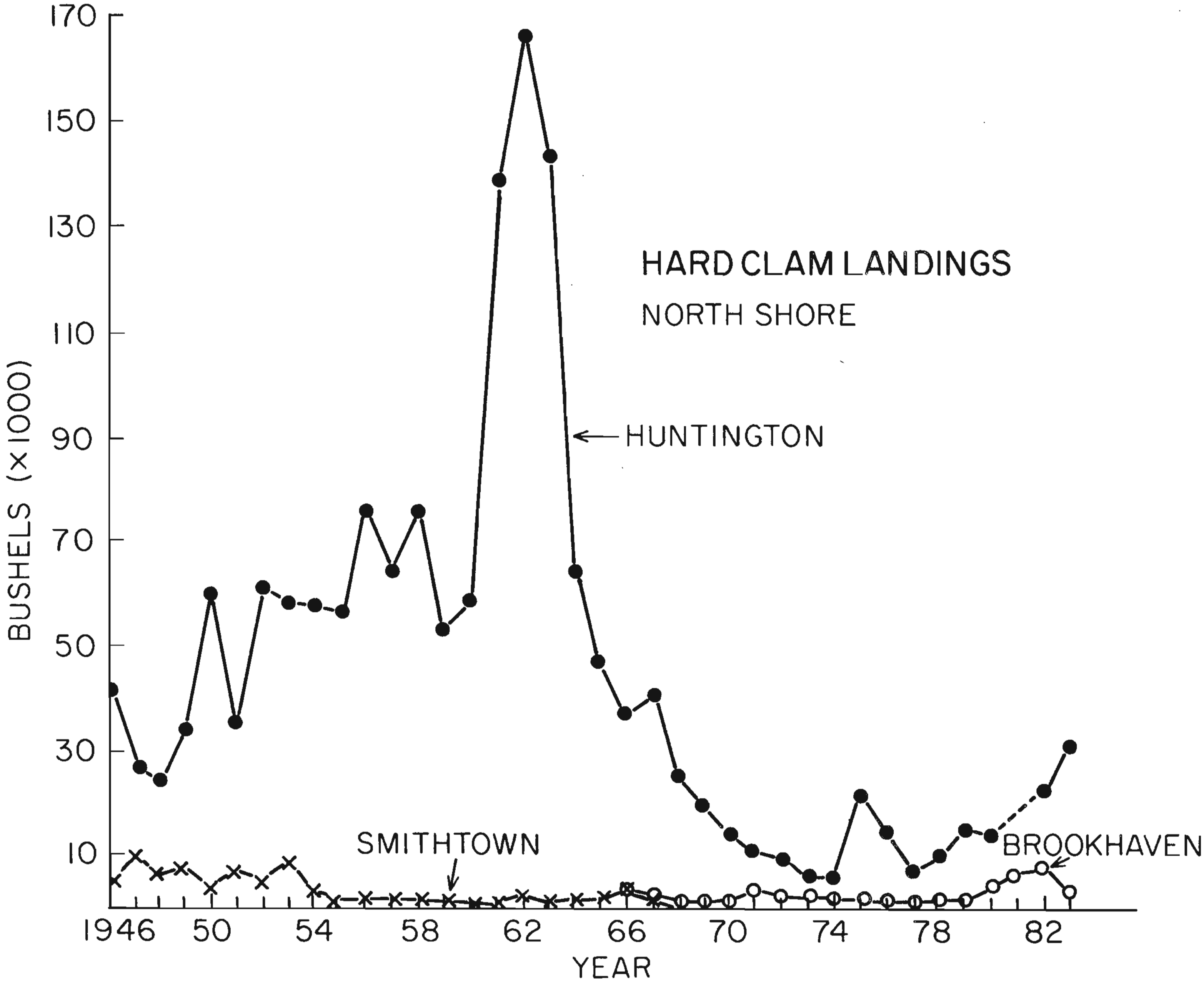


Figure VII - 2
Annual hard clam landings from Suffolk County's north shore

Changes in the total area closed to shellfishing also have contributed to fluctuations in the number of clams available to baymen. In June 1978 a section of Huntington Harbor which had been closed to shellfishing for 20 years was reopened but had to be closed again because of high coliform counts (The Long Islander 1978). Also in 1978, sections of Centerport and Northport Harbors were reopened (Newsday 1977) and have remained open (Figure VII-3 and VII-4). During the past three winters the Town of Huntington has attempted conditional openings in Northport Harbor. In the winter of 1981-82 approximately 75 acres were opened. Conditional openings were planned for the winters of 1982-83 and 1983-84, but poor water quality forced officials to keep the areas closed. The conditional opening criterion was that no rainfall greater than 0.25 inches in a 24 hr period (3:00 pm to 3:00 pm) had been recorded during the previous seven days. At the present time all of Huntington Harbor and parts of Centerport and Northport Harbors are uncertified (Figures VII-4 & VII-5). These areas were formerly considered productive according to R. Koopman (Town of Huntington, Personal Communication). Actively worked clam beds still exist throughout Huntington Bay and especially productive areas occur in Northport Bay.

The level of involvement by Huntington officials in shellfish management has been variable over the years. The amount of activity at any time appears to be set by a combination of the interest of local officials, pressure by baymen, and availability of funds. In 1956 the trustees consulted with the State Comptroller's office as to whether or not they had the right to regulate the shellfish industry. Considering the 300 year history of the trustees, a number of legal decisions in their favor, and various State laws it is, according to Kavenagh (1980), hard to believe that they would even question this right. In 1959 the trustees established a Harbors and Waterways Committee whose mandate included suggesting steps to insure shellfish conservation (Kavenagh 1980). According to R. Koopman (Town of Huntington, Personal Communication) this committee no longer exists. In 1962 the board of trustees appropriated $3,000 to transplant clams to an unpolluted area of Northport Harbor. In 1966 the trustees, along with the State Conservation Department, the U.S. Fish and Wildlife Service, George Vanderborgh of Long Island Oyster Farms, and Fred Schieferstein of the Baymen's Association began a program of planting clams in different areas to determine the best environments for their propagation (Kavenagh 1980). Over the next three years the experiment was funded by the trustees at a rate of $6,000 per year to purchase a total of 9000 bushels of clams for planting in designated locations.

In 1982-83 the Town of Huntington used funds provided by Public Law 88-309 (Aid to Commercial Fisheries) through the DEC to plant 300 bushels of spawner stock each year. Relays of hard clams from uncertified to certified areas were conducted during 1982, 1983, and 1984. In some cases the clams were replanted into closed areas that were slated for conditional opening in the winter. Seed planting has also been conducted in Huntington Bay as part of the 1976 lease agreement between the town and Long Island Oyster Farms. Under this

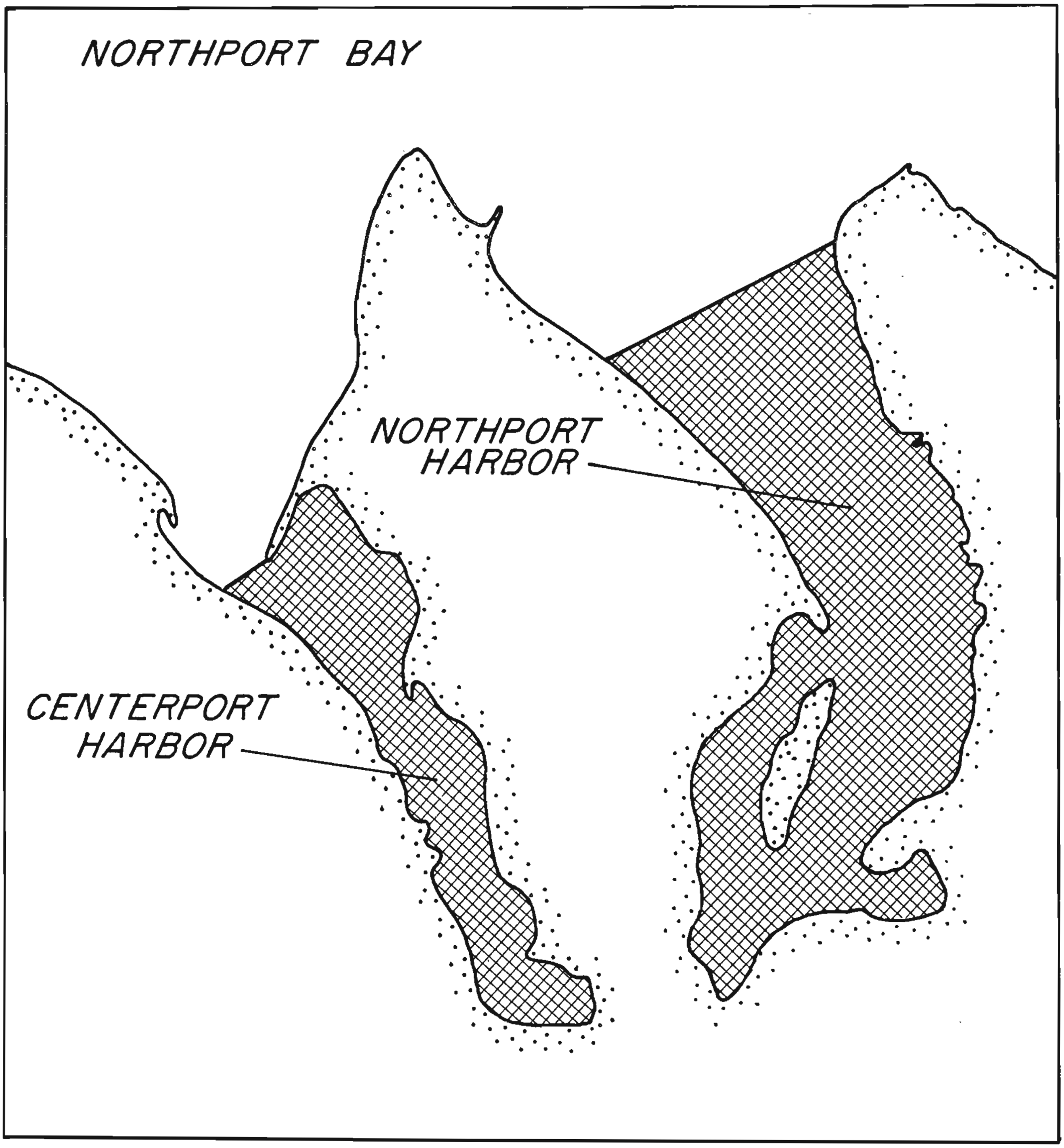


Figure VII - 3
Uncertified areas of Northport Bay - 1974

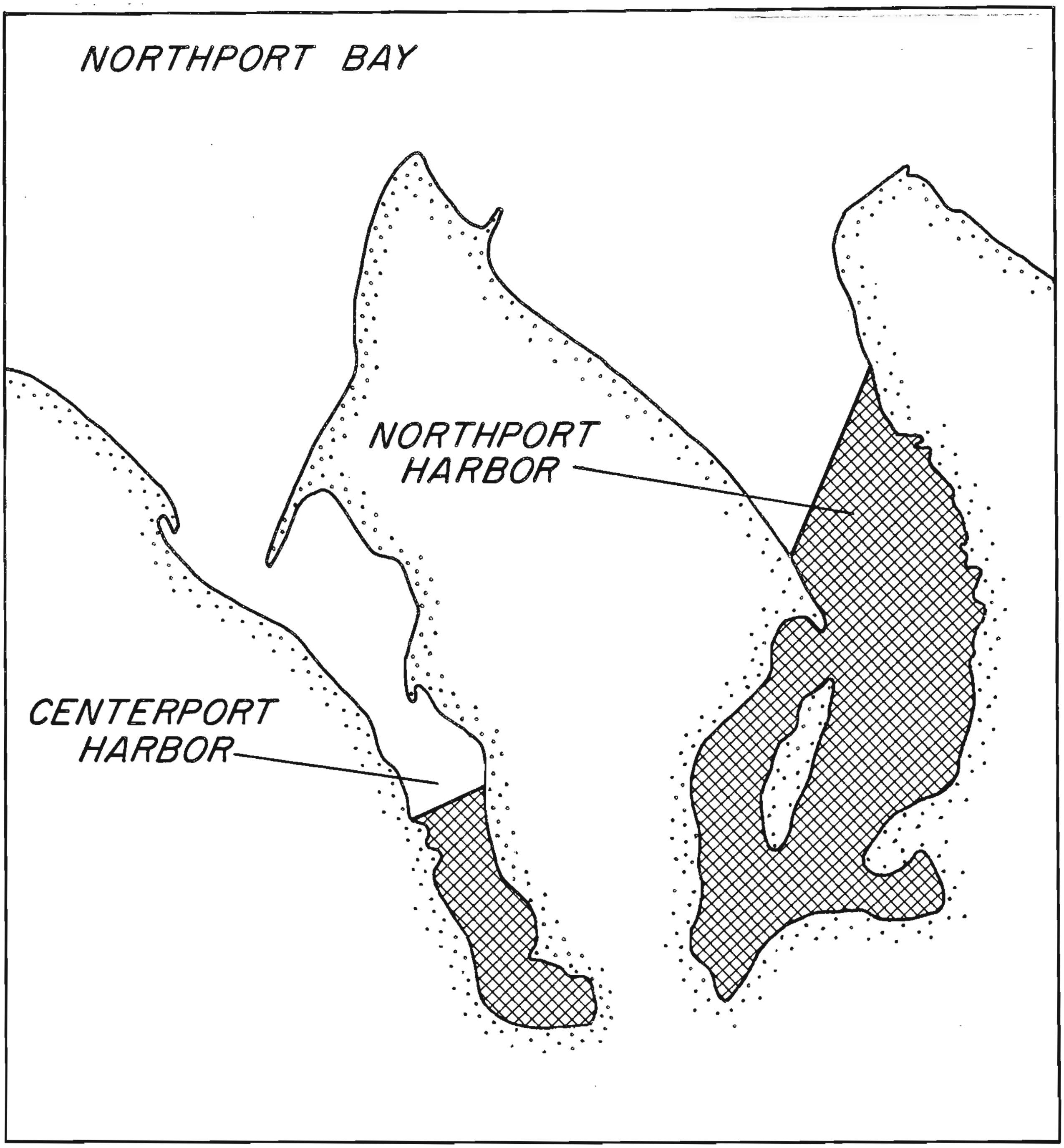


Figure VII - 4
Uncertified areas of Northport Bay - 1982-84

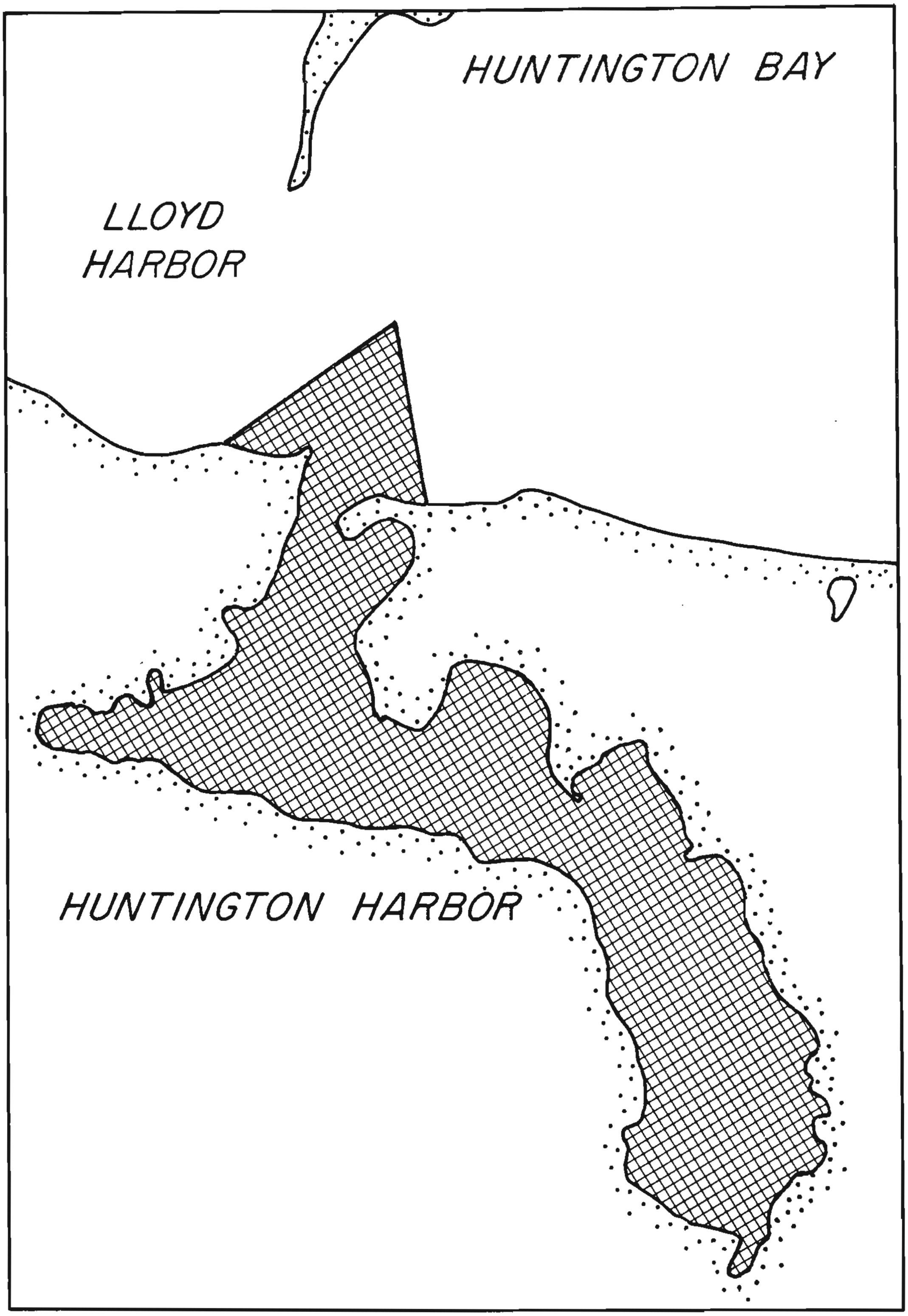


Figure VII - 5
Uncertified areas of Huntington Bay - 1984

agreement, 10 million clams 5 mm in size were planted. This program is to be reevaluated at the tenth anniversary of the lease.

Other North Shore Bays

Stony Brook Harbor, Port Jefferson Harbor, and Mt. Sinai Harbor have all supported small commercial hard clam fisheries. Closures of shellfish grounds have contributed to declining harvests in all three bays. In 1980 the Town of Smithtown appropriated $3,000 for the planting of seed clams in an attempt to revitalize the Stony Brook Harbor clam fishery. This program also made use of funds provided by Public Law 88-309 (Newsday 1980). Baymen continue to average from two to five bushels of hard clams per day from Stony Brook Harbor (S. Resler, Town of Smithtown, Personal Communication). DEC catch statistics show that landings from the north shore of Brookhaven Town increased substantially between 1980 and 1982, peaking at almost 8,000 bushels in 1982 (Figure VII-2). It cannot be determined from the catch statistics which bay, or bays, contributed to this increase or even whether it represents a real increase in landings or simply better reporting. It also is not possible to determine if landings were higher at any time prior to 1966 because landings from the north shore and south shore bays of Brookhaven were not considered separately in catch statistics from 1946 to 1966.

THE PECONICS FISHERY

Hard clam landings in the Peconic Bays and Gardiner's Bay (treated as one area, the Peconics, in DEC statistics) have never approached the peak levels seen on the north shore, and much less information is available on the fishery in this area. The largest landings in the Peconics occurred in 1946 and 1947 when a catch of over 70,000 bushels was reported each year. During the mid 1950s landings again reached approximately 50,000 bushels annually for four years (Figure VII-6).

Compared with more productive areas, such as Great South Bay, the densities of hard clams in the Peconics are quite low. Department of Environmental Conservation surveys conducted in 1979 and 1980 show that densities as high as 15 clams per 100 ft^2 (1.6 clams per m^2) occurred in only a few small areas (Figures VII-7 & VII-8). For comparison, Buckner (1984) reports an average density of 5 clams per m^2 for all certified areas of Islip waters. However, the DEC surveys did not include several small embayments which reportedly contain hard clam populations of harvestable density. According to John Plock Sr., (Shelter Island Oyster Company (Retired), Personal Communication) Three Mile Harbor to Northwest Harbor, on the south fork, and Mill Creek, on the north fork, are productive hard clam areas. Mr. Plock

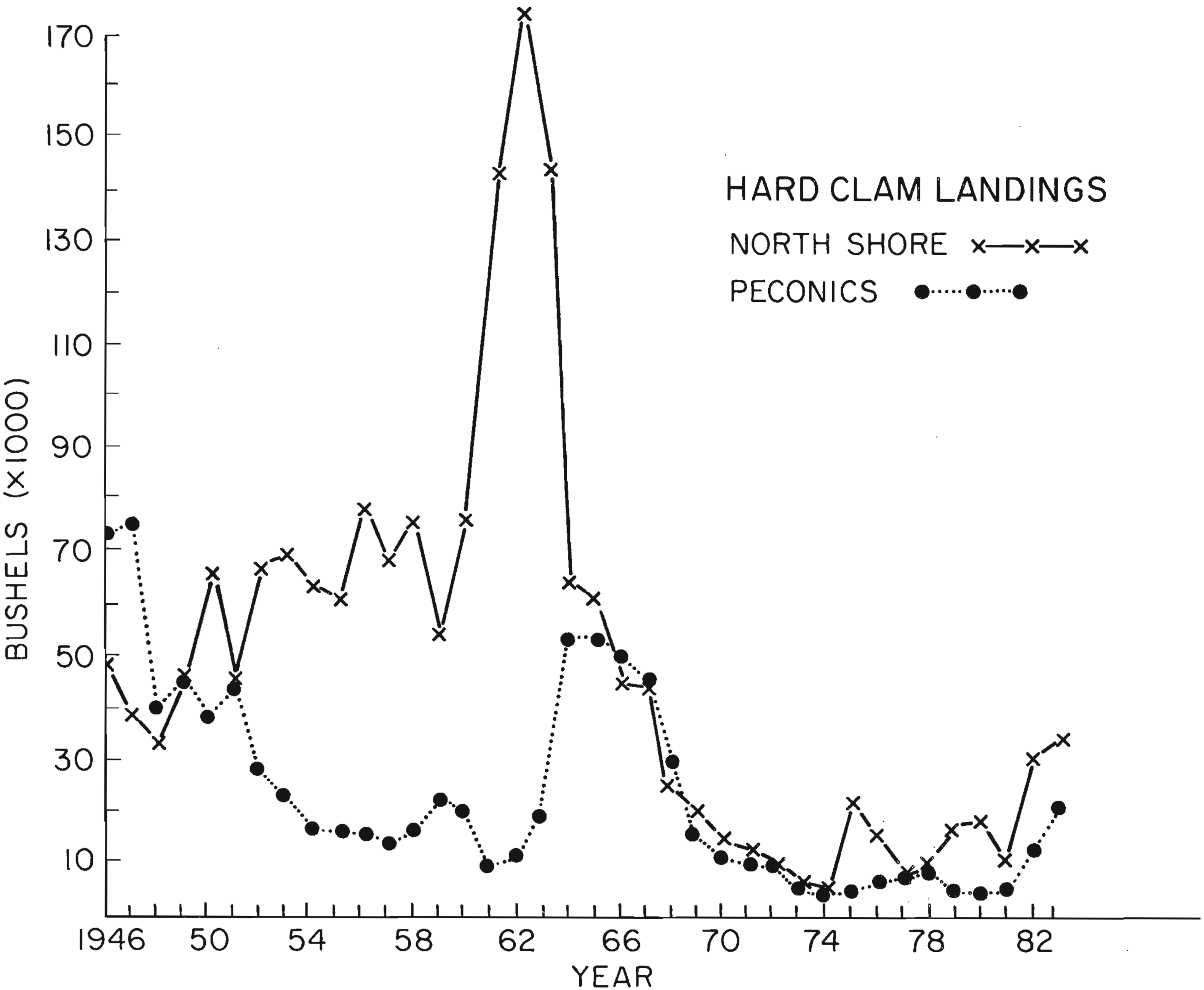
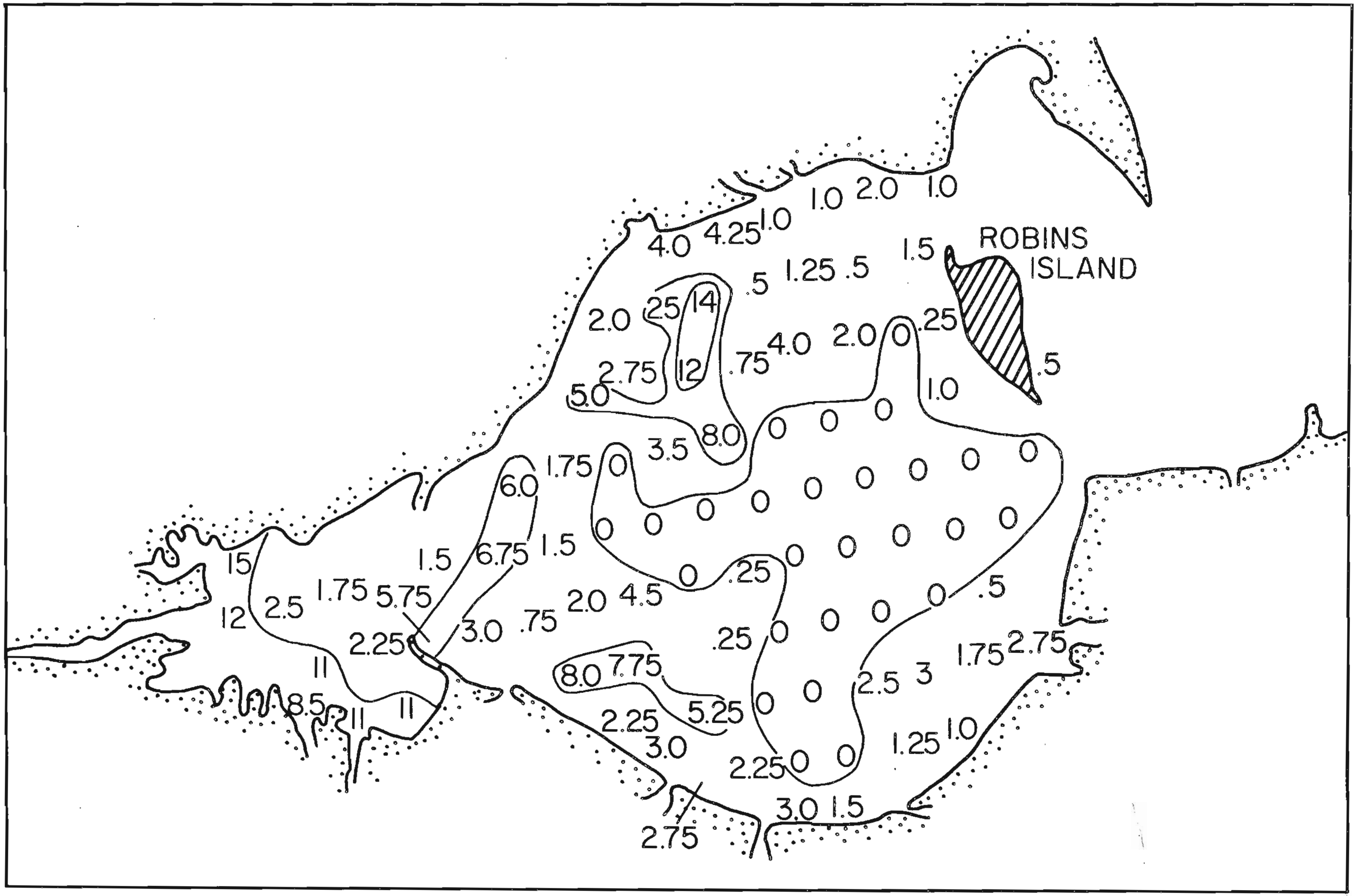

HARD CLAM LANDINGS
NORTH SHORE
PECONICS
BUSHELS (×1000)
170
150
130
110
90
70
50
30
10
1946
50
54
58
62
66
70
74
78
82
YEAR

Figure VII - 6


ROBINS ISLAND
1.0 2.0 1.0
4.0 4.25 1.0 1.0
1.5
.5 1.25 .5
2.0 .25 14
.25 2.0 2.0 0
2.75 12 .75 4.0
.5
5.0 1.0
8.0
3.5
1.75 0
6.0
15
1.5 6.75 1.5
12 2.5 1.75 5.75
2.25 3.0 .75 2.0 4.5 .25 .5
11
8.5 11 11
8.0 7.75
5.25
2.25
3.0
2.25
2.75
3.0 1.5
.25
2.5 3
1.75 2.75
1.25 1.0

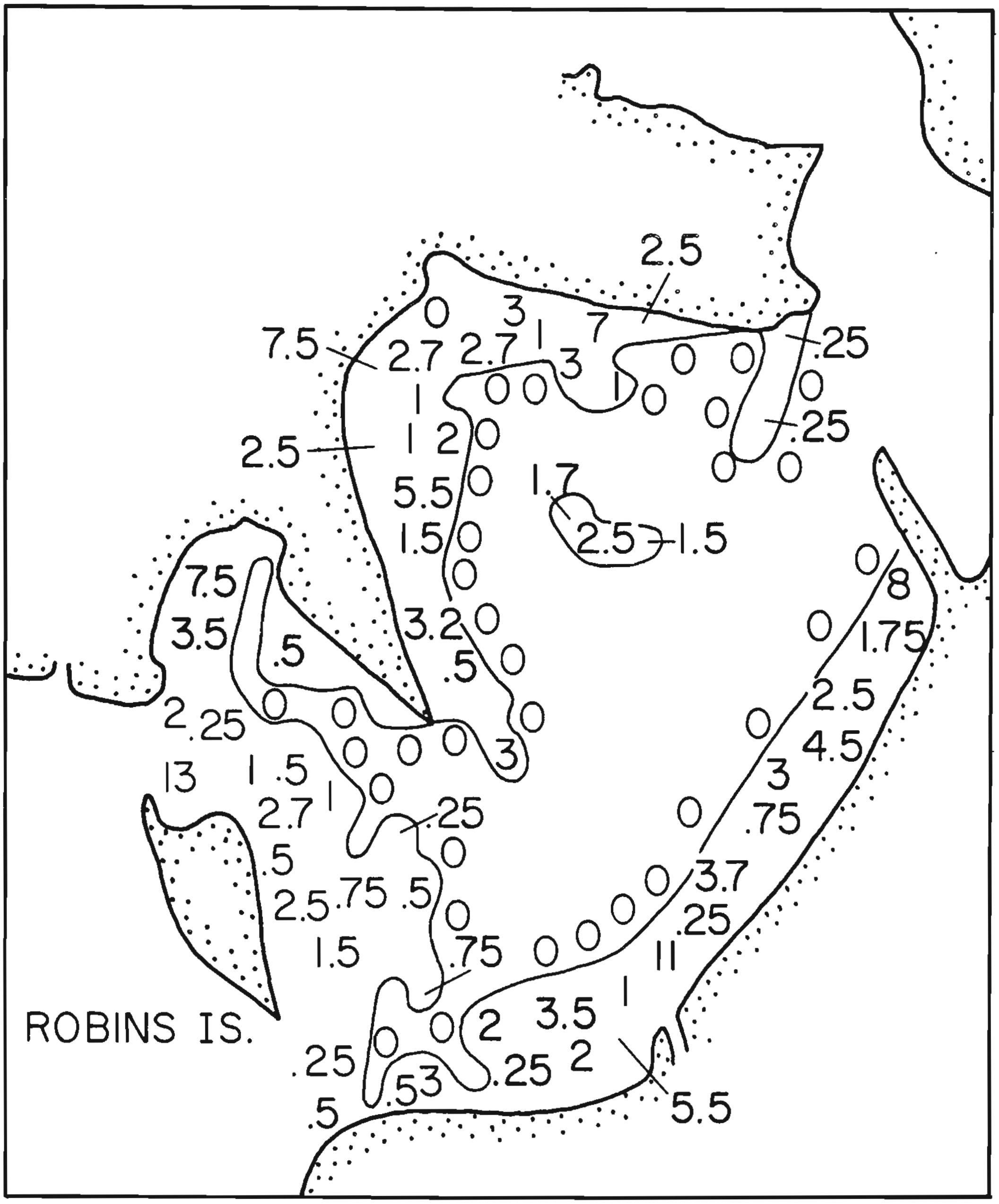


Figure VII - 8
Hard clam density (clam/100 ft^2) - Little Peconic Bay

also stated that, since he has been working the area (1935), hard clams have never been plentiful compared to oysters.

Poor water quality is apparently not a serious problem in the Peconics. Hardy (1976) cited three factors which make the Peconic Bay estuary relatively resilient to man's activities. These are, strong tidal flushing, excellent water quality in Gardiners Bay (the saltwater source of the Peconics), and the semi-rural development of the drainage area. In 1975 all open water areas of the Peconics had coliform counts well below the standard for closure and only Flanders Bay, Greenport Harbor, and Sag Harbor contained uncertified areas (Hardy 1976). In 1971 an area known as Stirling Basin, in Greenport Harbor, was reopened after having been closed since 1963. The area, which baymen estimated contained 10,000 - 20,000 bushels of clams, was closed again in January 1973 (Newsday 1971 & 1973). As of January 1984 these areas remained closed and part of North Sea Harbor had been added to the list (P. van Volkenburgh, DEC Bureau of Shellfisheries, Personal Communication).

As on the north shore, there has been a slight increase in hard clam landings in the Peconics since 1981. However it is not possible to determine whether this represents a significant trend or is simply part of the typical variation in hard clam landings.

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THE RECREATIONAL HARD CLAM FISHERY IN SUFFOLK COUNTY

INTRODUCTION

The recreational hard clam fishery in Suffolk County has a different significance in each of the county's ten towns. Each town has developed its own set of rules and regulations according to the status of the clam resource as well as the importance of its recreational fishery in relation to the commercial fishery. All towns enforce the state law requiring clammers who take over 1/2 bushel of clams per day to obtain a state commercial license of $75. Most of the towns also have their own commercial permit programs as well.

Prior to this study, there had been no county wide study of the recreational hard clam fishery in Suffolk County. A survey was performed in 1977 by the New York State Department of Environmental Conservation (DEC) in Great South Bay which found that only 0.73 percent of the yearly catch was taken recreationally (Fox 1977). This report did not include any other areas of Suffolk County.

In response to the need to understand the importance of the recreational fishery when making management decisions, a town by town study of the recreational hard clam fishery in Suffolk County was carried out. Very little documented information was available. Most of the data collected came from conversations with town officials, bay constables and baymen and were the results of their own field observations during the course of their jobs. Only Babylon and Islip were able to provide estimates of actual hard clam harvest based on survey studies. The results of the study are summarized in this paper.

BABYLON

The Town of Babylon requires that anyone who wishes to clam recreationally be a resident for at least six months and obtain a permit from the town for $5 fee. Permits are free for persons over 60. Enforcement of this law was rather lax prior to 1978. The number of recreational (personal) permits issued in the town of Babylon has dropped steadily from 2108 to 1975 to 1124 in 1984.

Babylon officials had been surveying the recreational clammers to determine their significance on the total harvest but discontinued surveying in recent years when the recreational catch was found to be such a small percentage of the total (K. Feustal, Town of Babylon, Personal Communication). When the personal limit of hard clams was recently lowered from 1/2 to 1/4 bushel per day as a conservation measure, no complaints were heard by town officials, probably because the recreational clammers were not getting even 1/4 bushel.

Most of the recreational clammers tread for clams on the south shore of Great South Bay where the water is too shallow for commerical diggers to operate. Because clamming grounds are separated, there is little competition between town groups in Babylon waters.

ISLIP

In the Town of Islip, the number of personal permits issued has decreased fairly steadily from 1984 to 1977 to 1007 in 1984. A study performed by the town in 1976 indicated that recreational clammers took about 4% of the total harvest (S. Buckner, Town of Islip, Personal Communication). According to town officials, there is no reason to believe that it has changed significantly since then.

Presently, there do not seem to be any major quarrels between recreational clammers and commercial clammers in Islip as there were in 1978. According to an article in the New York Times (Aurichio 1978), baymen were concerned about depletion of clam stocks and incited town officials to strictly enforce the permit laws. Town officials were caught between the desire to promote seasonal clamming as part of the tourist attraction to the area, and the need to protect the local shellfish industry.

BROOKHAVEN

Presently in the Town of Brookhaven, there is no permit program for recreational clammers. An unsuccessful effort was made in 1984 to get a permit law on the books. This effort will probably be intensified in 1985. Since there is no permit program in Brookhaven, it is difficult to determine accurately the number of recreational clammers. Field observations by Town bay constables indicate that the relative number of clammers has gone down in recent years because clam densities have decreased. According to the Chairman of the Brookhaven Baymen's Association, the amount harvested by recreational clammers is negligible compared to the commerical harvest (K. O'Mally, Brookhaven Baymen's Association, Personal Communication).

There are presently no real conflicts between recreational and commercial harvesters in Brookhaven. This has not always been so, however. In 1978 there was a strong feeling among commercial clammers that enforcement of permit and residency laws for recreational clammers was not strict enough and that something should be done. This prompted the Suffolk County Police Marine Bureau to increase its force from 12 to 20 men in an effort to crack down (Sgt. D. Hoffman, Suffolk County Police Department, Personal Communication). Even with the increased manpower, the problem of illegal clammers was still a big problem.

The harvest limit for resident recreational clammers is 100 clams. There is also a gear limitation law whereby recreational clammers can not use a rake with a handle longer than 7 feet. This law is designed to prevent people from clamming commercially, using commercial gear without obtaining a commercial permit.

HUNTINGTON

The hard clam fishery in the Town of Huntington is dominated by commercial clammers. The number of recreational clammers in Huntington has remained fairly constant over the past ten years, averaging about 600. A personal permit may be issued to anyone who is a resident, taxpayer, or the holder of a lease of at least three months term. The fee is $5 and there is a 1/2 bushel per day limit.

It was estimated that the recreational clammers harvest only a small percentage of the total clam take per year in Huntington (R. Koopman, Town of Huntington, Personal Communication). One of the main reasons that this is so is because the waters in most of Huntington Bay are too deep to allow treading for clams - the method used by most recreational clammers.

Relations between recreational and commercial clammers in Huntington have been good. In fact, there was a motion at one time among members of one of the baymen's associations to set aside an area for the exclusive use of recreational clammers. Apparently there was not enough interest in such a plan and it was dropped.

SMITHTOWN

It is estimated that in the Town of Smithtown, the recreational harvest is less than 15% of the total harvest (S. Resler, Town of Smithtown, Personal Communication). It is hard to quantify the number of recreational clammers in this town since there is no permit system for them, but according to one official, in Stony Brook Harbor, the main recreational area, about 30 clammers can be found on a summer day. Each of these diggers averages less than a few dozen per trip. Rakes used by non-commercial clammers may not have handles longer than 7 feet.

RIVERHEAD

Riverhead does not have a permit system for non-commercial clammers. A comprehensive permit and law enforcement program is being worked on now but is not expected to be in effect until May 1985. Since there is no permit system it is difficult to estimate the actual number of recreational clammers in the town, but it is thought to be negligible (A. Benjamin, Riverhead Baymen's Association, Personal Communication). Residents of Riverhead may take up to 1/2 bushel before they are required to obtain a state shellfish permit.

Much of the shallow accessible bay bottom in the Town is conditionally closed to shellfishing from pollution. Since law enforcement is minimal, these areas are often worked by recreational diggers causing friction with the commercial clammers who are aware of the laws and the reasons for them. Riverhead is the only town left in Suffolk County in which recreational clammers can use a rake with a mesh of less than one inch.

SOUTHAMPTON

Southampton Town has issued an average of 2500 personal permits in each of the past three years. Records were kept only for that period of time so no prior data were available. Personal permits are issued to freeholders, taxpayers, and people who have resided in the town for at least 12 months. Permits are also issued to students of Southampton College who have been in attendance for at least 12 months. There is no fee for this permit. Temporary residents may obtain permits for $5 for 15 days, $10 for 30 days, and $20 for 90 days. The limit for recreational clammers is 1/2 bushel per day. Use of SCUBA gear is not permitted during the collection of shellfish.

Recreational clammers are estimated to harvest about fifty percent of the clams in the Town of Southampton (T. Reeve, Town of Southampton Bay Constable, Personal Communication). There are many recreational clammers, compared to the number of full-time commercial clammers, and each averages about four dozen clams per person per trip.

SOUTHOLD

The first year that personal permits were issued in the Town of South was 1982. Since the, the number of permits issued has risen from 2289 to 2782 in 1984. There is a $3 fee for residents and a $5 fee for non-residents. Recreational clammers are estimated to take approximately forty percent of the hard clam harvest annually (F. Begora, Southold Baymen's Association, Personal Communication). During the summer there are sometimes problems as there are in the other towns, with people taking several times the legal limit of clams.

EAST HAMPTON

The number of people in the Town of East Hampton who hold personal clamming permits has been decreasing, from 3714 permits in 1974 to 2201 permits in 1984. To get a permit, the clammer must be 12 years or older and be a town resident for one year or be a taxpayer. The fee is $2 for the personal permit and there is no charge for persons over 65. There is a 1/4 bushel limit for hard clams and the average take for a recreational digger is greater than two dozen clams.

The recreational hard clam fishery in East Hampton accounts for about 60-70 percent of the harvest (R. Mamay, Town of East Hampton Bay Constable, Personal Communication). This is because there are large numbers of diggers in summer and the fact that there are only about 3 full-time commercial clammers and about 40 part-time commercial clammers. There have been no major confrontations between the two groups other than low key complaints.

In 1979, the twelve month residency requirement was found not to be binding in the U.S. District Court in the case of _Hassan vs. The Town of East Hampton_. According to the decision, a person applying for a shellfish permit only has to prove that he is presently a resident of the Town but there is no term of residency required. Therefore, anyone who rents a house, even for a short period of time, can get a permit as soon as they move in. The decision should set precedence in all the towns in Suffolk County, should people press for permits, since the finding was made in a federal court. As of January 1985, the twelve month residency requirement had not been removed from the East Hampton Town ordinance.

SHELTER ISLAND

Shelter Island's hard clam fishery is dominated by recreational clammers. In fact, there are no year round, full-time commercial clammers on Shelter Island (R. Clark, Shelter Island Baymen's Association, Personal Communication). A resident or anyone who has a lease of at least 30 days may obtain a personal license for $2 which entitles them to take up to 1/4 bushel of clams. The number of permits issued over the past 11 years has remained fairly constant, averaging about 1000.

An effort was made in 1978 to extend the right to go shellfishing to members of the immediate family of local residents. The Town Board was unsuccessful in this effort.

The better clamming grounds are found in those areas that are inaccessible to recreational diggers, therefore there are few confrontations between commercial and recreational diggers. Law enforcement is not very strict concerning checking for permits of summer recreational clammers. In fact, recreational clamming is so important here that the town seeding program is seen by some as a good will gesture from the Chamber of Commerce for the tourist industry rather than for the commercial shellfish industry.

Table VIII-1 shows that recreational clamming is most important on the eastern end of Long Island in the towns of Southampton, East Hampton, Southold and Shelter Island. These four towns account for about 80% of the recreational harvest while they represent only about 13% of the commercial harvest in Suffolk County. The most reasonable explanation for this is that there are fewer commercial clammers and many more recreational clammers in the eastern towns. The table also shows that the recreational hard clam harvest in Suffolk County accounts for about 15% of the total harvest.

The widely differing significance of the recreational fishery in different areas of Suffolk County makes it necessary to address each area separately when devising a resource management plan.

TABLE VIII-1

Commercial and Recreational Harvest for 1983

TOWN	COMMERCIAL HARVEST (BUSHELS)	ESTIMATED RECREATIONAL AS % OF TOTAL TOWN HARVEST	ESTIMATED RECREATIONAL HARVEST (BUSHELS)	ESTIMATED RECREATIONAL AS % OF TOTAL COUNTY HARVEST
BABYLON	32,889	2	653	0.2
ISLIP	72,314	4	3,013	1.0
BROOKHAVEN	84,966	5	4,472	1.5
SOUTHAMPTON	30,314	50	30,314	10.0
HUNTINGTON	31,704	3	980	0.3
EAST HAMPTON	1,944	65	3,610	1.2
SOUTHOLD	1,706	40	1,137	0.4
SMITHTOWN	1,432	15	253	0.1
SHELTER IS.	-	75	-	-
RIVERHEAD	108	5	6	0
	257,377		44,438	14.7

ESTIMATED TOTAL HARD CLAM HARVEST
FOR SUFFOLK COUNTY IN 1983 (BUSHELS) = 301,815

ESTIMATE OF RECREATIONAL HARVEST AS %
OF TOTAL COUNTY HARVEST IN 1983 = 14.7

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HARD CLAM MANAGEMENT IN NEW YORK-AN HISTORICAL OVERVIEW

INTRODUCTION

The growth of the hard clam fishery in New York since the 1930s has been caused by several factors. First, there has been a real increase in abundance of hard clam. Second, the abundance of oysters, which had been the principal shellfish harvested through the early part of this century, declined sharply causing a shift in harvesting emphasis. Finally, until the beginning of the century, hard clams were considered inferior to oysters by consumers and demand for them was consequently low; even if hard clams were present, they were often not harvested.

Management of the hard clam fishery goes back to colonial times. Many of the regulations, concepts and practices used to manage the hard clam fishery are, to a large extent, derived from those of the oyster fishery. Many are simply a substitution of one species for the other. Few of these management practices have been critically evaluated.

In tracing the history of hard clam management practices, some caution needs to be practiced. The historical record is very selective by its nature and often imprecise. Only events important to the observer are chronicled and just because an event is not in the record does not necessarily mean it did not occur. Care must also be taken in interpreting historical accounts since terminology, concepts, and definitions often change with time. Because Great South Bay has been the most important producer of hard clams in Suffolk County, this chapter will focus on the history of hard clam management in Great South Bay.

SHELLFISH MANAGEMENT

Fishery management embraces a variety of activities and practices which are of two basic types:

(1) efforts to increase stock size,

(2) efforts to control or limit harvesting.

For shellfish, the sanitary control of harvesting because public health is involved may be thought of as a third management activity. The history of hard clam management will be discussed by type rather than chronologically.

In Suffolk County, shellfish management occurs at 4 levels of government: Town, County, State, and Federal. The towns, by virtue of their establishment prior to the State of New York and their title to bay bottom, have the basic management responsibility. New York State has control over State waters and the sanitary control of harvesting in all waters. It also assists the towns in certain management activities. The towns and the State have established laws governing the harvesting of shellfish. The role of Suffolk County presently is limited to County waters in Gardiners and Peconic Bays, although at the turn of the century the County was much more involved in management of all waters. The County does, however, play an active role in enforcement of shellfish laws. The federal role is restricted to the National Shellfish Sanitation Program although at times it provides management funds such as under Public Law 88-309 (Aid to Commercial Fisheries).

EFFORTS TO INCREASE STOCK SIZE

Many activities have been undertaken to increase the size of the harvestable stock. Several have their origins in the oyster fishery. The history of those that have been identified are as follows.

Stock Augmentation

In 1939 Brookhaven Township (Brooklyn Daily Eagle January 1, 1938) and Islip Township (Suffolk County News February 11, 1938) appropriated funds for planting of "seed" clams. From subsequent reports, it appears likely that the clams were cherrystones and chowders but were called "seed clams" because they provided seed to the bay. This is not clear, however, since there is no reference to either the time or the location of planting, both of which are important considerations in spawner programs.

Spawner Transplants

In 1938, Islip Town appropriated $1,000 for the purchase of spawner clams. The clams were specifically to be those from out-of-state which "have been found to be prolific spawners when planted in Long Island waters" (Suffolk County News May 6, 1938). There is no mention of planting these clams after the native clams have spawned in an effort to prolong the spawning season, a goal of modern spawner transplants.

Planting of clams after native clams have spawned appears to have begun about 1963 (S.A. Hendrickson, New York State Department of Environmental Conservation, Personal Communication). In 1973, this activity was made eligible for 50% federal matching funds through Public Law 88-309.

Spawner Santuaries

Spawner santuaries are specially chosen and designated areas into which clams are planted to facilitate spawning (see "Spawner Sanctuaries", this volume). Harvesting is not permitted in the sanctuary so that clams may spawn repeatedly.

In 1955, adult clams were planted for spawning in a "sanctuary" established in Town of Babylon waters (New York State Conservation Department 1955). In 1957, an additional 400 bushels were planted in this sanctuary. Studies were conducted on setting and the hydrography of the area which indicated that, "setting of clam larvae would be expected to occur to the east of the sanctuary" (New York State Conservation Department 1958). The sanctuary was not continued after the second planting and there was, apparently, no evaluation.

In 1983, the Towns of Islip and Brookhaven established several spawner sanctuaries in Great South Bay. Siting of the sanctuaries was based on a computer model developed by Harry Carter of the State University of New York's Marine Sciences Research Center that predicted larval transport in the Bay. The Towns designated areas where they would like a set and the model showed where the adults would have to be planted.

Hard Clam Hatchery

In 1926, Wells was able to "propagate" hard clams at his experimental oyster hatchery in Oyster Bay, New York (New York State Conservation Commission 1926). Between 1931 and 1933, Joseph Glancy, working at the Blue Points Company in West Sayville, was able to grow hard clams from egg to larval stage through setting and up to over an inch in size (Van Popering and Glancy 1947). Cultured Clam, also known as Aquacultural Research Corporation, in Dennis, Massachusetts, was the first company to start a commercial hard clam hatchery, beginning production in 1965 (Vanderborgh 1980).

Seed Planting

According to Belding (1912), in 1909 a New York State planter purchased nearly 5,000 bushels of natural hard clam "seed" from Massachusetts at a cost of $3.00 per bushel and an additional 45,000 bushels from New Bedford and Fairhaven, Massachusetts. The "small quahaugs" were replanted in Long Island waters and after one year, based on growth experiments, the planter realized 4 bushels of marketable littlenecks for every bushel planted. The clams may have been grown out in shallow boxes or rafts (Kellog 1910).

In 1955, "juvenile clams" were planted in Great South Bay. An additional 5,000 juveniles were planted in 1956 and based on these plantings it was "anticipated that basic criteria can be developed for use in the cultivation of hard clams" (New York State Conservation Department 1957). Information is not available on sources, planting methodology, survival or how long the project was pursued.

Hard clam mariculture for restocking public underwater lands was more recently started on Cape Cod in the early 1970s (Abreau 1976). The Town of Islip was the first Long Island town to undertake a modern seed clam planting program, beginning in 1975 (S. Buckner, Town of Islip, Personal Communication). Other Long Island towns subsequently began mariculture operations and a number of towns are currently planting seed clams on public bottom.

Predator Control

Control of predators of oysters has been well established for quite some time and is an integral part of modern oyster farming. Control of predators of hard clams has been limited and restricted to experimental studies. Chemical control using pesticides was tested in experimental plots in Great South Bay in 1960 (MacKenzie 1977). Clam densities were found to be 7 to 8 times greater in the area where predators were removed than in natural sites. Because environmental concerns make the widespread use of pesticides unlikely, a scheme to mechanically remove predators was subsequently proposed by MacKenzie (1979).

A limited type of predator control is incorporated in the New York State Conservation Law wherein "starfish, drills (*Urosalpin cinerea*), periwinkle (*Littorinia*), and drum fish (*Pogonias chromis*) when taken shall not be returned alive to the waters of the state" (Laws of New York 1973). The destruction of starfish and other predators by law dates back to 1912 (Laws of New York 1912).

SANITARY CONTROL OF HARVESTING

Because shellfish from polluted waters can transmit human illness, many programs are designed to protect public health by controlling harvest. The two basic components are evaluating water quality in growing areas to determine which areas are safe for harvesting, and undertaking programs to prevent illegal harvesting.

Certification of Growing Waters

Out of concern for public health, the harvesting of shellfish from polluted waters has been prohibited since before the turn of the century. Sanitary inspections of shellfish grounds were established by New York in 1913 (Laws of New York 1913). It was not until 1925, however, that the National Shellfish Sanitation Program, which provides guidelines for shellfish sanitation practices and water quality standards, was established by the Federal government. Under this program, if water quality in the growing area meets the established criteria, the area is "certified" and taking of shellfish is permissible. If the area does not meet the standard, it is "uncertified" and the taking of shellfish is prohibited.

Seasonal Certification

Under seasonal certification, areas are open or closed if consistent seasonal changes in water quality occur. Sometime prior to 1952, the State permitted the seasonal opening of Moriches Bay in winter when water quality improved following the seasonal cessation of duck farming, the principal source of contamination (New York State Conservation Department 1957). The Moriches winter seasonal opening, which covered a relatively large area, was terminated in 1967. Summer closures are currently made adjacent to many marinas where increased boating activities during the summer causes coliform levels to rise.

Conditional Openings

It has been observed that, in certain areas, water quality deteriorates only following rainfall, because runoff carries contaminants into the water. During periods of little or no rainfall water quality is thus acceptable for shellfish harvesting. Conditional openings were first used in New York in 1977. Under this program, areas that are affected by rainfall are opened to shellfishing following seven consecutive days during which rainfall did not exceed 0.25 inches in a 24 hour period. While conditional openings can be undertaken throughout the year, many towns use them only in winter to provide additional area near shore for baymen to work when harvesting conditions are more difficult farther from shore.

Purification of Polluted Shellfish

A number of schemes has been developed for controlled cleansing or purging of polluted filter-feeding bivalves.

In 1922, New York State opened a chlorination plant to purify oysters as an alternative to "floating" oysters, a process that had been associated with human illness (New York State Conservation

Commission 1922). At the chlorination plant, oysters were placed in tanks into which seawater containing hypochlorite of sodium was added. The stated object of the procedure was to "...sterilize the outside of the oyster and to allow it, by natural processes, to free itself of such infected material as may be in its shell or body cavities. The edible portion of the oyster is not exposed to the action of any chemicals." The first mention of chlorinating clams was made in 1931 (New York State Conservation Department 1931). The process was not, however, used for "polluted" shellfish. Several chlorination plants were built in West Sayville, but the process appears to have been discontinued about 1932.

In 1938, the New York Legislature appropriated $15,000 to construct a chlorination plant to "treat shellfish" from Raritan Bay (New York State Conservation Department 1939). Experiments using chlorination were undertaken in 1941 and the method was considered "practical under certain conditions" (New York State Conservation Department 1942). No commercial scale operations appear to have been established.

In 1964, New York began a study to gather data to evaluate the feasibility of a commercial hard clam depuration plant. A demonstration plant was subsequently built in West Sayville (MacMillan and Redman 1971). The first commercially operated depuration plant opened in 1979 on Staten Island (J. Redman, New York State Department of Environmental Conservation, Personal Communication). The plant went out of business in 1983 from an inability to obtain a sufficient supply of hard clams.

Relays

In 1935, it was recommended that small hard clams be taken from condemned areas and replanted in approved areas "so that they might purify themselves and grow to be clams of marketable size" (New York State Conservation Department 1935). Three years later Brookhaven Township received 1500 bushels of hard clams from condemned waters off Staten Island for $0.75 a bushel (Brookhaven Town Records 1938). Five relays were undertaken in 1939. Most of the shellfish were purchased by private growers (New York State Conservation Department 1939).

In 1964, New York passed legislation establishing a shellfish transplantation fund to transplant shellfish from uncertified waters to certified waters. The purpose of the program was to deplete high concentrations of clams in uncertified waters that were attractive to illegal harvesting and, secondarily, to make available accumulated stocks for spawning and eventual harvesting (Hendrickson 1975). These relays were, for the most part, between towns. A federally funded program which provided 50% reimbursement for project costs, including shellfish transplant programs, was started in 1973 under Public Law 88-309 (Hendrickson 1975). Objections by baymen, and stock depletion, caused the last hard clam relay in Great South Bay to be undertaken in

1979. They are still undertaken in other areas such as Huntington Harbor.

EFFORTS TO CONTROL OR LIMIT HARVESTING

Controlling the harvest of shellfish can by useful in conserving and managing stocks. This is accomplished by regulatory control over harvesting and has been employed by the State of New York and individual towns since colonial times. Town laws often duplicate State Law but can be no less restrictive than the State law.

Minimum Size

Concern that taking of small clams would deplete hard clam stocks, caused New York to prohibit harvesting of hard clams less than 1 1/8 inches in thickness in 1893 (New York State Assembly 1894). The minimum size was changed to one inch in 1895 and possession of sublegal size clams made a misdemeanor (Laws of New York 1895). The minimum size was repealed sometime prior to 1912 as it does not appear in the consolidated laws of that year (Laws of New York 1912). The current New York State one inch minimum size was established in 1942 (Laws of New York 1942).

In 1898, the Suffolk County Board of Supervisors, predecessor to the current Legislature, passed a resolution prohibiting taking of hard clams less than one inch in thickness (Suffolk County Board of Supervisors 1898). This was made possible by a State Law passed in 1898 (Laws of New York 1898) wherein "boards of supervisors, have power to pass rules, regulations, laws and ordinances permitting, regulating, controlling or prohibiting the taking of shellfish". It is not known if this power has subsequently been rescinded.

Because there was no state minimum size until 1942, individual towns were free to set their own limit. In 1931, Islip prohibited taking of clams less than one inch in thickness. Baymen felt that the minimum size was not warranted and persuaded Islip to rescind the minimum size after it was in effect for only 70 days (Suffolk County News, August 18, 1931). A three-quarters of an inch minimum size was set by Islip in 1938 (Suffolk County News, October 14, 1938).

Gear Restrictions

Restricting the type of gear that can be used to harvest shellfish from public lands has been practiced for well over a hundred years. Early restrictions were often aimed specifically at oysters but usually applied to all shellfish. Restrictions were established by the towns, Suffolk County and New York State. [Gear restrictions do not, however, apply to leased or privately held underwater lands (Laws of New York 1972)].

In 1856, a prohibition against dredging oysters was incorporated in Brookhaven Town law (Brookhaven Town Records, May 4, 1856). In 1870, New York prohibited the use of dredges or drags to catch "oysters, clams, mussels, or shells in the Great South Bay" (Laws of New York 1870). In response to the development of small steam engines, which increased the efficiency of dredging, use of dredges operated by steam or weighing over 30 pounds for the catching of "oysters or other shellfish from beds of natural growth" was prohibited in 1888 (Laws of New York 1888). It was not until 1942 that State Law specifically prohibited the taking of hard clams "except by rake or tongs operated solely by hand power" (Laws of New York 1942).

In addition to outright prohibitions, legislation has set standards for permissible gear. In 1893, for example, New York established that rakes and tongs used to harvest hard clams had to have openings between the teeth of at least 1 1/8 inches (New York Assembly 1894), the same width as the minimum thickness of clams at the time. Brookhaven in 1963 prohibited rakes and tongs having teeth spaced less than one inch apart and the placement of netting between the teeth or bows of rakes and tongs (Ordinances of the Town of Brookhaven 1963). This ordinance is still in effect. The purpose of these restrictions was apparently to reduce the harvest of undersized clams.

Management Closure

Management closure includes any activity that prohibits shellfishing in otherwise harvestable (certified) areas. In 1977, Brookhaven Town initiated a seasonal closure program wherein areas adjacent to the mainland, which are protected from inclement winter weather, are open to shellfishing only in winter.

In 1984, Islip prohibited clamming in 1,700 acres where hard clam abundance was very low to enable the population to rebuild (Newsday, May 23, 1984). The area is to be seeded and will remain closed until stock abundance increases. Huntington has recently begun a similar closure (R. Koopman, Town of Huntington, Personal Communication).

Residency Requirements

Restriction of the privilege of harvesting shellfish to residents of the State or of towns claiming ownership of underwater lands has been practiced for some time. In 1678, Brookhaven prohibited non-residents from taking shellfish (Brookhaven Town Records, May 15, 1678). In 1857, New York established that only Islip residents could take shellfish from Islip bay bottom (Laws of New York 1857). In 1892, New York decreed that, "Only persons who have been actual residents of New York State for six months shall be entitled to gather shellfish from the waters of this state" (Laws of New York 1892). These types of residency restrictions remain in effect, although there is some concern that most may not be constitutionally acceptable in their present form.

PRIVATE CONTROL OVER PUBLIC BAY BOTTOM

A number of mechanisms have been used to enable private individuals to obtain sole use of segments of publicly owned underwater lands. The type of conveyance (rights, procedures, and regulations) is determined by the owner of the bottom. Leases are issued by towns, franchises and assignments by New York State, and grants (now leases) by Suffolk County.

The sole use of public bottom originated in the oyster industry. Individuals who wished to plant seed oysters needed the assurance that only they would benefit from their investment. There is, however, nothing that prevents leases or franchises from being used to culture hard clams.

Brookhaven Township was one of the earliest of the towns to issue leases. In 1829, Brookhaven trustees granted a 10 acre lease for the "laying and taking up" of oysters (Brookhaven Town Records 1829). It was not, however, until the early 1850s that Brookhaven began large scale leasing of bay bottom. Although leasing was initially well received, abuses of the program soon made it unpopular and the activity was largely curtailed. Brookhaven discontinued leasing at the turn of the century and in 1976 Islip terminated its leases. (In Suffolk County only Huntington currently leases underwater lands approximately 1,700 acres).

New York State first issued franchises in 1887 (Laws of New York 1887). These were held in perpetuity as long as the annual fee was paid. Franchises were discontinued in 1893 when the state established leases which were made on a bid basis and limited to 15-year terms (Laws of New York 1893).

The minimum size of areas leased by the State was 50 acres (Laws of New York 1893). In 1973, legislation provided for leases of 5 acres for "the purpose of off-bottom culture of shellfish" (Laws of New York 1973). In 1982, New York began what is known as "assignments" wherein rights to areas of underwater land (up to 5 acres) are issued in one-year increments.

In 1884, New York ceded over 100,000 acres of lands underwater in Peconic Bay and Gardiner's Bay and tributaries to Suffolk County for oyster cultivation (Laws of New York 1884). Under this law, Suffolk County was authorized to issue perpetual grants of 4 acre parcels to persons who agreed to plant a specified quantity of oysters within one year. If the land was not used for oyster cultivation, or taxes were not paid, it reverted back to the County.

Gradually, the status, location, and title of underwater parcels in the Peconic and Gardiner's Bay became uncertain and unclear. To correct this, in 1969 New York State passed legislation clarifying Suffolk County's management of underwater lands in Gardiner's and Peconic Bays for shellfish cultivation (Laws of New York 1969). Under this law, lands that had reverted to the State were returned to County control, existing oyster grants were ratified, and underwater lands were leased rather than granted. Before the underwater lands could be leased, Suffolk County had to prepare accurate maps of the underwater lands and establish appropriate regulations. Political pressure has blocked efforts to undertake the required mapping and consequently no new leases have been granted as yet.

LICENSES AND PERMITS

Licenses and permits serve two purposes. First, their sale can generate revenues to the issuing agency and second, control can be exercised over who harvests shellfish. In the mid 1800s, Brookhaven established a $1 license for harvesting shellfish; one-half of revenue generated went to "the poor" (Ingersoll 1881).

In 1942, New York established diggers permits for taking of shellfish (Laws of New York 1942). Each of Suffolk County's towns has its own shellfishing license permitting harvesting in town waters. Since town permits are issued only to town residents they serve to identify legal harvesters. In addition, the threat of permit revocation for breaking shellfish related regulations is seen as insuring compliance with the regulations.

CONCLUSIONS

Management of the hard clam fishery is well established. Over the years, a wide variety of programs and regulations have been started and many continue in effect. Although the origins of management activities are not always clear, all were designed and implemented in response to a problem or need. Critical evaluation of most management measures has not been undertaken.

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SUFFOLK COUNTY'S CHANGING

COASTAL ENVIRONMENT

POPULATION AND LAND USE IN SUFFOLK COUNTY

Population Overview

The original settlers of Suffolk County migrated from New England communities. Engaged in agricultural pursuits and fishing, they were able to maintain a self-sufficiency that endured almost to modern times. As late as 1920 the population of the Town of Southampton exceeded that found in either Babylon or Smithtown. The gradual growth from colonial times until World War II was due in large measure to natural increases. However, use of the automobile encouraged suburban growth in the west. The conversion of farms in Nassau and western Suffolk into mass residential communities changed the economy from an agricultural base to one of dependency on the New York City metropolitan area for jobs. In addition, internal economic shifts resulted in further changes in population centers. Meaningful periods of growth for both counties did not occur until after World War II.

Improved road facilities brought about in the rapid suburbanization of Suffolk County by the outward population surge from the New York City metropolitan area. Since 1950, all except the five eastern towns of Suffolk county have had large population increases. The County's total population since 1950 has grown by over one million persons. The Long Island Regional Planning Board (LIRPB) has estimated a total population of 1.3 million for 1984 (Table X-1). It is interesting to note that the dramatic rise and fall of hard clam production from Suffolk County waters in the 1970s occurred during a period of relatively low growth in the County's population.

Saturation populations[1] were calculated for the 10 towns in Suffolk County according to 1984 zoning regulations. Review of the data indicates that the populations of the Towns of Babylon and Islip on Great South Bay are nearly at their saturation levels. Brookhaven Town, however, has the capacity for an increased population of approximately 200,000. The five towns that border the Peconic/Gardiners Bay system (Southold, Riverhead, Southampton, Shelter Island, and East Hampton) have the potential to increase their aggregate population by approximately 200,000. Projected populations for the year 2020 indicate that most of the ten towns will approach their saturation populations. The Towns of Brookhaven, East Hampton, and Riverhead, however, are projected to be below their saturation populations at that time.

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[1]Saturation population is calculated by multiplying the total number of housing units permitted under existing zoning by an appropriate household size factor.

Table X-1
Historic Population of Suffolk County

Town	U.S. Census 1900[a]	U.S. Census 1950[a]	U.S. Census 1970[a]	U.S. Census 1980[a]	LIRPB Estimate 1984[b]
Babylon	7,112	45,556	204,256	203,483	204,657
Brookhaven	14,592	44,522	245,260	365,015	380,995
East Hampton	3,746	6,325	10,980	14,029	14,776
Huntington	9,483	47,506	200,172	201,512	201,416
Islip	12,545	71,465	278,880	298,897	299,674
Riverhead	4,503	9,973	18,909	20,243	21,125
Shelter Island	1,066	1,144	1,644	21,125	
Smithtown	5,863	20,993	114,657	116,663	116,196
Southampton	10,371	16,830	36,154	43,146	45,554
Suffolk County	77,582	276,129	1,127,030	1,284,231	1,306,559

[a] Long Island Regional Planning Board. 1982. Historical population of Long Island communities (1979-1980) decennial census data. Hauppauge, New York.

[b] ______________________. 1984. Population Survey - 1984. Hauppauge, New York.

In summary, the Towns of Babylon, Brookhaven and Islip have a projected population of 1,010,000 by the year 2020; an increase of 13% over the 1984 population. The five eastern towns have a projected population of 172,000 (257,000 seasonal) by 2020; this is an increase of 40% (60% seasonal) over 1984. It is important to note that the Town of Brookhaven, which has the greatest potential for increased population in the next 35 years, borders Long Island Sound and Great South Bay. Four of the eastern towns have shorelines bordering either Long Island Sound or the Atlantic Ocean, in addition to the Peconic/Gardiners Bays. Shelter Island, however, is totally surrounded by the Peconic/Gardiners Bay system (Table X-2).

Review of Land Use

The first settlements in Suffolk County date back to the mid 1600s when land ownership was deeded through special patents to a few individuals for large land tracts. Commercial maritime centers were established first at various locations along the shore. The climate and good soil conditions then attracted greater numbers to agrarian pursuit. By the mid-19th century, agriculture played a major role in Suffolk County's economy.

During the 1880s the first resort settlements appeared on the north and south shores, while the Hamptons become the playground of the more affluent. Small and large tract residential development began with increased mobility via automobile travel. As land became scarce in Nassau County during the 1950s, western Suffolk experienced rapid growth. Today, this urban pattern has extended into central Suffolk County.

Commercial development has traditionally followed residential development on Long Island. Retail and services are most prevalent in eastern Suffolk where the tourist trade is important. Other commercial interests in Suffolk include: professional office space, and automotive services, marine, and recreational activities.

Early industries in Suffolk County included cattle raising, farming, whaling, shipping, and fishing. By the mid-19th century the central role shifted from agriculture to general manufacturing. Since the 1930s the most significant new industry to emerge has been the manufacture of aircraft, which peaked during World War II. The huge population expansion that occurred after World War II led to the creation of large scale wholesale and service activities. Over the past 30 years, as industrial and commercial expansion continued on Long Island, new industrial and commercial complexes developed near major roadways, especially Long Island Expressway, because transport shifted from railroad to truck.

Quantitative data on historic land use in Suffolk County are limited; two comprehensive surveys were completed in 1966 and 1981. Land use has been generally divided into the following categories:

Table X-2
Population Projections for Suffolk County

Town	U.S. Census 1980	LIRPB Estimate 1984	Saturation Population[a] (according to prevailing zoning - 1984)	Projected Population[a] 2000	Projected Population[a] 2020
Babylon	203,483	204,657	215,632	212,000	220,000
Brookhaven	365,015	380,995	586,245	430,000	460,000
East Hampton	14,029	14,776	66,396	20,000	33,000
				40,000 (Seasonal)[b]	46,000 (Seasonal)[b]
Huntington	201,512	201,416	227,055	210,000	220,000
Islip	298,897	299,674	337,878	318,000	330,000
Riverhead	20,243	21,125	63,415	25,000	30,000
				35,000 (Seasonal)[b]	35,000 (Seasonal)[b]
Shelter Island	2,071	2,219	8,125	3,000	4,000
				6,000 (Seasonal)[b]	8,000
Smithtown	116,663	116,196	142,908	125,000	135,000
Southampton	43,146	45,554	117,453	58,000	75,000
				110,000 (Seasonal)[b]	125,000 (Seasonal)[b]
Southold	19,172	19,947	42,676	25,000	30,000
				38,000 (Seasonal)[b]	43,000 (Seasonal)[b]
Suffolk County	1,284,231	1,306,559	1,807,783	1,426,000	1,537,000
				1,524,000 (Seasonal)[b]	1,622,000 (Seasonal)[b]

[a]Long Island Regional Planning Board. 1984. Unpublished data.
[b]Seasonal figures include year-round populations.

residential, commercial, industrial, transportation, utilities and communication, institutional, recreational, agricultural, and vacant (Table X-3).

The total land area of Suffolk County is over 560,000 acres, or approximately 900 square miles. In 1981, approximately 57% of the land was undeveloped, i.e., used for recreation, open space, agriculture or was vacant; 25% was used for residential purposes; and the remaining 18% was divided among commercial, industrial, transportation, and institutional uses.

Between 1966 and 1981, Suffolk County lost over 50,000 acres of vacant land, leaving one-third of the total acreage in this category. Commercial and industrial use doubled in Suffolk County during this period, the greatest growth occurring in Brookhaven Township. Offsetting this change, recreational lands increased by over 30,000 acres. During the same period, the amount of agricultural land decreased by about 5,000 acres; however, the category still represents more than 8% of the total land area.

Future projections indicate that residential uses will continue to increase from 25% to approximately one-third of the County land area by the year 2020. Agricultural land use will decrease by about 20,000 acres during this period. Vacant land will also decrease, and about 22% (124,611 acres) of the County's total land area will remain in this category by the year 2020 (Table X-4).

For the Towns of Babylon and Islip, vacant land will have declined by the year 2020 to only 6.3% (5,782 acres) of their total acreage, whereas vacant land in the Town of Brookhaven will decline by 24,366 acres, to 22% of the total area of this town. Vacant land in Brookhaven, Babylon and Islip combined will decline from 71,351 acres in 1981 to 39,000 acres in 2020. The five eastern towns (Riverhead, Shelter Island, Southampton, East Hampton, and Southold) as a whole will retain approximately one-third of their land area as vacant by 2020 (79,352 acres), but will have lost 20,256 acres of this category from 1981 to 2020. It is projected that agricultural use will constitute over 15% of the total land area of the five eastern towns in 2020 (Table X-4).

IMPLICATIONS FOR SHELLFISHING

The commitment of roughly 75,000 acres of vacant and agricultural land in Suffolk County to built-up uses over the next 35 years, and the projected increase in population of 300,000 people by the year 2020 will have ramifications for the County's shellfish resources. This will occur in environmental impacts affecting spawning, survival, and growth; and availability of the resource to a potentially greater number of recreational and commercial harvesters. Population and land use changes should be considered in the analysis of alternatives for

Table X-3
Land Use of Suffolk County - Historical and Projected

Town	Year	Residential Acres	%	Commercial Acres	%	Industrial Acres	%	Transportation, Utilities, Communication Acres	%	Institutional Acres	%	Recreational Acres	%	Agricultural Acres	%	Vacant Acres	%	Total Acres	%
Babylon	1966	8,380	18	720	2	1,100	2	880	2	1,580	4	5,500	12	370	1	8,820	19	45,380*	100
	1981	15,298	46.8	756	2.3	1,303	4.0	1,940	5.9	1,649	5	9,576	29.3	74	.2	2,068	6.3	32,664	100
	2000	16,000	49	800	2.4	2,450	7.5	1,900	5.8	1,150	3.5	9,800	30	0	0	544	1.7	32,664	100
	2020	16,200	49.6	850	2.6	2,600	8	1,900	5.8	1,200	3.7	9,800	30	0	0	94	.3	32,664	100
Brookhaven	1966	22,720	11	1,140	1	1,060	1	9,560	4	9,760	5	8,710	4	11,560	5	92,210	44	208,370*	100
	1981	33,329	22.4	3,778	2.5	3,671	2.5	13,977	9.4	11,275	7.6	17,233	11.6	8,072	5.4	57,585	38.7	148,919	100
	2000	41,000	27.5	4,100	2.8	3,000	2	15,000	10.1	12,000	8.1	25,000	16.8	5,500	3.7	43,319	29.1	148,919	100
	2020	47,500	32	4,300	2.9	3,200	2.1	15,500	10.4	12,200	8.2	30,000	20.1	3,000	2	33,219	22.3	148,919	100
East Hampton	1966	3,300	7	270	1	110	-	1,000	2	640	1	5,000	11	2,420	5	30,850	66	46,560*	100
	1981	5,311	12.2	582	1.3	278	0.6	2,173	5	575	1.3	8,308	19	3,030	6.9	23,371	53.6	43,629	100
	2000	7,500	17.2	650	1.5	300	0.7	2,200	5	400	0.9	10,000	22.9	2,000	4.6	20,579	47.2	43,629	100
	2020	10,000	22.9	750	1.7	350	0.8	2,250	5.2	425	1	11,000	25.2	1,000	2.3	17,854	40.9	43,629	100
Huntington	1966	17,560	29	950	2	930	2	730	1	3,200	5	5,090	8	4,170	7	21,420	36	60,110*	100
	1981	28,832	48.5	1,458	2.5	1,686	2.8	4,081	6.9	3,705	6.2	10,230	17.2	3,958	6.7	5,548	9.3	59,496	100
	2000	31,900	53.6	1,700	2.9	1,800	3	4,250	7.1	3,300	5.5	11,000	18.5	2,000	3.4	3,546	6	59,496	100
	2020	33,500	56.3	1,850	3.1	1,900	3.2	4,250	7.1	3,300	5.5	10,750	18.1	1,000	1.7	2,946	5	59,496	100
Islip	1966	18,150	21	1,010	1	720	1	2,000	2	3,840	4	8,250	10	640	1	24,240	28	86,890*	100
	1981	20,243	34.4	1,889	3.2	1,323	2.2	5,566	9.5	6,239	10.6	11,703	19.9	162	.3	11,698	19.9	58,823	100
	2000	22,300	37.9	2,300	3.9	3,300	5.6	5,650	9.6	6,200	10.5	11,800	20.1	75	.1	7,198	12.2	58,823	100
	2020	23,300	39.6	2,450	4.2	3,600	6.1	5,650	9.6	6,300	10.7	11,800	20.1	35	.1	5,688	9.7	58,823	100
Riverhead	1966	1,600	4	210	1	140	1	6,790	15	260	1	3,310	8	19,550	45	10,200	23	43,590*	100
	1981	2,982	6.2	1,512	3.1	331	.7	7,268	15	549	1.1	4,606	9.5	19,216	39.7	11,972	24.7	48,435	100
	2000	4,200	8.7	1,800	3.7	800	1.7	6,400	13.2	600	1.2	5,400	11.1	17,500	36.1	11,735	24.2	48.435	100
	2020	5,100	10.5	2,000	4.1	1,000	2.1	6,200	12.8	700	1.4	5,800	12	16,000	33	11,635	24	48,435	100
Shelter Island	1966	660	9	40	1	10	-	10	-	10	-	2,400	33	80	1	3,680	50	7,350*	100
	1981	1,440	16.6	96	1.1	19	.2	164	1.9	549	6.3	3,581	41.3	439	5.1	2,385	27.5	8,673	100
	2000	2,000	23	100	1.2	25	.3	175	2	600	6.9	3,600	41.5	400	4.6	1,773	20.4	8,673	100
	2020	2,500	28.8	120	1.4	25	.3	175	2	600	6.9	3,650	42.1	350	4	1,253	14.4	8,673	100
Smithtown	1966	8,640	25	460	1	350	1	570	2	1,820	5	3,220	9	1,240	4	14,760	43	34,480*	100
	1981	12,586	37	1,029	3	684	2	2,526	7.4	2,794	8.2	6,371	18.7	1,138	3.3	6,887	20.2	34,017	100
	2000	15,000	44.1	1,200	3.5	1,400	4.1	2,500	7.3	2,600	7.6	6,500	19.1	600	1.8	4,217	12.4	34,017	100
	2020	15,900	46.7	1,300	3.8	1,525	4.5	2,500	7.3	2,600	7.6	6,500	19.1	400	1.2	3,292	9.7	34,017	100
Southampton	1966	8,500	8	1,150	1	400	-	2,500	2	3,350	3	5,360	5	12,450	12	51,710	47	109,530*	100
	1981	16,005	15.3	1,730	1.7	402	.4	6,162	5.9	2,784	2.7	9,472	9.1	16,918	16.2	50,867	48.7	104,336	100
	2000	21,000	20.1	2,000	1.9	425	.4	6,300	6	2,900	2.8	14,000	13.4	15,000	14.4	42,711	40.9	104,336	100
	2020	25,000	24	2,200	2.1	450	.4	6,500	6.2	3,000	2.9	15,000	14.4	13,500	12.9	38,686	37.1	104,336	100
Southold	1966	2,280	1	180	1	100	-	350	1	990	3	2,360	3	11,920	34	13,930	40	34,600*	100
	1981	3,846	14	794	2.9	100	.4	1,167	4.2	1,238	4.5	2,419	8.8	6,896	25.1	11,013	40.1	27,474	100
	2000	5,000	18.2	900	3.3	125	.5	1,200	4.4	1,300	4.7	2,900	10.6	6,000	21.8	10,049	36.6	27,474	100
	2020	5,800	21.1	1,050	3.8	150	.5	1,200	4.4	1,300	4.7	3,000	10.9	5,000	18.2	9,924	36.1	27,474	100
Suffolk County	1966	91,790	14	6,130	1	4,920	1	24,390	4	25,450	4	49,200	7	64,400	9	271,820	40	676,860*	100
	1981	139,872	24.7	13,624	2.4	9,797	1.7	45,024	7.9	31,357	5.5	83,499	14.7	59,901	10.6	183,394	32.4	566,466	100
	2000	165,900	29.3	15,550	2.7	13,625	2.4	45,575	8	31,050	5.5	100,000	17.7	49,075	8.7	145,691	25.7	566,466	100
	2020	184,800	32.6	16,870	3	14,800	2.6	46,125	8.1	31,675	5.6	107,300	18.9	40,285	7.1	124,611	22	566,466	100

*The 1966 total acreage included water areas within Town boundaries and delineated roadways under a separate category. For the 1981 acreages, only land areas were used and roadways were incorporated into various existing categories. Other slight variations between 1966 and 1981 include the use of different maps and techniques (hand count vs. computer map analysis) as well as boundary changes and annexations (current maps are deemed to be more accurate).

Sources:
1966 - NSRPB, 1968, "Existing Land Use." Hauppauge, New York.
1981 - LIRPB, 1982, "Land Use - 1981." Hauppauge, New York (Revised June 1983).
2000 - LIRPB, 1984, Projected Land Use, unpublished data.
2020 - LIRPB, 1984, Projected Land Use, unpublished data.

TABLE X-4

Land Use - Combined Totals for Vacant and Agricultural Uses in Suffolk County

Vacant

Town	1966 Acres	%	1981 Acres	%	2000 Acres	%	2020 Acres	%
Brookhaven, Babylon and Islip (combined totals)	125,270	36.8	71,351	29.7	51,061	21.2	39,001	16.2

Vacant

Town	1966 Acres	%	1981 Acres	%	2000 Acres	%	2020 Acres	%
Shelter Island, Southampton, Southold, Riverhead, and East Hampton (combined totals)	110,370	45.7	99,608	42.8	86,847	37.3	79,352	34.1

Agricultural

	1966 Acres	%	1981 Acres	%	2000 Acres	%	2020 Acres	%
	46,420	19.2	46,499	20.0	40,900	17.6	35,850	15.4

management of the hard clam resource. These changes will have long-term effects, not only on the resource, but in selection of management alternatives that are eventually implemented. Unfortunately, forecasting the nature of the impacts in any sort of quantitative way is impossible now, but important questions should be formulated:

(1) How will environmental modifications caused by land use and activity changes affect hard clam habitats?

(2) How will pollutant loadings to local bays be modified, and how will these modifications influence the hard clam resource?

(3) How will population growth modify the acreage of underwater lands certified for taking of shellfish?

(4) Can coliform control measures be implemented that will reduce the acreage of uncertified waters?

Coastal modifications, such as construction of bulkheads, marinas, berms and other man-made structures reduce the amount of natural shoreline along a given bay. Transformation of coastal wetlands, beaches and other habitates, i.e., the change from natural to developed shores, has implications for adjacent marine ecosystems. The percentage of natural shoreline adjacent to a bay may be an important indicator of the condition of the ecosystem in question. Unfortunately, no criteria exist which can be used to evaluate when the cumulative effects of shoreline change reach a critical threshhold as far as the ecosystem function is concerned. It is generally agreed that the edge effect associated with marine wetlands is of importance to local fisheries.

During the period 1950 to 1970, when Suffolk County experienced a growth of 400% in its population, dramatic changes were apparent in coastal land use and modification. In 1954, there were approximately 20,600 acres of tidal wetlands in Suffolk County; by 1971 only about 12,700 acres remained -- a 38% loss in 17 years (Green 1972; O'Connor and Terry 1972). The rate of wetland loss was curtailed by an increased environmental awareness and the subsequent passage of Article 25 of the New York State Environmental Conservation Law in 1973, and implementation of other regulatory programs at the town level. There are no data available to document either the rate of wetland loss or the absolute loss of wetland acreage in the County at the present time. By using land maps prepared in 1977, the Long Island Regional Planning Board estimated that 36%, or 351 miles, of Suffolk County's 987 mile shoreline was developed.

Population and land use changes will have a definite impact upon the distribution of waters that are certified for the taking of shellfish. Using population changes as an indicator of development, Maiolo and Tschetter (1981) found a statistically significant positive correlation between intensity of development and acreage closed to shellfishing during a 27-year period for two coastal counties in North Carolina. It was found that as the resident population of coastal counties increased, a resultant decline in water quality necessitated closure of additional shellfish harvesting areas. In Carteret County, North Carolina, an increase of 1,000 permanent residents in shoreline communities was found to be correlated with the closure of 200 acres of underwater lands to shellfishing; in New Hanover County there was a closure of 320 acres per increase of 1,000 residents.

An analysis of the change in areas uncertified for shellfishing in Suffolk County and the causes for such change has not been undertaken. While there is probably a positive correlation between suburban/commercial development and marine water quality deterioration, detailed studies would be needed to identify the relationships between population growth and land use changes, and deterioration of marine water quality in Suffolk County.

THE LONG ISLAND COMPREHENSIVE WASTE TREATMENT PLAN

The Long Island Comprehensive Waste Treatment Plan (LIRPB 1978) documented that stormwater runoff (overland flow and stream flow) was the primary contributor of coliform contamination to marine surface waters in Suffolk County, as opposed to point source contributors and groundwater underflow. This study evaluated alternative measures for control of coliform loadings to Long Island's surface waters. The study found that to achieve a reduction in the acreage closed to shellfishing would require implementation of measures to control stream flow and overland flow; control of one source without the other would result in little benefit. Modeling studies were employed to estimate the degree of improvement (acres open to shellfishing) and costs associated with various control measure plans. While predictions of improvement were made, and it would be possible that the benefits (i.e., harvest of shellfish) of opening uncertified shellfish grounds could compare favorably with the costs of the control measures, the report concluded that it would be, "inadvisable to incur large-scale costs for control measures at this time." This conclusion was made because there were limitations on the feasibility and effectiveness of control measures and the imprecision of clam population data. For example, there may not be sufficient depth to ground water for the installation and effective operation of leaching catch basins south of Montauk Highway in the area adjacent to Great South Bay. The information in hand indicates that, on an areawide basis, opportunities for preserving the quality of currently certified waters far exceed those for improving the quality of conditionally certified or uncertified waters.

Given these circumstances, it is likely that areas closed to shellfishing in Suffolk County now will remain closed over the long-term; the acreage closed to shellfishing in the County will probably increase in future, but it is not known by how much.

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SALINITY AND GREAT SOUTH BAY

INTRODUCTION

It apparently has been accepted as fact that over the past 15 years salinities in Great South Bay (GSB) have significantly increased (U.S. EPA Draft Report November 1982; EPA 1978). This conclusion was also reached by Hollman and Thatcher (1979) who analyzed the available historical salinity data for GSB between 1933 and 1977 and ascribed it to a step-wise increase on salinity between 1960 and 1965. The purpose of this section is to reconsider the matter taking into account more recent salinity data collected between 1978 and 1984.

It is important to understand that at any given time the salinity in GSB will vary from approximately oceanic in Fire Island Inlet to approximately fresh in the tributary rivers. What we are concerned with here is the trend or change over a long time in the quantity, S_T, the salt content of GSB which is given by

$$S_T\ (t) = \int_v S(v,t)dv$$

where S is the salinity and v the volume of GSB. S_T will vary, of course, from day to day, week to week, month to month, and year to year.

There are three possible causes of an upward trend is S_T[1]: an increased exchange of GSB with the ocean through Fire Island Inlet and Jones Inlet via South Oyster Bay; a significant increase in the exchange of Moriches Bay with the ocean through Moriches Inlet; and decreases in the inputs of fresh water to GSB, i.e., precipitation, streamflow, ground water influx, or some combination of all. Trends in S_T can be inferred by examining the evidence for the forgoing causes and by examining the available salinity records.

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[1] Other potential factors such as road salt and decreased submarine outflow due to Magothy pumpage have been shown to be insignificant (SCDEC 1978).

SALINITY DATA

In Table XI-1, we have summarized the historical salinity measurements that have been examined for purposes of this report. There are two points to be made regarding this data set. First of all, Source No. 1 salinities were taken at the Blue Points Company hatchery and are not strictly comparable with Source No's 2 through 7 all of which were located in the same general area, midbay between Nicoll bay and Fire Island, as shown on Figure XI-1. Second, Hollman and Thatcher combined midbay and hatchery values in their analysis (Hollman and Thatcher 1979) and, obviously, did not have available the values from the Blue Points Company hatchery (No. 1) and No.'s 3 and 5 from midbay post 1977. Accordingly, we have separated the hatchery salinities from the midbay values and show the hatchery values on Figure XI-2 and the midbay values on Figure XI-3. We have also added to Figures XI-2 and XI-3 the data collected since 1977.

The rationale for this data separation is shown in Figures XI-4 and XI-5. Figure XI-4 is a plot of monthly averages of the June-September salinities taken at the Blue Points Company hatchery (No. 1 in Table XI-1) versus monthly averages (June-September) of the Connetquot River flow for the years 1976-1983. The regression of salinity, S, on river flow, Q, is

$$S = 33.23 - 0.223\ Q \qquad (1)$$

The coefficient of determination of 0.78. According to Spearman's correlation test, if there were no correlation between S and Q, the probability of obtaining the observed results is less than 0.2%. Figure XI-5 is a plot of nearshore salinities measured at the Blue Points hatchery (No. 1 in Table XI-1) versus midbay salinities measured on the same day by the Suffolk County Dept. of Health (No. 3 in Table XI-1). It is clear from Figure XI-5 that the nearshore salinity in the vicinity of the Blue Points Company hatchery is consistently lower than nearby midbay values and that the reason is

Table XI-1

Historical Salinity Measurements for Great South Bay

Source	Period	Description	Location	Reference
1. Blue Pts. Co.	1940-1949; 1970-1984	Ave. of daily values June-Sept. (n = 120 for each ave.)	Blue Pts. Co. Hatchery	Personal Communication
2. Blue Pts. Co.	1967-1982	Ave. of single obs. at Sta. 1,2, & 3 throughout year; 86% bet. June-Sept. (n = 10 for each year)	B.P. Stations 1, 2,3. bet. Nicoll Bay and Fire Is.	Hollman and Thatcher, 1979
3. Suffolk County Dept. of Health	1977-1982	Ave. of biweekly obs. between June & Sept. (see Fig. 3 for n)	County Stations 150&170 bet. Nicoll Bay and Fire Is.	Personal Communication
4. Woods Hole Ocean. Inst.	1954; 1956-1959	Single obs. during July 1954; Aug. 1956; June 1957; June and Sept. 1958; July and Sept. 1959 (n = 6 for Sta. 3; 7 for Sta. 4)	WHOI Stations 3&4; same as Suffolk Cty Stations 150& 170	Hollman & Thatcher, 1979 WHOI Refs. 54-85;56-70;57-79; 58-57; & 60-15
5. Tetra Tech	1978-1979	Average of 4 sets of obs. taken 4x daily in Sept 1978 (n = 13) & 4 sets of obs. taken 4x daily in April 1979 (n = 14)	Tetra Tech Sta. 24; same as Blue Pts. Sta. 2	Personal Communication
6. Adelphi Univ.	1977	Average of biweekly obs. taken between May & Nov. (n = 10)	Adelphi Stations 24 & 25 bet. Nicoll Bay and Fire Island	Hair and Buckner, 1973
7. Jones Beach State Parkway Auth.	1962	Average of weekly obs. during July & Aug 1961 (n = 6 for each station)	Saville Stations 9 and 10	Saville, 1962

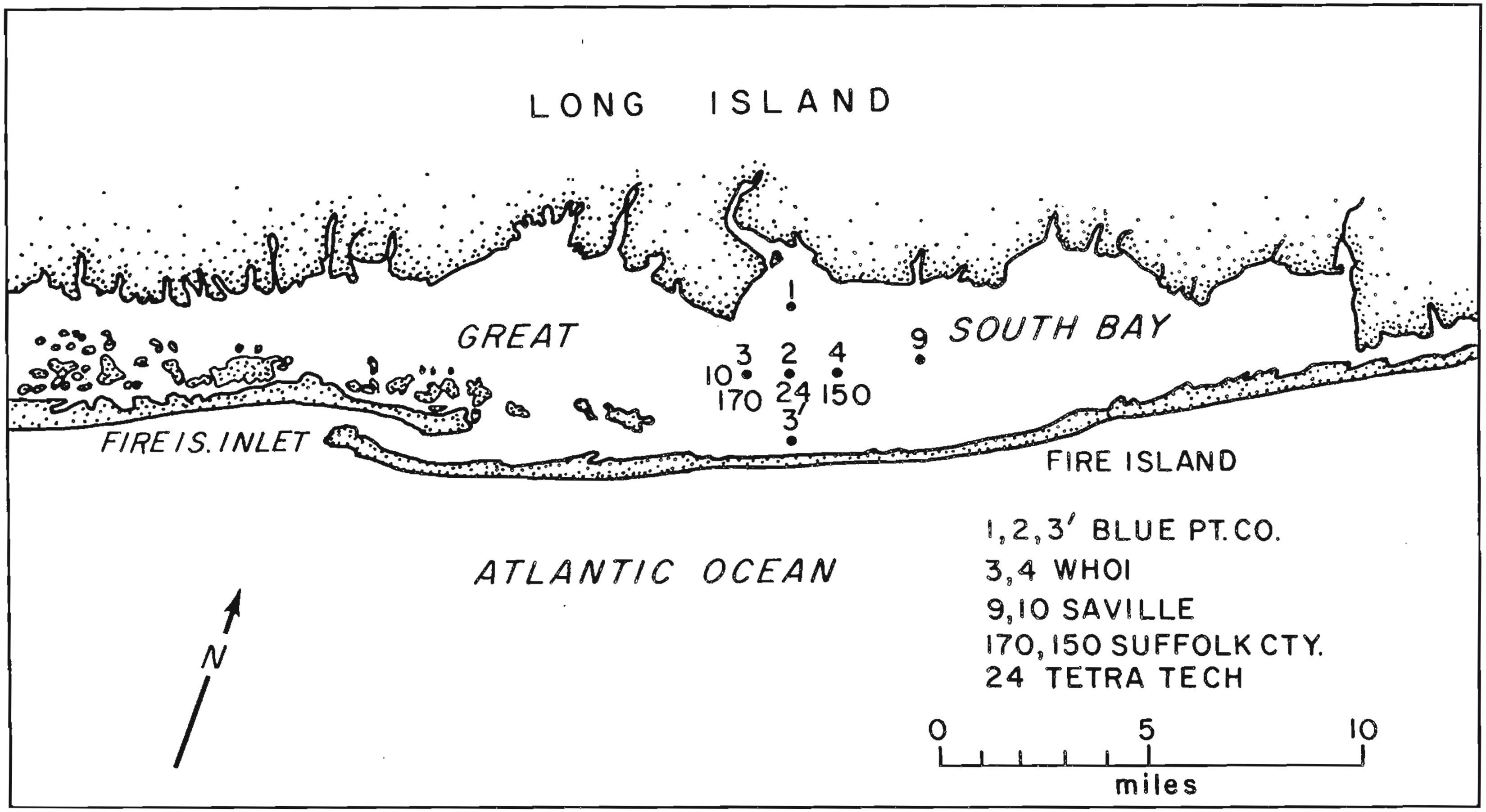
undoubtedly the discharge of fresh water from the Connetquot River (Figure XI-4). Further evidence of the fact that nearshore and midbay salinities should be considered separately is given in Table XI-2 below. Table XI-2 lists Hollman and Thatcher's correlations between the Connetquot River discharge and the salinity data according to his 4 periods. It can be seen that the midbay salinities (Peridos 2 and 4) are not significantly correlated with riverflow but that hatchery values (Periods 1 and 3) are.

Table XI-2

Correlations[2] of Connetquot River Discharge in CFS with Salinity Sets for Periods 1-4

Connequot R. Discharge, cfs	Period	Location
-0.94 (sig at 0.1% level)	1	Blue Points Co. hatchery (nearshore)
-0.66 (not significant)	2	WHOI Stations 3 & 4 (midbay)
-0.92 (sig at 0.1% level)	3	Blue Points Co. hatchery
-0.33 (not sig)	4	Blue Points Co. Stations 1,2, & 3 (midbay)
-0.64 (sig at 1% level)	Set	-----

[2]All correlations from Hollman & Thatcher 1979 (p. 19)


LONG ISLAND
GREAT SOUTH BAY
FIRE IS. INLET
FIRE ISLAND
ATLANTIC OCEAN
N
1
3 2 4 9
10
170 24 150
3′
1,2,3′ BLUE PT. CO.
3,4 WHOI
9,10 SAVILLE
170,150 SUFFOLK CTY.
24 TETRA TECH
0 5 10
miles

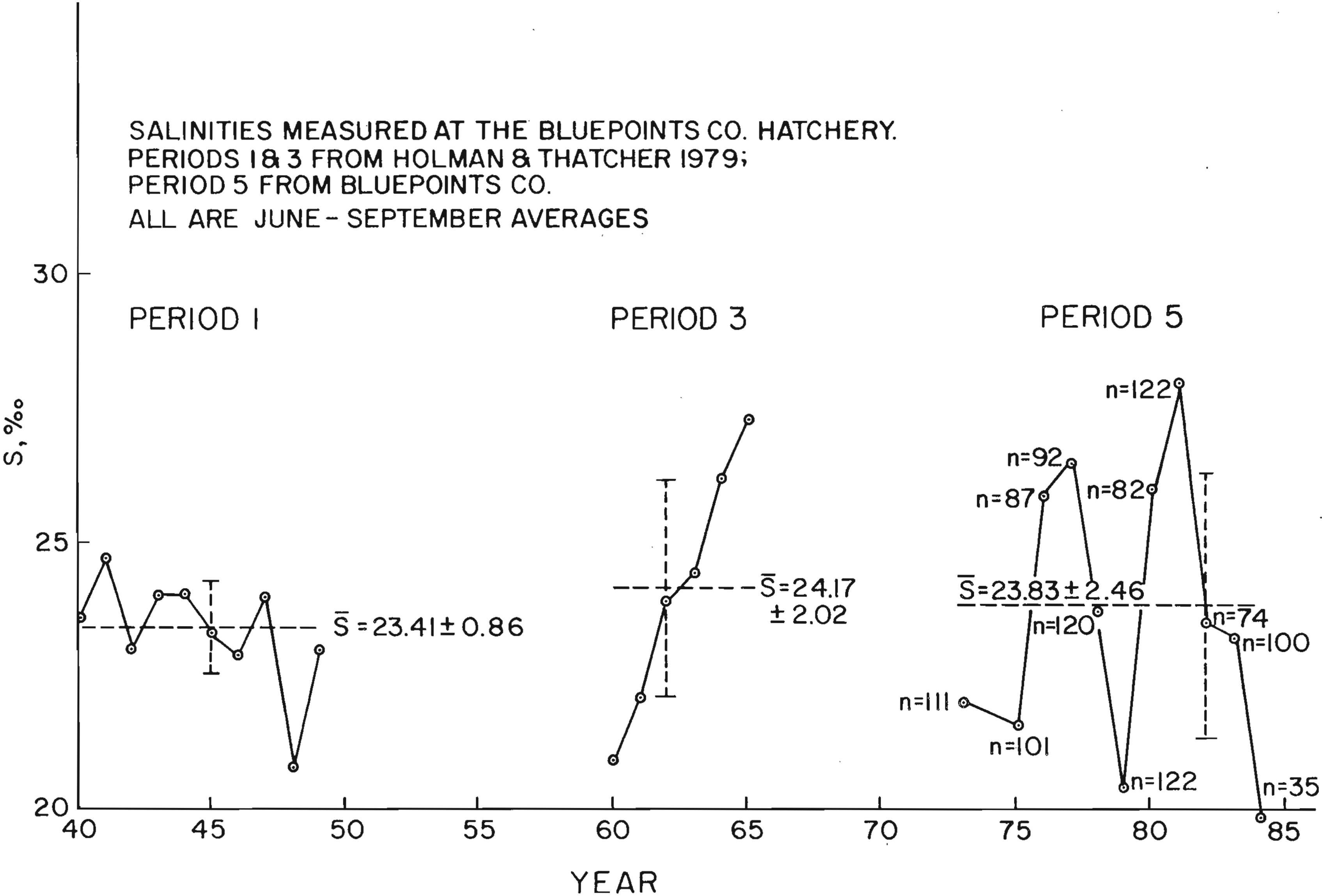


Figure XI - 2
Salinities measured at the Blue Points Co. Hatchery

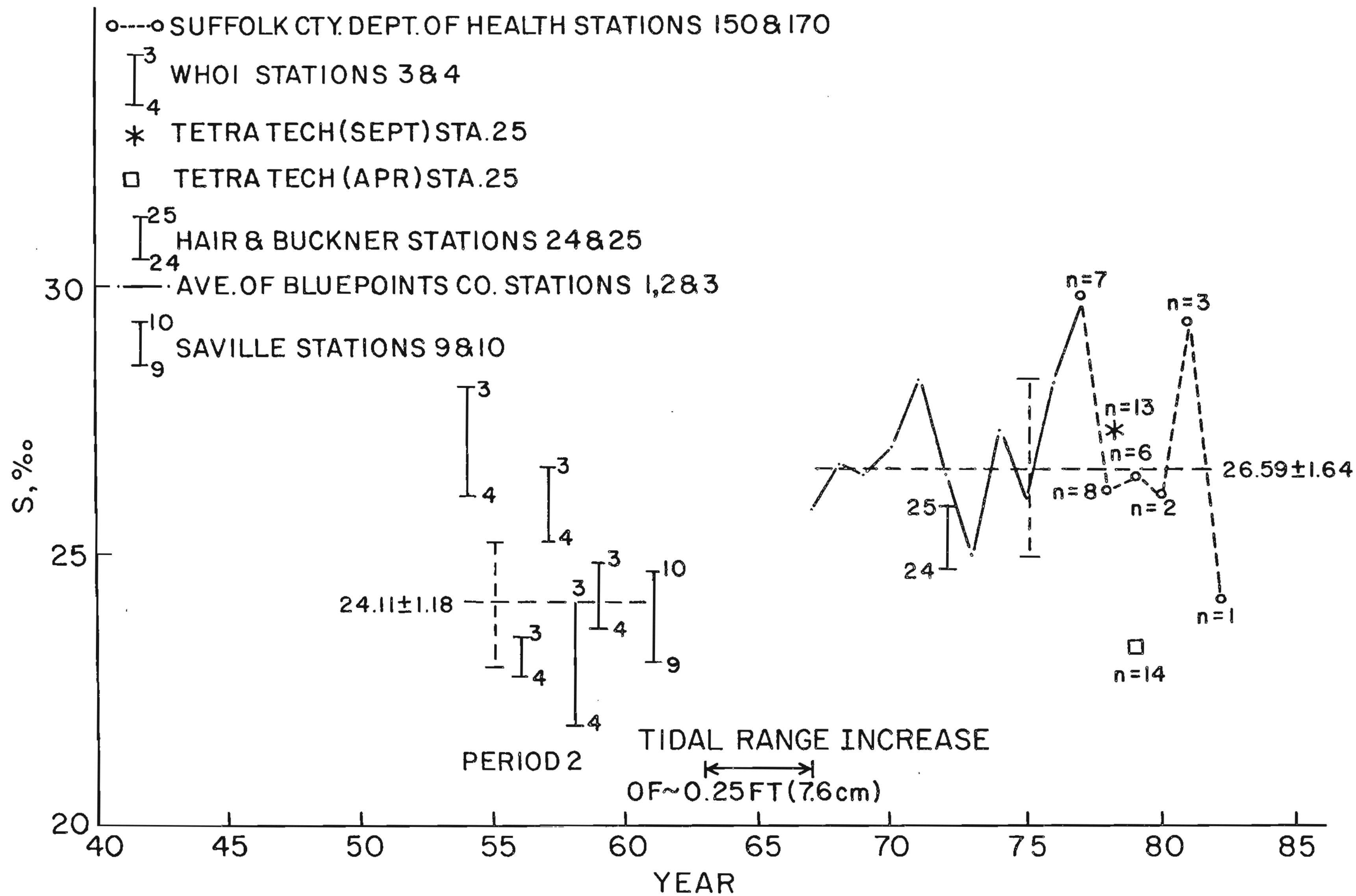

SUFFOLK CTY. DEPT. OF HEALTH STATIONS 150 & 170
WHOI STATIONS 3 & 4
TETRA TECH (SEPT) STA. 25
TETRA TECH (APR) STA. 25
HAIR & BUCKNER STATIONS 24 & 25
AVE. OF BLUEPOINTS CO. STATIONS 1,2 & 3
SAVILLE STATIONS 9 & 10
S, ‰
YEAR
24.11±1.18
26.59±1.64
PERIOD 2
TIDAL RANGE INCREASE
OF ~ 0.25 FT (7.6 cm)
n=7
n=3
n=13
n=6
n=8
n=2
n=1
n=14

Figure XI - 3

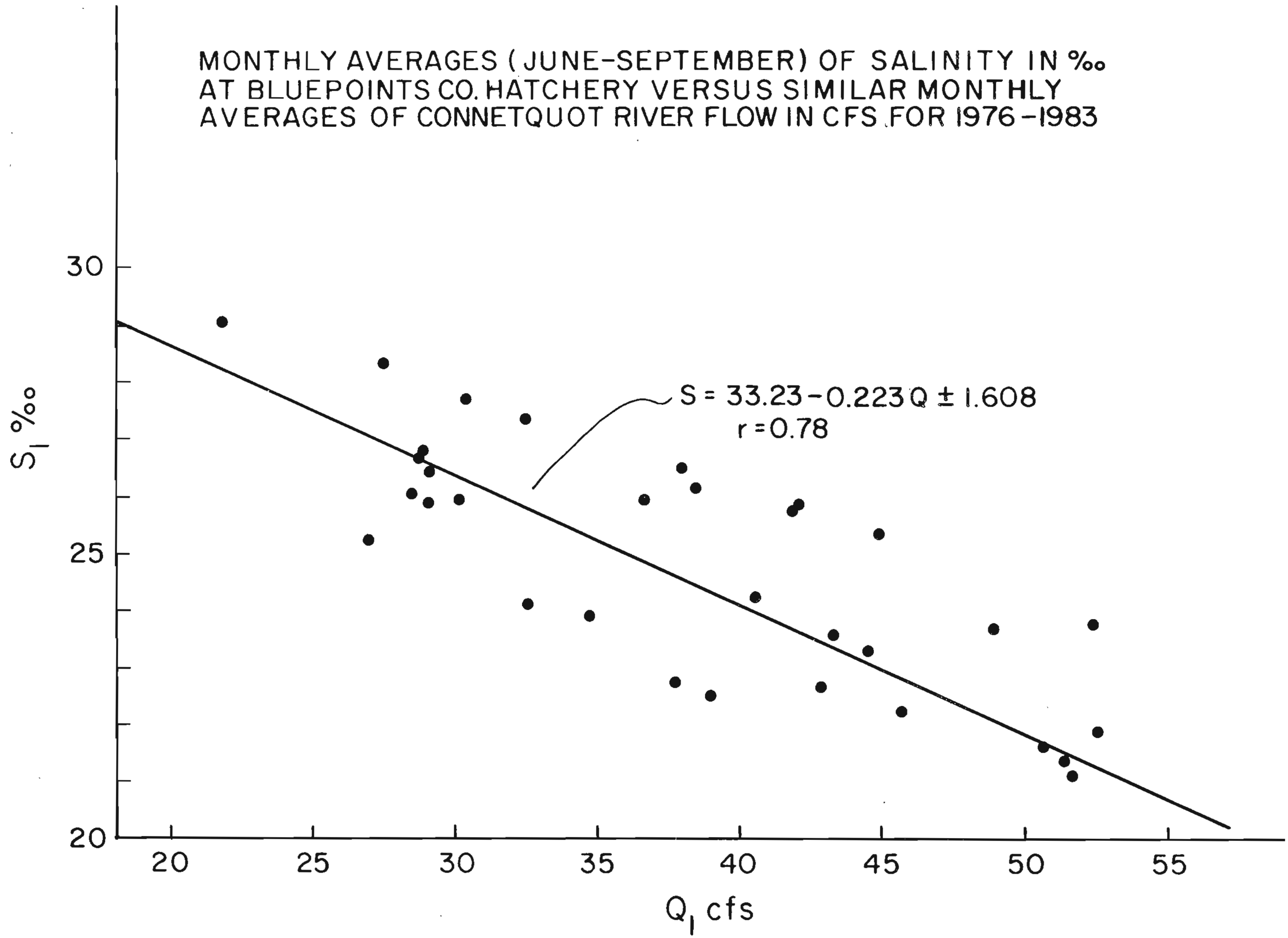

MONTHLY AVERAGES (JUNE-SEPTEMBER) OF SALINITY IN ‰
AT BLUEPOINTS CO. HATCHERY VERSUS SIMILAR MONTHLY
AVERAGES OF CONNETQUOT RIVER FLOW IN CFS FOR 1976-1983
S = 33.23-0.223 Q ± 1.608
r = 0.78
30
25
20
S_1 ‰
20
25
30
35
40
45
50
55
Q_1 cfs

Figure XI - 4

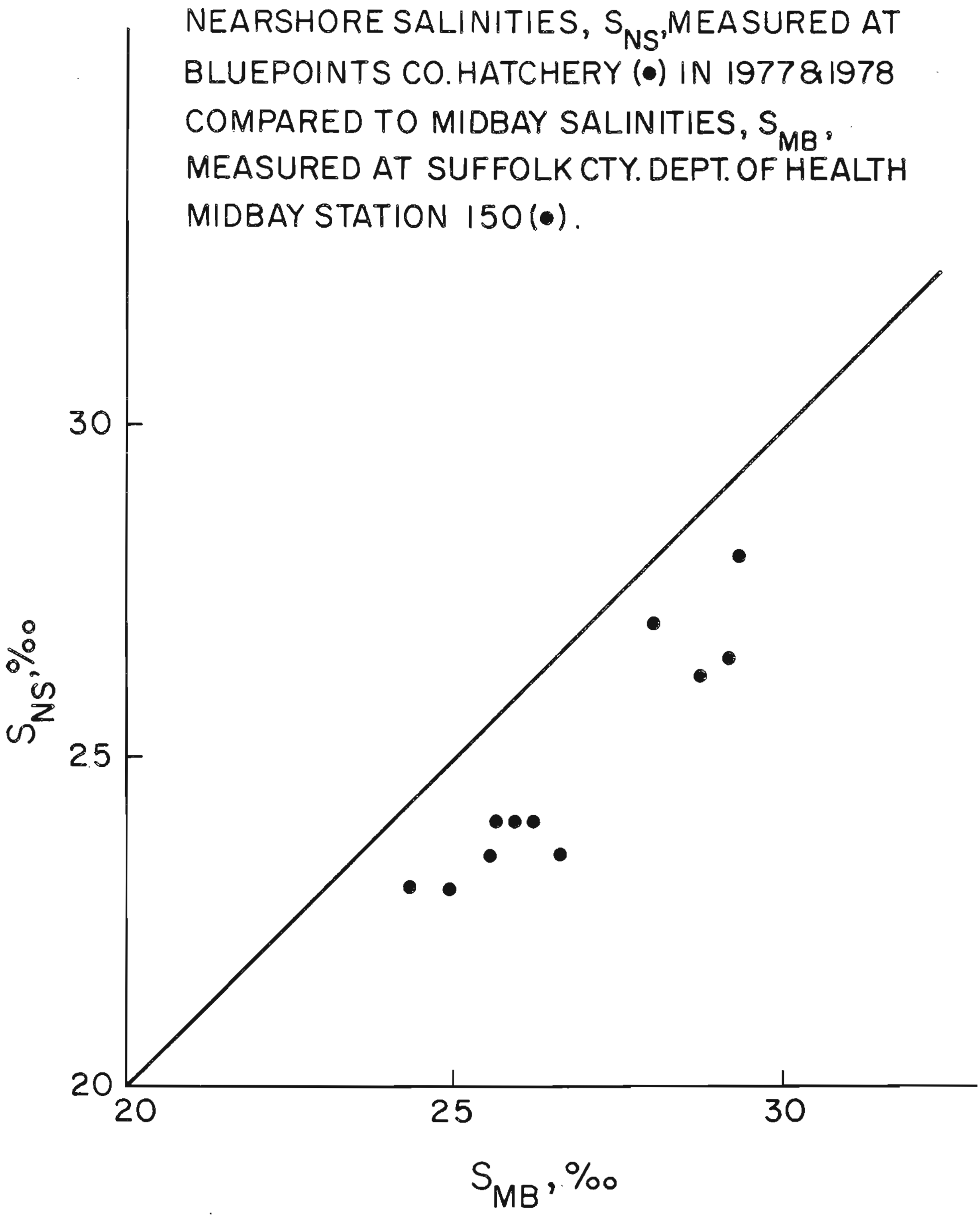


Figure XI - 5
Nearshore salinities measured at Blue Points Co.

DISCUSSION

The Case for a Salinity Increase

The evidence for a salinity increase is partly direct and partly indirect. The only direct evidence of a salinity increase, i.e., salinity measurements, is shown on Figure XI-3. On Figure XI-3 are plotted most, if not all, archived salinity measurements that have been made at or near the original Woods Hole Oceanographic Institution (WHOI) stations 3 & 4 since 1959. Stations 3 & 4 were occupied by WHOI during 1954, 1956, 1957, 1958 and 1959. They are located midway between Fire Island and the southshore of LI just south of Nicoll Bay (Figure XI-1). The difference in the means, 2.48 ^{o}/oo, for the period 1954-1961 (24.11 ^{o}/oo) and the period 1967-1982 (26.59 ^{o}/oo) is highly significant according to standard statistical tests. Although the data for the years 1967-82 are more numerous than those for 1954-61 (186 observations versus 25), a difference in means of at least 1.60^{o}/oo is highly probable[3]; the data reflect a real increase in salinity between these two periods.

Support for this conclusion can be found in the indirect evidence which consists of the well documented fact that the mean tidal range[4] at West Sayville rose from 0.664 feet to greater than 0.9 feet between 1963 and 1967 (Hollman and Thatcher 1979). During September 1980, the measured tidal range[5] at West Islip was 28.41 cm (0.93 feet) and 28.84 cm (0.95 feet) at Sailors Haven on Fire Island just across the bay from West Sayville. The correct order of magnitude of the mean midbay tidal range is considered to be 0.95 feet. From the increase in mean salinity we can make some very simple first order estimates of the required increase in tidal range as follows.

If we assume that the salinities in Figure XI-3 are representative of the mean salinity of GSB, and that the source salinity (oceanic) is 31.2 ^{o}/oo then the water budget is

$$Q_{in} + Q_{River} = Q_{out} \tag{2}$$

and the salt budget is

$$S_{in} Q_{in} - S_{out} Q_{out} = 0 \tag{3}$$

or from Eqs. (2) and (3)

$$Q_{out} = \frac{S_{in} Q_R}{\Delta S} \tag{4}$$

where $\Delta S = S_{in} - S_{out}$, Q_R is the fresh water inflow, and where Q_{out} and Q_{in} represent the volume rates of outflow and inflow, respectively, through all open boundaries, i.e., Fire Island Inlet, Narrow Bay, and the Robert Moses Causeway. Q_{in} and Q_{out} represent that part of the averaged flood and ebb flows, respectively, that is "new" water, i.e., those portions of the ebb flows that did not enter during previous floods (Q_o) and of the flood flows that did not leave on the previous ebbs (Q_{in}). S_{in} is assumed to be the salinity of the ocean and S_{out} the mean salinity of GSB during each period. The system is assumed to be in steady state, i.e., $\frac{\partial S}{\partial t} = 0$, for the pre-1963 period (1954-63) and the post-1967 period (1967-82). From Eq. (4) we have calculated Q_{in} and Q_{out} in terms of Q_R for present conditions and pre-1963 conditions. The results of these calculations are listed in Table XI-3.

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[3] 99% confidence limits are $1.6^o/oo < \bar{s}_{67-82} - \bar{s}_{54-61} < 3.36^o/oo$

[4] Includes both astronomical and meteorological tides.

[5] By MSRC, SUNY, Stony Brook

Table XI-3

Exchanges of GSB with the Ocean, Moriches Bay, and S. Oyster Bay from Estimates of the Mean Salinity of GSB

	S_{in}, °/oo	S_{out}, °/oo	Q_{out}/Q_{in}	Q_{out}/Q_R	Q_{in}/Q_R
Pre-1963 :	31.2	24.11	1.29	4.40	3.40
Present :	31.2	26.59	1.17	6.77	5.77

If the volume of water exchanged per tidal cycle is given by h, the tidal range, times the surface area, A, then Q_{in} is equal to some fraction, f, of hA/T or

$$Q_{in} = (hAf)/T \qquad (5)$$

where T is the tidal period, ~ 12.42 hours. From Eq. (5) then

$$\frac{(h)_{\text{pre-1967}}}{(h)_{\text{present}}} = \frac{(Q_{in})_{\text{pre-1963}}}{(Q_{in})_{\text{present}}} \qquad (6)$$

assuming that A, Q_R, T, and f did not change. Equation (6) gives an estimate for the ratio of the tidal ranges from the salinity as 0.59 compared to the measured ratio of 0.70. It can be seen that an increase in tidal range from 0.664 feet to 0.95 feet is insufficient to account for a salinity increase of 2.48°/oo--an increase of (1/0.59) 0.664 feet or 1.13 feet is required, assuming of course that 2.48°/oo is the correct value for the increase in mean salinity of GSB. It can be shown from equations (4) and (6) that an increase to 0.95 feet can account for 1.59°/oo to 1.76°/oo depending upon whether one uses the pre-1963 mean salinity or the present mean salinity as the basis for calculating the increase or decrease.

An additional reason for a salinity increase can be found in the precipitation record for the period 1951-1982 for JFK International Airport, Queens, New York (National Climatic Data Center, NOAA). Using these precipitation data, we calculated a 5 year running average so as to filter out variations with shorter periods and plotted these averages on Figure XI-6. Each data point on Figure XI-6 represents the difference between the running average for the previous 5 years and the mean precipitation in inches for the 32-year period between 1951 and 1982. Positive values represent "wet" periods and negative values "drought" periods. It can be seen from Figure XI-6 that the period 1964-1974 was an extremely dry period and undoubtedly exacerbated any salinity increase caused by increased tidal exchange. According to Hollman and Thatcher (1979), salinity and precipitation were highly correlated (r= -0.96) during period 3 (1960-65). It should be pointed out, however, that the period 3 salinities were hatchery values (Figure XI-2) and that the correlation is due largely to the underlying relation between precipitation and Connetquot River stream flow.

The Case Against a Salinity Increase

The direct evidence for a salinity increase was contained in the difference between the means for two sets of data, one set taken between 1954 and 1961 by WHOI (Guillard *et al.* 1960; Ryther *et al.* 1958; Ryther *et al.* 1957; Ryther *et al.* 1956; Bumpus *et al.* 1954) and Saville (1961) during summer months and consisting of only 25 observations and the other taken between 1967 and 1982 by four different agencies and consisting of 186 observations (Figure XI-3). Some of the data points on Figure XI-3 (which have been assumed to represent June-September averages) are based on as few as two observations; the most observations in a single data point are 13. The case for a salinity increase depends critically on the significance of our estimates of the various means with respect to the true mean values. A determination of the required record length of daily

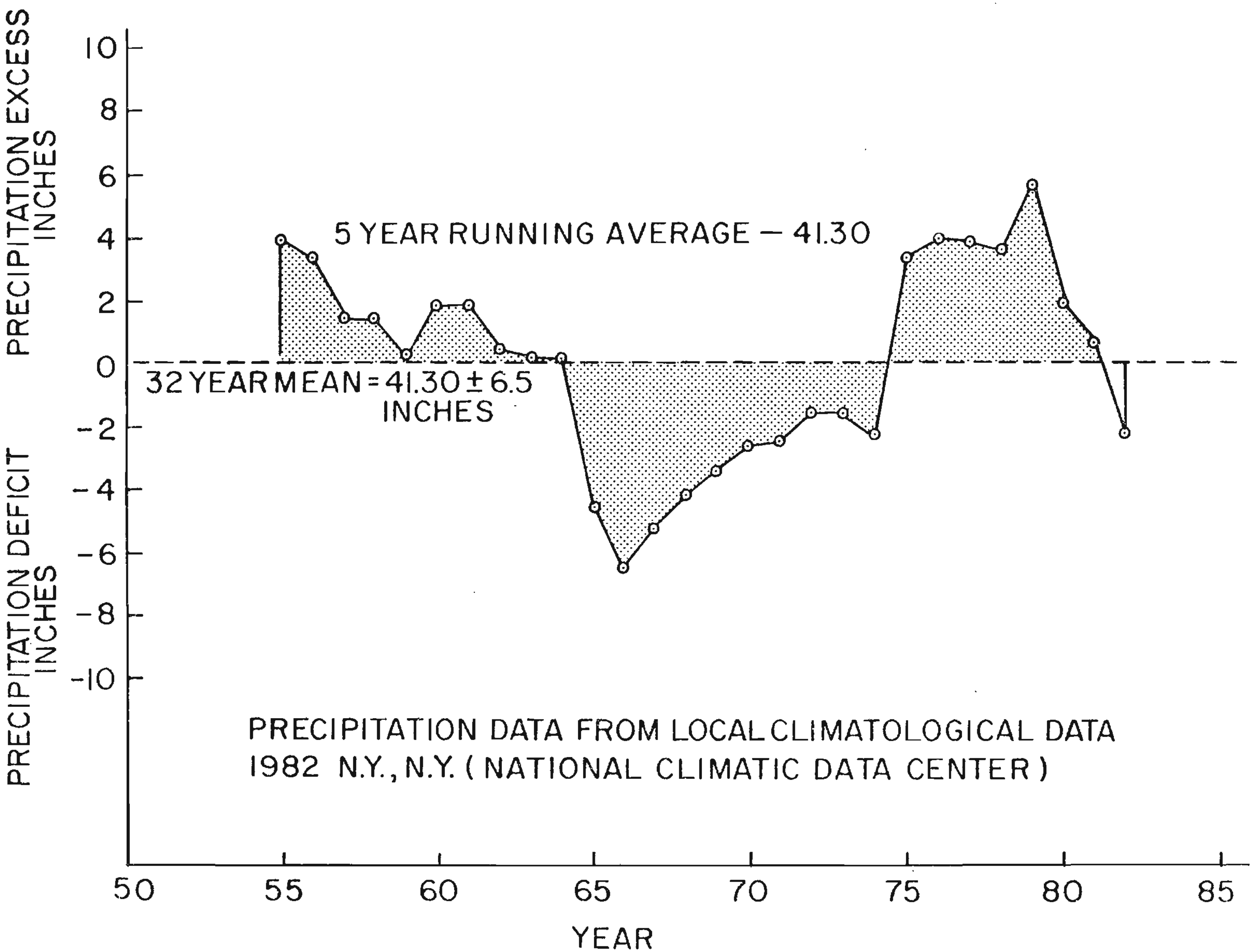

Figure XI - 6
Precipitation Data from Local Climatological Data 1982 N.Y., N.Y.

observations of salinity so that a significant estimate of the true mean value is obtained is beyond the scope of this paper. It is clear, however, that the record length must be significantly longer than the time scales of the processes which produce variance in the record. Apart from aperiodic causes such as inlet changes, the most important processes are astronomical tides (period of 12.42 hours) and wind driven subtidal exchanges (meteorological tides with periods of 7 and 4 days) of GSB with either the ocean through Fire Island Inlet or Moriches Bay[6]. The 7 day exchanges are considered most important since they are simultaneous inflows (or outflows) through Fire Island Inlet and Narrow Bay at approximately the internal horizontal mixing time scale for GSB thus enhancing the exchange of lower salinity GSB water with saltier ocean water. A record length of at least a month of daily observations would be required to average out these periodic causes; daily observations from June through September would be even better. The data available to us and plotted on Figure XI-3 obviously fall far short of meeting this criterion and must be recognized for what they are -- poor estimates of the true June-September mean values.

The June through September averages for period 5 measured at the Blue Points Company hatchery (Figure XI-2), however, are based on daily values and, except for 1984, include an average of 83% of the days in the 122 day observation period. They should, therefore, be reasonable estimates of the true mean summertime salinities for the years 1973-1984. According to Hollman and Thatcher (1979), the average salinities for periods 1 and 3 on Figure XI-2 are annual averages of daily values measured throughout the year. As near as can be determined, the observations were distributed more or less equally throughout the year since that is current practice.

[6] It is interesting to note that the high values of salinity on Figures XI-2 and XI-3 for 1980-81 coincide with the breach in Moriches Inlet which opened on 15 January 1980 and was closed in February 1981.

It is clear from Figure XI-2 that there is no discernible trend for the years 1940-1984; statistically the difference in the means for the 3 periods is not significant even at the 10% level. The trend within period 3 was previously explained as caused by the cause and effect relation between hatchery salinities and Connetquot River discharge (precipitation). Of most significance, however, is the absence of any trend within period 5. This, together with the absence of a trend in the post 1967 salinity data in Figure XI-3, and the fact that tidal ranges have not significantly changed since 1967, indicate that all of the evidence we have is consistent with the hypothesis that salinities in GSB are not now increasing and have not increased since the mid-1960s.

WHAT ABOUT THE FUTURE?

The available records show (Figures XI-2 and XI-3) that there is considerable annual variance in the average summertime (June-September) hatchery and midbay salinities. Much of the variance in the hatchery record can be explained by fluctuations in Connetquot River stream flows but midbay salinities appear to be more dependent on other causes, such as inlet bathymetry, at Moriches and Fire Island, and baywide stream flows through precipitation. As a result, a minimum of 5 to 10 years of daily observations between 1 June and 30 September would be required to detect a trend in the record. If such a data set could be taken each summer and maintained at, say, 3 to 4 middepth locations in GSB, salinity trends could be documented satisfactorily, although after the fact. Logical agencies to carry out this monitoring effort are agencies of the County, the 3 towns and the Blue Points Company. As noted earlier, the Blue Points Company presently makes daily salinity measurements at the hatchery. They should be encouraged to continue this series and, if possible, take concurrent measurements of salinity at Station 2 (Figure XI-1) during the summer months. Station 2 is a key station since it is located in an area where the salinity closely approximates the mean salinity of GSB.

Other useful indirect evidence of salinity trends can sometimes be found in records of precipitation (NOAA), stream flows (USGS), tidal range (Suffolk County DPW), and inlet dredging (USACE). These data should be collected annually and studied for changes or trends to provide advance warning of corresponding salinity changes.

The monitoring program discussed above is quite modest in scope. All towns maintain small boats and presumably have personnel assigned to their environmental conservation departments who could make these observations. If not, perhaps local high school science departments could be interested in participating. What is required is a commitment on the part of an agency to initiate and maintain a salinity monitoring program over a period of time long enough to provide useful data (5 to 10 years).

As noted above, one of the locations where the salinity should be monitored is Station No. 2 on Figure XI-1. Other locations could be identified by exercising a salinity model of GSB presently under construction at the MSRC. Presumably the model could be exercised under various scenarios of inlet bathymetry and baywide stream flow to identify several widely separated locations in GSB which are most sensitive to these parameters.

Finally, if such a monitoring program is to be conducted, it should be coordinated by a single agency so as to ensure appropriate data quality through calibration and intercomparison.

Managers of the hard clam resource in GSB must decide the importance of salinity levels in GSB, either real or perceived, and if important, undertake a monitoring program, such as that described above, which is properly designed to provide the information necessary to answer the question. The present system of the County and the towns occasionally sampling throughout their waters is an inappropriate application of resources if the intent is to detect trends.

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EFFECTS OF DREDGING ACTIVITIES ON HARD CLAMS

BACKGROUND

Dredging for the maintenance of channels and harbors takes place in virtually all of Suffolk County's bays. Dredging is essential to maintain coastal waterways because estuaries are sites of rapid sediment deposition. Most dredging in Long Island waters is done either with a suction dredge or a bucket and scow. Dredged material can be disposed of by dumping on land (for use as fill, beach nourishment, or aggregate), by open water discharge, or confinement in the marine environment. This section is concerned primarily with the effects of dredging and open water discharge on hard clams (*Mercenaria mercenaria*).

There are five general ways in which dredging and dredged material disposal can affect marine organisms, including hard clams:

(1) Disturbance of benthic communities by removal or burial;

(2) Increased suspended sediment in the water column and associated effects;

(3) Changes in circulation resulting from changes in bathymetry;

(4) Changes in habitat resulting from changes in substrate;

(5) Release of pollutants from dredging and disposal of contaminated sediments.

The relative importance of each of these varies with the specific characteristics of the dredging and disposal sites and with the character of the material being dredged. For hard clams, as for any organism or community of organisms, it is necessary to take into account the life cycle of the organism, the meteorological and oceanographic conditions at the time of the dredging operation, and the characteristics of the site to predict possible effects on the animals.

The most obvious effects of dredging and disposal are physical disturbances created by dredging and burial by disposal of dredged material. Revelas (1984) noted that hard clams are considered a moderately rapid burrower and that individuals have been found at a depth of 21 cm in sediment. It seems, therefore, that burial by dredged material presents a much less serious hazard for hard clams than it does for sessile bivalves such as oysters. One exception is probably the disposal of high organic content silt and clay on clam beds since this material is an unsuitable substrate for *Mercenaria mercenaria*. Physical disturbance by dredging presents a serious problem if a substantial clam population exists in a channel or harbor to be dredged. The Suffolk County Channel Dredging and Spoil Disposal Guidelines (Suffolk County Planning Department 1985) recommended that significant hard clam stocks be removed from channels prior to dredging.

To understand the direct and indirect effects of increased suspended sediment loads resulting from dredging operations, it is necessary first to review how dredging and disposal change suspended sediment loads. Increases in suspended sediments occur during dredging and open water disposal. During open water disposal more than 95% of the material is deposited rapidly on the bottom and does not affect turbidity of local waters (Schubel and Wise 1979). The spatial extent and duration of increased turbidity varies with the type of operation, sediment characteristics, and local oceanographic conditions. Typically the plume of suspended material disappears within 1-2 hours of the cessation of an open water disposal operation (Schubel and Wise 1979; Morton 1977). It should be pointed out that most dredging in local bays involves disposal along the shoreline, and not disposal in open water. This practice decreases further any potential problems of turbidity.

Hard clams are suspension-feeders, and are directly affected by the concentration of suspended sediment in the water. According to Bricelj (1984), growth of juvenile hard clams is adversely affected by suspended sediment loads in excess of 44 mg/l when exposed continuously for 21 days. Suspended sediment values easily exceed this value during open water discharge but only during disposal and for a period of 1-2 hours after disposal is stopped. However, eggs and larvae of *Mercenaria mercenaria* may be more sensitive to suspended sediment loads than juveniles and adults (Morton 1977). The fact that eggs and larvae are in the water column in summer should be taken into account when scheduling dredging projects.

Kaplan *et al.* (1974) reported no apparent mass mortality in the hard clam population as a result of release of suspended material during dredging of a shallow lagoon (Goose Creek) on eastern Long Island. They did report a reduction in the hard clam population as a whole. Presumably, much of this was caused by mechanical removal of clams in the dredged channel. Less than a year after the dredging operation two commercial clammers working the area reported no substantial change in the size of their catch.

Indirect effects of increases in suspended sediments include increased light attenuation, and release of nutrients from the suspended material. Both of these have an effect on phytoplankton, the principal food of hard clams. The effects, however, are opposed to each other so that the overall impact on phytoplankton production probably is negligible (Schubel and Wise 1979; Morton 1977). Kaplan *et al.* (1974) suggested that nutrient release resulting from dredging could cause a change in species composition of the phytoplankton present. Nutrient over-enrichment is favorable to blooms of blue-green algae and small diatoms which are not a good food source for hard clams (Bass 1983; Morton 1977). Field studies have not demonstrated over-enrichment as a result of dredging and the effects of dredging operations on phytoplankton production appear to be short-term (Morton 1977).

Changes in bottom topography resulting from dredging or dredged material disposal may cause changes in the hydrodynamics of the bay which may, in turn, affect hard clams. Possible ways in which hard clams might be affected by hydrological changes include; redistribution of sediments; development of low oxygen conditions; and salinity changes.

Dredging resulted in a substantial change in current velocities and sedimentation in Goose Creek according to Kaplan *et al.* (1974). They did not report a direct effect on hard clams. However, Morton (1977) suggested that such changes in sedimentation may result in habitat destruction for benthic organisms. Anoxic or low oxygen conditions may occur--severely stressing the benthic community--when the water column becomes stratified over areas dredged substantially below (>3 m) surrounding depths (O'Connor 1973). Most Long Island bays are too shallow to become stratified regularly, but deep holes in Hempstead Bay have reportedly become anoxic in summer (O'Connor 1973). Since these areas are likely to have low current velocities and fine-grained, organic-rich substrate hard clams will probably not exist there even under oxygenated conditions.

The modification of inlets by dredging can lead to changes in the salinity of bays. The effect is generally to increase the tidal exchange with the ocean and, therefore, to increase the salinity of the embayment. The result may be to provide more favorable conditions for invasion by major hard clam predators such as whelks and starfish (U.S. EPA 1982). The relationship between inlet modification and salinity in Great South Bay is discussed elsewhere in this report ("Salinity and Great South Bay").

Sediments in coastal locations heavily affected by man's activities may be contaminated with heavy metals, halogenated hydrocarbons, and pathogenic bacteria and viruses (Schubel *et al.* 1979). These may be released into the marine environment when dredging and disposal of contaminated sediments occurs. The effects of such contaminants on marine organisms is complex and not well understood. Morton (1977) emphasized the need to consider all life stages of an organism when effects of toxicants are assessed. Little information is available on the biological effects of heavy metals and various hydrocarbons on hard clams although benthic bivalves (including hard clams) are known to accumulate trace metals from the environment (Knutson 1984). Regardless of the impact on organisms, toxic and pathogenic substances accumulated by hard clams may cause disease in humans if these animals are consumed.

A number of methods are available to reduce mobilization of contaminants from sediments during dredging and disposal (Schubel *et al.* 1979). Most of these involve confining dredged material and maintaining separation from the marine environment by covering with clean substrate. It also may be advisable to conduct dredging operations during winter and early spring when hard clams are generally inactive.

Although many potential effects associated with dredging operations might have an adverse impact on hard clams, no long-term detrimental effects have been reported for Suffolk County waters.

This is not to say that harmful effects cannot occur. Care needs to be taken when planning and conducting dredging and disposal operations to minimize the potential for impact. Lack of knowledge of the effects of dredging operations on bivalve eggs and larvae makes it particularly important to avoid operations which might jeopardize their survival and metamorphasis. The Suffolk County dredging guidelines recommend that major dredging operations be scheduled to minimize their effects on fish and shellfish reproduction.

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MANAGEMENT ALTERNATIVES

AN INTRODUCTION AND FRAMEWORK FOR MANAGEMENT ALTERNATIVES

For any fishery, there exist a variety of management alternatives to maintain the harvestable stock at various levels. Any management strategy is an attempt to affect the stocks in one of four general ways:

(1) to decrease natural mortality;

(2) to limit fishing mortality (harvest);

(3) to increase recruitment (input) to the harvestable population;

(4) to increase growth (of individuals).

The management alternatives for Suffolk County's hard clam fishery can be classified on the basis of how each affects the fishery. Among those alternatives considered in this report, predator control is the only one which attempts to limit natural mortality. Placing limits on total harvest is the ultimate goal of selected closure, limited entry or catch, and the landings tax and harvest quotas recommended by economists. Seed planting and spawner sanctuaries aim to increase recruitment to the harvestable stock of hard clams. Relay of clams from uncertified to certified areas also increases the legally harvestable stock, although it does not increase recruitment in the strict sense. Selecting clams for rapid growth may shorten the rotation time of closed areas, thereby increasing the yield per unit time.

Existing hard clam management practices attempt to control harvest (through gear restrictions and size limits) and increase recruitment (by seed planting and spawner sanctuaries). Enforcement of hard clam laws is a component of any management alternative and is discussed here as it influences the effectiveness of attempts to restrict harvest or increase recruitment.

Private mariculture is discussed in this report although it is not a management tool for the public fishery. Private mariculture is part of a more broadly defined hard clam industry and as such affects and is affected by the public fishery.

The management alternatives assessed in this report are listed in Table XIII-1.

Table XIII-1

Hard Clam Management Alternatives Assessed in this Report

Maintaining Present Management Practices

Some of the Socio-Cultural Bases and Implications for Management

Seed Planting

Spawner Sanctuaries

Predator Control

Selected Closure of Harvest Grounds

Limited Entry and Harvest Quotas

The Economics of Management Alternatives

Private Mariculture

Law Enforcement Aspects of Hard Clam Management

PROJECTED CONSEQUENCES OF MAINTAINING PRESENT MANAGEMENT PRACTICES

Introduction

At a minimum, control of the hard clam fishery must meet certain basic requirements. The public health must be guarded, and therefore, certain areas contaminated with harmful wastes must be off limits to clammers. A minimum legal size limit also has been fixed, namely, one inch across the valves. The logic of this particular size may be argued: perhaps it should be somewhat larger; but there is no doubt that a minimum size should be enforced. Small clams are the most valuable, and the spawning potential of the stocks must be protected. Unfortunately, small clams produce considerably fewer eggs than larger clams. Harvesting on the public grounds is limited to tongs, rakes, or hand harvesting, in other words mechanical methods are prohibited. This is probably a social, rather than a conservation measure, although that can be argued, also.

Under present levels of enforcement none of these controls is adequately enforced. Clammers do enter uncertified areas and take legal and sublegal sizes. The fact that these areas, for the most part, contain larger stocks of clams than certified areas, shows that enforcement is not entirely lacking. Considerable amounts of undersized clams enter the market, many of them from certified areas no doubt, which shows that the minimum size limit is not adequately enforced. Probably the requirement that only hand-held devices can be used to take clams on the public grounds is the most effectively enforced, because other types of gear are hard to conceal. Nevertheless, violations of this restriction also are found occasionally. Clamming at night is prohibited, but violations of this restriction are common.

Other management practices presently in use include seed planting and spawner transplants. At current levels these are of questionable value, principally because they produce insignificant numbers as compared with natural supply of clams.

The Current Situation

The hard clam population in Great South Bay is low as compared with the Bay's potential. The industry is capable of exploiting a set as soon as it reaches legal size. In fact it can take some of the set before it reaches legal size and get away with it. At minimum legal size, potential egg production is only about one-fifth to one-tenth the egg production of chowder-size clams. If substantial numbers of sublegal size clams are taken, the spawning potential of the population is reduced. The level of enforcement is inadequate, so that even the preservation of spawning stock is not being met.

The Outlook

Under present circumstances the clam harvest in the long run will continue to decline. The decline will not be regular, because setting will vary depending upon natural conditions. The average size of clams also will continue to drop. Both trends probably will reach a limit when clams over minimum legal size become virtually nonexistent, although production may continue to drop if enforcement cannot be improved. The harvest is unlikely to go completely to zero, because before it does, some clammers will drop out of the fishery to take up a more profitable trade. Some clammers will remain, and the number of clammers will fluctuate as the supply fluctuates. The price of littlenecks probably will continue to rise as the supply becomes scarcer, but the fishery in Great South Bay probably will have a decreasing effect on the market price of clams if other areas continue to contribute more to the total clam supply. If the total supply continues to decline, and substitutes are not available, then increasing demand for a smaller number of clams will continue to place stress on the resource.

It is a virtual certainty that the hard clam fishery will not spontaneously rejuvenate. Without changes in existing management practices, it is likely to collapse almost entirely. Even if changes are made in the management program for the fishery, enforcement will have to be improved if the program is to be effective. Further study is needed to determine the cost of improved management and enforcement so that this may be weighed against the value of the industry as a whole.

Some of the Socio-cultural Bases

and

Implications of Management Strategies

Any future management strategy for Suffolk County's hard clam industry must take into account the social and cultural characteristics of the population of shellfishermen. Yet these characteristics are little known. Basic social scientific research is needed which can provide a detailed understanding of the human component of the fishery. Such knowledge is essential for two reasons: (1) to assess the relative "fairness" of possible management strategies, and (2) to predict reactions to those strategies.

On the first point, concerning "fairness", while such data will not provide legislators and managers with answers to questions of distributive justice, they may at least better identify the interest groups involved. We should know far better than we do, for example, to what extent there are self-defined groups (rather than statistical categories) of "full-time baymen", and what the composition of the varieties of part-timers is. When phrases such as "a way of life" are bandied about in political contexts, it would help to have some notion of what that way of life actually is, and to what extent it depends on different ranges of maritime activities. This is not to suggest that any such study will determine the value, in non-economic terms, of any such pursuits either to those who clam, or to those who watch, but such studies might reveal, for example, a geographical variation which managers might take into account in devising management strategies.

On the matter of predicting shellfisherman behavior in reaction to various management strategies, it would seem that all we have to go on at present is the calculating "everyman" of classical economics. Some observers have noted the inadequacy of such models in the case at hand, and the model is accordingly modified by a variety of stereotypical notions rather randomly gathered from the friends and enemies of clammers. In place of drab economic man--ever capable of calculating costs and benefits that elude the rest of us--we have more colorful extremes. There is "foolishly irrational" man, unable to perceive the effects of his actions, or "traditionally irrational" man, unwilling to sacrifice a "way of life" for economic gain. While there well may be some truth in all stereotypes, it seems at least ironic that we are willing to settle for a far less rigorous grasp of the characteristics of the fishermen population that we are for, say, starfish. As noted in connection with the question of fairness, predictions of reactions to management strategies should take note of internal variations in the fishing population: e.g., sub-groups based on degree of economic and cultural commitment to clamming and other maritime pursuits. Such sub-groups may co-exist in any given location or may vary significantly by locality. Until basic research is conducted which can arrive at a description of the actual fishing population and its regional variation, it is difficult to see how we can gauge reactions to such strategies as limited entry or the promotion of public or private mariculture.

Geographical variation, for example, may suggest a variety of approaches to the problem of limited entry. In some areas it might make sense to incorporate local baymen's groups into the process of defining the conditions of limited entry, and to count on their participation in the enforcement process as well. Such cooperation is not unprecedented, and is probably contingent on the composition of the association, the relation of that group to the general fishing population, and the process through which limited entry or any such management strategy evolves (e.g. from whom it is seen as issuing). For the same reasons the formation of social cooperatives in suitable areas might be encouraged and aided by the appropriate government agencies. In other regions such an approach might be less feasible. While the tradition of township governance may pose problems to the coordination of county-wide management schemes, might it not also be viewed as an asset, providing a pre-existing framework for policy variation when such variation makes sense?

Some light on the relation of group structure to such questions of management policy is cast by a consideration of what might be called "self-regulation" or "self-policing". Although fisheries economists, among others, talk as if there existed only two sorts of marine tenure, individual/private and unregulated public (with access and effort restricted only by formal government measures), there are many examples of what might be termed intermediate forms. It is not at all unusual for communities of fishermen, particularly those exploiting such inshore and stationary resources as shellfish, to lay corporate, if "unofficial", claim to more or less well-defined territories. Such group control may involve not only the prevention of outsiders from fishing within such territories, but also the regulation of fishing behavior by "insiders".

The best described case of such local territorialism, complete with restrictive rules and sanctions for offenders, is that of the Maine lobstermen (Acheson 1975). Acheson describes two sorts of communal territorialism along the coast of central Maine: (1) "nucleated", where "men from each 'harbor gang' have a strong sense of territoriality close to the mouth of the harbor where they anchor their boats..." but this ownership weakens the farther out one goes "... and eventually includes large areas which overlap with others territories and are fished by both groups; (2) "perimeter defended", wherein very well defined land-based communities control equally delimited watery grounds. The significant differences between these two types has to do not only with the extent and definition of territories, but more importantly with the degree to which the respective community types successfully limit entry and fishing effort within those bounds. The perimeter-defended type does much better on both counts: insisting on local residence, land-ownership and social acceptability for allowing access, and making corporate decisions to limit the gear and even to close areas. Both elements rest upon the ability of the group to communicate in such a way as to reach such corporate decisions, and to sanction offenders effectively. Such sanctions run the gamut from verbal warnings, to destruction of gear, boats, and even homicide. The continuance of such systems in such places attests to their local "legitimacy" (as opposed to legality).

There is a tendency among anthropologists and others concerned with such social/economic systems to assume that their existence and effective operation rest on traditional communality, i.e. long-term (several generations +) co-residence with much kinship inter-relation. Acheson mentioned in passing, however, that the most effective of these perimeter-defended territories surrounds an island on which a number of lobstermen have purchased land (to justify their access) but all of whom live elsewhere in widely scattered home-sites. This seems much more like a voluntary association than a community, and is thus possibly more relevant to other fisheries where local communities are not so well-defined as in Maine (e.g. Great South Bay).

There are many other such examples elsewhere in the world (see Taylor 1981, for example). The critical problem posed by the existence of such self-defined and self-policied fishing communities, as far as the present document is concerned, is the designation of conditions under which such systems arise, and the social/political processes that maintain them. Here the data are unfortunately weaker, mainly because few such studies have been conducted so far.

The relevance of such self-policing groups to the Great South Bay hard-clam fishery may be greater than first appears. First of all, it is not clear that some self-policing does not already go on. Apparently, nobody has looked into it. The degree to which governmental laws are broken is not a very good guide to the presence or absence of such systems. There may well be various kinds of "traditional" restrictions and sanctions operating in at least some geographic quarters. If they do exist, they will not be unearthed by survey research. Secondly, the comparative study of such systems elsewhere may suggest the sorts of conditions under which they might arise and operate, and as the Maine data indicate such conditions may not be confined to "traditional communities". Thus an assessment of self-policing as a management alternative rests, first of all, on discovering to what extent and under what circumstances various kinds of self-policing may already go on.

Variation through time is as important to consider as variation in space. It must be remembered that any profile or description of the fishing population of Suffolk County, or any poll or survey of their attitudes and values is a snapshot at a particular moment in time. However such information is gathered, the social and cultural configurations so revealed are subject to several kinds of fluctuation.

First, neither the social relations nor the culture (values, beliefs, world view) of any group (fishermen or scientist included) is necessarily internally consistent. People, as individuals and as members of groups, are perfectly capable of holding contradictory values (for example) and will experience little dissonance unless such values are evoked simultaneously by certain situations. A clammer, to take an appropriate example, may extol the virtues of a "free bay" and "private property" as fundamental values, depending on the resource and the particular configuration of personal as well as surrounding circumstances. Moreover, it is not always apparent whether such values "cause" behavior, or are rather espoused as *post hoc* justifications (though not usually cynically). In either case, however, on Great South Bay and elsewhere, for well over one hundred years, opposing sides on the question of public versus private lands have maintained the ultimate American virtue (as opposed to just sub-cultural virtue) of their respective positions.

There also are more long-term fluctuations in the social and cultural characteristics of fishermen. In some cases, at least, there may be a "developmental cycle" consisting of several life-career stages through which shellfishermen tend to pass, each of which is characterized by more or less typical clusters of attitudes and behavior. Such is certainly the case in many maritime cultures, and the degree to which apparently different types of fishermen are really different stages of a developmental cycle would have very important ramifications for policy and management decisions.

A good example can be offered from New Jersey's Delaware Bay oyster fishery, where the disappearance of tonging in the 1960s not only excluded the class of permanent tongers from the fishery, but also eliminated the entry stage by means of which many of today's dredgers got into oystering. Thus it is crucial for us to understand baymen's careers as processes rather than static pursuits.

There are yet longer-term fluctuations in the life of baymen. If shellfishing is a "traditional" pursuit in Suffolk County, that is not to say that it has been static historically. As with natural systems, social systems prove to be dynamic when viewed over the long term. It is important to remember, for example, that the entrepreneurs who began today's corporate shellfishing enterprises arose from the ranks of local baymen. When townships began leasing grounds for oyster farming in the mid-nineteenth century, it was not outside capitalists who took advantage of the opportunity, nor did those who leased ground think of themselves as sacrificing a "traditional way of life" to become businessmen. Well into the twentieth century many baymen who defended a free bay for seed oystering and clamming were anxious to lease grounds for their own oysters as well. Such baymen entrepreneurs also were members of baymen's associations which fought for the preservation of the "commons", in part because their seasonal and developmental cycle depended on it, but also because they felt that the larger companies were the only ones likely to profit from an extensive privatization of bay bottom. These baymen complain of the degree to which markets were controlled by the larger companies, preventing their own advancement in the industry. Thus it may be that much of the hostility aimed at the larger companies, and vented in political settings, is not so much rooted in an opposition to all entrepreneurial enterprise on Suffolk County's waters, but rather in the perception that no real opportunities of that nature are available to the "little guy". A long range view does suggest that shellfishing, as with other industries, tends toward a concentration of capital which increasingly limits entry and advancement--unless prevented from doing so by government "interference." The political tradition of Suffolk County's baymen developed as a response to these conditions (Taylor 1983).

A historical view of shellfishing industries also points up some interesting variations among regions of the United States. One thing made apparent from a comparison of, for example, Great South Bay with Chesapeake and Delaware Bay fisheries, is that the respective paths these industries have followed can only be explained by a model which takes into account more than ecological factors and general economic processes. The social and cultural character of the regions in general, and of the shellfishermen in particular, have had distinctive effects on the development of these local industries. If an understanding of the historical path of such industries requires a grasp of political, social (e.g. class, network, sub-groups and developmental cycles) and cultural factors, then it follows that accurate predictions of their futures will also rest on such knowledge.

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SEED PLANTING

INTRODUCTION

Planting of hatchery-produced juvenile (i.e. "seed") clams is one way of augmenting natural recruitment of hard clams. Most Suffolk County towns purchase 3-7 mm seed clams from commercial hatcheries at a cost of about $15.00 per thousand. Smaller clams (0.3 - 0.5 mm) may also be purchased at a lower price (about $2.00 per thousand). These very small clams, sometimes called "post-set", can then be cultured in raceway or upflow systems until they reach 3-7 mm.

Evidence from field and laboratory studies suggests that predation makes clams 3-7 mm in size too small to maintain a satisfactory survival rate if planted without protection. Analysis of trial field plantings carried out in coastal waters of Eastern Long Island by Flagg and Malouf (1983) demonstrated that at planting sites where mud crabs (*Neopanope sayi*) were abundant, clams less than 25 mm in shell length experienced nearly 100% mortality in a few weeks. Mud crabs are extremely abundant in many Long Island bays, including Great South Bay. For example, one survey by WAPORA, Inc. (1981) found up to 100 mud crabs per m^2 in Great South Bay. These crabs have a short life cycle and can reproduce up to four times per season. Laboratory studies by Landers (1954) and by Gibbons (1984) have shown that mud crabs can crush and consume hard clams up to about 30% of their own carapace width. That is, an adult mud crab (about 25 mm in width) can prey on hard clams up to about 8.0 mm in shell length. Laboratory studies have shown that a single adult mud crab may consume 5-100 small clams per day, depending on the size of the clams and on environmental factors such as temperature. The combined effects of mud crab abundance, their high reproductive potential, and their voracity make them the most serious predator of juvenile hard clams in local waters.

Larger juvenile and adult hard clams are subject to predation by larger species of crabs [e.g. Calico crabs, (*Ovalipes ocellatus*)], and by a number of other predators including whelks (*Busycon canaliculatum* and *B. carica*), starfish (*Asterias forbesi*), and drills (*Urosalpinx cinerea* and *Eupleura caudata*). However, these predators tend to be less abundant than smaller crabs. Consequently, it is generally accepted that to have a reasonable chance of success, seed clam planting programs on Long Island must involve planting of clams that are too large to be consumed by mud crabs.

Most existing seed planting programs include a "nursery" system to culture the seed from 3-7 mm to 20-25 mm. Several types of nursery systems may be employed. Clams may be placed directly on the bottom in pens or in plots prepared with stone aggregate to provide protection from predators. This method is simple and inexpensive, but usually results in relatively high mortality. More satisfactory results may be obtained by placing the small clams in trays containing sand or gravel substrate which are then placed in racks or rafts in areas where they will be protected from severe wave action. Rafting systems produce rapid growth and relatively high survival (50-90%), but they are more expensive than bottom plots and are subject to storm damage and vandalism.

Experience has shown that in local waters hard clams do not grow significantly when water temperatures are lower than about 15°C. This restricts the growing season to the period May to November, roughly 180 days. However, in most nursery systems, growth to 20-25 mm can be achieved in one season. In general, juvenile hard clams (3-25 mm) can be expected to grow about 0.09 mm per day during the growing season. This means, for example, that approximately 160 days would be required to grow a clam from 6 mm to 20 mm. This further implies that clams obtained late in summer may not have sufficient growing time to reach planting size before the onset of colder weather.

Following the nursery phase, field planting is generally accomplished by placing 20-25 mm clams directly on the bottom without any form of protection from predators. When predator protection is provided it is usually minimal (e.g. stone or gravel beds). The rate of survival of clams planted in this manner is to a great extent dependent on the choice of planting site. Assuming that the planting site is otherwise suitable for hard clams, predator abundance is probably the most important factor in site selection. Whelks, oyster drills, and moon snails (*Polinices duplicatus* and *Lunatia heros*) are major predators of clams larger than 25 mm. Where these larger predators are abundant, small clams may survive but may be lost to predation only after they reach 20-25 mm (Flagg and Malouf 1983).

Existing Seed Planting Programs on Long Island

All of the towns in Suffolk County have used or are using seed planting in the management of their hard clam fisheries. All but one of these (Huntington) have existing programs for planting seed clams. Funds for these programs have come from the towns themselves and from the New York State Department of Environmental Conservation (DEC) on a matching funds basis. During the period 1979-83, DEC provided a total of $99,700 to the towns on Long Island for their seed planting programs. These funds have been supplied to DEC through the National Marine Fisheries Service as result of public law 88-309 (Aid to Commerical Fisheries). DEC officials have reported that competion for these funds from other programs has reduced the amount of money available to towns for seed planting. Several towns (East Hampton, Shelter Island, and Southampton) have expressed reluctance to accept federal and State funds for seed planting activities, fearing that this would jeopardize residency restrictions on shellfish harvesting.

One problem which towns have encountered in their seed planting programs is lack of an adequate supply of seed clams from hatcheries. At times, hatcheries have been unable to supply enough clams, of the proper size, at the time needed. Five shellfish hatcheries on

Long Island produce seed clams. Of these, only two report having seed available for sale on a regular basis. In addition, several towns purchase seed from a supplier in Massachusetts. None of the towns involved in seed planting has plans to build a hatchery of its own.

Table XIV-1 summarizes seed planting activities conducted by the towns of Suffolk County.

Summary of Town Programs

The Town of Islip, which has conducted seed planting programs since 1975, has determined that small scale plantings do not make a significant contribution in augmenting natural stocks (Buckner 1981). As a result, seed purchases have been increased with a goal of planting 5 million clams per year on 3000 acres of bay bottom. This seed planting program will become part of the new, comprehensive Town shellfish management program (Davies 1984).

Table XIV-1

Summary of Town Seed Planting Activities
(from Davies 1984)

	Year seed planting began	1983 number of seed purchased	1984 number of seed proposed
Babylon	1978	1,000,000	2,000,000
Brookhaven	1978	3,000,000	3-4,000,000
E. Hampton	1981	100,000	200,000
Huntington	1981	program terminated after 1981	
Islip	1975	none	7.5-10,000,000
Riverhead	1984	none	unknown
Shelter Is.	1981	100,000	100,000
Smithtown	1980	none	1,000,000
Southampton	1979	115,000	115,000+
Southold	1982	180,000	200,000

To facilitate evaluation of the effectiveness of its seed planting program the Town of Babylon has planted the *notata* variant[1] of hard clams. Based on commercial catches of up to 70% *notata* clams in planted areas, Town officials feel that they are getting significant seed clam survival (Davies 1984).

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[1]This genetic variant is easily recognized by dark colored, radial streaks on the shell.

Babylon Town Bay managers consider seed planting an important tool for augmentation of stocks in those areas to which larvae cannot be targeted from spawner sanctuaries because circulation patterns are not satisfactory. Compared with other towns on Great South Bay, Babylon has relatively few certified, workable areas (water depth great enough to allow the use of boats). Sites have been selected for seed planting which cannot be targeted with larvae and are certified and workable. Over the past five years about 900 acres of Bay bottom have been planted with seed clams (K. Fuestal, Town of Babylon, Personal Communication).

The Towns of Brookhaven, East Hampton, Southampton, and Shelter Island also are conducting seed planting activities as an integral part of their hard clam management practices. Town officials in East Hampton and Southampton are committed to the concept of seed planting and have increased the size of their programs over the past several years. The Town of Shelter Island has been planting seed clams for several years and is exploring the feasibility of holding clams on rafts until they reach harvestable size. Although the Town of Brookhaven has been planting seed clams for the past six years, Town officials would like to see either direct evidence of return harvest on seed planted, or an increase in harvest in Town waters before increasing funding for the program. Even without such evidence, however, funding from the Town probably will continue at its present level. No evaluations have been made of the contributions of Brookhaven's seed planting program to hard clam stocks, and none is underway at the present time.

Smithtown, Southold, and Riverhead all have begun seed planting activities relatively recently and evaluations of the programs are unavailable. The Town of Smithtown began its seed planting program in 1980, but no clams were planted in 1982 or 1983. Plans are underway to renew seed clam planting in 1984 with the purchase of 1,000,000 seed clams. The Town of Southold has conducted a small scale seed planting program for the past two years, and the Town of Riverhead plans to conduct its first seed planting in 1984.

EVALUATION OF SEED PLANTING PROGRAM

None of the Suffolk County town seed planting programs has been evaluated in a rigorous way. The evaluation of seed planting programs as a management tool must include three primary elements:

(1) goals of the program

(2) scale of the program

a. number of seed planted

b. number of harvestable clams resulting from the planting

(3) total cost of the program

a. relative to total funds available for hard clam management

b. relative to the scale of the program

The cost and scale of a seed planting program need to be considered within the context of the program's goals. Program goals might reasonably be (1) a quantitative contribution to the fishery (i.e. simply putting more clams in the bay), (2) formation of a self-sustaining population, or (3) maintenance of an important recreational fishery. The acceptable cost of a program might vary considerably depending on its goal. For example, if the goal is to support a recreational fishery with substantial economic return to an area, a very expensive seed planting program might be worthwhile. Seed planting is currently being used in support of the recreational hard clam fishery in Barnstable County (Cape Cod, Massachusetts).

The following example illustrates how the costs of carrying out a seed planting program, of a size which might typically be conducted in Great South Bay, can be evaluated. The costs presented below are approximate, and are used here only to illustrate some of the factors that should be considered in evaluating costs and benefits from seed planting programs.

Cost of planting 2 million 25 mm clams:

6 mm clams from hatchery at $15 per 1000

nursery costs (to grow to 25 mm) $10 per 1000

Total = $25 per 1000

Total costs to rear two million clam to 25 mm = $50,000

Assuming that these clams will be harvested as soon as they reach legal size, and that the planting program was conducted in a town with a current harvest of 100,000 bushels per year (equal to Islip's landings in 1982), Table XIV-2 shows expected results depending on the proportion of the seed planted which ultimately are harvested.

Depending on the site of planting and other factors (e.g. size of seed, time of year planted, etc.), it may be optimistic to expect even 15% of the seed planted to survive to minimum legal size and be harvested. In our hypothetical example, a town with hard clam landings of 100,000 bushels per year which spent $50,000 on a seeding program which added two million seed clams to the town's stocks would increase its total landings by a maximum of 4% if all survived, and the increase in landings would probably be closer to 1%. This increase may or may not be worthwhile, depending on the goals of the town's seeding program. A seeding program at least ten times larger--and ten times more expensive--would be necessary to have s substantial impact on the total fishery; to increase landings by 10-40%.

There are several ways in which a shellfish manager or bayman might evaluate the results of a seed planting program such as the one illustrated. If the program produces 2000 bushels of clams (i.e. 50% survival of seed) and if the average fulltime bayman harvests 320

Table XIV-2

An example of the contributions a seeding program which adds 2 million seed clams could make to a town's hard clam fishery with a wild harvest of 100,000 bushels/year.

If % of seed harvested is	Then, Bushels of littlenecks from the seed equals	Which account for % of total harvest	And the cost to produce each bushel from seed is
100%	4000	4%	$12.50
50%	2000	2%	$25
25%	1000	1%	$50
15%	600	0.6%	$83

bushels annually, then the program conceivably could provide enough clams to support 6 baymen. From a bayman's point of view, if he pays $75/year for a commercial license and if he is able to harvest one additional bushel of "counts" (minimum legal size) worth $75, then the seed planting program has paid the cost of his license. The shellfish manager also should consider the cost of the program as a fraction of the money available to manage the fishery and determine whether or not other management strategies might contribute more effectively.

Although seed planting may not be a practical management alternative for substantially increasing the number of clams available for harvest, it can be used to rehabilitate stocks in specific areas. In areas where all of the following criteria are met, seed planting might be used as a means of rehabilitating a public, commercial fishery:

(1) hard clam stocks in the area have been reduced below harvestable densities (3-5 clams per m^2),

(2) circulation patterns make "targeting" the area with larvae from a spawner sanctuary difficult, or biological factors

(predator abundance) make survival of newly set clams unlikely; or the combined effects of circulation and biological factors act to create a situation in which successful recruitment cannot be expected more frequently than once every five years,

(3) physical and biological characteristics of the area will ensure a survival rate of at least 10% from 25 mm to littleneck size; (a) the area has firm stable substrate that is primarily sand, (b) large predators (blue crabs, whelks, starfish) are not abundant, (c) dredging or pollution will not create survival problems.

Proper evaluation of seed planting efforts clearly must be based on estimates of survival and, ultimately, rate of harvest of the seed planted. Such estimates require the use of seed clams that can be distinguished in some way from naturally set clams at the time of harvest. Techniques such as marking seed clams with alizarin, tetracycline, or paint have been used; however, use of a genetic "marker" of some type is probably the only practical way to identify hatchery produced clams for large scale plantings. Seed clams which have a relatively rare genetic trait can be planted after surveys have determined the natural frequency of that trait at the planting site. Changes in the frequency of the trait among all size class can be determined in subsequent years to provide an estimate of the survival of the planted clams to recruitment. The use of the *notata* shell coloration variety is ideal for this purpose. The *notata* variety is relatively rare in Great South Bay, but it appears to survive and grow well in the Bay. Given sufficient lead time, hatcheries can and do produce large quantities of *notata* seed. Obviously, if stock augmentation programs make use of large numbers of *notata* variety clams, its usefulness as a marker will gradually decline.

Continuing population surveys must be an integral part of any systematic evaluation effort. These surveys obviously are required to estimate mortality and growth rates of planted clams. However, the surveys should also be used to provide comparisons of recruitment rates among seeded areas and between seeded and non-seed areas. That is, the surveys should be used to compare survival of planted seed among sites and to evaluate the relative contribution that seeding programs make to recruitment at specific sites as well as to overall recruitment in the Bay.

Regardless of the economic evaluation of seed planting programs, they are popular politically. Many baymen view seed planting as having direct and tangible returns in exchange for their license fees. Town officials, in turn, often accept the views and advice of baymen and are likely to continue planting seed clams even though the available data indicate that at their present scales, these activities contribute little to total town hard clam landings. The rate of survival of planted seed clams and their overall contribution to recruitment have never been assessed for any relatively large scale town programs. This information is essential to an objective assessment of the role that seed planting could play in hard clam management in Suffolk County.

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SPAWNER SANCTUARIES

BACKGROUND

One hard clam management practice used in Suffolk County has consisted of bringing in spawners from colder regions to augment spawning stocks and to extend the spawning period. These adult clams, after serving their purpose, presumably were harvested. Recently, the spawner transplant strategy has been refined in the concept of the spawner sanctuary. In the spawner sanctuary concept an area is located, set aside, and stocked with fecund, low market value, large adult clams such that the probability of sets of spat from these sites would be maximized in previously selected certified areas identified as good areas for clam development. To be most effective clams in the sanctuaries would have to be protected against poaching. This would be accomplished by creating obstructions to tonging and raking; added patrols would also be helpful. Since the clams placed in the sanctuary would be large, preferably chowders, they would be of relatively low market value; a further disencentive to poaching.

The spawner sanctuary concept is not a new idea. According to the Annual Report to the State Legislature of the New York State Conservation Department for the year 1956, "20,000 adult clams for spawning stock were planted in the sanctuary established in the Town of Babylon section of Great South Bay." It is not clear what is meant by the term "sanctuary" and there is little additional information about the project, at least in the annual report.

Although the main strategy of the sanctuary proposal developed by the Marine Sciences Research Center (MSRC) was to maximize sets in preselected target areas, other benefits would be gained from such a practice. A sanctuary makes sense biologically since it decreases inter-clam distances thus increasing the probability of fertilization, and it is a good (conservative) management practice since it provides for protection of the investment in spawners.

Fertilization of *Mercenaria mercenaria* eggs follows the discharge of eggs and spermatozoa from the siphons of adult clams. Approximately 14 hours after fertilization embryos develop into fully-shelled, planktonic larvae (Carriker 1961). Since larvae lack the ability to swim against all but the weakest of horizontal currents, their dispersal is determined almost entirely by circulation patterns. The key to predicting larval dispersal, therefore, is a proper understanding of the circulation and mixing processes in the water body of concern in summer when hard clams spawn. Application of the spawner sanctuary concept to a specific water body thus requires detailed information on the flow field, i.e., velocities and diffusivities, on spacial and temporal scales as small as 100-500 m and 1-10 minutes, over the domain of interest, and for a typical summertime period of at least 25 days.

Such detailed information can be obtained only from numerical modelling techniques. Fortunately, such a model existed for GSB as a result of work accomplished under the Great South Bay Study.[1] The existence of this model provided an opportunity for scientists of the MSRC to refine and apply the spawner sanctuary concept to GSB. The complete analysis is contained in Carter *et al.* (1984). That report, summarized here, provides details of their rationale, the results for 15 sites (4 for Islip, 6 for Brookhaven, and 5 for Babylon waters), and the management implications in terms of total set, setting densities, and post setting survival rates for resource enhancement.

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[1] A comprehensive study of the GSB environment sponsored by the New York Sea Grant Institute.

MODELLING THE LARVAL DISPERSION

A computer model known as CAFE, originally developed under the Sea Grant program at the Massachusetts Institute of Technology (Conner *et al.* 1973; Wang and Conner 1975; Pagenkopf *et al.* 1976 and Wang 1980), was used to simulate the advective current field within the Bay. In the model, motion results from wind acting on the sea surface and pressure forces caused by differences in sea level. The motion is then modified by bottom friction and the earth's rotation. That is, observed sea surface elevations at each open boundary and the observed temporally varying surface wind stresses are used to force the model. The model also requires depths at nodal points (intersections) of the triangular elements (Figure XV-1). With these inputs, the model then computes horizontal currents at nodal points under the combined influence of astronomical tides, winds, bottom friction, and Coriolis force.

To simulate larval spreading in Great South Bay, it is necessary to apply advective and turbulent diffusive velocities to a cluster of particles and track each particle of the cluster in time. Since CAFE provides advective currents at the nodes of the grid, the initial advective velocity of each particle at time T_o can be computed through interpolation once the triangular element in which each particle is located initially has been assigned. A small random velocity, numerically generated using the Markov-chain model developed by Awaji (1982), is applied to each particle to simulate diffusion. Once the advective and diffusive velocities of the particles are known, they are summed and multiplied by the time step Δ t to obtain the position each particle will assume at time T_o + t. With these new positions, a new set of advective and diffusive velocities is then computed for each particle and these velocities are used to transport the particles from time T_o = t to T_o + 2 t. A Δ t of five minutes was used in the GSB model. By repeating this procedure 5184 times (18 days x 24 hours x 12), the particles are transported forward in time thus simulating larval dispersion processes within the Bay.

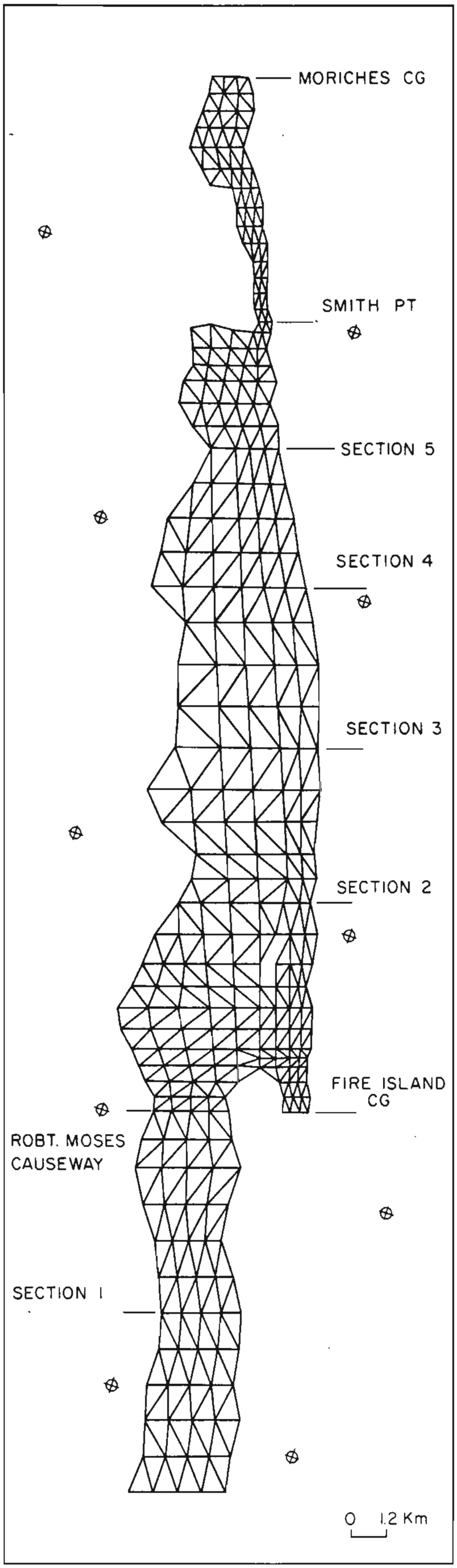


Figure XV - 1
Finite element grid for Great South Bay

Given a brood stock location--a spawner sanctuary--the areas within which larvae from the sanctuary will most likely set can be estimated very simply by running the larval dispersion model forward in time for the appropriate period. To establish the most desirable location to create a sanctuary, however, it is necessary to hindcast the location of the sanctuary, given the locations of the target areas on which the sets are to be maximized. This is a more difficult problem. In order to utilize the larval dispersion model for this purpose, a seven-step rationale was developed.

THE RATIONALE

To determine the origin of larvae that set some 10-20 days after fertilization on a designated site, a step-by-step approach is required. The following rationale was proposed (Carter *et al.* 1984):

Step 1. Exercise a numerical hydrodynamic model under the combined influence of actual summertime tides and winds to calculate the horizontal currents at a suitably dense array of points over the area of interest. This was done for GSB for the period September 1-28, 1980 and the velocities were archived. The wind conditions for that period were typical for GSB for June, July, and August.

Step 2. Simulate the diffusive processes that waterborne particles are subject to by means of small, additive, random, turbulent velocities.

Step 3. Identify the location(s) of sites where setting is desired. This information must come from hard clam managers.

Step 4. Simulate the release of a large number of particles (200-300), evenly spaced over the entire area of interest and subject them only to advection.

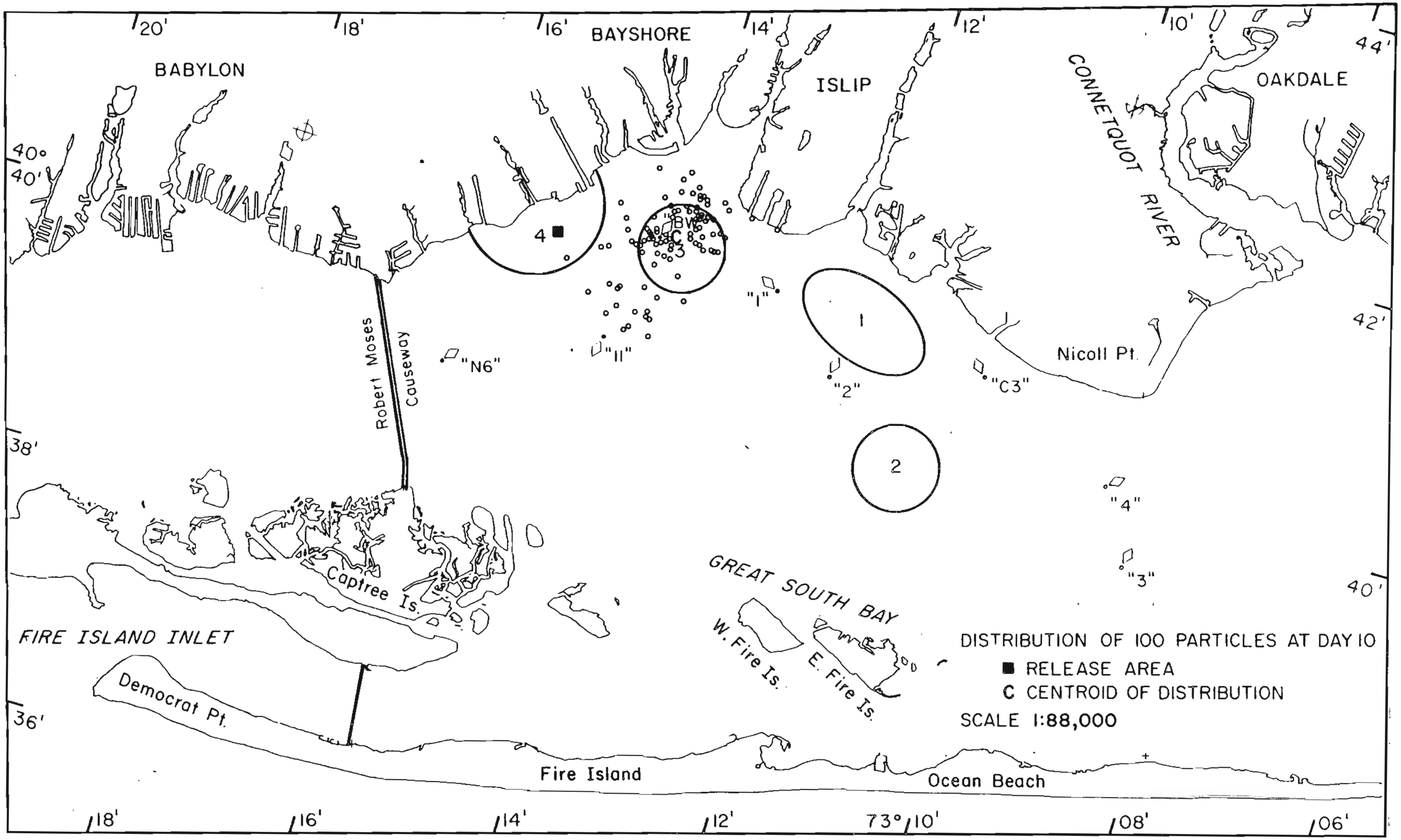
Step 5. Analyze the results of these releases, day by day, identifying the release point(s) of the particle(s) most frequently located in the desired site(s) between 10 and 20 days after release.

Step 6. Assign advective and turbulent velocities to a cluster of particles (100) located at the release point(s) identified during step five and follow the cluster for 20 days. These 100 particles are initially arranged uniformly over a small area (75m x 75m) and represent larvae from 1000 bushels of chowder size hard clams arranged at a density of 36 clams/m^2.

Step 7. Relate the area within each cluster envelope to setting density, total set, and required post-set survival for enhancement.

RESULTS

Details of applying the step-by-step rationale described above to determine the best location to establish a particular spawner sanctuary are given in Carter *et al.* (1984). Only the results of selected experiments are repeated here. The Islip experiment consisted of releasing 100 particles representing the larvae from 1000 bushels of chowder size clams arranged 36 clams/m^2 over a 75m x 75m square. The results are given in Figures XV-2 - XV-10. The small □ represents the location of the spawner sanctuary identified by the seven step rationale.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Nicoll Pt.
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Democrat Pt.
W. Fire Is.
E. Fire Is.
Fire Island
Ocean Beach
20'
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16'
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73° 10'
08'
06'
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DISTRIBUTION OF 100 PARTICLES AT DAY 10
■ RELEASE AREA
C CENTROID OF DISTRIBUTION
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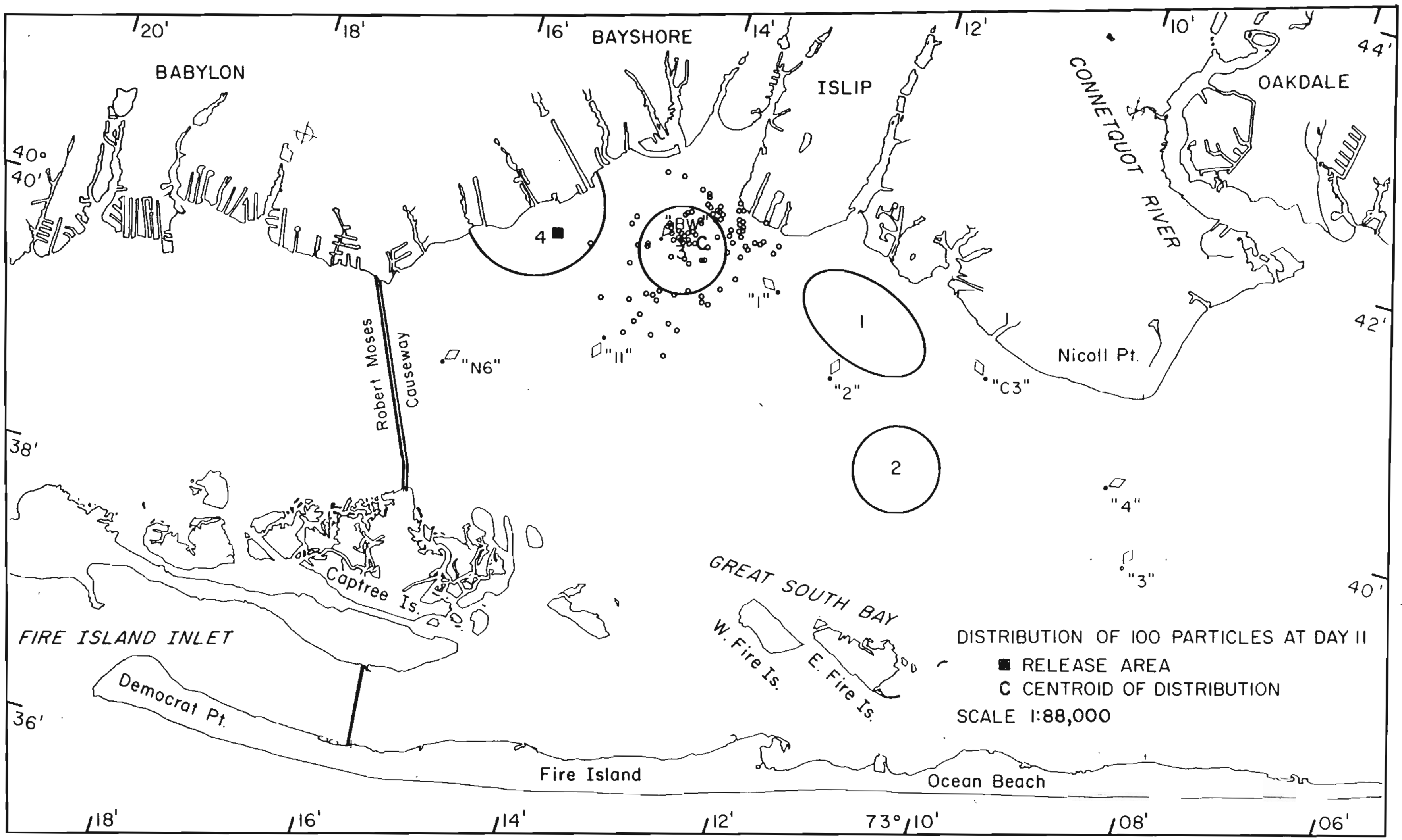
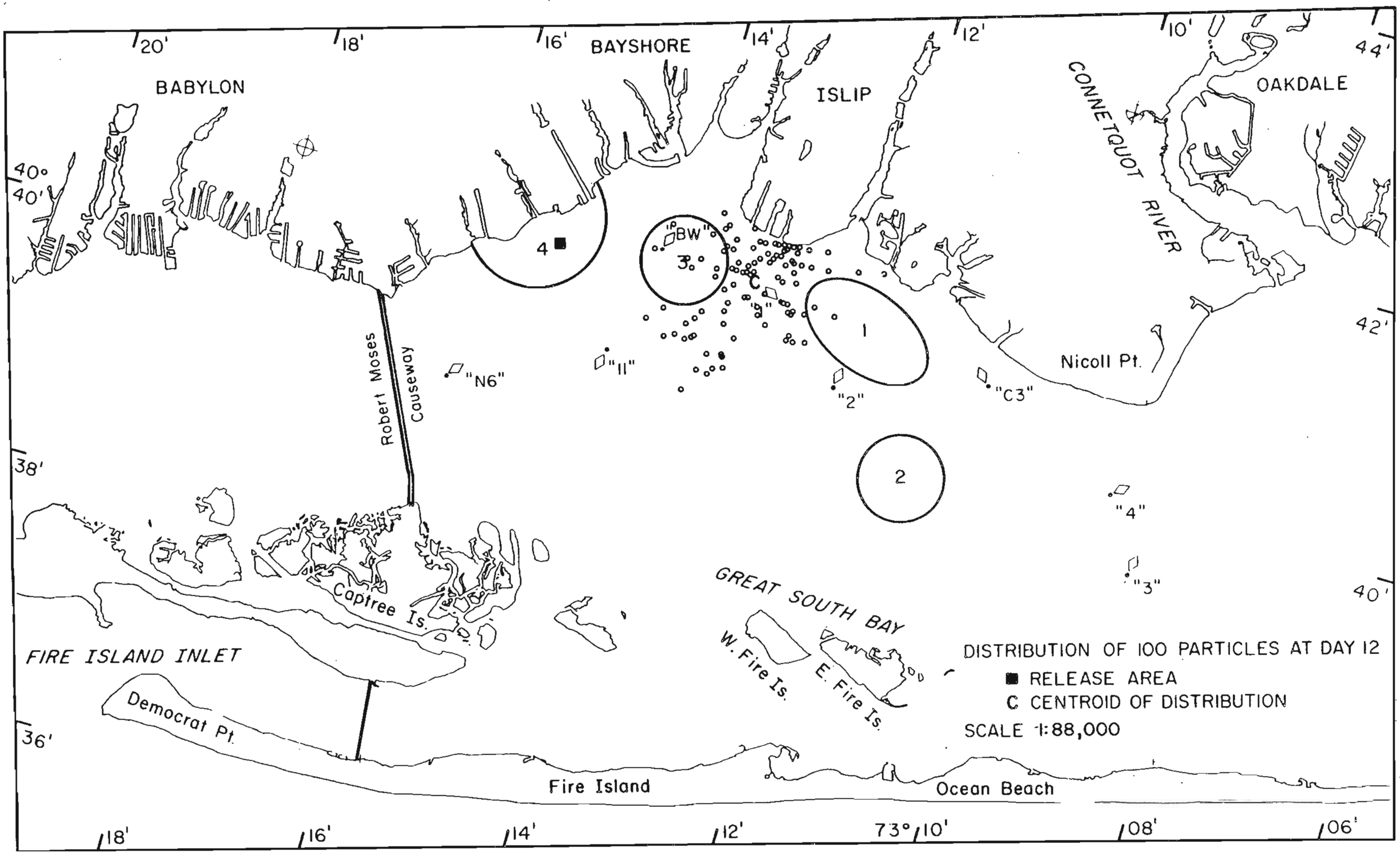


Figure XV - 3
Particle distribution 11 days after release relative to productive areas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DISTRIBUTION OF 100 PARTICLES AT DAY 12
RELEASE AREA
C CENTROID OF DISTRIBUTION
SCALE 1:88,000

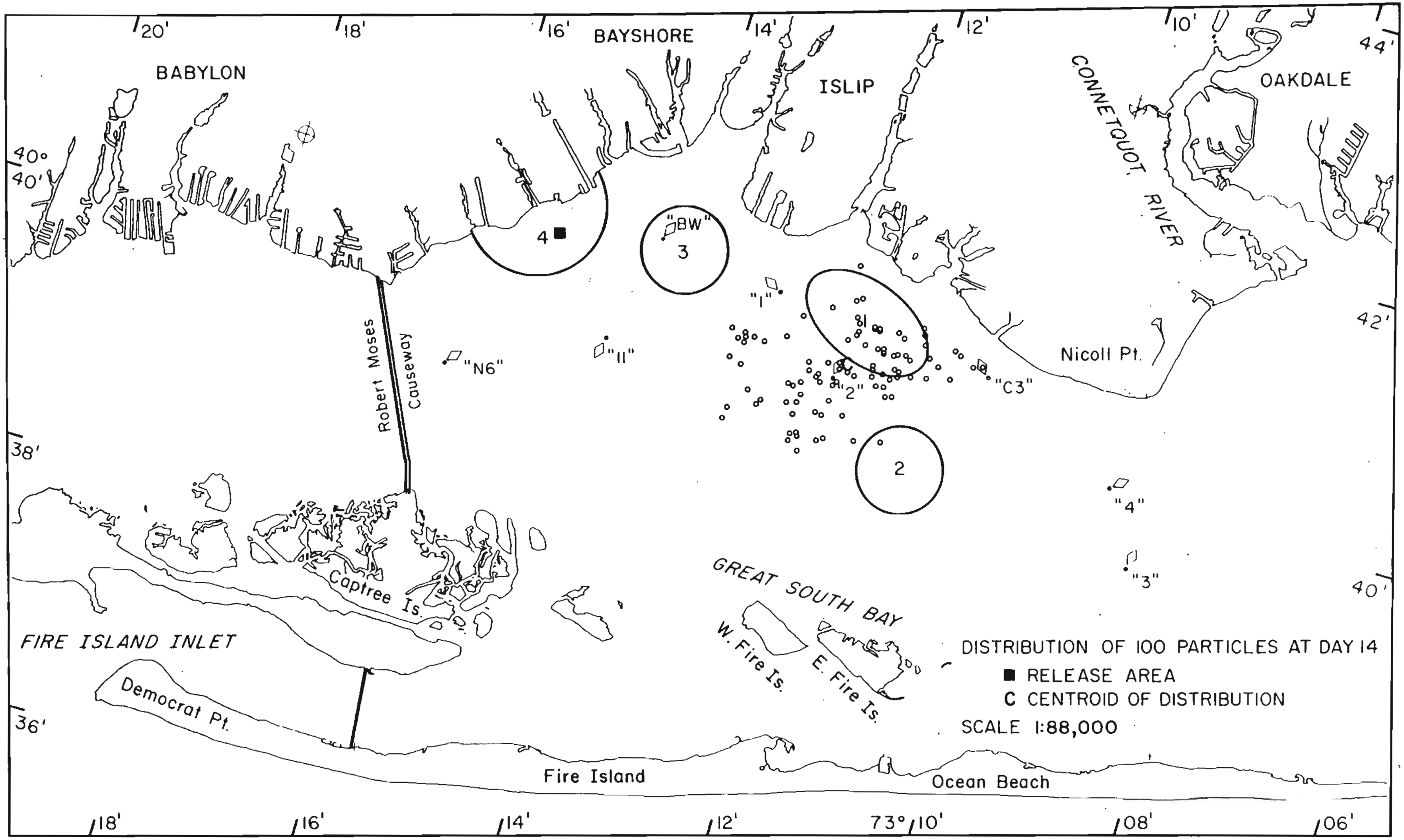
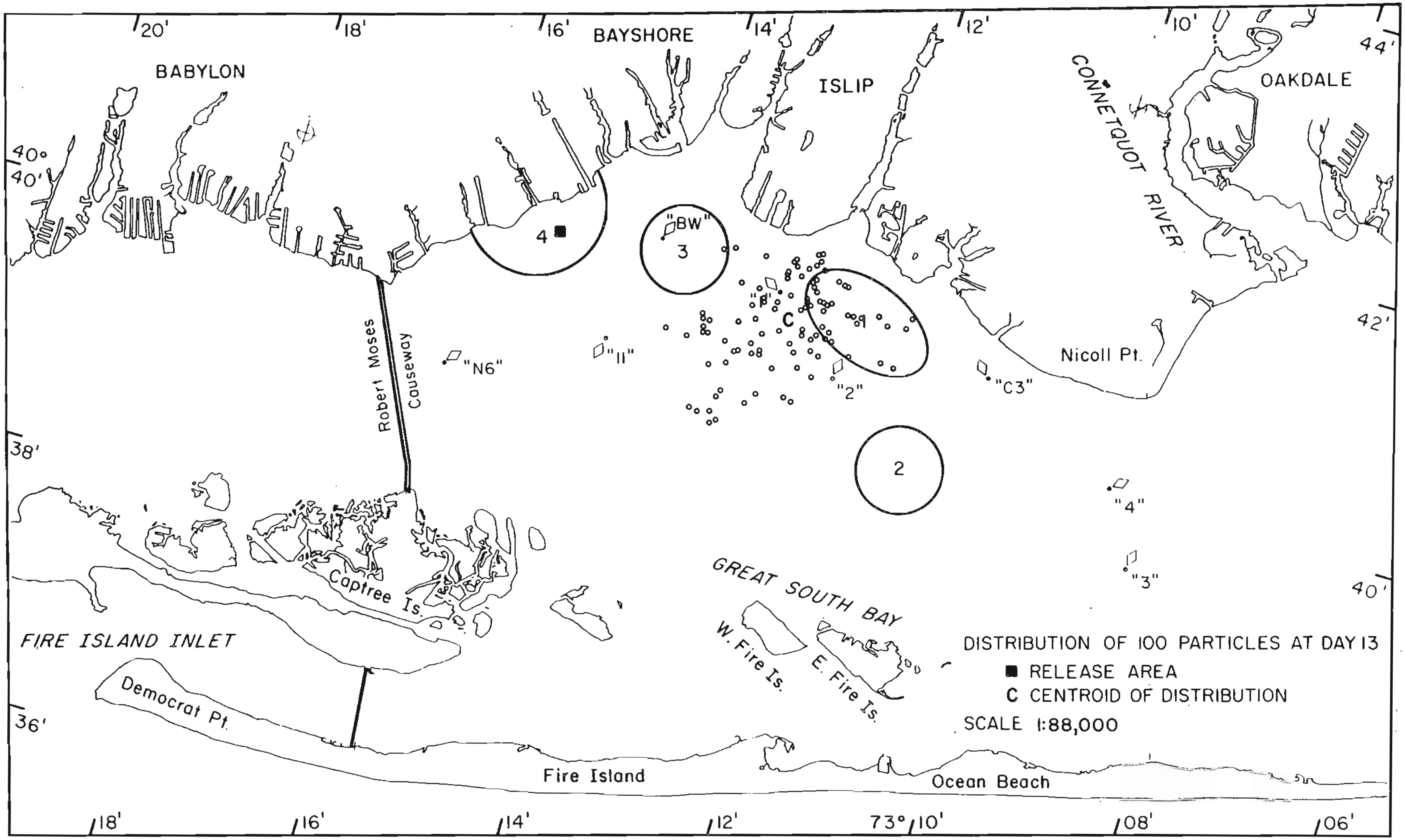


Figure XV - 5

Particle distribution 13 days after release relative to productive areas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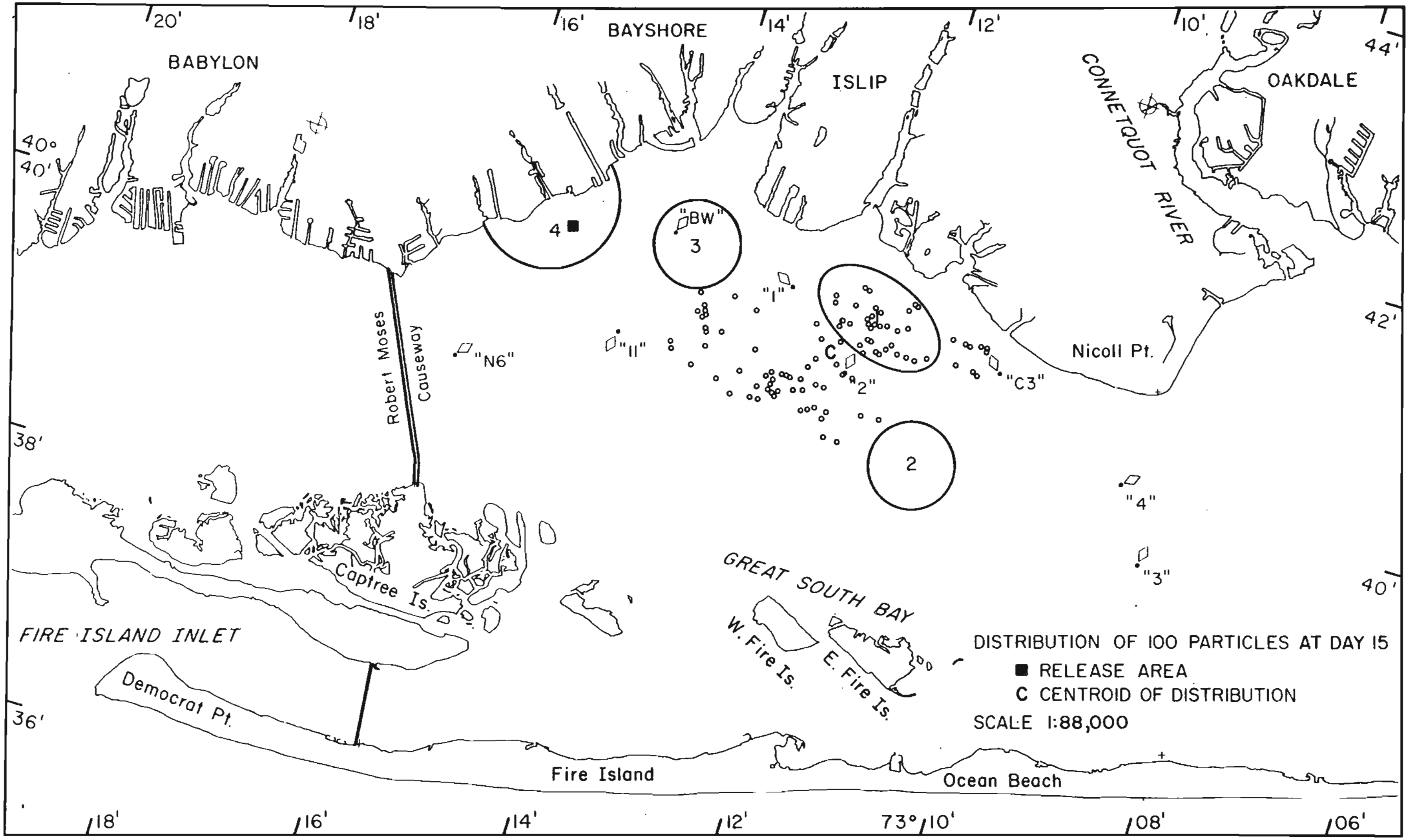
DISTRIBUTION OF 100 PARTICLES AT DAY 13
RELEASE AREA
C CENTROID OF DISTRIBUTION
SCALE 1:88,000



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"N6"
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DISTRIBUTION OF 100 PARTICLES AT DAY 15
RELEASE AREA
C CENTROID OF DISTRIBUTION
SCALE 1:88,000
20'
18'
16'
14'
12'
10'
73° 10'
08'
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40° 40'
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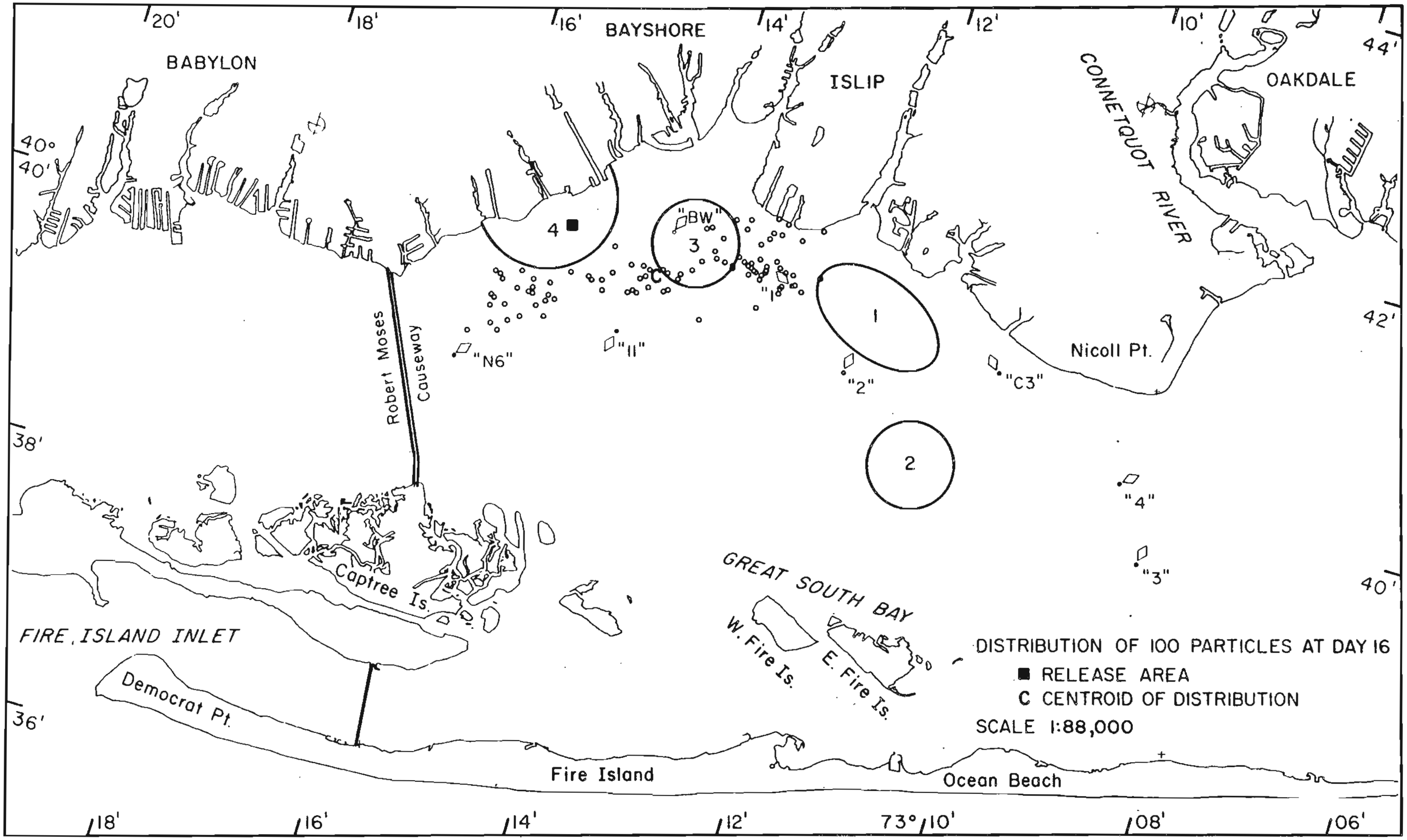
Figure XV - 7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"4"
"3"
DISTRIBUTION OF 100 PARTICLES AT DAY 16
RELEASE AREA
C CENTROID OF DISTRIBUTION
SCALE 1:88,000
20'
18'
16'
14'
12'
10'
73° 10'
08'
06'
40° 40'
38'
36'
44'
42'
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Figure XV - 8

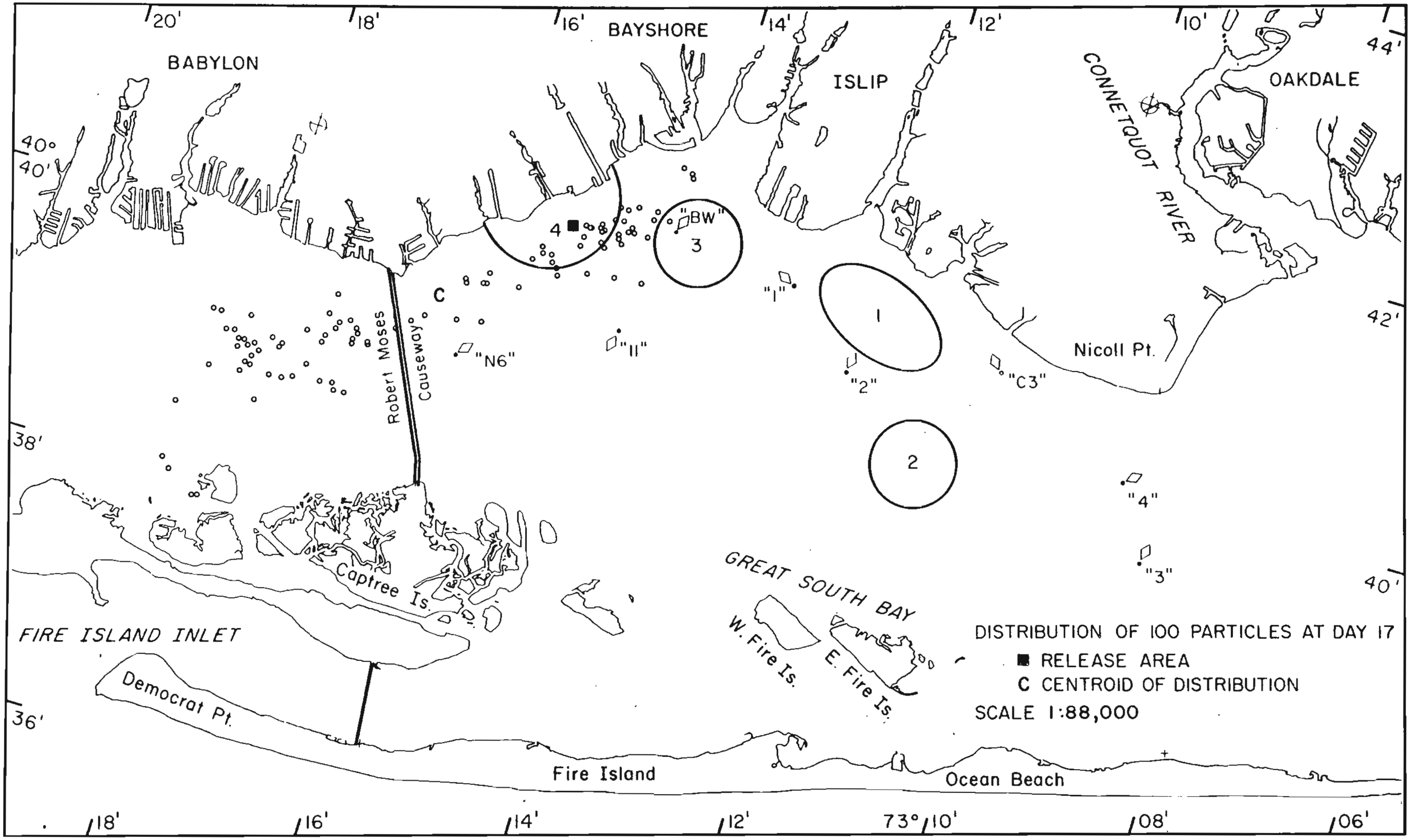
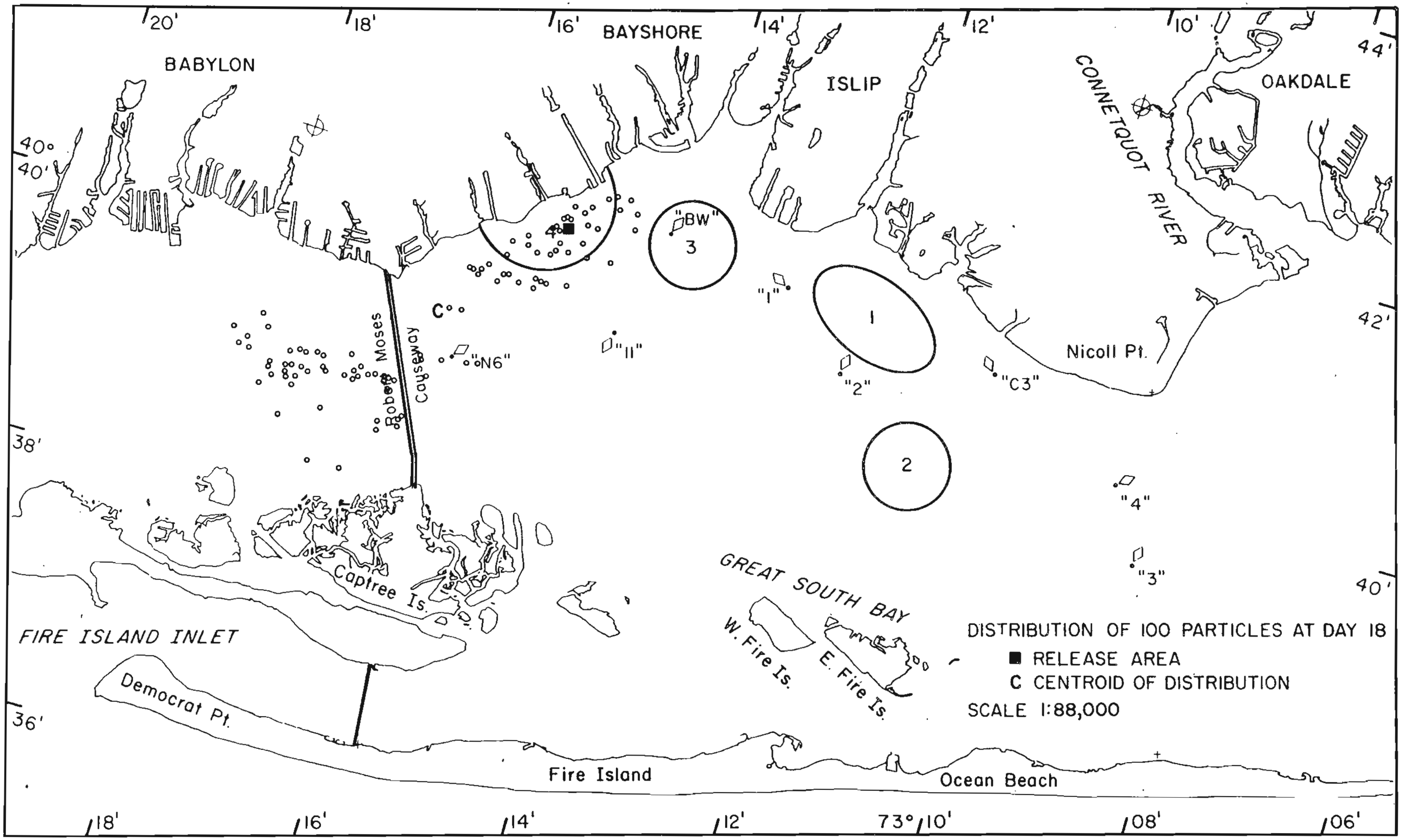


Figure XV - 9

Particle distribution 17 days after release relative to productive areas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40° 40'
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16'
14'
12'
73° 10'
08'
06'
DISTRIBUTION OF 100 PARTICLES AT DAY 18
■ RELEASE AREA
C CENTROID OF DISTRIBUTION
SCALE 1:88,000

The results from Brookhaven were relatively straightforward and are not shown here. The situation with Babylon, however, was quite different from either Islip or Brookhaven. In addition to regular astronomical tidal currents in GSB, two additional modes of circulation are important. One is caused by coastal sea level set-up or set-down produced by winds parallel to the coast ($249^{\circ}/069^{\circ}$). The second mode (less important) is a direct, unidirectional, response to the local wind. The first mode has a predominant period of 7 days; the second, 3 days.

In Babylon, as a result of these two modes of circulation, westerly winds (the predominant summertime condition) cause coastal sea level to drop, resulting in strong flows out of GSB through Fire Island Inlet and into GSB from South Oyster Bay. This means there is a vigorous exchange of most of Babylon waters with the ocean through Fire Island Inlet. The trajectory analysis (step 5 of the rationale) suggests that most of the area south of the east-west navigation channel seems to participate in this exchange, with the area north of the navigation channel sloshing back and forth between either South Oyster Bay and Babylon or Babylon and Islip. For this reason one cannot identify a spawner sanctuary site south of the navigation channel which will, with a high probability, provide sets in Babylon waters; most of this region seems to exchange regularly during summertime conditions with the ocean through Fire Island Inlet on a time scale shorter than the time for setting to commence, i.e., 7-8 days. The best location for a spawner sanctuary in Babylon waters is within the small triangular area bounded by the east-west navigation channel, Willets creek, and the Keith canal. Some late sets (16-18 days) from the Islip spawner sanctuary will occur in Babylon waters, however (Figures XV-9 and XV-10).

Interpretation of the Results

The envelopes of the computed distributions of the 100 particles released (Figures XV-2 - XV-10) may be used to estimate the distributions of hard clam larvae as a function of age (Step 7) if we take into account the following factors:

(1) the mortality of the larvae, and

(2) the absence of velocity shear in the vertical direction in the model.

The mortality of the larvae was taken into account by assuming that 53% of the larval population existing at any one time will die in the succeeding 24 hours. This estimate is based on a reanalysis (Carter 1981) of data taken in 1948-51 in Little Egg Harbor, New Jersey by Carriker (1961). To put it another way, this value represents a survival, after 20 days, of only slightly more than one larva out of every one million larvae produced. Mortality as used here includes disappearance, for whatever reason, prior to metamorphosis. It does not include failure to metamorphose since our mortality estimate is based on Carriker's study of early and late planktonic larval stages.

The combined effect of velocity shear in the vertical and vertical diffusion enhances horizontal diffusion. The model contains no vertical shear in the velocity[2]. The effect of vertical shear on the larval concentration values assigned to the particle envelopes has been accounted for by using some results contained in Carter and Okubo (1965) and two dye studies carried out in GSB, one in 1976 and one in

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[2]The model (CAFE) provides averages over the water column of the velocities, i.e., vertical averages.

1980. The effect is marked, and details of how it has been accounted for are contained in Carter *et al.* (1984) and will not be repeated here. Concentrations of larvae can be assigned to each envelope, and the total number of larvae contained within each envelope and the density at setting can be calculated. Setting is assumed to take place between 10 and 20 days after the time of fertilization (t=0). For these calculations, it was assumed that 1000 bushels of brood stock were placed in the sanctuary, that half (500 bushels) were female and that their fecundity was 6 x 10^6 eggs/clam (Bricelj 1979). The results of making these calculations for typical sites in Islip, Babylon, and Brookhaven are given in Table XV-1. The survival percentages in Table XV-1 were obtained by the following method.

Current market values (November 1983) are $0.05/clam for chowders and $0.18/clam for littlenecks. Therefore, it is only necessary to harvest at least 1 littleneck for every 3.6 chowders purchased for brood stock for a sanctuary of 1000 bushels to be cost effective. In the last column of Table XV-1 we have converted this requirement into percent survival between setting and littleneck size. For example, in Islip according to Table XV-1, 5.20 x 10^5 larvae will be alive at t = 14 days. Of these, 10.69% must metamorphose and survive to littleneck size to recover the cost of the brood stock ($10,000). It should be noted that the percentages in the fourth column of Table XV-1 have been calculated on the basis of a single spawning. Multiple spawns, in successive years, will reduce these percentages by the number of spawns.

MANAGEMENT IMPLICATIONS

Unfortunately, the data in Table XV-1 cannot be interpreted directly in terms of harvest. Other factors not previously considered must be taken into account. It was noted earlier that the mortality accounted for in the analysis included only early and late planktonic stage mortality. On settling out of the water column at the end of

Table XV-1

N^*, the total number of hard clam larvae within the cluster envelopes. C_1D, the setting density in larvae/m^2, and required survival in % for sites in Islip, Babylon, and Brookhaven. See Figures XV-2-XV-10.

ISLIP

t(days)	C_1D	N^*	Required[a] Survival %
10	4.96	1.53×10^7	0.36
11	1.91	6.51×10^6	0.85
12	0.75	2.73×10^6	2.04
13	0.30	1.32×10^6	4.21
14	0.12	5.20×10^5	10.69
15	0.05	2.08×10^5	26.75
16			
17			
18	<0.01	1.81×10^4	>100.00

BABYLON

t(days)	C_1D	N^*	Required[a] Survival %
10	5.08	7.72×10^6	0.72
11	1.96	3.32×10^6	1.67
12	0.77	1.05×10^6	5.30
13			
14	0.12	3.56×10^5	15.62
15	0.05	1.32×10^5	42.12
16	0.06	6.30×10^4	88.25
17	0.01	3.11×10^4	>100.00
18			
19	<0.01	7.30×10^3	
20	<0.01	2.42×10^3	

BROOKHAVEN

t(days)	C_1D	N^*	Required[a] Survival %
10	4.96	1.47×10^7	0.38
11	1.92	6.18×10^6	0.90
12	0.75	2.51×10^6	2.22
13	0.30	1.21×10^6	4.60
14	0.12	5.08×10^5	10.94
15	0.05	2.18×10^5	25.50
16	0.02	9.27×10^4	59.98
17	0.01	5.08×10^4	>100.00
18	<0.01	2.04×10^4	>100.00

a--assuming they grow to littleneck size their planktonic existence the larvae must find suitable substrate and metamorphose into the setting stage where they alternate between byssal attachment and crawling; many do not successfully matamorphose. Our analysis also has not included post-set predation. It is fair to say that almost all benthic organisms including blue crabs (*Callinectes sapidus*), spider crabs (*Libinia emarginata*), mud crabs (*Neopanope sayi*), horseshoe crabs (*Limulus polyphemus*), and oyster drills (*Urosalpinx cinerea* and *Eupleura caudata*) are potential predators of post-set clams. The clam densities in Table XV-1, C_1D are not large, of the order of 5 clams/m^2 or less. This suggests that the productive areas selected for stock enhancement must also be areas of low predator density, either naturally or by some type of predator control. Setting densities can be increased, however, by adding additional spawner stock. C_1D will increase in direct proportion to the increase in brood stock. For example, a sanctuary with twice as many clams will produce twice as many larvae per m^2 (C_1 in Table XV-1).

The required survival percentages in Table XV-1 indicate that the brood stock producing late sets (>16 days) will not replace themselves each time they spawn. $^*N$, however, will increase in direct proportion to the number of spawnings. Assuming that the spawner stock will be fecund for at least five years on the average, the survival percentage needed (Table XV-1) can be reduced five-fold. Spawner sanctuaries, therefore, should not be considered short term solutions to stock enhancement.

It should also be noted that the envelopes contain only 2-5% of the total larvae that ultimately set; the other 95-98% set outside the envelopes. Presumably significant number of these will survive to market size. What we have accomplished is to ensure that the highest <u>concentration</u> in the patch of planktonic larvae will be located within a previously designated area <u>at the time of setting</u>.

Finally, one should not judge the success or failure of a single management alternative such as a spawner sanctuary, by whether or not it can be shown to completely rehabilitate the resource. Rehabilitation of the resource and stabilization of the fishery are, of course, the pervasive goals of management. However, an individual management alternative could be considered a marginal success if the value of additional harvest exceeds the cost of the program. The program costs that need to be considered are the costs of establishing and protecting the sanctuaries, since the cost of the brood stock can be recovered at any time by opening the sanctuary to harvesting. Furthermore, assuming that any additional set will be harvestable in two years and, as before, that the spawner stock will be fecund for at least five years on the average, the comparison of costs should be made over a period of at least five years. Attainment of this more limited objective as a measure of success seems highly probable.

The number of pounds of hard clam meats landed in New York declined from a maximum of 9 million pounds in 1976 to 2.7 million pounds in 1984. At the same time, the value in dollars per pound rose from $1.18 to $1.60 in 1982. Assuming that these rates also apply to GSB, one measure of a rehabilitated resource would be a doubling[3] in value of the annual harvest. Another, more restrictive measure, would be an increase in the harvest to 9 million pounds. However, since it has been shown that this level of harvest, especially in GSB, was due to overharvesting this is not a reasonable goal for resource management. A more reasonable goal would be to increase the standing stock in the target areas.

In the previous section, it was stated that the 1000 bushel spawner sanctuaries proposed for the Towns of Brookhaven, Islip and Babylon would most likely result in stock enhancement at least

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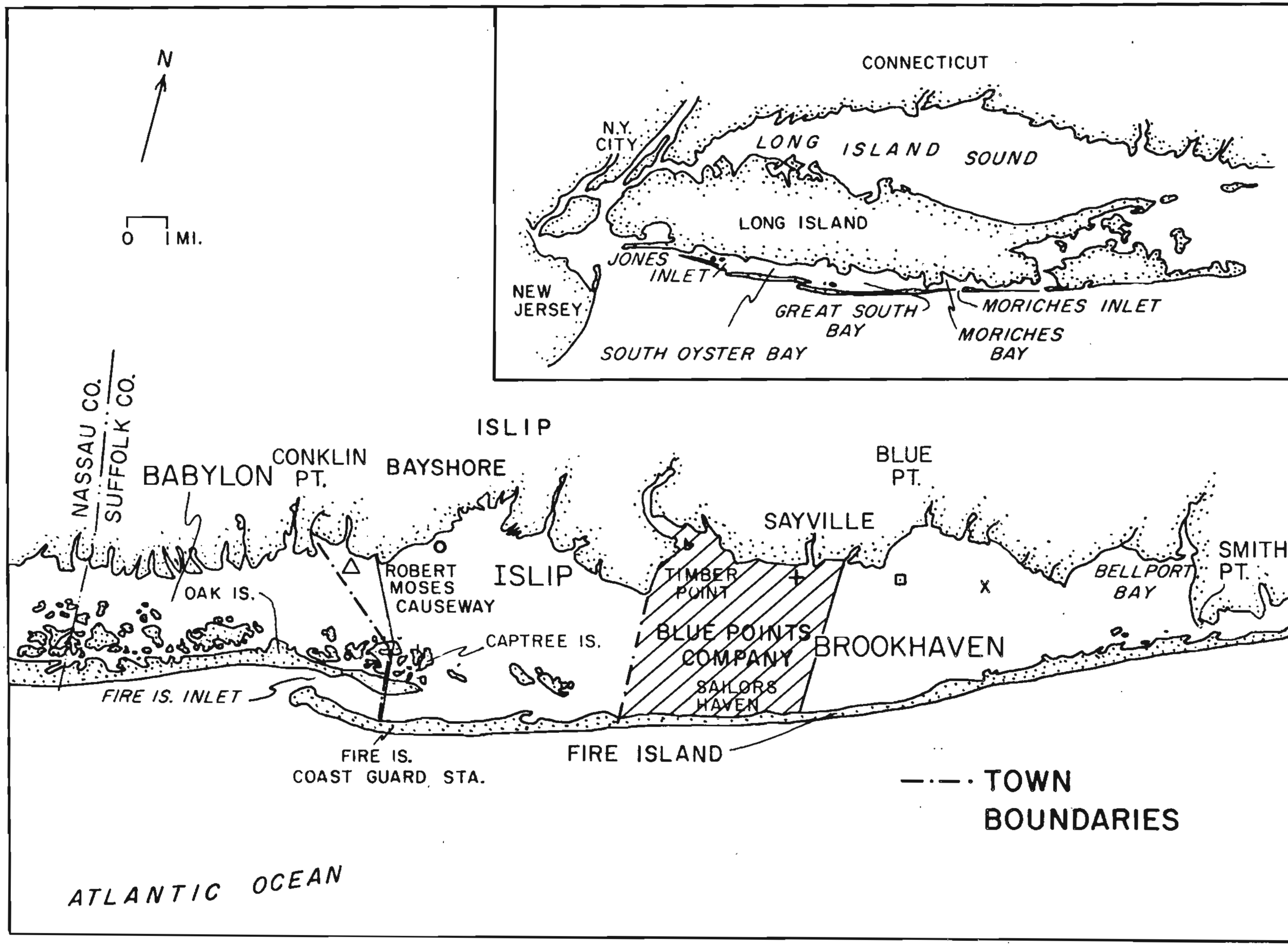
[3] 9×10^6 lbs x \$1.18 = $2 \times 3.4 \times 10^6$ lbs x \$1.60



CONNECTICUT
N.Y. CITY
LONG ISLAND SOUND
LONG ISLAND
NEW JERSEY
JONES INLET
GREAT SOUTH BAY
MORICHES INLET
MORICHES BAY
SOUTH OYSTER BAY
N
0 1 MI.
NASSAU CO.
SUFFOLK CO.
BABYLON
CONKLIN PT.
BAYSHORE
ISLIP
BLUE PT.
SAYVILLE
SMITH PT.
BELLPORT BAY
ROBERT MOSES CAUSEWAY
ISLIP
OAK IS.
CAPTREE IS.
TIMBER POINT
BLUE POINTS COMPANY
SAILORS HAVEN
BROOKHAVEN
FIRE IS. INLET
FIRE IS. COAST GUARD STA.
FIRE ISLAND
TOWN BOUNDARIES
ATLANTIC OCEAN

Figure XV - 11

sufficient to recover the costs of establishing and protecting the sanctuaries. It would be desirable, however, to develop a more quantitative measure of success for a sanctuary. The division of management responsibilities for GSB among Islip, Babylon, Brookhaven, and the Blue Points Company (Figure XV-11) make such an assessment difficult since the physical processes that spread the larvae throughout GSB are not subject to jurisdictional boundaries. It is almost impossible to find a potential sanctuary location within one town that does not to some extent provide sets to, or receive sets from, another jurisdiction. This is particularly true for Babylon which receives larvae spawned in Islip and may also benefit from stock located further to the west in South Oyster Bay (Nassau County). In the Town of Brookhaven and the Blue Points Company, a target located in the western part of Brookhaven waters would require a sanctuary located on Blue Points property. There may also be sanctuary locations in either Islip or Brookhaven which would seed Blue Points property.

EVALUATION OF SPAWNER SANCTUARIES

Two of the Towns, Islip and Brookhaven, already have established spawner sanctuaries in accordance with the recommendations contained in Carter *et al.* (1984). Brookhaven has distributed 2000 bushels of clams over five sites. Islip has one sanctuary inside Bayshore Cove where 3000 bushels of clams have been planted. There are plans to add clams to this site and set up a second sanctuary inside Babylon Cove. Neither Town has yet made any evaluation of its spawner sanctuary programs, although both have plans to begin to do so. Since Brookhaven has established five sanctuaries, it will be extremely difficult to unambiguously assign increases in standing stock in a particular target area to the responsible sanctuary or sanctuaries.

Shellfish managers in Islip will conduct larval tows during the upcoming spawning season. Presumably, an attempt will be made to identify increased numbers of clam larvae as a result of the spawner sanctuaries. The Town of Brookhaven plans to evaluate one sanctuary, if funds become available, by planting newly set clams of the *notata* variety in that sanctuary's setting envelope at densities approximating those in Table XV-1. By monitoring changes in the ratio of *notata* to the rest of the population, initially and at intervals over a period of years, they hope to determine recruitment and post-set mortality.

The evaluation of a spawner sanctuary must take into account the two possible ways in which the program might fail. These are (1) failure of larvae produced by clams in the sanctuary to reach the target site, and (2) failure of metamorphosed clams to survive at the target site. It is, therefore, essential that sanctuary and target site be evaluated. An evaluation protocol to meet these criteria would make use of the *notata* variety of clams to evaluate changes in standing stock. This scheme calls for planting chowder size *notata* clams (>200 bu) in the sanctuary in question as well as seeding the target area with non-notata post set seed clams. Prior to seeding or planting the chowder size clams, a detailed survey of the sanctuary and associated target areas would be carried out in late summer. The purpose of this survey would be to establish existing conditions in the target area and the sanctuary as to size distribution and population abundance for *notata* and non-notata varieties. The *notata* brood stock would then be placed in the sanctuary to be evaluated. Non-notata post set would be planted in the target area and planted seed and natural set would be followed for survival to 25 mm. This would be followed by annual surveys of the sanctuary and target area for at least five consecutive years. By the third year, any increase in standing stock that occurred as a result of the sanctuary would be measurable. These surveys must also be carried out in the fourth and fifth years. Appropriate sampling devices for this survey would include some type of quantitative sampler such as a bucket dredge.

The advantage of this protocol over that described above for Brookhaven is that it evaluates metamorphosis at the target area and, in addition, post-set survival to marketable size. Additional brood stock could be added to the sanctuary being studied at any time, of course. All that is required is knowledge of the total number and size (to estimate fecundity) of clams involved.

Also closely related to sanctuary evaluation is the problem of protecting the adult clams in the sanctuary from poachers. This is important for two reasons. First, it is essential that the sanctuary stock be maintained at some known quantity. Second, the cost of protecting the sanctuary bears on the matter of cost effectiveness. The placement of obstructions to raking is regulated by the U.S. Army Corps of Engineers. Proposals to place obstacles outside navigation channels are reviewed by the Corps on a case by case basis with consideration given to water depth, size of the obstacles and location. Placement of obstacles is generally not permitted within navigation channels (R. Tomer, U.S. Army Corps of Engineers, New York District, Personal Communication). The Town of Brookhaven was prevented, by such restrictions, from placing obstacles in four of the five spawner sanctuaries it has established and at the present is relying on the unpopularity of chowders with baymen (due to their low market value) to protect these sanctuaries. Islip has located its sanctuaries in uncertified waters for protection. Patrols, the only other means of protecting sanctuaries, add to the cost of the management alternative.

Finally, any evaluation process selected should take into consideration the fact, presented earlier, that most (95-98%) of the larvae that set will set outside the target area sanctuary, although at lower densities. Some, presumably, will survive to be harvested.

IMPLICATIONS FOR OTHER LONG ISLAND WATER BODIES

The spawner sanctuary concept might be appropriate for many other bays and estuaries in Suffolk County such as, Moriches Bay, Shinnecock Bay, the Peconic Bays, and Huntington Bay.

As noted earlier, however, application of the spawner sanctuary concept to a specific bay or estuary requires detailed information, i.e., velocities and diffusivities, on scales as small as 100-500 m and 1-10 minutes over the entire domain of interest for a typical summertime period of at least 25 days. Such detailed information can be obtained only by constructing a numerical, hyrodynamic computer model of the system. In addition, measurements of sea level at appropriate locations in the system and surface winds are needed. The measurement program must cover at least the summertime period between June and September. A numerical, hydrodynamic model currently exists at the MSRC for Moriches Bay together with appropriate sea level and wind data for running the model. In addition, the Peconic Bay system is being modelled through support provided by the New York Sea Grant Institute.

One might initially address the smaller north shore bays such as Huntington Bay with dye tracer studies. By releasing a known quantity of dye in the system and observing its exchange with Long Island Sound, an estimate of the residence time or exchange rate for the system could be obtained. If that residence time were less than 7-8 days, a sanctuary would be inappropriate since most of the larvae produced by such a sanctuary would be flushed into Long Island Sound prior to setting. Such dye studies would cost about $25,000 for each bay. If the residence time were >20 days, the bay would be suitable for sanctuaries and development of a model together with a measurement program discussed above would be indicated. A model for these smaller bays together with the required measurement program would cost about $50,000. If one takes into consideration the large tidal exchange between the north shore bays and the Sound, it is probable that residence times are closer to 7-8 days than to 20 days, making them unlikely candidates for spawner sanctuaries. The dye tracer studies would confirm or deny this.

Shinnecock and Moriches Bays are probably more appropriate for establishment of spawner sanctuaries than the north shore bays since their tidal range is much reduced. Their smaller size makes them somewhat less appropriate for sanctuaries than GSB, however. As noted above, a suitable model and data base are available for Moriches Bay. Application of this evaluation procedure to Moriches would not only address the suitability of Moriches for spawner sanctuaries but would probably permit an evaluation of Shinnecock Bay as well since both are approximately the same size, shape, and depth and have a central opening to the ocean.

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PREDATOR CONTROL AS A MEANS OF IMPROVING HARD CLAM PRODUCTION

INTRODUCTION

Control of predators on hard clam grounds needs to be considered in at least two different contexts: (1) where mariculture is considered feasible; and (2) where the objective is to improve production on naturally reproducing clam grounds. Keeping predators out of a relatively small area into which seed clams are planted may be feasible if certain conditions are met, e.g., clams can be protected with aggregate and large destructive predators can be excluded with fences. This would not be feasible over large areas and other methods would have to be used. The situation also will vary with locality, so that each set of conditions must be carefully evaluated as to the kinds of predators present, and physical factors which might affect predator control.

TYPES OF PREDATORS

Potential predators of hard clams are many, and they vary with the size of clams to be protected. Larval and early post-set clams cannot be protected economically, and probably do not need to be. Fecundity is so high that even if only a small fraction of the larvae settle a substantial set can still occur. Important predators of early post-set clams, such as grass shrimp (*Palaemonetes vulgaris*), hermit crabs (*Pagurus longicarpus*), and waterfowl, also probably do not need to be considered. On grounds that have large populations of adult hard clams (or other suspension feeders) these filter larvae out of the water column and may compete with newly set clams for food. Few, if any, young clams survive in such places. The principal predators along the coast are mud crabs (*Neopanope sayi*), green crabs (*Carcinus maenas*), rock crabs (*Cancer irroratus*), oyster drills (*Urosalpinx cinerea* and *Eupleura caudata*), whelks (*Busycon canaliculatum* and *B. carica*), moon snails (*Polinices duplicatus* and *Lunatia heros*), sea stars (*Asterias forbesi*), and various fishes, including rays (Dasyatidae, Myliobatidae, and Rhinopteridae), northern puffer (*Sphoeroides maculatus*), tautog (*Tautoga onitis*), and summer flounder (*Paralichthys dentatus*). Some are more destructive than others, and a different group of major predators may occur in different environments. For example, the major predators in the Peconic Bays are different from those in Great South Bay. Undoubtedly many other species are predators on hard clams, but these appear to be the most important once the clams have settled on the bottom. Various combinations of predators dominate at different places along the coast, depending upon the salinity, the amount of protection from waves, and so on. In Great South Bay the major predators are mud crabs and oyster drills (MacKenzie 1977; WAPORA, Inc. 1979), and moon snails and whelks (Greene 1978). Gibbons (1984) studied the depredation of mud crabs, calico crabs (*Ovalipes ocellatus*) and hermit crabs. Predation is especially destructive of young clams shorter than about half an inch (1.27 cm). This makes artificial cultivation expensive, because clams must be held under some form of protection until they are at least this long.

METHODS OF CONTROL

Five general methods have been proposed for protecting young clams from predators: (1) control by chemical methods such as Polystream or lime; (2) placing aggregate on the bottom and protecting against wave action with baffles, and perhaps against fishes with fences; (3) development of mechanical methods, e.g. a collector of some sort that would remove predators without disturbing the bottom; (4) placing clams on the bottom in screened boxes, in hanging screened trays, or protected by fences; (5) taking advantage of ecological knowledge to protect young, for example, by using oyster toadfish (*Opsanus tau)*, which eat crabs but not hard clams (McDermott 1964).

CONTROL BY CHEMICAL METHODS

Control of predation on oysters and clams by chemical methods works under some circumstances. MacKenzie (1970) found that, provided that currents were not too strong, a mixture of Polystream (polychlorinated benzenes) and Sevin (1-napthyl-N-methylcarbamate) mixed with sand and spread over an oyster ground killed drills and other snails. Although oysters (*Crassoatrea virginica*) and clams accumulated small residues in their tissues, these residues were lost in time. The method, however, will not work if currents are too strong, or if too much silt is deposited on the ground and there is some evidence that these chemicals have an effect on the growth of oysters and clams. The method is not likely to be practical for clams which are harvested over wide areas from a natural crop. Furthermore, use of polychlorinated benzenes probably should be prohibited on ethical and legal grounds.

Quicklime (CaO), on the other hand, does not have these disadvantages. No known adverse environmental effects have been found and it breaks down quickly in the environment. Quicklime will kill other soft-bodied organisms in addition to sea stars. It is presently used to control sea stars on oyster beds by F.M. Flower and Sons, Oyster Bay, Long Island. The suggestions of Loosanoff (1961) should be followed in using lime to destroy sea stars.

THE AGGREGATE METHOD

The aggregate method has been tried and found to be practical in Chincoteague Bay, Virginia by Castagna and Kraeuter (1977) and in some other places, e.g. North Carolina (Porter 1972). Flagg and Malouf (1983) have reviewed the method and found that the kinds and abundance of predators present influenced the results so strongly that general recommendations could not be made. In New York waters they found that survival exceeded 10% only when clams were at least 20 mm long at planting. Where significant populations of whelks were present seed as large as 23 mm had total mortality. Andrews (1970) found that hard clams in Virginia were most abundant on shelly oyster beds, and suggested that they were protected against predation by the shells. The aggregate method is certainly worth testing further, but at present in New York there has not been enough testing to determine whether it is practical and economical. In fact, where there are many mud crabs, the gravel appears to provide cover for them and actually increases predation (Flagg and Malouf 1983).

MECHANICAL METHODS

The mechanical method proposed by MacKenzie (1979) has some merit, but it has never been tested. The cost of treatment was estimated to be $30 to $50 per acre, however, which is not exactly modest. In Great South Bay, for example, the cost would be of the order of at least a million dollars, perhaps much more, and it is quite likely that it would have to be repeated at intervals of less than one year. The method does not appear to be practical for a large area or for natural crops. There also would appear to be serious problems with other fishermen if quantities of blue crabs (*Callinectes sapidus*), flounders (Pleuronectiformes), or other important species were caught.

SCREENED BOXES, CAGES, OR FENCES

Screened boxes, cages, or fences also do not appear to be practical for large areas. Even on small plots or nursery areas, boxes or cages have a tendency to clog and thus affect the growth of the clams. They must be cleaned periodically if clams are to survive. The cost of cleaning and keeping boxes or cages in good repair would appear to be prohibitive. Fences are subject to damage by storms or vandals, and vandalism would be a problem in maintaining the stock of clams. This highly labor intensive and costly method of controlling predators might work on a small scale, but is not practical for large scale clam growing.

USING TOADFISH OR OTHER SAFE PREDATORS

The presence of toadfish on a clam ground appears to offer some promise. On grounds where toadfish are present, survival of clams is good, but in most cases fencing would be necessary and the fences would need to be kept in good repair. Often, the best methods turn out to be those which rely upon ecological knowledge for their success. The argument is that methods that work under natural conditions are the best and probably will also end up being least expensive. The use of toadfish seems at least partly to satisfy those conditions, but it would not be practical for large areas.

OTHER POSSIBLE METHODS

The whole subject of "environmental awareness" needs to be pursued further. The goal would be to understand clam predator life cycles and environmental tolerances well enough to predict when there will be reduced populations of a particular predator species, what defences clams have against them, and how conditions could be altered in the most favorable direction. Seed clams could then be planted in ways to maximize survival.

Other methods suggest themselves. Where whelks are abundant, a whelk fishery could be developed. Whelks are good to eat and stocks could thus be kept low. Bounties on sea stars and whelks might be a possibility, although it is difficult to imagine that this would have much impact. Another possibility might be to use sound to repel crabs and other predators. This also would work best on small plots, and probably would not be applicable to large areas. At present, predator control is incorporated into New York's Environmental Conservation Law, Article 13-0337 which states: "starfish, drills (*Urosalpinx cinerea*) periwinkle (*Littorina*) and drumfish (*Pogonias chromis*) when taken shall not be returned alive to the waters of the state". This list could be expanded to include other predators.

Why is Great South Bay potentially the best producer of hard clams anywhere along the coast? We know, or think we know, some of the good features: (1) it is relatively shallow; (2) it is at least partially protected against strong winds; (3) the salinity range is ideal for survival of young clams and is low enough to deter some of the predators; and (4) some predators are prevented from entering the Bay by their ecological requirements, for example, it is too far north for major incursions of blue crabs in most years, and too far south for major incursions of green crabs. We need to search for other conditions that are especially favorable and could be enhanced in some way. The ecological approach appears to offer the best possibilities for success in predator control.

WHY CONSIDER PREDATOR CONTROL?

The primary reason for considering predator control is that predation may be the most important factor controlling recruitment, although not the only one. There is also considerable social and political pressure to do something about predators. On the other hand, it must be remembered that the outcome of some attempts to control predators in terrestrial environments has had disastrous results, and this must be guarded against.

Predation probably needs to be addressed on a water body wide basis. In some marine systems, only one or two key predators may be important, and removal of these could permit expansion of the clam populations. In other marine systems there may be such large collections of different predators, that removing one or two will only allow others to increase their predation, thus countering attempts at removal. In developing a predator control plan, the choice will depend upon the spectrum of predators present. If only one or two are present, then it may be feasible. If many are present, then a different strategy, or perhaps no strategy at all, may be necessary. The strategy will also depend upon the magnitude of the predator's feeding rate. Removing a slow feeding predator may not be as effective as removing a fast feeder. It probably would be useful to rank predators in terms of importance, and to understand how their importance varies under different conditions. Conditions under which predator control is not feasible or cost-effective should be known. Size-specific predation rates should be known, for example. Control will require a knowledge of each predator's life history, and of key or limiting factors that control predator distribution and abundance.

RECOMMENDATIONS

Several methods of controlling predators of hard clams are available to New York managers. None, in our opinion, has been tested adequately in New York waters, and some have not been tested at all. Chemical control using hazardous substances is not recommended because it carries with it hazards to humans and to other marine organisms. Chemical control with quicklime might be feasible under some conditions. The aggregate method has possibilities, and it might be applicable to New York waters, but more research needs to be done. The mechanical method proposed by MacKenzie (1979) might also be investigated, but field work should be preceeded by a feasibility study because it is not certain that the method is cost-effective. Another promising method would be to determine in what other ways ecological knowledge might help to improve survival of young clams. This is certainly the best strategy for oysters (McHugh 1972), and there is no reason why it should not work for clams also. One way would be to use the predator-control capabilities of oyster toadfish, but that is not the only possibility, or necessarily the best. Other possibilities should be considered, for example, a whelk fishery, or bounties, or the use of sound as a repellent.

Of all the methods suggested, the aggregate method appears to be the most practical at the moment. There are some constraints, for example, does the use of aggregate actually favor abundance and destructiveness of mud crabs? On the other hand, planting of shell, such as surf clam (*Spisula solidissima*), ocean quahog (*Arctica islandica*), or scallop (*Argopecten irradian*) shells, over large areas of Great South Bay and other areas in New York, might be relatively inexpensive. An initial feasibility study, including the question of costs, ought to be carried out, remembering that the cost would be largely a one-time expense, and therefore could be amortised over a long period. If this feasibility study proves favorable, then a small scale study should be made to determine the value of shell planting as a feasible method of improving survival. If that works, then large-scale shell planting could be carried out. The principal attraction is that baffles and fencing would not be needed. This method, if it turns out to be feasible, takes advantage of ecological knowledge, and the cost would be reasonable.

Recommendations for predation control need to take into account the environmental conditions of the waterbody being considered. There are important differences between Great South Bay and the Peconic Bays in density of clams. Density in Great South Bay appears to be roughly ten times that in the Peconics. Salinity in the Peconic Bays is higher, and there are more whelks and sea stars. This great abundance of large predators probably is connected with the lower abundance of clams. Unless predation can be controlled in the Peconics other management tools probably are useless. A study of the major differences between the two environments probably would be worthwhile.

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SELECTED CLOSURE OF HARVEST GROUNDS

INTRODUCTION

Closing of selected areas of shellfish harvest ground can be used to manage a fishery. The ways in which selected closure might be used can be divided into four basic categories. The most appropriate choice would depend upon the goal, or goals, of the management plan. The four strategies are:

(1) Closing of areas with a high proportion of small clams until they have reached legal size,

(2) Closing of an area after some previously estimated optimum yield has been reached,

(3) Closing of areas until the harvestable population has reached some minimum acceptable threshhold level (crop rotation),

(4) Closing areas temporarily to spread out harvest pressure or maintain an area of high density near shore for harvest during adverse weather conditions (winter grounds).

Any of these selected closure strategies can be used in combination with other management alternatives such as seed planting, spawner sanctuaries, limited entry or catch quotas and might prove more effective in combination than alone.

SELECTED CLOSURE BASED ON SIZE OR OPTIMUM YIELD

Several selected closure strategies have been used successfully for management of shellfish resources. In the state of Maine the Department of Marine Resources (DMR) has recommended a management plan for soft clam, *Mya arenaria*, which includes selected closure as a basic component. Although the management plan was developed by the State, each town must manage its own resources through a local shellfish conservation ordinance which must be approved by DMR. As of 1983, 42 towns in Maine had adopted DMR approved municipal ordinances (Newell *et al.* 1983).

Management closures under the Maine plan include those areas with a high proportion of small clams (less than 2 inches) and beds from which an estimated optimum yield has already been removed. Determination of areas to be closed is made by conducting an intensive population survey at least once every three years, and less intensive surveys annually. Harvest grounds with a high concentration of small clams are closed to eliminate harvesting pressure until the clams have reached legal size. Information obtained from population surveys is also used to estimate the yield of each bed. When the harvest from a bed has reached the estimated optimum yield, it is closed until a new survey indicates a significant population of harvestable size clams. This type of selected closure is, by definition, combined with a harvest quota. However, catch is limited on an area by area basis rather than for the whole fishery.

CROP ROTATION

The third type of selected closure, which might be termed "crop rotation", consists of temporarily restricting access to a section of the fishing ground. In this way stocks in the closed area can be built-up, provided that recruitment exceeds loss to natural mortality and harvesting is prevented by law enforcement.

By dividing the fishery into a number of parcels, or plots, a system of alternate closings and openings can be established so that at least one plot of high abundance is always available for harvesting. For any geographic location, the number of plots should be kept to a minimum and should be simply delineated. This will facilitate surveillance by law enforcement personnel as well as monitoring changes in population abundance. In addition, recruitment and mortality rates should be considered when estimating the length of time that areas will remain closed. For example, McHugh (1981) suggested that the bay bottom in the Town of Islip could be divided into three areas, two of which would be closed while the third remained open. The three areas would be rotated yearly so that each would be open every third year. Since recruitment rates in these waters have averaged only about one clam per m^2 in recent years (Buckner 1984), more time and consequently additional plots, perhaps four or five, may be required to achieve the same desired level of increased stock abundance.

Islip is the only town in Suffolk County that currently is evaluating the feasibility of crop rotation as a component of their shellfish management program. Of the estimated 15,000 acres of harvestable bay bottom managed by the Town of Islip, approximately 3,000 acres were closed to harvesting in 1984. A population survey was performed in the area prior to closing and surveys are planned for each succeeding year to monitor the rate at which the stock rebuilds. In a portion of the closed area, seed planting is being carried out to evaluate the potential of its use on a large-scale in the rehabilitation of closed sections of the fishery. Recruitment rates and changes in population density will be compared among seeded and non-seeded sections of the closed area, and open areas of the fishery.

Crop rotation does not differ fundamentally from closing of grounds after an estimated optimum yield has been removed. The primary difference is that the latter strategy assumes that some minimum population of clams must remain in an area for it to return to a harvestable stock size. This is true if recruitment to an area originates with adult clams in that same area, or if the presence of adults of the same species is required to induce larval settlement. To determine whether or not a bed should be closed after some estimated yield has been removed, it is necessary to have information about the source of larvae which set in that location and the setting behavior of the species involved.

To be optimally effective, crop rotation should be combined with some type of limited entry, limited catch, or both. If information on transport of planktonic larvae and requirements for settlement indicate that a local population of adults is necessary for further recruitment then a harvest quota needs to be established. Limited catch might also be recommended to prevent overharvesting of plots which remain open prior to the first reopening of an area with replenished stock. Effectiveness of a crop rotation program could be diminished if reopened areas were subject to uncontrolled harvest by an unlimited number of baymen. Stocks might quickly be reduced to a point where clamming again would be unprofitable.

Long-term benefits of a system of crop rotation could be achieved if the plan were used in conjunction with additional regulations to control the rate at which the resource was exploited (Buckner 1983). For example, the number of baymen in the fishery could be limited so that an acceptable average annual catch per harvester would be made available. In addition, annual or daily harvest quotas or a combination of both could be imposed to ensure a minimum income per individual.

WINTER GROUNDS

The fourth type of selected closure is the preservation of "winter grounds" by closing a protected, nearshore area in summer to maintain stock density for winter harvest. Three criteria should be used in selecting winter grounds:

(1) the site must be accessible to clammers during inclement weather,

(2) there must be an existing stock of harvestable density,

(3) the site must be easy to patrol during the closed period.

The Town of Huntington has recently implemented this type of selected closure with the closing of a portion of Centerport Harbor from April 1 to December 15, 1984. In subsequent years the closed area will be rotated among other harbors. The goal of the program is to build up the stock in the closed area by cessation of harvest and by relay of clams from uncertified areas. The program has not yet been evaluated. A similar program was attempted by the Town of Brookhaven during the past year but the area selected for winter grounds could not be opened because an emergency decertification was necessary.

CONCLUDING COMMENTS

All selected closure strategies require population assessments as an integral part of the management program. These assessments should include an initial survey of recruitment rate, fishing mortality, and natural mortality for the species considered. Annual, although less detailed, surveys also are required to evaluate the effectiveness of the closure program and to determine the appropriate time to reopen closed areas. The costs of these surveys should be included in the cost of the management program. In Suffolk County adequate knowledge of hard clam population dynamics exists only for Town of Islip waters (LIRPB 1983). Islip's hard clam management program now includes selected closure and the cost of the necessary population assessments has been incorporated into the cost of the program. However, no actual estimates of the cost of starting the selected closure program are available since it began only in 1984.

Enforcement costs would also increase with a selected closure program since the closed areas must be marked and patrolled. Enforcement costs could be minimized by making the closed sections simply and clearly delineated and easily observed. However, given the difficulties which law enforcement officials have in preventing poaching of clams from uncertified waters, cooperation and support of local baymen seems vital to the success of any selected closure program.

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LIMITED ENTRY AND HARVEST QUOTAS AS TOOLS
FOR MANAGING SUFFOLK COUNTY'S HARD CLAM FISHERY

INTRODUCTION

Historically, management of Suffolk County's hard clam fisheries has involved attempts to augment clam stocks and to restrict clam harvests. Two of the most common methods of restricting clam harvests--limiting the number of people engaged in the fishery (limited entry) and setting harvest quotas--however, have not been used. In this section we review the conceptual underpinnings of these two management tactics, relate them to major characteristics of Suffolk County's hard clam fishery, and assess the extent to which either or both tactics could contribute to the attainment of a variety of management objectives. The focus of the discussion will be on the biological, economic, social, legal, and administrative aspects of limited entry and harvest quotas. Political palatability will be dealt with only as it affects the other aspects, particularly administrative feasibility. This discussion assumes that other hard clam management strategies and regulations now in effect will continue.

THE PROBLEM

Much of Suffolk County's hard clam resources have been over-harvested, particularly the stocks in Great South Bay (Buckner 1984). It is not surprising that this should have occurred given the increase in clam abundance in the early 1970s, strong demand and high market price for clams, and relatively low entrance costs to the fishery. These factors combined to induce increasing numbers of people to enter the fishery in the early and mid 1970s. Presumably, total harvest quickly exceeded the sustainable yield of the resource and clam abundances began to decline. The extent to which natural events also played a role in this decline is unknown. As stock levels plummeted, so did total clam harvests. New York State production of hard clams, most of which came from Suffolk County, dropped from 9 million of meats in 1977 to less than 3 million pounds in 1984. While high market prices kept average clamming income steady for a brief time during this period of declining stocks and harvests, eventually individual catches fell so low that clamming was no longer profitable and clammers began to leave the fishery, a trend that continues.

The above sequence of events illustrates the near-universal principle that unregulated access to common property fishery resources leads to biologic and economic depletion of stocks. Such a situation is generally seen as undesirable and, hence, there is a need for regulations to limit fishing effort or access. In the hard clam fishery these regulations have taken the form of a minimum size limit, a ban on clamming at night, and a restriction on gear to hand-held implements. It is obvious that these regulations can not restrain the total harvest to a level the resource can support.

Restricting the number of participants in the fishery and setting catch quotas are two management measures that would limit total catch.

LIMITED ENTRY AS A CONCEPT

Before discussing limited entry as a management tool, it is necessary to define some terms. In this discussion limited *effort*, or access, refers to any measure that constrains the ability of an individual to participate in a fishery as he or she otherwise might have wished. Size limits, closed seasons and areas, gear restrictions, and quotas are examples of effort limitations. Limited *entry* refers to any measure that constrains the ability of an individual to participate in a fishery at all. Effort limitation generally has as an objective the sustained biological productivity of a fishery resource. Entry limitation has as a primary objective the allocation of harvest among fishermen. As will be developed below, only when accompanied by limitations on fishing effort does limited entry effectively serve the attainment of resource conservation goals.

Limited entry is primarily a method of allocating revenue to the participants in a fishery to improve their individual economic performance and that of the entire fishery. It is based on the observation that, as long as average individual revenues exceed average individual costs in a fishery, individuals will continue to enter that fishery until such time as the average individual economic rent (revenue minus costs) of each participant is zero. This results from a finite number of fish being spread among an increasing number of fishermen, whose individual costs keep rising even as their catches are declining. Thus, even in a totally unregulated fishery, forces are at play that drive fishermen to the break-even point. Christy (1978) observed that the introduction of regulation (effort controls) has the effect of raising fishing costs and reducing freedom of choice for fishermen as their gear and fishing operations become increasingly restricted. The theoretical end point of any fishery, whether regulated or not, is thus the same--an abundance of fishermen harvesting a minimum of fish with a great deal of effort for little or no profit. Apparently, the only way to avoid this undesirable situation is to control entry to the fishery.

Restricting the number of participants (or vessels) in a fishery can be done in several ways. Entry can be limited directly by establishing a limit to the number of licenses issued. This not only limits the number of persons (or vessels) allowed to engage in a fishery, but the licensing criteria can be used to control other characteristics of the fleet or fishing population. Entry can be limited indirectly through imposition of landings fees or taxes which would make it impossible for newcomers or marginal fishermen to compete. Finally, harvest quotas may be issued to individual fishermen, who may buy and sell them to and from one another.

Implementation of these alternatives, singly or in combination, involves a host of technically and politically difficult decisions which many management agencies are loath to face.

EVALUATING ENTRY AND ACCESS LIMITATION SCHEMES

There are a multitude of private and public rights and interests in fishery resources and in their effective management. As these rights and interests often are incompatible, fishery management frequently incorporates multiple, often conflicting objectives. The major criteria for evaluating any fishery management program, including efforts to limit entry, are biological effectiveness, economic effects, social equity, administrative feasibility, legality, and political feasibility (Cicin-Sain 1978). Biological effectiveness is generally recognized as a *sine qua non* in fisheries management on the grounds that any management program that does not maintain a reasonably healthy resource is a failure. The following sections apply these criteria to hypothetical programs to limit licenses and set harvest quotas in the clam fisheries of Suffolk County. The degree to which the program appears to meet the criteria are discussed along with potential problem areas that managers need to be cognizant of if such a program is to be started.

LICENSE LIMITATION IN THE HARD CLAM FISHERY

Biological Effectiveness

By itself, a direct limitation on the number of licensed fishermen will not reduce the tendency to overharvest a fishery. There is an abundance of empirical evidence from existing limited entry programs to show that total fishing capacity and effort will continue to increase as long as there is a profit to be had in the fishery. This will occur through investment in more efficient gear, in larger vessels, or in increased fishing time. Limited entry alone will not limit total harvest. Limited entry must be combined with limits on each individual's catch, by a bag limit or controls on effort, to effectively limit total harvest. In the hard clam fishery, restriction of gear to rakes and tongs and prohibition on clamming at night restricts the number of clams that an individual can harvest by restricting his effort. Thus, limiting entry in the hard clam fishery has the effect of establishing a limit on total harvest. This limit on the total harvest of the fishery should reflect the sustainable yield for the stock(s) being exploited. Sustainable yield refers to a level of harvest that the stock(s) can support over an extended period of time.

The sustainable yield of hard clams has never been determined for any of the bays of Suffolk County, although estimates have been made for Great South Bay (Smith 1979) and Conrad (Appendix A). Stock assessments carried out by the Town of Islip offer an empirical basis for determining a sustainable yield for hard clams in that Town's waters. However, applying the concept of sustainable yield to the management of hard clam fisheries requires the identification of equilibrium environmental conditions and biological relationships involving hard clams that persist over an extended period. There is little evidence that such stability has ever been present in these systems. The hard clam's inshore environment is a strenuous one, subject to unpredictable and aperiodic changes in response to a variety of natural and anthropogenic forces with resulting impacts on hard clam abundance and distribution. Determining a meaningful maximum sustainable yield in such a setting is difficult.

The hard clam fishery is a single-species fishery and a program of limited entry might not be readily adapted to changes in hard clam abundance. McHugh (1978) noted the problem in setting harvest capacity in limited entry programs, risking having too much capacity in times of resource scarcity or too little in times of abundance. In multiple-species fisheries, fishermen can transfer effort to other species when stocks of the primary fish or shellfish decline. Baymen do not have this luxury. Natural stocks of other inshore shellfish on Long Island are too small to sustain a major redirection of effort from the hard clam. Indexing the number of clamming licenses to estimates of hard clam standing stock would be necessary to make optimal use of surplus clam production and to prevent overharvest. This would require a more comprehensive program of monitoring hard clam populations than currently exists.

Economic Effects

The economic effects of license limitation in the hard clam fishery can be examined from at least four aspects: the impact on previous license holders who are unable to secure licenses; the impact on those who gain licenses; the impact on total economic rents from the fishery; and the impact on the relative efficiency of the fishery. Of these, perhaps the most straightforward economic effect is on those excluded from the fishery. They would be deprived of any income from clamming and might find few alternative uses for their gear and boats. A strong argument might be made on ethical grounds that some compensatory action should be taken for people who have been deprived of their chosen livelihood by such governmental action. It should be noted that limited entry, *per se* is thought not to constitute a "taking" of private property in the legal sense, and thus compensation would not be required (Koch 1978).

While it is probable that some increase in the overall economic efficiency of the hard clam fishery would accrue from limiting the number of clamming licenses, efficiency of harvest has never been an operative goal in the hard clam fishery. This is demonstrated clearly by the restriction of gear to hand-held implements. To economists, one of the beauties of limited entry schemes incorporating transferable licenses is that, once the licenses or quotas have been issued, the determination of who fishes and who does not is made by the fishermen themselves. Those most desirous of staying in the fishery bid up the price for the licenses and/or quotas. Social Darwinists would say that those who are most willing to pay for the privilege of fishing are in all probability those most successful at it. The result of having a fishery in which the most successful fishermen pay for the privilege of continuing to fish would be maximum catch at the least total cost. Regardless of the merits of this argument, such a scenario would occur in the hard clam fishery only if the individual harvest quota were set significantly lower than the total number of clams that the average bayman is able to harvest. Lacking this, there would be little incentive for a bayman to acquire additional quotas since he would be unable to harvest that amount of clams.

The effects of license limitation in the clam fishery on individuals retaining licenses would depend on the extent to which license limitation controlled the total harvest to a level that was sustainable by the resource. Should the reduced harvest capacity allow stocks to rebound, then catch would increase and, within bounds, revenue to individual baymen also would rise. Conrad (1983) found that most of the baymen's costs were variable costs (fuel and opportunity cost of time) and these averaged $40-$60 per day. There is no reason to expect that these costs would increase under conditions of stock resurgence (just the opposite, in fact) and, thus, net income to baymen should increase. The interactions among supply, demand, and price have not been fully explicated for shellfish. Conrad (1980) did not find the expected inverse relationship between total harvest and price of Great South Bay hard clams at Fulton Market. Since the demand for hard clams is quite elastic with respect to price, if production continued to rise the price per pound for hard clams would eventually reach a peak and then decline. Given the relatively high market price for clams, significant increases in baymen's net income may accrue from an expanding resource base. While the frequent criticism of limited entry as a tactic that creates a class of elite "millionaire" fishermen may not be directly applicable to the hard clam fishery, some mechanism, such as an appropriate tax, might be required to prevent individual income from growing to outlandish proportions. Monies thus acquired might be used to support research and/or administration of the program. Another alternative, of course, would be to raise the number of licenses issued.

Social Equity

Any attempt to fix the number of licenses in the hard clam fishery must fairly and reasonably allocate the benefits of the fishery to those with an interest in or a right to it. These would include diggers, buyers, wholesalers, retailers, resource managers, and the general public. Determining and balancing the complex mix of interests and rights held by these groups is a difficult task, but one that must be addressed if a proposed license limitation scheme is to be equitable. Excellent discussions of the general role of such deliberations in the formulation of limited entry programs are found in the comments of Orbach (1978) and Cicin-Sain (1978). For the hard clam fishery, important issues of social equity to be considered in an entry limitation program are described briefly below.

Number of Licenses

The number of licenses to be issued should reflect balance between the need for biological conservation of clam stocks and the need to provide a reasonable livelihood for clammers. In previous limited entry programs, the prospect of limited entry has often led to substantial increases in license applications just prior to beginning the program as fishermen rushed to "stake a claim" to the fishery, exacerbating the problem of setting a fair number of licenses.

Part-Time Clammers

Part-time clammers may require special consideration. One school of thought holds that full-time fishermen are more professional than part-timers, are more inclined to cooperate with resource managers because they have greater dependence on the resource, introduce a greater degree of stability into a fishery, and should be given all or the lion's share of the licenses. A differing view is held by those who see part-time involvement in a fishery as a necessary precursor to full-time status and take note of the increasing incidence of part-time employment as a result of shorter work weeks. Part-timers and seasonal full-timers far outnumber year-long, full-time clammers working in the fishery, although the full-time baymen account for most of the harvest.

Criteria and Mechanisms for Licensing

Mechanisms and criteria for license allocation would have to be developed. No criteria are needed if licenses are awarded by lottery. In an auction, one's ability to secure a license depends on how much money one has and is willing to spend. Licenses can be awarded on the basis of some demonstrable level of financial dependence on clam digging (which might exclude part-timers), or on the basis of the extent of past participation in the fishery; or all current license holders can simply be "grandfathered in" at the outset and some provision made for non-renewal of expired licenses. Any criteria used to allocate a fixed number of licenses may adversely affect individual clammers or groups of clammers. Given the paucity of information on the social and cultural composition of Long Island clammers and their mores, values, and reasons for participating in the fishery, it is difficult to forecast such adverse impacts and to prescribe a particular set of criteria for license allocation that would minimize description. We recommend strongly that such information be developed.

Transfer of Licenses and Future Issues

Provisions for subsequent allocation and transferability of licenses would need to be developed. Some provisions would have to be made to allow for new entrants to the fishery over time. Failure to do so might risk legal challenge on the basis that a "closed class" of clammers had been created by the license allocation program. This challenge might be successful unless it was demonstrated that such a class was necessary to attain the objectives of management in establishing the limited entry system. An annual auction or lottery might be employed or the licenses could be made transferable among baymen.

Compensation

Concerns for equitability might dictate that provision be made for compensation of clammers not awarded a license. This could be done through direct compensation at an established rate, purchase of idled boats and gear, or training programs to help these persons secure alternative employment.

Windfall Profit to Licenses

The dividing line between reasonable and unseemly individual income in the clam fishery is a difficult line to draw, but it is clearly inappropriate for government action to create conditions that lead to the concentration of great wealth in a few hands, and at the same time restrict the opportunities to compete for this wealth. The need to prevent windfall profits falling to the fortunate license holders requires that managers involve themselves in determining what is an acceptable personal income from clamming. It is generally thought that full-time clammers who harvest throughout the year average $25,000 in yearly income and pay no income tax. An income of $25,000 in 1984 dollars might be an appropriate target figure. Provision for determining the average earnings of a clammer and for capturing income substantially above whatever target figure is chosen should be considered in the formulation of a license limitation scheme. This will probably prove philosophically distasteful to many managers and will undoubtedly be difficult to do in practical terms as long as the clam fishery operates on an individual clammer-buyer basis.

Legal Issues

Limited entry schemes are mentioned explicitly in the Magnuson Fishery Conservation Management Act (PL 94-265) as a possible, although last-resort, management alternative for fisheries conducted in the Fishery Conservation Zone (FCZ). Koch (1978) found that limited entry programs formulated under this Act probably were Constitutionally-sound, although specific components might be susceptible to legal challenge if poorly drafted. This legal robustness is attained by closely relating the specific provisions of limited entry programs to the overall goals of national fisheries management enunciated in the legislation. The hard clam fisheries of Suffolk County are not covered by the provisions of PL 94-265 and are conducted entirely withing the jurisdictions of New York State and local municipalities. A license limitation program proposed in this fishery would have to be part of a broader fisheries management plan which explicitly stated the goals of hard clam management and which showed a demonstrable and appropriate relationship between the specific provisions of the licensing program and those goals.

State law empowering the Department of Environmental Conservation (DEC) to issue permits to take shellfish for commercial purposes makes no provision for restricting the numbers of permits. New legislation would be required to limit the number of State shellfish permits issued. The management authority of the individual towns also does not include authorization to restrict the number of licenses. Local ordinances, resolutions, and perhaps action by the State Legislature would be required to create this authority. The history and extent of jurisdiction over shellfish resources varies among the towns of Suffolk County and the legal action required to begin a limited entry program for hard clams would vary somewhat from town to town, as would the locus of authority to set license limits which could be vested in the town board or the town shellfish management agency.

Administrative Feasibility

It generally is held that starting a limited entry program will substantially reduce the administrative costs of managing the fishery. The reduction in the number of fishermen is seen as leading to lower enforcement costs, to easier record keeping, to more accurate assessment of total harvest capacity, and to creation of a group of fishermen who, because their licenses instill a greater sense of ownership in the resource, are more inclined to cooperate with managers in other measures to control fishing effort.

Harvesting hard clams from town waters requires a permit from the State and the town; harvesting in waters under State or County jurisdiction requires only a State permit. Thus an individual town could start a limited entry program for hard clams by itself or in cooperation with the State (DEC). In either case, the question of issuing permits to harvest species of shellfish other than hard clams [bay scallops (*Argopecten irradian*), mussels (*Mytilus edulis*), oysters (*Crassostrea virginica*)] would have to be settled. At present DEC has a single permit to cover the harvest of all bivalve shellfish species. Participation in a hard clam limited entry program might require the issuance of separate hard clam diggers permit. The exclusive jurisdiction enjoyed by most towns over shellfish resources in town waters, the political influence of baymen, and their entrenched positions in shellfish management bodies militate against establishment of a separate commission or other body to administer a hard clam limited entry program.

Information

An information system would be required for the clamming industry and the clammers themselves for use in allocating licenses and monitoring the effectiveness of the license limitation program. Biological, economic, social, and cultural information of the sort not now available would be required; a system would have to be developed to acquire this information and make it available in a timely fashion and in forms appropriate for decision makers.

Education

A program would be required to educate the public, particularly the clamming public, about the intent of a license limitation program, how it would work, and the criteria that would be used in issuing licenses.

Monitoring

Provision would have to be made for adequately monitoring and evaluating the program in terms of overall management goals in light of changing conditions in the fishery and making frequent adjustment of the program to avoid unforeseen adverse impacts.

Enforcement

Enforcement costs under a program of limited licenses are unclear, but might approximate those of the current fishery. This would be particularly true if licensed fishermen's income rises substantially, leading to increased tendencies to dig without a license.

CATCH QUOTAS AS A CONCEPT

Catch quotas can be imposed on a fishery-wide basis as a total allowable catch (TAC) and/or applied to individual units (fishermen or vessels) in the fishery. The primary purpose of quotas is conservation of the resource through direct limitation of catchers, but quotas can have significant economic and social repercussions for a fishery. Fishery-wide quotas impose a limit on total harvest, which individual quotas do not unless accompanied by some form of entry limitation. Strictly speaking, quotas are examples of limitations on fishing effort, although if quotas are set low enough they may effectively limit entry to a fishery by making it impracticable for many fishermen to continue to harvest.

QUOTAS IN THE HARD CLAM FISHERY--FISHERY-WIDE QUOTA

Biological Effectiveness

A total allowable catch (TAC) quota is perhaps the most effective mechanisms for restraining the total harvest in a fishery like that for the hard clam. A maximum harvest level would be set on a seasonal or annual basis that met the joint objectives of stock rebuilding or maintenance and economic viability for baymen. Existing catch recording systems maintained by DEC and the National Marine Fisheries Service could provide sufficiently timely information on catches to signal when the quota had been reached. At that point all clamming would be prohibited for the remainder of the season or year. The quota would have to be periodically reviewed and modified to reflect changes in stock abundance.

Economic Effects

The impact on total economic rent in a hard clam fishery operating under a fishery-wide quota depends on the degree to which the level of harvest allows stocks to rebuild, leading to larger net revenue from the fishery. In such a situation, the average costs to clammers would be increased by an amount related to the time that their gear was idled during periods of closure. During such periods, clammers would be forced to find other employment. This might not pose much of a problem for part-timers, but might cause great difficulty for full-timers, especially if the closures occurred frequently. Because a TAC quota allows unlimited access, it probably would not improve the financial situation of the clammer in the long run.

Social Equity

A total fishery quota does not involve significant allocational decisions by clam managers and, hence, the question of the equitability of distribution of benefits from the fishery is moot. Such a quota would potentially deprive all clammers of a certain portion of their livelihood, along with all others in the market chain who trade in hard clams. Consumers would be affected by being unable to purchase legally harvested Long Island hard clams for some period(s) of the year.

Legal Issues

The individual towns would be the logical entities to develop an overall quota program. They are not currently empowered to do so under town shellfish ordinances.

Administrative Feasibility

Apart from enforcement costs, a TAC program would not involve unreasonable administrative burdens. Enforcement costs, however, are likely to be substantial. The desire to harvest as much of the resource as possible before the quota is reached may impel a greater percentage of diggers to harvest clams from uncertified waters. Also, during periods of closure, there would be great incentive to harvest clams for a black market.

QUOTAS IN THE HARD CLAM FISHERY, FISHERY-WIDE & INDIVIDUAL QUOTAS

Biological Effectiveness

Incorporation of individual quotas into the hard clam fishery in conjunction with an overall quota would not significantly change the biological impact of the program on the hard clam resource.

Economic Effects

It is assumed that individual quotas in the hard clam fishery would be transferable through sale to other diggers, as suggested by Conrad (1983 and Appendix A). If the quotas specified not only a total bushel harvest, but also the size composition of clams allowable for harvest, the aggregate impact of the individual quotas might be to move the fishery toward a stock age structure and level of production that would represent Conrad's bioeconomic optimum (Appendix A). Economic impacts on individual diggers from such a quota system would depend on the choices made by individuals, whether to increase or decrease or hold constant their quota through trading with other diggers.

Social Equity

Many questions concerning the equity of limited entry pertain to a clam fishery regulated by individual quotas. Resource managers would have to decide how many quotas to offer, how many of the various size clams would be harvested, the duration of the quota, as well as the process by which the quotas were assigned.

Legal Issues

The legal issues are the same as Overall Fishery Quotas described previously.

Administrative Issues

Substantial administrative costs would be associated with a system of individualized harvest quotas in the hard clam fishery. To equitably allocate and set quotas, detailed knowledge of the operations of individual baymen may be required. As noted by Conrad (1983) a record keeping system would be required to track the harvest of individual baymen and to record transactions involving their quotas. The enforcement costs of such a program would be substantial; certainly higher than those associated with today's fishery.

CONCLUSION

One of the most pressing needs for hard clam management in Suffolk County's hard clam fishery is to effectively regulate total harvest. Given the current limitation on the ability of an individual to increase his production because of gear restrictions, limited entry and an overall catch quota appear to be two management alternatives that would more effectively restrain harvests than current regulations. But each would increase the role of management agencies in the economic and social regulation of the fishery to a far greater extent than ever before.

The utility of limited entry and/or catch quotas as management tools depends heavily on the objectives of hard clam management.

- Maximum Sustainable Yield (MSY). Maximum Sustainable Yield is defined as the maximum harvest that can be extracted annually from a fishery resource over an extended period of time. Because bay environments and their hard clam stocks vary, there is some doubt about the usefulness of the concept of sustainable yield in managing Suffolk County's hard clam resources. As noted, limited entry and a fishery-wide catch quota would restrict total clam harvests and could be used to manage the fishery for MSY. A total catch quota would be more attractive to managers, and most likely to baymen, than a limited entry program, because it has a more direct limitation on total harvest and has greater administrative simplicity.

- Maximum Employment with a Minimum Threshold Income for Baymen. Any program that seeks to preserve a minimum income for clammers requires entry limitation or individualized catch quotas. Other management practices cannot protect individual baymen's income from being progressively diminished through entrance of new diggers into the fishery.

- Maximum Economic Rent. The role of entry limitation and individualized catch quotas in maximizing present net economic revenue (total landed value minus harvesting plus administrative costs) of the hard clam fishery is discussed elsewhere in this volume (Appendix A).

- Maximize Recruitment/Standing Stocks. This is not a long-term management objective, but a temporary goal to rebuild stocks to a level at which a respectable MSY or OSY (optimum sustainable yield) can be attained. A management program solely focused on rebuilding stocks would be best served by a moratorium on harvesting. This is equivalent to a complete limitation on entry.

The four alternative management objectives discussed involve, explicitly or implicitly, determination of a total allowable yield and restriction of clam harvests at or below this level. As discussed above, programs to limit entry or set harvest quotas appear to be the only effective means of limiting total harvest in the hard clam fisheries and, thus must be part of any management program that seeks to attain this objective.

The purpose of this section is to highlight the many complex factors one must consider when formulating and implementing a limited entry or catch quota program for hard clams. Each existing limited entry program in other fisheries is unique; responding to the particular set of biological, technical, social, political, legal and administrative characteristics that define each fishery. No attempt has been made here to describe and evaluate a specific entry limitation program for hard clams. This would be a task for those charged with managing the resource. The above remarks could serve as a framework around which such a task could be undertaken.

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THE ECONOMICS OF MANAGEMENT ALTERNATIVES FOR THE HARD CLAM IN GREAT SOUTH BAY, NEW YORK[1]

EXECUTIVE SUMMARY

by

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[1] See Appendix A for the complete analysis.

INTRODUCTION

This Executive Summary reports on the major conclusions and recommendations of a more technical bioeconomic study entitled "The Economics of Management Alternatives for the Hard Clam in Great South Bay, New York" and contained in Appendix A. This summary is organized into four brief sections: (1) conclusions of the technical study, (2) discussion of the sensitivity of those conclusions to parameter values or alternative model formulations, (3) summary of the implications of the technical bioeconomic analysis, and finally, (4) a review of the management program recommended in the technical report and comparison with a set of more traditional management policies.

CONCLUSIONS OF THE TECHNICAL REPORT

Two yield functions were estimated based on reported landings and the number of permits issued by the Towns of Babylon, Islip and Brookhaven. Estimates of maximum sustainable yield were 243,750 bushels (about 2.9 million pounds) for the logistic model and 358,682 bushels (about 4.3 million pounds) for the Gompertz model. Reported landings exceeded both estimates during the period 1970 to 1979. This would indicate that the resource was harvested at rates that exceeded recruitment and that stocks were significantly reduced. Depending on the standing stock in 1970, estimates of the standing stock at the beginning of 1984 ranged from 575,481 to 3,148,784 bushels (6.9 to 37.8 million pounds).

If no management action was taken and the hard clam resource continued to be harvested under essentially open access conditions, it is likely that the stock of clams may increase slightly to between 2.5 and 4.0 million bushels and support yields in the neighborhood of 216,000 to 350,000 bushels (2.6 to 4.2 million pounds) per year. This would be a slight improvement over the landings reported in 1982 and 1983, perhaps indicating that stocks have been reduced below the "zero profit" level and the continued exit of baymen from the fishery may allow for a slight recovery in the next few years.

While a slight improvement from the status quo might take place with no new management initiative, the perpetuation of open access is not without a cost. Under a program which allows stocks to rebuild to between 4.5 and 5.5 million bushels (54 and 66 million pounds), it would be possible to generate *net* revenues of between $2.5 million and $7.7 million, annually. The yield under an optimally managed fishery is estimated to be between 197,000 and 315,000 bushels (2.4 and 3.8 million pounds). This is about the same as the level of harvest under open access (no new management programs). The difference is that the stock is maintained at a higher level thereby reducing the *cost* of harvest and generating positive net revenues in the indicated range ($2.5 to $7.7 million annually in 1984 dollars).

The time necessary to rebuild stocks to the optimal 4.5 to 5.5 million bushel level via natural recruitment is significant. The fastest way to rebuild stocks would be through the imposition of a moratorium on harvest. Given estimates of the intrinsic growth rate and the environmental carrying capacity in Great South Bay, it would take at least nine years to establish an optimal stock with no intervening harvest. This time might be shortened if effective seed clam or transplant programs were instituted. The economic desirability of such programs was *not* evaluated in Appendix A, but is considered elsewhere in the report.

If stocks could be rebuilt through natural recruitment or artificial enhancement, some management policy to restrain landings would be needed to prevent a return to the open access conditions of low stocks and limited yields. While several policies are feasible, perhaps the most compelling from a bioeconomic perspective would be a program containing the following elements:

(1) A system of transferable quotas where a subset of baymen chosen by lottery are entitled to harvest some fraction of a total (aggregate) target yield. Each entitled baymen may harvest all or a portion of his quota allotment or he may sell it to another qualified bayman through a town or State run auction. Quota share or the number of active baymen could increase over time if stocks increase to the point where they could support increased aggregate yield.

(2) Quota holding baymen would be required to register their landings at a town or State run landing station. The bayman's catch would be recorded, cumulated with previous landings, and compared with his total allowable quota. If the bayman wished to harvest more than his current entitlement he would investigate the cost of increasing his quota by buying unused entitlements through the auction. If shoreside work or other circumstances precluded the harvesting of his entire initial entitlement he could offer the remainder for sale through the auction.

(3) Because recent problems with the taking of clams from uncertified waters have been serious, spot sanitation checks would be made on clams brought to the official landings stations. This would serve as an incentive for authorized baymen to harvest from certified waters. Authorized baymen would then be given the option of selling directly to a licensed dealer or having the State or town sell their clams through a certified public auction. It is likely that wholesalers would find the public auction attractive knowing that they are guaranteed a fresh, sanitary product. The public auction would also aid in enforcement of the overall program. Nonauthorized (i.e., nonquota-holding) baymen who illegally harvest clams would be forced to sell under the stigma that their clams might be unsanitary.

(4) The size of the initial quota share, the period for which it pertains, the eligibility of active baymen in subsequent lotteries, and the maximum allowable quota share (initial plus purchased at auction) are program details which would have to be worked out in advance to the satisfaction of baymen, biologists, and town and State officials. It

is important for all participants to realize that the total quota (and thus the individual shares) would be adjusted through time in response to estimates or stock and year-class abundance.

SENSITIVITY OF CONCLUSIONS

The numerical estimates of maximum sustainable yield, optimal standing stock, and potential net revenues should be "taken with a grain of salt." While the estimates of stock, landings, and effort were not particularly sensitive to changing parameter values, a more fundamental question must be asked: "How sensitive are the results to the type of model (or specification) used in the technical study?" The answer to this question is less reassuring. In another study using a more complex multiple cohort model the author obtained significantly larger estimates for optimal stocks and yields. This earlier analysis was *not* based on an approach which estimated parameters from reported landings and permit numbers. Rather, the multiple cohort model was built-up from previous biological research on growth, mortality, and fecundity of the hard clam. The differences in yield and net revenue estimates between the two models might give some indication of the amount and value of harvest which goes "unreported."

The estimate of maximum sustainable yield seems consistent with the view that the resource stock was "mined" during the 1970s. It also seems safe to say that yield must be restrained to perhaps 150,000 bushels if recruitment is to exceed harvest and stocks are to be rebuilt. The simple biomass models employed in the technical study might be criticized on the following grounds.

Biomass models cannot account for important age-structured aspects of the hard clam fishery. In particular the effect of spawner sanctuaries and maximum size limits cannot be considered.

Single species biomass models have no explicit consideration of the effects of predator or competing species.

The biomass models were deterministic; that is, no random or "stochastic" components were contained in the models. Such random shocks (e.g., weather) obviously affect the environment of Great South Bay and, in turn, its ability to support the hard clam and other species.

Finally, lack of statistical significance in the estimation of yield functions is understandable in light of the above, but is nonetheless disturbing. This "lack of fit" casts doubt on the validity of simple biomass models for characterizing the bioeconomics of the hard clam resource.

While the numerical estimates reported in the Appendix A and summarized here should be taken with a grain of salt, the conclusions on the effect of open access harvesting during the 1970s and the need for control over future harvest (if the resource is to recover) remain valid. The rationale for the management program summarized in the preceding section remains compelling regardless of the exact numbers.

IMPLICATIONS

The implications of the technical study are straightforward:

The decline in stock and yields during the 1970s was most likely the result of biological overfishing; that is, harvest in excess of natural recruitment;

Stocks need to be rebuilt if yields are to be increased and the fishery made profitable;

If stocks are to be rebuilt by natural recruitment, yield must be restricted below growth to allow a net increase in the standing stock. Stocks might also be increased by artificial means (seeding and transplant programs) although the economic effectiveness of such programs has been questioned.

A more active management role by towns or the State will be costly. Perpetuation of the status quo, however, involves an opportunity cost: foregone net revenues if the fishery were better managed. To be effective a management program must be enforced. Great South Bay is a shallow and highly accessible body of water. Commercial clamming is a low capital, low cost activity, thus enforcement of reduced or restricted landings might be costly. The enforcement costs of a particular management program will depend on how the baymen (active or potential) view the program. If a program is started which a majority of baymen view as necessary and fair, enforcement costs will be lower than if a program is viewed as unnecessary or unjust.

The cost of any, more active, management program is speculation at this time. The principal recommendation of the technical study presented in Appendix A is that some yield restricting management program needs to be undertaken. Further, that program (or programs) should be properly viewed as an experiment. The program should be adaptive to allow policies to be modified as information and experience is gained on the dynamic response of the resource, baymen, and town and State officials. In concluding this Executive Summary, let us briefly compare the management proposal from Appendix A with more traditional management policies.

MANAGEMENT ALTERNATIVES

The management program briefly described in the first section of this summary has many desirable attributes from a bioeconomic perspective. That program was based on (1) a lottery to determine access to the resource, (2) transferable quotas, (3) official landings stations, (4) spot checks on shellfish sanitation, and (5) a public auction of legally harvested clams. To increase the stock of hard clams this management program relied on an aggregate target quota less than natural recruitment, along with enforcement to prevent illegal harvest by nonquota holders (or excessive harvest by quota holding baymen).

Reestablishment of hard clam stocks appears to be a lengthy process; perhaps at least nine years with no intervening harvest. Several artificial techniques may augment natural recruitment and thus speed-up recovery time. Planting of seed clams, and spawner sanctuaries may increase the stocks of harvestable clams in the future. The question becomes whether any of the artificial techniques can have a significant effect on recruitment while producing positive net benefits (present value of revenues exceeding present value or costs).

From an ecological and economic point of view it would make sense to form a County-wide management authority. Towns have been reluctant to consider such a management compact for fear of losing control over harvest within their historical waters. It is conceivable that each town could implement the bioeconomic program outlined above. However, the costs of program administration (record keeping, enforcement, landings stations, and auctions) would be higher if they were repeated in each town. Because tidal circulation and wind driven currents do not recognize town boundaries, individual towns may not undertake actions which could improve the productivity of baybottom in neighboring towns. Economists refer to such phenomena as "externalities" and a County-wide management authority would seem the most logical way to "internalize" them.

Several methods to restrict landings to allow for net natural growth have been attempted in other fisheries. Most have limitations and are viewed (by economists) as inferior to transferable quotas. A brief summary of some of the more popular attempts to reduce effort or yield would include the following.

- Seasonal Closures: This regulation may reduce effort and landings, but is usually justified in terms of protecting the resource during a critical stage in its life cycle. Effort and yield is often more intensive during the open season and the open access problem persists.

- Total Aggregate Quota: Total landings are monitored and when the aggregate quota is reached the fishery is closed. This perpetuates the "Easter Egg Hunt" mentality by fishermen as they race to catch as much as possible before the fishery is closed. Fishing under such conditions is not likely to be least costly.

- Individual Quotas: Each fisherman is entitled to harvest a certain amount. Fishermen must be monitored and catch recorded to determine when a particular fisherman has caught his quota. If no limit on the number of fishermen is imposed, individuals may find it impossible or uneconomic to achieve their quota and de facto open access persists.

- Limited Entry with Individual Quotas: With limited entry it is more likely that a management agency can control total landings and assure fishermen the opportunity to catch their individual quota profitably. A problem arises, however, in that more efficient fishermen may be excluded from the fishery and the total (aggregate) quota would not be harvested at least cost.

- Limited Entry with Individual Transferable Quotas: This is the program proposed for the hard clam resource. Similar to limited entry with individual quotas, but the fact that quotas would be transferable would allow the more efficient baymen to bid away quotas from less efficient baymen. In theory, the aggregate quota would be harvested at least cost.

Other management alternatives include doing nothing. Continuation of the status quo incurs no new management costs. With such a policy the fishery is likely to remain mired in its current depressed state and its potential profitability a subject of speculation.

COMPARISON OF NET REVENUES

The essential elements of the economics of management alternatives for the Great South Bay (GSB) hard clam fishery are contained in Tables XIX-1 (Also Table A-3) and XIX-2 of Conrad's technical paper (Appendix A). A non-quantitative description of the terms used in these tables follows.

r = Intrinsic rate of growth of the hard clam population

K = Maximum population level that can be supported by the environment (based on food, habitat, and other environmental factors).

q = "catchability coefficient" - assumes that for a given amount of fishing effort the catch is proportional to the stock size.

p = price per bushel in dollars - weighted average of littlenecks, cherrystones, and chowders.

c = cost of fishing for the average permit holder for one year. Assumes 75 eight hour days of clamming per year at $5.00 per hour for the harvester's time plus boat, gear and fuel.

δ = "discount rate" - a factor which describes the rate of return on capitol elsewhere in the economy. Empirically derived.

E = Fishing effort - measured by number of commercial licences.

X = Standing stock or population of hard clams of legally harvestable size (in bushels).

Y = Yield or harvest per year (in bushels).

Table XIX-1

Equilibria in the Logistic-Based Model

		r = 0.13 , K- 7.5×10^6 , q = 2.0×10^{-5}			
		p = 60 c = 4,000 δ = 0.05	0 = 60 c = 3,000 δ = 0.05	p = 60 c = 4,000 δ = 0.10	p = 50 c = 4,000 δ = 0.05
Maximum	X_{MSY} =	3,750,000	3,750,000	3,750,000	3,750,000
Sustainable	Y_{MSY} =	243,750	243,750	243,750	243,750
Yield	E_{MSY} =	3,250	3,250	3,250	3,250
Open	X_∞ =	3,333,333	2,500,000	3,333,333	4,000,000
Access	Y_∞ =	240,740	216,666	240,740	242,000
	E_∞ =	3,611	4,333	3,611	3,033
Maximum	Y_0 =	5,416,666	5,000,000	5,416,666	5,750,000
Net	Y_0 =	195,601	216,666	195,601	174,416
Revenue	E_0 =	1,805	2,166	1,805	1,576
Bioeconomic	X^* =	4,946,330	4,380,780	4,615,384	5,380,033
Optimum	Y^* =	218,942	236,853	230,679	197,695
	E^* =	2,213	2,703	2,500	1,837

Table XIX-2

Net Revenue (NR) at Equilibrium - Logistic-Based Model

NR (dollars) = Total Revenue - Total cost - (Y)(p) - (c)(E)

	p=60 c=4000 δ=0.05	p=60 c=3000 δ=0.05	p=60 c=4000 δ=0.10	p=50 c=4000 δ=0.05
max. sustain. yield	1,630,000	4,880,000	1,630,000	-813,000
open access	400	960	400	-32,000
max. net revenue	4,520,000	6,500,000	4,520,000	2,420,000
bioecon. optimum	4,290,000	6,100,000	3,850,000	2,540,000

These two tables are derived from two bioeconomic models for the GSB hard clam fishery. The models, in turn, are based on two different growth functions or mathematical expressions which describe the growth of the hard clam population. Overall, the logistic model seems to be the more plausible model for the GSB hard clam resource. To avoid confusion only the logistic-based model will be considered here. For the models to be useful it is necessary to obtain reasonable estimates of r, K, q, p, c, and δ for the GSB clam fishery. Conrad has obtained values for these parameters from available data on numbers of permits, hard clam landings, clam prices, and estimates of baymen's costs, and carrying capacity (K) of GSB. A complete description of how these numbers are arrived at can be found in Appendix A.

The bioeconomic model and the bioeconomic parameters can be combined and used to predict standing stock, harvest, and effort when the fishery is managed for alternate goals. Table XIX-1 (Also Table A-3) gives the calculated values of stock (X), harvest (Y), and effort (E) given four different management goals and four sets of values for p, c, and δ. Maximum sustainable yield (MSY) is a purely biological concept; the maximum harvest that can be sustained over the long-term with a given growth rate and carrying capacity. The open access alternative allows the baymen's profit (after costs have been covered) to approach zero by allowing unlimited access to the fishery. Maximum net revenue seeks to produce the greatest total revenue from the fishery. The bioeconomic optimum manages for maximum total value of the resource. This means that clams are considered for their value to the resource if left in the bay and their value to the economy if harvested. An optimum harvest is then calculated which will maximize the total value for the given set of economic and biological conditions. These last two alternatives increase the net revenue by maintaining larger standing stocks (thus decreasing the cost of fishing) and dividing a slightly reduced harvest among fewer baymen.

For each set of predictions given in Table XIX-1 (Also Table A-3) a value can be obtained called Net Revenue (NR). This value is obtained by subtracting the total cost of fishing from the revenue produced, or (Y)(p) - (c)(E) = NR. Values for NR calculated from Table XIX-1 (Also Table A-3) are given below (Table XIX-2 (Also Table A-4)). Net revenue is the profit obtained by the baymen over and above their minimum (break even) cost of fishing.

In several of the scenarios shown here the net revenue is less than zero. The fishery could continue only for a short time under these conditions because the baymen would be receiving compensation for their time at a rate less than could be earned outside the fishery. These tables demonstrate that open access management leads to a relatively large harvest but that the revenues are spread among a large number of baymen such that each does little more than break even. Although managing for maximum sustainable yield results in the largest harvest, net revenue is still low because the number of baymen is large and stocks are low. The maximum net revenue and bioeconomic optimum alternatives result in a larger net revenue from the fishery. The difference between the two is that the bioeconomic optimum alows stocks to be maintained at a slightly lower level and provides a larger harvest spread among more baymen while still maintaining a reasonable profit from the fishery. A plan for managing the GSB hard clam fishery for the bioeconomic optimum is contained in Conrad's technical paper (Appendix A).

PRIVATE MARICULTURE

INTRODUCTION

The term mariculture describes activities in which natural life cycles of marine organisms are manipulated to enhance production. In New York, mariculture of the hard clam usually focuses on hatchery production of clam larvae, nursery production of seed clams and field growout to market size. These intensive procedures involve efforts to propagate clams in small volumes of water and to grow clams on densely planted tracts of bay bottom. Hard clam production through mariculture does not depend upon sophisticated equipment, does not have to be undertaken on a large scale and does not necessarily involve significant capital expenses. It does require access to marine habitats which are capable of supporting dense clam populations, and experience or training in culture methods.

In the face of declining landings, mariculture could be an important part of an overall approach for managing Suffolk County's hard clam fishery. However, the practice of private mariculture is not a management alternative in the strict sense; it is an industry just as the commercial fishery is an industry. The management alternatives considered in this report are efforts to enhance and maintain landings of hard clams in the commercial catch fishery. A decision to allocate tracts of the marine habitat to private mariculture is a management decision. The subsequent practice of private mariculture is not a management activity, although large-scale development of private mariculture could affect the managed catch fishery. The distinction between management alternatives for the public fishery and private mariculture is further obscured because many methods used to manage natural stocks for the catch fishery are the same as those used by the private mariculturist to produce hard clams. This commonality of methods makes private mariculture operations affect the manner in which natural stocks are managed. Therefore, the first topic to be addressed in this chapter will be the relationship between private mariculture and public mariculture programs to augment natural stocks.

Suffolk County is indeed fortunate to possess natural habitats which have in the past produced more hard clams than any other single area of the United States. Declines in landings in the catch fishery stimulated the interest of governmental officials, resource managers and aquaculture entrepreneurs in the development of private mariculture--development which could increase competition for these productive natural habitats. The catch fishery requires free access to bay bottom to achieve these landings while private mariculture depends upon exclusive use of portions of the same habitat for purposes of hard clam culture. On a County-wide basis, private mariculture and the catch fishery are not mutually exclusive, but no given tract of bay bottom can be shared. If the County is to continue to derive economic gains from the wild harvest or culture of hard clams, this conflict over allocation of public resources to competing industries will have to be addressed. Therefore, the second section of this chapter evaluates private mariculture as a means of sustaining Suffolk County's overall production of hard clams in conjunction with a revitalized and stabilized catch fishery.

There are serious constraints to the development of private mariculture of hard clams in Suffolk County. The economic feasibility of hard clam culture has not yet been demonstrated, although small scale operations hold much promise. Public opposition to mariculture development is apparently based on the perception that private mariculture would eventually involve large corporations and the leasing of thousands of acres of bay bottom, although neither condition is required to culture hard clams. This chapter closes with a discussion of this impasse to development of private mariculture.

PRIVATE VERSUS PUBLIC MARICULTURE

Mariculture may be undertaken with either public or private funding; the differences between these two approaches are significant and worthy of further consideration.

In broad terms, public mariculture programs use public funds provided through government agencies to increase harvestable stocks of aquatic resources for the benefit of the public, including the fishing industry. Public mariculture generally means replenishment programs for important commercial and recreational fisheries. By definition, if not by law, harvestable stocks enhanced by public mariculture programs must be equally available to all of the public whose taxes and fees underwrote the program. This implies that at some point in the organism's life cycle, public mariculture programs must distribute the cultured stocks to the public and thereby relinquish control over the fate of the "crop." The benefits of public mariculture are obvious when stocks are made available to the public at harvestable sizes (e.g., freshwater lakes stocked with cultured, adult trout for recreational fisheries). However, for hard clams, the benefits of public mariculture are equivocal.

Town programs survive on limited budgets; they can buy or produce a relatively large number of very small seed clams or a smaller number of larger seed clams. Because there is considerable local support from baymen for highly visible seed planting programs which release as many seed clams as possible, town programs tend to plant very small hard clams onto public grounds where they face at least two more years of growth before reaching legal harvest size. After such planting, very little is done to assure the growth and survival of this publicly-owned crop. Public mariculture of the hard clam is intensive up to the point of seed planting at which time it ceases to be mariculture at all. The "abandonment" at release is the most important feature of public mariculture as practiced for the hard clam in Suffolk County. At the time of planting hard clam seed, no one has derived any benefit from the efforts of the public mariculture program. Benefits from this form of abbreviated mariculture depend on the survival and growth of clams in the uncontrolled, poorly understood and often highly variable natural environment.

On the other hand, private mariculture uses private funds and resources to maintain as much control over the crop as economically feasible until such time as the greatest economic benefits may be derived from the sale of products, either marketable littlenecks or seed clams. The benefits, usually cash revenues, accrue solely to the individuals or corporations whose resources were used to generate the revenues. The private mariculturist has made a more significant, personal investment of time and money in a crop than the taxpayers or bayman who have relatively minor involvements and personal investment in the public mariculture and planting of seed clams.

Hard clam mariculture can be practiced full-time or part-time by individuals, informal groups or even corporations. Hard clams can be cultured by individuals operating on a small scale with minimum capital investment (e.g., Clam Farm, Fishers Island), or even as an adjunct activity to participation in other aspects of the hard clam catch fishery (e.g. Coastal Farms, Water Mill). Partnerships of two or three people could culture hard clams on a part-time basis with rotating responsibilities for the operation. Larger, self-governing cooperatives could share the costs and benefits of expensive equipment and centralized marketing connections. Unless otherwise regulated through restrictions on leases or assignments of bay bottom, corporations (e.g., Blue Points Company; F.M. Flower & Sons) can use larger scale facilities for hard clam production through mariculture.

Whatever the scale, the goal of private mariculture is to generate income as profits for the investor and employment for the mariculturist (although in small operations the investor and mariculturist are often one and the same). Public mariculture strives to augment natural stocks in a public fishery. While the goals of public and private mariculture are very different, the relationship between these two approaches to hard clam production is very important for two reasons.

First, all current public mariculture activities (seed planting programs) obtain post-set or very small seed clams from private mariculture operations on Long Island and out of state. Lacking a public hatchery, seed planting programs of Suffolk County towns depend on private mariculturists for clam seed. Private mariculturists in turn derive economic benefit from these public programs. For many private mariculture operations, the sale of seed clams could be a significant source of revenue (e.g., Aquacultural Research Corporation, Dennis, Massachusetts; Shinnecock Indian Tribal Oyster Project, Southampton; Shellfish Inc., West Sayville). Sales of seed clams enable the private mariculturist to diversify sources of revenue while gaining the all important cash flow required for continued development of methods to culture clams to market size. Sales of clams to Long Island seed planting programs (total worth of $50,000 in 1983) might increase if private mariculturists could supply cultured seed on a regular basis.

Secondly, the private mariculturist requires allocation and exclusive use of segments of bay bottom for culture of clams for the retail market. New York State, Suffolk County and the towns in the County, which operate public mariculture or seed planting programs, influence or control leasing of submerged lands for private mariculture. Thus, the State and towns regulate the space required by the private operator while the private operator produces seed clams needed by the towns for seed planting programs. This interdependency between bottom leasing and replenishment of the public fishery is an important opportunity for development of private mariculture in the County.

An example of successful cooperation between public interests and private mariculture is the relationship of Frank M. Flower & Sons (Bayville) with the Town of Oyster Bay. Since 1981, the Flower & Sons lease of bay bottom for oyster and hard clam culture has required that they culture 600,000 seed clams (2 mm) for the seed planting program of the Town. Additionally, the firm is required to make their vessels and crews available to the Town for a specified number of days each year for work in support of the public fishery (e.g., predator control, shellfish surveys, preparation of public bay bottom). In return, Flower & Sons has retained their lease on approximately 2,000 acres of Oyster Bay bottom and have done so with the support of local baymen who view the seed planting program as an important management approach for the hard clam fishery in Oyster Bay. The general acceptance and stability of this lease agreement has solidified the firm's position in shellfish mariculture. It should be noted that this private firm, a long-standing institution in that community, was able to develop a good working relationship with the relatively few full-time baymen in Oyster Bay. It remains to be demonstrated that new public-private cooperative programs can develop today in towns where the number of baymen is significantly greater (e.g., Brookhaven, Islip). For example, Long Island Oyster Farms was required to culture and plant seed clams on behalf of the Town of Huntington, an arrangement which was dropped because baymen of Huntington opposed it. An accurate understanding of baymen's attitudes and behavior toward private mariculture is needed if there is to be cooperation between baymen and private mariculturists.

Private mariculture operations can serve as critical proving grounds for development and evaluation of mariculture methods later transferred into public practice. For example, F.M. Flower & Sons initiated a hard clam seed planting program in 1983 which they will evaluate over a longer term (4-5 yrs) than has heretofore been possible within any public program (D. Relyea, F.M. Flower & Sons, Personal Communication). The relationship between private and public mariculture of the hard clam is complex and may benefit the private and public sectors through cooperative lease agreements and technology transfer, Figure XX-1.

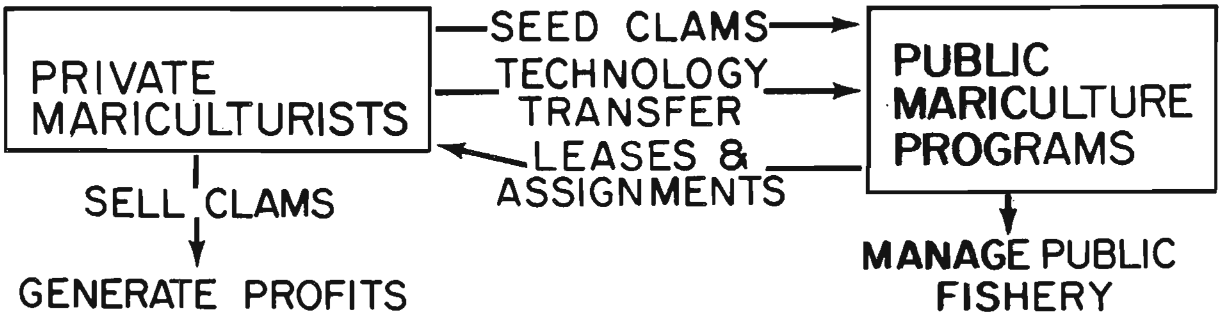

Figure XX-1. Relationship between private and public mariculture.

EVALUATION OF PRIVATE MARICULTURE

As noted earlier, private mariculture is not a management alternative to regulate production of a public fishery but because private mariculture affects and is affected by the status of the public resource, we have evaluated it in this report. Private mariculture is best evaluated in terms of its success and failures in technical, economic, legal and political areas.

Technical Evaluation

Mariculture of the hard clam involves four relatively distinct phases of production: the hatchery, where adult clams are spawned and eggs reared through the larval stages for approximately two to three weeks; the land-based nursery, where the very small post-set clams (0.65 mm shell length) are cultured to a more handleable size of 3-7 mm; the field nursery, where 3-7 mm juveniles are reared to a size more appropriate for release, typically 17-25 mm; and finally, growout, where seed clams are grown to market size (>50 mm).

Private mariculturists have been successful notably in developing and refining technical methods of hatchery production. Although temporary failures of hatchery production are not unknown, the production of many millions of newly set hard clams (<1 mm) is routinely achieved. For example, Blue Points Company of West Sayville produced 100-150 million 0.65 mm hard clams in 1983 and will probably produce more in 1984 (S. Czyzyk, Blue Points Company, Personal Communication). Such levels of hatchery production could easily overrun the capability of the nursery phases of clam production where technical approaches are more site-dependent and less refined.

Land-based nursery systems involve pumping natural seawater rich in phytoplankton through a large number of relatively small (18" diameter) "upwelling" columns each of which contains several thousand seed clams. The clams filter out phytoplankton which are maintained in suspension by the vertical motion of the pumped seawater which also tends to suspend the clams and prevent accumulation of feces and sediment. As the seed grows, the biomass is thinned out by transferring some of the clams to additional upwelling columns thus increasing the scale of the land-based nursery as the stock grows from post-set sizes (0.65 mm) to the 5-6 mm sizes needed in the next phase of production.

To date, mariculturists have not succeeded in resolving two major shortcomings of land-based nursery production: (1) the production system requires an ever-increasing supply of seawater which must be pumped at ever-increasing costs, and the quality of which (particularly in terms of phytoplankton content) cannot be controlled; and (2) whereas millions of larvae are reared in each hatchery culture, only thousands of seed may be handled in each of the small upwelling columns. The lack of larger-scale upwelling columns, or other alternative methods for rearing small seed clams, represents a bottleneck in the overall production of hard clams. For example, the land-based hard clam nursery of Flower & Sons can accommodate only half of their production of clam post set, and the remainder are discarded (D. Relyea, F.M. Flower and Sons, Personal Communication).

Small seed clams from the land-based nursery are transferred to the field nursery at 3-7 mm shell length. The placement of seed clams into the field obviates the need for pumped seawater but exposes the young clams to natural causes of mortality, most notably predators. Technical approaches to the field nursery are diverse with no clearly superior methods prevailing. Seed clams can be placed in mesh or screen covered trays which are nestled into the bay bottom, or supported just above the bottom, or even suspended from floating rafts. The trays may or may not contain gravel or crushed shell as a substrate in which the clams can bury themselves. Seed clams can even be planted outside of mesh covered trays directly onto bay bottom on which gravel has been spread as a protective refuge. Those successful methods which promote rapid growth and high survival trend to be more intensive and thus more costly in terms of equipment and labor. Less intensive practices usually result in poorer yields of seed clams for growout.

The goal of the field nursery is to culture 5-6 mm seed clams to a size suitable for release into the natural habitat. Large seed clams are less likely to be killed by predators than small clams when they leave the field nursery and are planted. Therefore, the field nursery is used to rear clams to as large a size as is feasible. Clam seed of 20-25 mm usually can be grown in a nursery system in one season, and seed of this size is preferred for planting. For most private mariculturists, it is prohibitively expensive to intensively culture large numbers of seed clams much beyond this size although at least one mariculture firm, Coastal Farms of Water Mill, sets out seed clams in large, off-bottom trays which are tended until harvest as littlenecks (C. Steidle, Coastal Farms, Incorporated, Personal Communication).

On Long Island, with the exception of Coastal Farms, the level of husbandry declines in private mariculture as the clams enter the final phase of culture, growout. As in the nursery, there is no consensus among clam mariculturists on the best approaches to growout. The bay bottom on which the clams are planted may be covered with gravel, shell and/or netting for protection of the seed (Clam Farm, Incorporated, Fishers Island), predators may be removed from the site prior to planting (F.M. Flower & Sons), or no actions may be taken to prepare the planting site (Blue Points Company, Sayville). Efforts to insure the survival and rapid growth of the clams may continue, but for the most part, yields of harvestable clams from the growout of seed on private grounds are unpredictable, highly site-dependent, and may be too low to justify the efforts and expenses preceding harvest.

During growout, hard clams typically are planted at much higher population densities (up to 200 clams per square foot) than found in natural populations which are patchy and may range in density from 0 to 20 per square foot. Thus, if conditions are favorable for growth and survival of planted clams, one would expect each acre of planted and tended bay bottom to yield more harvestable clams than each acre of public bay bottom. For example, the Clam Farm anticipates harvesting more than 500 bushels of cultured littlenecks in October, 1985 from several 12 ft x 100 ft plots (75 clams per square foot) covering less than 1 acre of their assignment of bay bottom off Fishers Island (S. Malinowski, Clam Farm Incorporated, Personal Communication). These yields per acre suggest that significant mariculture production of hard clams may be achieved on relatively limited areas of bay bottom minimizing competition for space with the fishery on public grounds.

Blue Points Company has access to sufficient acreage of productive bay bottom (approximately 3,000 acres of their 13,000 acre holdings) to permit planting 17-25 mm seed at densities of only 2-5 clams per square foot on the assumption that growth and losses from predation are improved at these more natural densities without tending the crop.

Economic Evaluation

The major economic advantage for private mariculture of hard clams comes from the unusual price structure of the market. Unlike most other crops where market values climb primarily as a function of product weight, minimum legal size clams, or littlenecks, fetch a much higher price than do the larger cherrystones or chowders. Therefore, very little incentive exists to culture hard clams beyond the size of the littleneck. Consumer demand has always been a prerequisite for successful development of mariculture production of any species; strong consumer demand and pricing of the hard clam market are key economic advantages for private mariculture.

The private mariculturist is able to gain further economic advantage by coordinating harvests with predictable seasonal peaks in market prices (e.g., Christmas season). Baymen working low density or dispersed natural stocks are obliged to harvest clams whenever possible and, lacking facilities to hold the catch for extended periods, to sell them at prevailing rates. The mariculturist probably knows the size and specific location of his crop and can postpone harvest until market conditions are most favorable.

Additional economic benefits may be secured by private mariculturists who opt to distribute and market their product at the retail level. This vertically integrated approach (from spawned egg to retail consumer) has found favor in fledgling mariculture industries where profit margins are initially low as the industry reinvests in further development. Direct retail marketing is not likely to be a difficult task in light of strong consumer demand, however few mariculturists have either the experience in marketing strategies or the time to pursue retail sales.

As noted earlier, private mariculturists of the hard clam can diversify sources of revenue through sales of seed clams to public seed planting programs or to other private mariculture firms whose activities are limited to nursery and growout. At present, there appears to be a trend toward specialized and separate production of post-set clams by hatcheries which sell to nursery operators who in turn produce seed clams for sale to private mariculturists and town programs for final growout.

It is noteworthy that at least two groups (Aquacultural Research Corporation, Dennis, MA and Clam Farm, Inc., Fisher's Island) have sought permission of the New York State Department of Environmental Conservation to market 25 mm seed clams directly to the restaurant trade in New York (for use in soups) and in Pennsylvania (as steamed clams served at bars). Such markets would be important sources of revenue for those in a position to produce 25 mm seed clams. However, the required changes in regulations would promote the illegal harvest of wild seed clams which would be difficult to distinguish from cultured seed, and therefore, no action has been taken to change regulations which prohibit direct sale of seed clams to consumers.

The real and potential economic advantages for the private mariculture firm are counterbalanced by costs of production and further offset by poor returns of planted seed clams after growout. In simple terms, the profitability of hard clam mariculture depends primarily upon the cost of producing seed clams and the survival (recovery) of the clams to market size.

Elsewhere in this report and Malouf (1984) estimated the total costs of seed production at $25 to $35 per thousand seed clams (25 mm), including costs incurred in the hatchery and the land and field-based nursery operations. At prevailing retail values of $85 per bushel of littlenecks (500 count), 15-21% of the planted seed must be recovered after 2-3 yrs of growout just to cover seed production costs of $25-35 per thousand. Furthermore, these estimates do not include expenses associated with planting, maintaining and harvesting the clams, depreciation of equipment or the loss of earning power of money tied up in facilities and inventory of undersize, unmarketable clams. High rates of recovery at harvest must be achieved to cover all costs and provide a profit, yet documented estimates of survival to 50 mm rarely exceed 15% and often are less than 1%.

While the costs of production are reasonably well understood and predictable, methods to insure substantial harvest are not. Clearly, the economic outlook for private mariculture hinges on development of technical advances which improve growth, survival and recovery during growout.

In mariculture, research programs should focus on predator-prey relationships (to develop predator control or avoidance methods), genetic variability (to select for rapidly growing or disease resistant broodstocks), reproductive cycles and energy budgets (to improve species specific culture practices), ecological relationships of larvae (to predict and enhance natural recruitment), the carrying capacity of the environment, and the environmental impact of mariculture activities. There also is a clear need for socio-economic studies of attitudes of key interest groups (commercial fishermen, mariculturists), jurisdictional responsibilities for leases and promotion of mariculture, and the economic soundness of various approaches to development of the mariculture industry (individuals, cooperatives, corporations).

Legal and Political Constraints

> "The relative status and significance of mariculture on Long Island will decrease in the future if a change in the perception of mariculture as a legitimate coastal zone activity on behalf of State, County, local government and the public does not occur."

> "With a few exceptions, government has generally shown a lack of interest in encouraging private mariculture in its Long Island coastal zone. Government inertia, funding constraints, local public opinion against private mariculture development of any sort as voiced by commercial fishermen groups, and a lack of knowledge on mariculture itself are the causes of government inaction." (Koppelman *et al.* 1979).

> "Private investors believe New York to be disinterested in aquaculture and therefore many do not select the state for siting their industry. Without encouragement for such investment, aquaculture will continue to be a small, almost hidden, enterprise" (Squires 1984).

The development of new mariculture enterprises in Suffolk County's coastal zone is restricted by technical criteria for culture of various species; and by commercial limitations of mariculture and the ability of the culturist to acquire ownership, lease, or access to coastal waters and underwater lands with characteristics compatible with the criteria. Growth of private mariculture will require a change in attitudes by government and public alike and implementation of baywide management plans that sub-divide and allocate available areas to competing uses. Improved management, and in some cases further restrictions, will be necessary to assure equitable access to common property marine resources by competing groups.

LONG ISLAND AS A LOCATION FOR MARICULTURE DEVELOPMENT

Long Island has an exceptional set of natural, human and industrial resources conducive to development of coastal zone mariculture (Davies 1984):

(1) Local waters are rich in nutrients and are exceptionally disease free. The annual regimes of water quality parameters, particularly temperature, are favorable to the reproduction, growth and survival of target mariculture species. Concentrations of toxic pollutants are generally very low, and toxic "red tides" (dinoflagellate blooms) that have resulted in shellfish toxicity and the closure of shellfish grounds to protect public health have not occurred in New York state waters.

(2) Long Island firms have already demonstrated the successful culture of the eastern oyster (*Crassostrea virginica*). The hard clam (*Mercenaria mercenaria*) and some finfish species are raised commercially at the present time and offer an opportunity for increased production in the future. Other candidate species include bay scallop (*Argopecten irradian*), blue mussel (*Mytilus edulis*), American lobster (*Homarus americanus*), American eel (*Auguilla rostrata*), winter flounder (*Pseudopleuronectes americanus*), soft clam (*Mya arenaria*), bait worms and marine plants.

(3) Some Long Island communities rely heavily on marine-related economic activities, and a marine-oriented labor force is available for mariculture operations.

(4) Knowledge and expertise in mariculture technology is locally available. Ten mariculture firms currently operate on Long Island; five of these firms have shellfish hatcheries and one, a finfish hatchery. Academic research institutions, such as the Marine Sciences Research Center, at Stony Brook, State University of New York and government agencies,

including the New York State Department of Environmental Conservation, and some town bay management programs, have extensive expertise with mariculture activities.

(5) There is strong support by commercial fishermen of government-sponsored mariculture research and activities geared to the propagation of hard clams on public bay bottom. This support is primarily caused by declining yields from the wild fishery.

(6) High quality seafood products, which command premium prices, are already grown, harvested and marketed on Long Island. Successful marketing systems have been developed to take advantage of the Island's proximity to a major metropolitan area with diverse ethnic groups. There appears to be a large domestic market potential for additional quality shellfish and finfish products.

Despite the advantage listed above, some problems still inhibit investment in Long Island mariculture ventures:

(1) Lack of action by the State of New York and Suffolk County has tended to discourage additional mariculture development on Long Island. This attitude, resulting from positions taken by commercial fishermen and other segments of the public, has discouraged some local firms and individuals, as well as those from outside the region, from considering Long Island as a location for mariculture enterprises.

(2) Secure, long-term access to additional bay bottom for use in culture operations is generally not available.

(3) Financing is difficult to obtain because the uncertainty cost associated with mariculture ventures is high. The high cost of energy on Long Island may also discourage mariculture development here.

(4) There is strong local opposition to extensive private control of marine lands. Local commercial fishermen apparently believe that mariculture ventures, once established and expanded or consolidated into large-scale operations, will restrict access to heretofore public fishing grounds and eventually lead to elimination of commercial fishing in coastal waters as a way of life.

(5) Anglers, recreational boaters, and shoreline residents have opposed mariculture activities.

(6) Gaps and ambiguities exist in State and local laws regulating the conduct of mariculture activities. The resulting uncertainty and the split of jurisdiction and responsibilities among State and local governments have impeded progress in the allocation of common property marine resources for mariculture use.

Government Posture on Mariculture Development

Obtaining rights to utilize common property marine resources for private mariculture activity in Suffolk County is problematical. At present, only one of the ten townships in Suffolk County leases underwater land to private concerns for shellfish culture. A total of 699 ha of underwater land in the Town of Huntington is leased to one firm with a term that expires in 1995. The remaining towns have not demonstrated an interest in leasing lands for mariculture ventures. This situation effectively curtails development of new private mariculture ventures utilizing underwater lands owned by the towns.

The State of New York through its Department of Environmental Conservation (DEC) has not leased any underwater lands for shellfish culture purposes in Long Island Sound, Gardiners or Peconic Bays, even though it has been empowered to do so since 1972 under Section 13-0301 of the Environmental Conservation Law. About 20,000 ha of underwater lands were franchised or leased by the State under previous laws during the peak of Long Island's oyster industry in the early 1900s. Most of these lands have reverted to the State; oyster franchises on 686 ha in Long Island Sound remain in effect. DEC has recently developed a program where interested parties can acquire a "Temporary Marine Area Assignment" for the placement of off-bottom structures for shellfish culture on State-owned underwater lands. Such assignments, which cover circular areas approximately 2 ha in size, must be renewed annually. To date, DEC has issued two assignments--one at Fishers Island, the other in Long Island Sound adjacent to the Town of Huntington.

The total acreage of underwater lands owned by Suffolk County is small compared to that owned by the towns and the State. Suffolk County owns several small tracts of underwater land in Great South Bay and Narrow Bay, and also has the authority to issue shellfish cultivation leases in Gardiners and Peconic Bays where underwater lands are owned by the State.

Suffolk County once was active in managing the Gardiners and Peconic Bays area for oyster culture pursuant to State law (L 1884 ch 385 as amended). After the decline of the oyster industry in the northeast, County activity and interest waned. Perplexing jurisdictional regimes and the need for a more modern administrative mechanism led to, "An Act to cede lands underwater of Gardiners and Peconic Bays to Suffolk County, and in relation to the management of such lands for the cultivation of shellfish," (L 1969, ch 990) passed by the State Legislature. Under this law, Suffolk County has authority to lease underwater lands for shellfish cultivation and to develop an overall shellfish management program for the area. Of the 43,000 ha of bottom land under county shellfish management authority, about 3,400 ha are under the private control of 24 corporate and individual owners as a result of grants made by the County in the past. Chapter 990 requires that the underwater lands within 1000 ft. of mean high water (6,600 ha) be exempt from any leasing program, and hence, reserved for public use. The remaining acreage in the region--32,900 ha--is potentially available for shellfish mariculture through lease in agreement with Suffolk County. Further reductions in this acreage figure must be made to maintain public access to productive bay scallop beds and to avoid conflicts with other users. However, because the requirements of Chapter 990 have not been met, Suffolk County does not have the power to implement shellfish management activities, nor does it have a regulatory program or plan upon which they should be based. Suffolk County's power to implement leasing is also contingent upon meeting the requirements of Chapter 990.

RECENT DEVELOPMENTS

Eliminating the constraints to mariculture development will require action at the State, County and town levels. Koppelman *et al.* (1979) recommended the following actions:

(1) reform of laws governing culture activities in Long Island coastal waters

(2) town consideration of the potential and significance of mariculture activities in the development of flexible bay management programs that reserve the option of leasing marine areas under town jurisdiction for mariculture;

(3) preparation of comprehensive mariculture management programs and policies by the State and Suffolk County.

Symposia on the subject of mariculture have called upon governments to allocate a portion of the marine area under their control for conduct of commercial mariculture activities (Fink 1980; Schubel 1982).

The New York Sea Grant Institute final draft report, "Aquaculture Development in New York State" (Squires 1984) identified opportunities associated with expansion of aquaculture in the State (alternative marine-oriented employment; new source of local seafood production; expansion of local and export seafood markets), as well as constraints on such expansion (restricted access due to the existing legal framework; limited capital availability for investment; regulatory costs; conflict with other user groups, etc.). It also defined a course of action in the form of recommendations that can be used by lawmakers, agency officials and others wishing to promote aquaculture over the long-term in the State, regardless of whether or not the final report is formally adopted by the State Legislature. There is no need to repeat all the recommendations here. Two worthy of mention, however, are:

(1) the assignment of the task of promoting aquaculture development to a state agency (such as the Department of Agriculture and Markets as evidenced by their recent request for proposals on aquaculture development, or the Urban

Development Corporation through their implementation of an aquaculture demonstration project); and

(2) the need for a conference involving State agencies (DEC and Office of General Services) and Suffolk County "to clearly identify lead responsibility for making underwater lands available for aquaculture development in New York." Authority to implement a regulatory program involving the granting of leases would be established "through the conference."

OUTLOOK

We have defined private mariculture, described the interdependencies between public and private programs and evaluated private mariculture in technical, economic, legal and political terms. Next we turn to the question, what is the near-term outlook for the development of private mariculture generally and for private production of hard clams specifically?

It is not clear at this point that private mariculture of the hard clam is a profitable venture although there are promising operations such as the Clam Farm on Fishers Island. The economic outlook for hard clam culture hinges primarily on technological improvements to increase survival during growout. Economic feasibility is not likely to be demonstrated until someone gains exclusive access to a segment of bay bottom, resolves these technical barriers and makes money raising clams. Until then, hard clam culture remains a risky enterprise. Very few people are willing to take financial risks required to develop a new industry, especially in the face of local opposition to leases and assignments of bay bottom. At the same time, opposition is unlikely to moderate in favor of an economically unproven activity. The result is an impasse to development. Figure XX-2 illustrates, in a very simplified manner, the impasse which constrains development of private mariculture on Long Island.

A few individuals working on DEC's temporary assignments might eventually resolve major technical problems to growout and make profits culturing clams. If their examples generate public and governmental support for private mariculture, the impasse might eventually break down (right hand side of figure). If jurisdictional barriers to leases were legislatively removed regardless of local opposition (left side of figure), private mariculture activities might increase more rapidly, eventually breaking down the impasse. However, in this case the costs and risks of developing successful methods might be greater than if these methods were developed by individuals on a small scale. The role of private mariculture in the future of the hard clam industry of Suffolk County is perhaps best examined as scenarios representing integrated analysis of events likely to occur over the next 10 to 15 years. We have restricted the discussion to three different scenarios. Each is presented as a set of assumptions

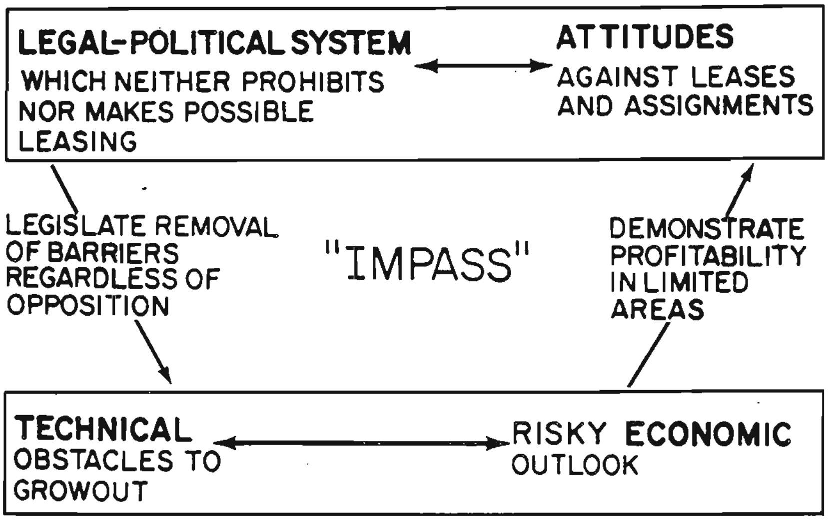

Figure XX-2. Summary of relationships among technical, economic, social and legal forces which maintain the impasse to mariculture development in New York.

and probable consequences, although the actual outcome is likely to be based on some combination of these, and as yet unknown events. The objective of presenting these scenarios is to stimulate thoughtful discussion, not to predict the future.

Scenario I: "Political and Social Status Quo"

Assumptions:

Current attitudes of commercial fishermen toward the development of private mariculture will persist. It is generally believed, although not confirmed through research, that these attitudes are strongly negative.

The catch fishery for hard clams is "institutionalized" as a way of life, but it has failed recently because the significant decline in landings has led to a reduction in employment opportunities (fewer active clammers).

The population of Suffolk County will continue to grow. Eastern Suffolk County towns will face greater pressure from residential and commercial developers than they face now. Population growth will increase the likelihood of degradation of the coastal environment and will increase pressure to allocate marine resources to specific user groups.

Consequences:

Efforts to modify numerous legal and financial constraints on the development of private mariculture will not be initiated or will fail to materially alter the restrictions on private mariculture. Sea Grant Institute recommendations will not be adopted. State, County and towns will not promote private mariculture.

Out of state investors and entrepreneurs will seek other more favorable locations for development of this industry.

The few private mariculturists now operating in Suffolk County will persist, but only as long as their access to bay bottom is assured, and environmental degradation does not affect their ability to culture and market a crop, and they can document a profit from the activity. If any of these mariculture operations fail, for whatever reason, they are very unlikely to be replaced or reinitiated, that is, private mariculture will decline in the County.

Private mariculture as a legitimate industry and use of the coastal zone will not be "institutionalized" and will shrink from "a small, almost hidden, enterprise" to a further reduced position.

The political influence of baymen will become less important as their number relative to the general population is reduced.

As more of the County is developed, common property marine resources will be specifically allocated to prominent user groups (recreational boaters, anglers, shoreline residents) and degradation of the coastal environment, on which the catch fishery and private mariculture depend, will become likely. Landings in the catch fishery, which apparently have been cyclical in the past, will continue to rise and fall but peak landings over the long term will decline.

If private mariculture is not legally and economically "institutionalized," and if employment in the hard clam catch fishery continues to shrink, both forms of hard clam production will be given very low priority as marine resources are reallocated, further reducing the importance of Suffolk County's hard clam resource and its economic impact.

Scenario II: "Modest Endorsement of Mariculture Development"

Assumptions:

Of the more than 50 recommendations summarized in the New York Sea Grant Institute's "Aquaculture Development in New York," legislative action will be taken on only two of the major points in spite of continuing negative attitudes of baymen:

(1) A state agency will undertake responsibility as the lead agency for promotion of aquaculture;

(2) A conference of DEC, New York State Office of General Services, Suffolk County and possibly town governments will clarify lead responsibility for making underwater lands available for aquaculture development.

Through expanded research and development, some technical advances will be made in resolving major problems in hard clam mariculture, including the improvement of survival of hard clam seed during growout to market size.

The population of Suffolk County will continue to grow. Eastern Suffolk County towns will face pressure from residential and commercial developers. Population growth will increase the likelihood of degradation of the coastal environment and will increase pressure to allocate marine resources to specific user groups.

Hard clam landings in the catch fishery continue to fluctuate but peaks of landings are never as great as those of the late 1970s. Sustained employment opportunities in the fishery will not increase, and probably will decline.

Consequences:

A limited number of very small-scale private mariculture operations will be started, at first on privately held lands or on DEC assignments, but eventually through leases of small tracts (<5 acres each) of State-owned bay bottom. The total area under private control probably will not exceed 500 acres.

Attitudes of baymen will moderate. Interest in mariculture will develop because the catch fishery will not improve and because small-scale hard clam mariculture on State assignments and leases will be demonstrated as profitable and will not interfere with the wild fishery.

One or more towns will elect to stabilize hard clam production and harvests for their town residents through the establishment of a town mariculture cooperative operated on town held lands by 25-30 town residents. Total area of bay bottom under culture will be approximately 200 acres.

Total annual harvests from all mariculture production of hard clams will exceed 400,000 bushels (a conservative estimate based in part on The Clam Farm's operation: 75 clams per square foot (average size, 35 mm) in small plots spread out on less than 700 acres of bay bottom intensively managed by 100-150 people). Mariculture production added to the unchanging landings of the catch fishery (200,000 bushels per year) will total more than 600,000 bushels, a figure close to peak landings of the late 1970s. Consumer demand will be as strong as during the earlier peak of supply and mariculturists and catch fishermen will sell at profitable levels. Strong demand for 5-7 mm seed clams (250 million for mariculture; 5 million for town programs) will support the nearly year-round operation of 2-3 privately operated hatcheries employing an additional 25 people in the industry.

The trend for consolidation of these many small-scale operations into a few well-capitalized corporations is probably a principal fear of catch fishermen. Restrictions on assignments and leases will be developed to prevent monopolization of bay bottom by a few large corporations.

Through increases in total hard clam production, private mariculture and the catch fishery will be seen as high priority uses of coastal areas. The hard clam activities of catch fishermen and culturists will be institutionalized and persist as the common property marine resources are allocated.

Scenario III: "Mariculture of Alternate Species"

Assumptions:

The presumed negative attitudes toward private mariculture on behalf of hard clam catch fishermen will continue, principally because their way of life is threatened by private control of bay bottom now open for clamming.

Legislative action will be taken (1) to promote aquaculture through an appropriate State agency, and (2) to clarify responsibility for making bay bottom available for aquaculture (see assumptions of Scenario II).

The population of Suffolk County will continue to grow, increasing (1) the likelihood of degradation of the coastal environment and (2) pressure to allocate marine resources to specific user groups.

Hard clam landings in the catch fishery continue to fluctuate but peak landings are never as great as those of the late 1970s. Sustained employment opportunities in the fishery do not increase, and probably decrease.

Consequences:

A limited number of small-scale private mariculture operations will be started on privately held bay bottom and on DEC assignments (with local endorsements). To minimize conflict with the hard clam catch fishery, oysters and/or mussels will be cultured and all assignments are sited where there are not natural populations of clams, oysters, or scallops.

If capitalization of small-scale operations into large-scale operations is carefully regulated to limit corporate control of bay bottom, baymen may view private mariculture as a legitimate use of marine resources.

Through demonstration of profitable operation of oyster or mussel culture on a small scale, underemployed clammers will be drawn into mariculture as a means of preserving their way of life in the face of declining landings in the catch fishery.

As technical advances are made to improve survival of bivalves during growout to market size, baymen and mariculturists alike turn to mariculture production of hard clams.

Successful culture of alternate species in itself could lead to the "institutionalization" of private mariculture as a legitimate use of marine resources, but by generating interest in mariculture in general, the culture of alternate species will also materially aid in the development of private mariculture of the hard clam.

Lessons To Be Learned from Scenarios

Instead of discussing two separate hard clam industries, the catch fishery and private mariculture, we might discuss a single industry, hard clam production, which may be pursued by either of these two approaches, or by some combination of the two. There are traditions and strong social reasons for ways in which baymen define their careers, but there is no practical need to rigidly categorize an individual as a baymen or as a mariculturist because the goals of each are closely related and the endeavors of both are threatened. While development of private mariculture is constrained legally and politically, the baymen's way of life is threatened equally by significant and possibly continuing decreases in hard clam landings. Long Island no longer has the environment or the population it had 50 to 100 years ago when the baymen's way of life was defined. In the face of changes brought about by continuing gradual increases in the County's population, it may be in the best interests of baymen and mariculturists to work toward the "institutionalization" of hard clam production to assure the industry's success and continuance through a diversified approach which combines catches and culture. Indeed, many baymen may find it necessary to include some level of private mariculture in their activities to preserve their more traditional lifestyles.

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LAW ENFORCEMENT ASPECTS OF HARD CLAM MANAGEMENT

INTRODUCTION

The need for enforcement in the shellfish industry began as early as the eighteenth century with the first governmental statutes regulating the harvest of shellfish (Kavenagh 1980). Laws were enacted by regional authorities in an attempt to protect the resource and control access to it. But, because marine resources held historical and legal status as a common property to all citizens, an "open resource" (Acheson 1974), baymen resisted conformity to legal prescriptions which interfered with their historical right to use the waters. Management of the resource by legal interdict required a means of forcing adherence to the laws.

The present status of the enforcement of shellfish laws was determined by interviewing attorneys, policemen, harbor masters, conservation officers and a private industry representative. A complete list of those contributing to this report is given in Appendix A.

Discussed here are the current problems of enforcing hard clam fishery laws in Suffolk County. The initial focus is on Federal, State and local mandates which establish the scope of managerial interests and the legal basis by which these interests are implemented. Thereafter, specific examples of enforcement problems are discussed. Finally, Appendix B gives an estimate of the cost for a maximum enforcement situation.

FEDERAL GUIDELINES

In 1925, under its constitutional right to "regulate commerce with foreign nations and among the several states" (Article I, Section VIII), Congress vested authority in the U.S. Public Health Service (PHS) to regulate the interstate transport of shellfish. The growing concern over incidences of typhoid, traced to the consumption of tainted shellfish, led the PHS to convene a conference to discuss the problem of maintaining sanitary conditions in the harvest, transport and sale of shellfish. Federal and State authorities, and representatives of the shellfish industry participated. The outcome of this cooperative effort to evaluate and understand the resource was the National Shellfish Sanitation Program (NSSP)(1925), espousing the following principles:

(1) shellfish represent a valuable natural food resource;

(2) cultivating, harvesting, and marketing of this food resource were valuable components in the financial bases of many coastal communities;

(3) a State and Federal program was necessary to permit the safe use of this resource; and

(4) the transmission of disease by shellfish was preventable and therefore not to be tolerated (NSSP Report 1925).

Studies have documented thoroughly that shellfish can carry human pathogens. Typhoid, gastroenteritis, infectious hepatitus and food poisoning have been linked to the consumption of shellfish tainted with bacteria or viruses. Petroleum products, polychlorinated biphenyls (PCBs), heavy metals, radionuclides and naturally occurring biotoxins also may contribute to degrade the shellfish food crop (Becker 1983).

The concurrence of fecal-coliform with many of these factors has given it a credible status as a barometer of the sanitary condition of potential shellfish harvesting areas. The Food and Drug Administration (FDA) has therefore used this standard in its definition of suitable public health guidelines:

> "Shellfish-borne infectious diseases are generally transmitted via a fecal-oral route. The pathway can become quite circuitous. The cycle usually begins with fecal contamination of the harvesting waters. Feces deposited on land surfaces can release pathogens into surface waters via run-off. Most freshwaters eventually empty into an estuary, where fecal bacteria and viruses may accumulate in sediment and subsequently can be resuspended. Microbes are removed from the water column by filter-feeding molluscs, and from the sediment by detritus-feeding molluscs. Molluscs concentrate microorganisms, including those pathogenic, during their normal feeding activity." (FDA 1984).

Although the Federal Government has no specific law concerning the shellfish industry, its impact on management is clearly reflected in State Laws which conform to its recommendations. Two aspects of today's shellfish industry are the focus of managerial effort: maintaining shellfish as a viable natural resource, and protecting the public health. The primary objective of Federal offices, now administered by the FDA, is to insure that food shipped interstate is safe for consumption. It is the state's responsibility to define what constitutes a tolerable fecal-coliform concentration in its waters. Where the state fails to do so, the FDA may take legal action to quarantine harvesting areas and shellfish products, at the minimum detectable level of fecal contaminants (FDA 1984). Annual inspections of shellfish processing plants enables the FDA to assess each state's conformity to NSSP guidelines. Each month the Federal agency publishes a list of issued interstate shippers licences.

The enforceability of FDA guidelines is dependent on state laws and these must reflect the full scope of the federal guidelines.

"State laws or regulations shall provide an adequate legal basis for sanitary control of all interstate phases of the shellfish industry. This legal authority shall enable one or more departments or agencies of the State to classify all actual and potential shellfish waters for harvesting on the basis of sanitary quality and public health safety; effectively regulate the harvesting of shellfish; effectively prosecute persons apprehended harvesting shellfish from restricted, prohibited, or nonapproved areas; regulate and supervise the shipment and storage of shell stock, and the shucking, packing, and repacking of shellfish; certify and decertify interstate shellfish shippers; make laboratory examinations of shellfish; seize, condemn or embargo unsafe or uncertified shellfish; and restrict the harvesting of shellfish from particular areas and suspended interstate shippers certificates in public-health emergencies." (FDA 1984).

Three classes of individuals are cited as potential usurpers of the resource: "those who are ignorant of the law, those who believe the law is unjust or unreasonable, and those who have no regard for the law" (FDA 1984). Equipment should be adequate to enforce the laws against the worst of these because, "patrol failure may nullify the public-health safeguards resulting from the sanitary survey" (FDA 1984). Such equipment should include "patrol boats capable of operating in open waters (small, high-speed, readily transportable boats); patrol automobiles; aircraft; two-way radios for coordinating patrol activities; radar surveillance systems; and night scopes" (FDA 1984).

Aware of the critical relationship between arrests made, prosecution and future illegal activities, the NSSP promotes one final recommendation in its compendium of guidelines for the states; the courts must prosecute.

"The adequacy of State Laws as a basis for prosecution is an important component of (enforcement) activity. Shellfish patrol will probably be ineffective if State laws are so written or interpreted that violators cannot be successfully prosecuted, or if penalties are so small that they are economically unimportant in an area where local public opinion does not support the need for the restriction or the judges and/or prosecuting attorney is not fully aware of the public-health hazards associated with the crime." (FDA 1984).

N.Y. STATE SHELLFISH LAWS

The State of New York conforms to the guidelines of the National Shellfish Sanitation Program. Although the Federal mandate is to protect the public health, the State assumes a broader responsibility which includes the protection of the natural resource.

The Fish and Wildlife Law defines in considerable detail the State's regulatory control over the hard clam fishery. Enforcement of the State's shellfish laws is the responsibility of the Department of Environmental Conservation (DEC) (New York State Environmental Conservation Laws (ECL) 1984).

The DEC is commissioned under Environmental Conservation Laws (ECL) Articles 11 and 13, known as The Fish and Wildlife Law, which provide for the management and regulation of shellfish in New York waters (Becker 1982; Mirchel 1980). It's major responsibility is protecting the public health rather than protecting the hard clam stocks (FDA 1984 unpubl. report; Mirchel 1980). DEC law enforcement comes under the jurisdiction of the Division of Law Enforcement. The Bureau of Shellfisheries is responsible for; the certification of harvestable waters; harvest procedures; times, tools and size limits; inspecting shippers, processers and retailers; issuing shellfish permits; conducting sanitary water analyses for shippers and processers; and operating the State's shellfish transplant or relay program (FDA 1984 unpubl. report). The DEC also works in conjunction with the Department of Health in order to protect the public's health. It is their responsibility to inform prosecutors and the judiciary hearing the cases, of the health hazards of clams harvested from polluted waters (FDA 1984 unpubl. report). However, it is concerned mostly with violations of the sanitary codes and cases that involve interstate and intrastate transportation of unsafe clams.

LOCAL ORDINANCES

Town shellfish laws essentially recapitulate those of the State but also add some clauses relevant to local interests. Examples include, regulation of the dimensions of tongs and rakes, restriction of fishing in town waters to town residents, and controls on recreational clamming.

The Suffolk County Police Department Marine Bureau (SCPD) enforces all the environmental conservation laws and town ordinances. Their time is divided between boating safety patrols, larceny investigations, beach patrols and shellfish enforcement. The latter has lowest priority (Mirchel 1980). The SCPD is the most extensively equipped of the enforcement agencies. Their equipment includes high speed boats, land-based radar, an air boat (for patrolling when the water is frozen), helicopters, and night surveillance equipment. Because of the availability of equipment and manpower, the SCPD patrols at night more regularly than the State or town enforcement agencies. Most of their shellfish enforcement effort is directed toward Great South Bay because of the importance of the resource there. Lesser effort is made on Long Island's north shore. No patrols are conducted in the five easternmost towns in Suffolk County due to the relatively minor hard clam resource there (D. Hoffman, SCPD, Personal Communication).

The next level of enforcement is the town agencies whose officials are given authority by each town to enforce the town ordinances. These officials also have the authority to enforce the State ECL's. Their area of jurisdiction includes; installation, maintenance and removal of navigational aids; ensuring boater safety; beach patrols; enforcing shellfish laws; and rescuing disabled boats. Each town agency is organized with slight differences but most have harbor masters or bay constables. However, the town of Islip has a separate marine law enforcement division, the Islip Harbor Police, whose duties include pollution control and participation in shellfish management programs. They are equipped to handle most small to medium pollution incidences. The patrol boats also have water sampling pumps onboard to sample the water for the bay managers. In the Town of Babylon, shellfish enforcement and bay management are part of the Department of Environmental Control. Therefore, one person supervises both operations, which is a more efficient system (K. Fuestal, Town of Babylon, Personal Communication).

Suffolk County Police Department officers have the authority to ticket a violator for either town or State laws, depending on the severity of the crime and/or if the violator is a repeat offender. The fine schedule for infractions of local laws is approximately equal to that of the State. A first offense of harvesting from uncertified waters carries a fine of $250-$500, or imprisonment of up to 15 days, or both. The second such offense within five years carries a $500-$1000 fine and/or six months imprisonment. A similar fine schedule is designed to deter harvesting of undersized clams. Whereas the State Environmental Conservation Law (1984) asserts that misdemeanor violators shall be fined, relieved of license to fish or, in the case of a third time offender, their boats shall be forfeited, local laws go one step further and carry the threat of incarceration (Babylon Shellfish Laws 1980; Brookhaven Shellfish Laws 1978).

ENFORCEMENT PROBLEMS

Although State and local authorities recognize the possibility of complicity between harvesters and commercial buyers in violating shellfish laws, and account for this in the laws, the major force of legal activity is focussed on the fishing baymen and their harvest procedures (Mirchel 1980).

The growth of the hard clam industry in the 1960s and 1970s resulted primarily from healthy profits accruing to those relatively few professional clammers who had "suffered through the lean years" of the late fifties (Losee 1983). These individuals, having no historical attachment to the industry, often gratified their short-term interest in profits without regard for the long-term health of the fishery (Losee 1983). This generally took the form of poaching in uncertified waters as well as taking undersized clams.

The traditional baymen held a sense of personal responsibility for the resource; making large scale, expensive efforts to enforce harvest restrictions unnecessary. With the influx of new baymen, and as poaching became more attractive, enforcement needs increased dramatically (Losee 1983). Enforcement agencies, unequipped to provide adequate policing, were slow to respond. In addition, the judicial system was ineffective in prosecuting cases.

Since the 1983 shellfish-related disease outbreak, enforcement efforts have been expanded significantly (Becker 1983). However, because of the problem of dealing with intractable baymen and the extensive uncertified acreage to be patrolled (some 6500 acres in Great South Bay alone (Mirchel 1980), enforcement efforts continue to fall short of their intended purpose. The many creeks and rivers that supply Suffolk County's coastal waters cannot be adequately patrolled at present manpower levels. In part this can be attributed to insufficient funds appropriated specifically to protect the hard clam resource. However, the lack of a coordinated patrolling effort by the three levels of enforcement also translates into reduced enforcement efficiency.

Fundamentally, the need for coordination arises from insufficient manpower and equipment in any one of the agencies to completely service the closed areas. The DEC has only 15 Environmental Conservation Officers and two supervisors for their 24 hours-a-day, seven days-a-week effort to enforce Fish and Wildlife laws and other environmental quality laws in Suffolk County (FDA 1984). These officers can allocate less than half of their time specifically to the hard clam problem. Instead of conducting general surveillance patrols, they conduct specific patrols aimed at apprehending know violators (R. Otterstedt, DEC, Personal Communication). The SCPD is similarly limited in the time it can allot to hard clam enforcement, much of its effort being directed to boating safety, beach patrols, larceny and more serious crimes.

The lack of coordinated effort between State, County and local police agencies produces redundant effort and a less comprehensive enforcement program. Although the officers of the DEC's division of Law Enforcement, the SCPD and the local township bay constables cooperate to apprehend suspected shellfish law violators, joint coordinated patrolling is usually limited to exercises or specific investigations. While the DEC has recently engaged in such actions with SCPD officers in the most problematic patrol areas and in night patrols, day to day contact is still minimal. These initial efforts by the DEC to coordinate such activities have been codified in an "enforcement patrol document" which is designed to expand on this approach to solving the problem of overlapping jurisdictions (R. Otterstedt, DEC, Personal Communication).

Communications among agencies participating in joint patrols are limited by inadequate equipment. Because their radios are not sufficiently powerful to receive DEC reports, it often is necessary for local constables to borrow radios from the SCPD for the purpose of participating in these coordinated activities. Consequently, it is only during these relatively infrequent ventures that the DEC's frequency is monitored. While the DEC and towns of Islip and Smithtown monitor the SCPD frequencies, the reverse is not true. Although the DEC is the lead agency in the enforcement effort, it tends to be isolated from local enforcement agencies. It is this isolation that the DEC is presently attempting to redress. Actual comparisons of manhours spent patrolling the waters, by different agencies, is difficult because there is no standardized recording of the patrol hours. A comparison is shown in Table XXI-1. These numbers indicate approximate hours spent during 1982 and 1983. The SCPD spends more time patrolling than the other agencies and conducts more night patrols.

The enforcement by Blue Points Company far exceeds that of any government enforcement agency. They patrol their grounds 24 hours a day, seven days a week. Company representatives feel that this is a necessity to prevent poachers from seriously depleting their clam stocks. Patrols decrease the amount of poaching, but do not prevent it entirely. Poaching is a frequent occurance; only the blatant offenders are prosecuted. Extensive records are kept of persons seen digging on company grounds; only repeat offenders are charged. The level of enforcement on Blue Points Company grounds is artificially high compared to public grounds. Baymen know that these grounds are actively cultivated, therefore the incentive to poach there is increased.

POTENTIAL TO IMPROVE ENFORCEMENT

Each of the three levels of enforcement meets some of the requirements for conducting a coordinated enforcement effort. The DEC has well trained officers and a mandate to oversee the general protection of the resource. The SCPD and bay constables have more intimate contact with local customs and baymen, and the SCPD has sufficient manpower and equipment. Were these resources coordinated, the duplication of effort would be reduced and more areas could be patrolled more of the time. Enforcement of this magnitude requires a large amount of money. Lack of money is the limiting factor for the State and Municipal enforcement agencies.

TABLE XXI-1

Enforcement Agency Comparison

Agency	Area of jurisdiction	Number of personnel*	Patrol hours for 1983	Source
DEC	Long Island	1 Capt., 2 Lts. 13 Co's	2,034.5 hrs.**	FDA
SCPD	Suffolk Co.	1 Capt. 3 Lts. 3 Sgts. 56 Officers	224-330 hrs./wk.	D. Hoffman
Babylon	10,000 acres	2 fulltime 9 seasonal	1,894 hrs.**	K. Feustal
Islip	20,000 acres	6 fulltime 4 seasonal	168 hrs./wk.	A. Loffler
Brook-haven	16,000 acres	5 fulltime	135 hrs./wk.	T. Loquori
Blue Points Co.	14,000 acres	6 fulltime 3 parttime	360 hrs./wk. 18,000 hrs./yr.	D. Uttley

* Number of personnel for the summer of 1983.

** Total hours spent on shellfish enforcement for 1983.

JUDICIAL COMPROMISE

Even if it were possible to apprehend all violators of hard clam laws, considerable enforcement problems would still exist. Enforcement is ineffective if the violators are let off with minimal fines. This has been and still is a problem with the judicial system. There are two basic aspects of this problem; 1) judiciary's lack of recognition of the importance of the shellfish laws both with respect to the diminishing resource, and the potential health hazards; and 2) the design of the system; rotating district court judges and "turnstyle justice", coupled with the practice of "plea bargaining." The second problem is ingrained and very hard to rectify, the first problem, however, can be alleviated. The consequences of the first problem lead to inconsistent imposing of penalties. Despite the new State shellfish laws, mandating specific fines, judges retain the judicial perogative to either dismiss cases for which they believe the assigned minimum fines are too high, or to permit plea-bargaining whereby misdemeanors (such as the taking or holding of clams from uncertified waters) are reduced to a "rakes overboard" civil violation (J. DeSalvo, Town of Islip, Personal Communication).

Although some violations have minimum fines, some judges may still impose a lesser fine. It is then up to the prosecuting attorney to inform the judge of the minimum fine. In some cases, instead of submitting to this, the judge grants an unconditional discharge. In Islip, a case was dismissed because a certified document indicating the closed waters was not available (a photocopy of the document is inadmissable in court). The conditional uncertified areas are the most cumbersome to prosecute because prosecutors need to determine if more than .25 inches of rain has fallen during any of the previous seven days. These cases are usually reduced to lesser charges unless a strong case can be built.

Plea-bargaining can be useful in the prosecution of hard clam cases. It enables prosecutors to get at least a minimal fine levied in situations where the presiding judge might dismiss the case altogether and allows more cases to be processed. However, this results in a reduced deterrent for violators because they spend less time in court and pay smaller fines. Because local courts are more familiar with the concerns of the fishery, conservation officers are often more inclined to write tickets for violations of town ordinances. Convictions and fines generated by these courts have been consistently higher than those of the state district courts (FDA 1984).

AN INFORMED JUDICIARY

The rotating of judges through the judicial system prevents them from becoming knowledgable about the hard clam situation. Many district court judges view the clam penalties as unjustifiably harsh relative to the cases they are accustomed to dealing with. Compared to the other serious crimes against people which they hear on a regular basis, harvesting undersized or tainted clams for consumption seems trivial. Attempts to educate judges and attorneys by having them accompany officers on shellfish patrols and attend seminars by enforcement officials have been discouraging and largely unsuccessful (D. Hoffman, SCPD, Personal Communication). Judicial compromise and minimal fines, which averaged approximately $25 prior to 1980 and have been only marginally higher since, have tended to prevent existing laws from serving as a deterrent.

The DEC has recently initiated a "court-liason" program designed to establish direct correspondence between conservation officers and the courts. The program depends upon the establishment of uniform appearance dates for conservation law violators and the presence of conservation officers in court on these dates. The officers provide the court with necessary information and recommend fines. The alleged poacher's prior convictions records are also presented, which enables judges to better understand the importance of prosecution and fining in the enforcement of State shellfish laws (R. Otterstedt, DEC, Personal Communication). The most effective solution is rewriting the town ordinances and State laws to include minimum fines (L. Cavalla, Town of Brookhaven, Personal Communication). The baymen will know that minimum fines will be imposed for each offense; this will act as a greater deterrent. Along with this, many of the fines will be increased to be a realistic deterrent. This is presently being done in Brookhaven and was done in Islip about two years ago. If, however, the fines are set too high, then the judges will be likely to grant more unconditional discharges because the minimum fines are too severe.

The New York State laws have also been improved. In 1983 Governor Cuomo signed into law a bill (A-4772[S-3730]) that outlines penalties for harvesting shellfish from uncertified waters. This law specifically states penalties for first and repeat offenders along with increases in the fines. (For a more detailed review see the FDA 1984 unpubl. report) In addition to this law, the DEC has begun a license revocation program. From the spring of 1982 to the spring 1983 over 149 shellfish permits were revoked and over 191 diggers were placed on probation (FDA 1984 unpubl. report). A list of these individuals is distributed to all the law enforcement officials in Suffolk County. The most recent list contains over 80 names of individuals on probation. This program, along with tougher laws and more patrols, has had a definite impact on the poaching problem.

The decrease in poaching has also been a result of economics. The uncertified areas (like GSB in general) have decreased hard clam densities (Buckner 1984). This increases the time required to harvest a profitable amount of clams, increasing the chance of being caught in uncertified waters. Now that enforcement and fines have increased, the incentive to poach is further reduced.

A final solution would be to try the shellfish cases and possibly all the ECL cases in a separate court. This would be similar to the traffic court system, which is able to process a large volume of cases expeditiously because the courts are familiar with the issues. Administrative hearings have also been suggested to handle all the conservation cases (A. Loffler, Town of Islip, Personal Communication). A few cases have been settled in the past with these hearings, but a judge is still required to review the case (R. Otterstedt, DEC, Personal Communication). In 1983, a bill to implement the administrative hearing program was defeated in the State Senate (FDA 1984 unpubl. report). Although many have welcomed this idea there is still not enough support for it to be implemented.

VOLUNTARY HARVEST RESTRICTIONS

Elsewhere in this report self-policing in fisheries is discussed as a method of restricting harvest. In a self-policed fishery "traditional" restriction and sanctions are maintained by communal agreement. In 1983 a voluntary program to prevent harvest in uncertified waters was begun by a group of baymen working with State and County officials. Although this is not strictly "self-policing", it is a voluntary effort on the part of baymen to enforce regulations for the good of the fishery. This program, the Green Seal Program, allows tamper-proof sealed bags to be used by the harvester. These bags remain sealed until they reach the consumer and can be traced to a specific harvester and harvest location. The Green Seal Program is intended to guarantee that clams sold to consumers were harvested from certified waters and thus restore consumer confidence in Long Island clams.

Recent enforcement problems in the towns are also being dealt with. For example, in Islip laws are being written and amended to prevent commercial and recreational diggers from being on the same boat. Another problem in Islip and Brookhaven involves baymen who do not have a permit or fail to carry it with them. Since permits are only dated, not time stamped, the bayman can purchase a permit after being issued a summons. The attorneys and harbor police would like to have an ordinance imposing a mandatory fine for not presenting a license (J. DeSalvo and A. Loffler, Town of Islip, Personal Communication); time stamping the permits when issued may be implemented as a solution (L. Cavalla, Town of Brookhaven, Personal Communication).

Despite all the problems cited, enforcement of hard clam laws has improved over the past five years. The laws have become more defined, fines increased, licenses revoked or suspended, the courts have become tougher, patrols increased, and interdepartmental communication has improved. Generally the system as a whole has improved to a point where it is deterring would-be criminals. All the law enforcers interviewed are satisfied with the enforcement they provide given the present conditions. However, if the number of baymen increases more manpower and equipment will be needed in order to keep pace with the industry.

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APPENDIX A

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Otterstadt, Richard, Captain NYSDEC Law Enforcement Division, Region 1

Uttley, Dave, Blue Points Company

APPENDIX B

THE ESTIMATED COST OF THE MAXIMUM ENFORCEMENT SCENARIO

The Blue Points Company patrols the company's grounds 24 hours a day, seven days a week. Two men are sent out on each patrol, which equals 360 hr./wk. of patrol time. Of this time only about one hour per week is spent on non-patrol duties. The full-time employees receive \$16,000/yr. without overtime (~\$50,000/yr.). The total cost is approximately \$200,000 per year to maintain this level of enforcement. The cost to patrol all of Great South Bay at this level is extrapolated from these costs.

In order to extrapolate the patrol costs, the calculations will be based on 360 hr./wk. of patrol time and only full-time employees (excluding overtime or benefits). Blue Points Company's expenditures per acre per year are \$14.29. This value is multiplied by the acreage to yield the cost for all of GSB. In Table XXI-2 this is listed as total extrapolated costs. The adjusted total cost accounts for labor cost differences between Blue Points Company and the towns. The town's average labor cost for enforcement is \$20,000/yr., which equals \$9.62/hr. The adjusted total cost is determined by multiplying 360 hr./wk., 52 wk./yr. and \$9.62/hr., plus \$50,000 (the 1983 equipment cost for Blue Points Company), divided by 14,000 acres equals \$16.43/acre/yr. The adjusted total cost is then multiplied by the acreage of bay bottom in each town to obtain the total estimated cost. The total cost for patrolling all of GSB 24 hours a day, seven days a week is almost one million dollars per year.

The second scenario based on Islip's projected costs is not included because the information needed was unavailable. The memo outlining the enforcement costs could not be found.

TABLE XXI-2

Estimated Costs of Enforcement

Agency	Area of jurisdiction (acres)	Total costs* for 1977 ($)	Total costs* for 1977 ($/acre/yr)	Total extrapolated costs ($/yr)	Adjusted total costs ($/yr)	Adjusted total costs ($/acre/yr)
Babylon	10,000	64,673	6.47	143,000	164,300	16.43
Islip	20,000	109,461	5.47	286,000	238,600	16.43
Brookhaven	16,000	102,000	1.95	228,800	262,880	16.43
Blue Points Company	14,000	102,000	7.29	200,000	200,000	14.29
Total		307,280		857,800	955,780	

* From Mirchel 1980.

THE HARD CLAM RELAY: NEW JERSEY'S PROGRAM AND THE OUTLOOK FOR SUFFOLK COUNTY*

*This chapter is based on a document prepared by William P. Jenks, Bricktown, N.J. and Bonnie J. McCay, Cook College, Rutgers University.

HISTORICAL BACKGROUND

Some Key Dates in the History of New Jersey's Hard Clam Relay Program

1914	First "condemnation" of shellfish beds in New Jersey
1920	First shellfish "relay" from polluted to clean waters, Navesink River, Monmouth County (followed by Atlantic City 1925 Wildwood 1926; revived in 1930s)
1961	Hepatitis epidemic; closure of many clamming areas in New Jersey
1970	Relay started, Lakes Bay
1973	Extended to all areas between Absecon Bay and Scull Bay in Atlantic County
1974	Soft Clam Depuration Plant, Highlands
1975	Relay extended to Reed Bay, to Great Egg Harbor
1976	March 7th: Resource Survey of Shrewsbury River; Plan for Northern Monmouth County Hard Clam Relay Proposed, and Opposed by Northern Monmouth County Clammers.
1977	Manasquan, Shark Rivers Relays Began; Tuckerton Creek Emergency Relay
1977	Soft Clam Depuration Plants, Highlands
1978	Meeting at Monmouth Beach Marine Police Station: Gale Critchlow, Jack Osborn, and many clammers from Belford and Highlands. It was decided that no relay would start until a depuration plant was built.
1980	Manasquan River, Shark River Relays
1981	Manasquan River, Shark River Relays
1982	Shark River Relay
1983	February 28th: Shark River Relay, 6 days a week June 1st: Navesink River Relay, 2 days a week July 1st: Hard Clam Depuration Plant, Highlands (Harvey) Followed by Shrewsbury River, Sandy Hook Bay Relays, 3 days a week after political pressure

1984 Navesink River, Shrewsbury River, Sandy Hook Bay, 3 days a week and then 5 days after political pressure.

Some Hard Clam Relay Facts

By 1980, 57,065,940 clams had been relayed. In 1980 the relay accounted for 20% of the total hard clam landings in New Jersey. In 1983 10,000,000 more clams were relayed from Monmouth County bringing the total number at the beginning of 1984 to 67 million clams which had been transplanted in New Jersey.

Pollution Problems and Relays: The Early Years

New Jersey's hard clam relay program is a response to the problem of pollution and public-health hazards in the shellfish-bearing waters of the State. These problems are very old and widespread, and are almost inevitable consequences of the urbanization and industrialization of the Middle Atlantic coastal regions. In New Jersey and neighboring New York waters the pollution problems were recognized as early as the 1880s and the resultant public health hazard in 1907. The water quality classification of the State's waters followed numerous surveys and shellfish-linked epidemics in the first decades of the 20th century. By 1914 the State had begun closing shellfish beds in "sewage polluted thorofares." Matwan Creek, which empties into Raritan Bay, was the first to be condemned. Numerous and larger condemnation followed soon afterwards, especially in the backbay waters behind Atlantic City, in south Jersey, and in the large bays, tidal rivers, and creeks of Monmouth and Middlesex Counties in northern New Jersey.

Hard clam relays are among the ways that baymen and State of New Jersey officials have tried to deal with the problem of condemned waters, including the problem of enforcing closures when the incentives to poach or bootleg clams is strong. Clam relays, with the major goal of depleting the resource in polluted waters to reduce the chances of contaminated clams making it to market, are almost as old as the official condemnation of shellfish waters in New Jersey. The first relays took place in 1920 in the Navesink River, northern New Jersey, and in 1925 and in 1926 in Atlantic City and Wildwood in southern New Jersey. The programs were short-lived, but were revived during the Depression years for a while because of strong social pressure to provide more opportunities for the unemployed of the State--a second important goal of New Jersey's relays. We do not know how these relays were organized, but accounts in State records suggest that cheating was a major problem and a reason for their short lives.

1961 Closure of Major Shellfishing Beds

A hepatitis epidemic of 1960-61 linked to clams from Raritan Bay, northern New Jersey, led to today's relay programs. In June 1961, Raritan Bay and the Lower (New York) Bays were condemned. In addition, State and federal authorities surveyed and closed to shellfishing half of Sandy Hook Bay, all of the Shrewsbury, half the Navesink, all of Shark River, Manasquan River, and many portions of the bays all the way down the coast. Within the next decade all of Monmouth County's waters would be closed to shellfishing. Not only were hundreds of clammers closed out of the waters they had worked in for years, but others found that, due to the hepatitis scare, the market for New Jersey clams had almost disappeared. Baymen could not sell clams. Stan Cottrell, a major hard clam dealer in the Barnegat Bay region of the State, planted 7 million clams that summer because he could not sell them. Other buyers refused to buy from clammers.

The situation became desperate and clammmers began to the look for other jobs. Some went into other kinds of bayman or fishing work, some stayed and tried to make a living bootlegging clams. One of the authors (Jenks) of the report upon which this chapter is based was able to get a job in October 1961 with the State's Division of Shellfisheries as a protector or "clam warden," and worked primarily in the northern region. The State badly needed more enforcement officials because illegal clamming grew rapidly in the 1960s and the "pirates"--using large boats for hard clams in the Raritan, Sandy Hook and Lower Bays as well as those using small boats for soft clams in shallower waters nearby--were highly sophisticated and used paid lookouts.

The baymen organized and used political pressure to get help from the government. One thing they wanted, especially the baymen of Belford and Highlands, Monmouth County, was a clam depuration plant. Between 1962-1967 Dr. Harold Haskin and Zell Steever ran an experimental depuration plant at the Marine Police station garage at Monmouth Beach, using two U.S. Public Health Service grants ($150,000 at first, $100,000 later on). This involved large wooden storage tanks, a load of PVC pipe and plywood trays with ultra-violet lights. Jenks helped with his tongs in the patrol boat catching clams for the plant, and found very high densities of clams, taking as many as 3100 littlenecks in 1 hr. 15 min. Clearly, the resource was there. But results of the experiments were inconclusive, especially for viral depuration, and nothing was done for hard clam depuration until about 1980, when the Highland area obtained permits for soft clam depuration and the first plants for that purpose began in 1974 and 1977. Hard clam depuration did not begin until 1983.

Baymen began pressuring the State for hard clam relays in the 1960s. At first, the only ones who were successful were those of southern Jersey. Soon after the hepatitis scare and closures of 1961, an organization of south Jersey baymen, led by Dick Crema and Dick Backley, began to pressure for a hard clam relay in the Atlantic City area. Their objective was the same as that of the Federal government (FDA): to deplete the "hot spots" of dense and abundant clams in order to stop bootlegging. From the clammers' perspective, bootlegging meant the risk of a bad name for their product. These clammers suggested to the State in 1969 that a relay based on individual leasehold be used to solve the problem.

Lakes Bay and Other Relays of the 1970s

Finally, in 1970 a relay began between the condemned waters of Lakes Bay, near Atlantic City, and the clean waters of Great Bay. Working very closely with the baymen on the design of the program, the State created a system of leased lots in Great Bay, to which the relayed clams were taken on a State boat. The clammers harvested the clams in Lakes Bay, under supervision of the State, put the clams in marked bags on the state boat, the Senator Sharp, drove to the docks at Great Bay and joined up with the state boat when it arrived to watch the state dump their bags on their lots. In later years of this Lakes Bay relay, the system was changed to allow more baymen to participate and to reduce the expenses of the State. For example, instead of using the state boat to transplant the clams, baymen were allowed to put the bags of clams into trucks that they rented, which were sealed by the State, and to transport them to the Great Bay lease lots themselves.

At first the leases were 0.5 acre in size, divided into sections labeled A,B,C, as in today's program (Figure XXII-1). Eventually 150 lease lots were created for the relay. Today they are 1.5 acres, and over 200 exist on the charts, but relatively few of those are used. Initially, their overall number was limited to what the State estimated the boat could carry, and access to the leases was on a first-come-first-served basis. There were some problems with this, as the waiting list grew and as some baymen were accused of holding onto leases without actually using them, reducing opportunities unfairly for others. In addition, because the relay lease lots were only in Great Bay and since those who obtained leases were primarily from that area, baymen farther north who wanted to participate found it very difficult to do so. When the State stopped using the Senator Sharp to transplant the clams, this allowed some changes since the boat's carrying capacity was no longer a limiting factor. One change involved allowing some baymen to participate in the relay without having leased lots. They could obtain a special license that allowed them to harvest from condemned waters and to sell what they harvested to other harvesters who held licences for leased lots. In later years, leases were also allowed for relaying purposes in other areas, especially Tuckerton Bay and Swan Point, upper Barnegat Bay.

The Lakes Bay relay was highly successful judging from the number of people who participated and the number of clams taken. Catch per unit of effort rose and fell, as expected in an intensive harvest situation, and so did the number of clammers involved. However, the original idea of "depletion" proved not so easily attainable as expected, because the resource was, and is, exceptionally resilient, with frequent years of good recruitment and growth. Fortunately,

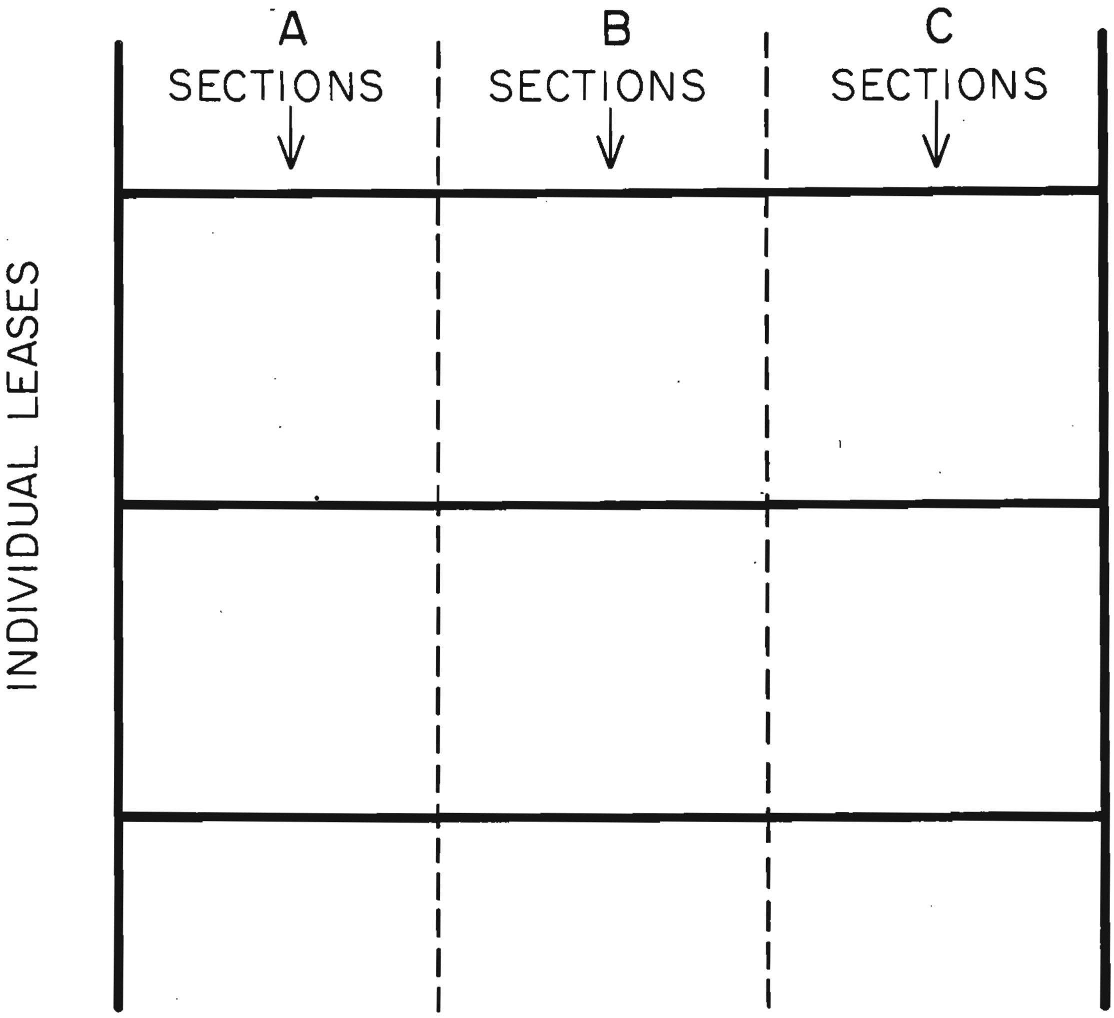

Figure XXII - 1
Diagram of individual 1 1/2 acre leases
divided into A, B, and C sections

improvements in pollution abatement in that area led to reclassification of the water quality of Lakes Bay and enabled a "seasonal opening," so that clammers of South Jersey can work there without a relay during the winter months. Consequently, the Lakes Bay relay ended in 1979. Smaller relays in that area, in the small backbay areas between Absecon Bay and Scull Bay in Atlantic County, had begun in 1973 and in Reed Bay in the same area in 1975; these continued into the early 1980s.

The Northern New Jersey Relay

In 1976 a plan for a hard clam relay from Shark River, Manasquan River, the Shrewsbury and Navesink Rivers, and from Sandy Hook Bay to relay lease lots in clean waters of the State was prepared by baymen in Ocean County and other areas in cooperation with State officials. On March 7, 1976 four clammers participated in a resource survey of the Shrewsbury River toward this end. Clammers of northern communities objected, however, to the idea of a relay. They still wanted a depuration plant. Among their reasons were (1) the long-distance between their homes and docks and the clean water relay lease lots in Barnegat Bay, Tuckerton Bay, and Great Bay; (2) the related difficulty they anticipated in protecting the property they created by dumping clams there; (3) preference for rapid turnover of and payment for clams versus having to wait for 30-45 days after the relay.

The proposal for a "northern relay" raised the issue of territorial rights. In New Jersey the "law of the sea," at least since landmark State and Federal legal cases of the 1820s and 1830s, is that the tidal, navigable waters and resources within the State's territory belong to all citizens of the State "in common." The State is the locus of public trust "ownership." There is no allowable individual, township, or county claim to superior property in or jurisdiction over those resources. However, here as elsewhere there are territorial traditions and sentiments and informal ways of enforcing them (i.e. "State ownership" but "county and town feeling"). The intensity of the northern baymen's feeling about territorial rights was enhanced by the sentiment that since they had waited so long (since 1961) for a legal way to catch the clams of the north, the clams belonged to them. In this case, northern baymen enforced their claims to exclusive rights to the clams in the northern bays and tidal rivers by using political pressure to halt further consideration of a hard clam relay.

Bumper stickers appeared with the slogan, "Clams Stay in Raritan Bay." Meetings with the State and with clammers who wanted a relay were explosive, and the final agreement, after a great deal of hard work on the part of a few of the clammers, was that a relay would be acceptable if and only if the State permitted a hard clam depuration plant as well. The State's Department of Environmental Protection was in the middle, trying to appease both sides as well as State and Federal public health agencies. The clammers finally won both a hard clam depuration plant and a northern relay more by sheer persistence than through efforts of the State, despite the well-meaning efforts of some state officials who were limited by their superiors and state politicians.

Although initially stymied by northern Monmouth County resistance to the relay and by the State's reluctance to approve a hard clam depuration plant, baymen from areas to the south of the Raritan Bay region persuaded the State to allow relays in less controversial territories. In 1977, upon news of the dredging of Tuckerton Creek, Gordon McCourt, a southern New Jersey clammer, persuaded the governor to allow an "emergency relay" to make use of the clams that would otherwise be destroyed. A quick survey of the creek had shown an estimate of one and one-half million hard clams there. The question as to where to put all those clams resulted in the creation of 150 "temporary" lease lots of one-half acre each at a site in upper Barnegat Bay known as Swan Point. One hundred thirty men applied for leases for this relay, and within two and one-half to three weeks all of the clams were removed. This was a one time only relay but it was important in cracking open the notion that the only place to put relay clams was in Great Bay. Accordingly, the State allowed two more relays in 1977, in the Manasquan and Shark Rivers, Monmouth County, south of the region most fiercely defended by the baymen of Highlands and Belford. The Tuckerton Creek and Manasquan River relays were classic "depletion" relays, characterized by large harvests for a very short period of time, until the resource was exhausted. The Shark River relay was similar, but the resource proved resilient enough to enable a handful of men to stay with it until 1983.

The eventual beginning of the northern relay, at first in the Navesink River in June 1983, and in the Shrewsbury River and Sandy Hook Bay soon afterward were due largely to the participation of a few baymen in what one baymen called, in an important essay on the topic, "The Politics of the Clam Bed" (Bill Bauer 1983). The participation by baymen also led to improvements in the organization and operation of the relay. Baymen worked with State senators and assemblymen as well as with State officials of the Departments of Environmental Protection (DEP) and of Health (DOH). Decision making by the State was, to a large extent, a function of political pressure via the politicians involved. The baymen tried unsuccessfully to use the law to force the State to open the northern relay through a large suit against DEP by a baymen's organization of Ocean County and through civil disobedience.

Baymen also worked informally amongst themselves to discuss the issues that divided them and to try to work out mutually acceptable arrangements. For example, to diminish opposition to the relay, Jenks helped some Belford clammers obtain relay leases in Barnegat Bay and even helped them plant their clams, with his own boat, once the northern relay began. He tried to persuade the owner of the hard clam depuration plant that finally began in the summer of 1983 to obtain relay leases himself, since they would help him deal with inevitable gluts on the market. His response, however, was "I would lose face", since he had been publicly opposed to the relay. Conflicts between soft clam and hard clam harvesters in the northern relay area were handled informally, prior to a shellfish council meeting where the agreement was formalized. Private and official meetings with the state officials concerned as well as numerous telephone calls were also essential to the genesis and further development of the northern hard clam relay. It is doubtful that the northern relay could ever have been begun, much less continued and improved, without informal politicking among baymen and between a few highly motivated baymen and state government officials.

RELAY LEASES

The New Jersey hard clam relay program involves the use of leased lots for the placement of clams taken from polluted waters. Clammers work with the State to identify areas suitable for the lots, both in terms of state needs for easy surveillance and in terms of clammers' needs for accessibility and suitable bottom for planting.

The leases are for 1.5 acres, divided into 3 half-acre sections (A,B,C). Just as in some farming systems in which crops are rotated, in the relay lots are rotated. Clams are being dumped on one lot while they are being harvested from another. The decision to close one of the sections and to move to the next for dumping relay clams is usually made informally among relay clammers in consultation with the State chief of shellfisheries and head of the division of water resources who oversee the program. The decision is then formalized at a meeting of the Atlantic Coast Shellfish Council. This decision can be extremely important for the clammers, whose incomes depend heavily on having clams ready for the peak market periods. For example, in the spring, the first lot section used must be closed early enough for it to be reopened to harvest by the July 4th holiday weekend. The State determines the time that a given set of lots may be harvested according to the general rule of 30 days after dumping plus satisfactory test results. The relay leases are lined up one next to another, and all of the "A" "B" and "C" section crosscut the leases in a line (Figure XXII-1) making it relatively easy for a shoreside enforcement officer to determine whether a clammer is in the authorized plot when harvesting.

There is an annual fee of $50 for the lease of one unit (1.5 acres). The relay clammer must also obtain a $25 relay license, and the normal $25 commercial shellfishermen's license. A relay clammer who does not want to plant on a lease may obtain another license, for $25, which allows him to harvest on the relay and sell to a lease-lot holder. Leases must be renewed annually. To retain the right to hold a lease, the clammer must participate in the relay, unless he has valid medical reasons for not doing so.

The relay lease lots may not be used for purposes other than holding relayed clams. Clammers who want leases for other purposes, such as mariculture or storage of clams taken from certified areas may obtain them through the Atlantic Coast Shellfish Council, an industry advisory group to the Department of Environmental Protection which decides on applications for such leases. If a relay lease is not being used, it should return to the State and be available to another relay clammer. If, however, a clammer decides not to participate in the relay he has a period of time during which he may harvest the clams he planted the previous year.

Hard clam relay leasing has not been controversial in New Jersey. Many of the clammers were already familiar with the use of shellfish leases, since they had inherited or purchased old leases that had originally been created for oyster tranplanting. Some also were able to obtain new leases, but only in bottomlands that State biologists showed to be nonproductive for shellfish. The latter is an inheritance from times past when clammers and small-scale oystermen did object strenuously to the creation of private leaseholds in the waters of New Jersey. The basic principle behind such objections remains and is addressed in the hard clam relay program: small-scale shellfishermen should be protected from competition and takeover by large-scale entrepreneurs and corporations. No individual can accumulate exclusive rights to the bay bottom through the lease lots because only one lot is allowed per individual, and the leases is valid only as long as its holder participates in the relay. In addition, these leases, like others in the State, must be in places which biological surveys show are not naturally productive for shellfish.

On the other hand, one of the greatest attractions of the hard clam relay program to New Jersey's baymen is that it gives them access to a lease in the bay bottom and hence to some of the benefits of "private ownership."

Seven Advantages of a Hard Clam Relay

From a Clammer's Perspective

In this section Mr. William Jenks, a New Jersey clammer, identifies seven advantages of a hard clam relay from a clammer's perspective.

(1) It makes a businessman out of a clamdigger, because he has an inventory of clams on his lease. He is more dependable and valuable to a dealer or a fish market.

(2) He can continue clamming when the market is oversupplied.

(3) He has access to better clamming. Today, in the open areas of South Jersey, 200-500 clams are considered a "good day's take;" on the northern Monmouth County hard clam relay grounds 2000-3000 clams are seen as a "good day's take."

(4) He is depleting the dense stocks of clams in condemned waters, making pirating unprofitable and removing incentive to piracy.

(5) He is utilizing a renewable resource that is otherwise wasted or marketed illegally through piracy.

(6) After a day of relaying he is just too tired to think about pirating from closed areas that night.

(7) It is endorsed by the Federal Government (FDA, EPA).

There is a further important point to be made. In the New Jersey relay program, much of the costs of transplanting clams and enforcing regulations, which can be considerable, are passed on to the individual lease holders--the clammers. Leaseholders are motivated to accept those costs by the benefits they gain from having access to otherwise "condemned" clam beds and from the ways that using leases enhance their marketing position.

RELATIONSHIPS OF RELAY CLAMMING OTHER ACTIVITIES

Few of the New Jersey relay clammers rely entirely on the relay for their incomes. One typical pattern is to clam in open waters in South Jersey for one or two days to make money to live on for the week, then come up to the Monmouth County relay for 3 days or so to put clams on the relay lot for future harvesting. Another is to combine relay clamming with a part-time non-clamming job or other bayman work (eeling, crabbing, etc.). Some relay clammers do not use the leases, but sell their clams directly to others who are working the lease lots.

It also is possible to clam on the relay for part of the week, and to clam for the Highlands-based hard clam and/or soft clam depuration plants for the remainder. When the northern relay began in June 1983 this option was not exercised because of the politics that separated the relay clammers, who were mostly from Atlantic Coast areas south of the relay sites, from the "depuration clammers" who were mostly from Highlands and Belford, near the relay sites--which are the same as the depuration clamming sites. However, as the hard clam depuration plant owner began to limit what he would buy from the depuration clammers because of limited plant capacity and market demand (especially for chowders), some of the depuration clammers became relay clammers as well. The State does not allow the clammers to do both depuration and relay clamming on the same day, however.

ENFORCEMENT PROBLEMS

Enforcement is a major limiting factor to the relay in general and to the attractiveness of participating in the relay in particular. The State of New Jersey has very few people available specifically for enforcement of fisheries regulations. One result is that the leasehold property created in the relay lots is not adequately protected from poachers. Relay leases are marked with stakes and, for surveillance purposes, are within easy sight of shore. It is easy for a prospective thief to watch relay clams being dumped and mark the spot, returning at night to take the clams. Thousands of dollars worth of clams have disappeared from some relay leases this way, leading some relay clammers to quit.

The clammers try to monitor activity on the relay lease lots sometimes by rotating night patrol responsibilities. The south Jersey Lakes Bay relay was fairly well monitored this way; large numbers of men were involved, and thus each man had to take his turn only about once a month. The northern relay has proved more difficult to monitor. After the initial bonanza of June 1983 when as many as 100 men were involved, the numbers tapered off to 10-20, of whom only a handful planted in the lease lots. This meant that each man had to patrol one or more nights a week, and it simply did not work. Recently a clammer who puts his relay clams in the Tuckerton Bay lease area has asked the Township to erect a light to help reduce poaching.

Clammers also have tried to gain stiffer penalties for clam thieves. When it appeared that the northern Monmouth County relay would begin in 1983, work began with a State senator and his staff on a bill, passed 14 months later despite some objections from the New Jersey Farm Bureau, that restored an old shellfish law enabling confiscation of the boat (and, in this case, clamming equipment) for invasion of leased ground. So far there have been no convictions of this type, but clammers hope that the law will deter thieves. One goal of the clammers involved in getting this bill passed was to mollify the northern Monmouth County clammers who had insisted that the relay was no good for them because of the likelihood that clams would be stolen from their relay leases. The bill, S. 1170, was necessary because the situation had favored the clam thieves, who, if arrested and convicted, were likely to be fined only $25 to $50, if anything, for acts that could gain them as much as $300 worth of clams for about 20 minutes of work. There has also been talk at the Atlantic Coast Shellfish Council of trying to educate local judges who hear these cases and who often treat theft from clam leases as less important than ordinary property theft. Clammers otherwise are forced to use vigilante methods.

TOWARDS AN IMPROVED HARD CLAM RELAY PROGRAM

The success of a hard clam relay depends very much on how it is designed. New Jersey's program has evolved slowly, and sometimes painfully, with the State taking the style of decision-making known as "incrementalism" or "muddling through" rather than full-scale planning involving a look at a wide variety of alternatives and careful consideration of objectives and means of attaining them. The State has taken its incremental steps primarily because it was forced to do so by baymen and politicians. Much has, however, been learned from the process that may be of use to other states, counties, townships, and baymen's groups interested in beginning a relay.

Recommendations For Selection of Grounds for Proposed Relay Leases

In this section, Mr. William Jenks makes some recommendations concerning the selection of grounds for relay leases.

(1) Grounds should permit easy surveillance from shore. This is important since water-based surveillance by enforcement officers is expensive and difficult during bad weather. In addition, lease lots and boats must be marked with identification codes that are easy to see from shore.

(2) Grounds should have suitable bottom texture, not silt or grassy bottom where clams are likely to die or be inaccessible to the clammer's reach.

(3) There should be no danger of sea lettuce accumulating over the grounds and smothering the clams. This was a problem in the inshore relay lease lots in the Swan Point area where for 2-3 weeks of the year sea lettuce is sometimes six inches to one foot deep on the bottom.

(4) Local clammers should participate in the selection of relay sites. Problems such as sea lettuce accumulation cannot always be determined by on-spot surveys. Clammers in the area are likely to know where and what has happened in the past, how frequently such hazards occur, and under what conditions (e.g. prevailing winds) they occur. The use of baymen to help in site selection has been extremely important in New Jersey's program.

(5) A place to load and unload and dock space for the planting boats should be available near the relay site.

It is hard to find the right combination of the above conditions plus the critical one of good water quality. One problem posed by the need for easy surveillance from shore and accessibility to suitable docking and loading/unloading space nearby is that sites chosen for these reasons may be threatened by pollution, since they may be in the path of what seems an inexorable activity in New Jersey--marina and condominium development. To maintain the relay, the clammers must stay in the battle of trying to halt polluting coastal development, but ultimately must rely on the State and Federal governments' commitment to water quality and environmentally sound coastal zone management. This applies to more than just the relay lots. The relay itself is allowed only for waters classified as moderately, not heavily, contaminated with bacteria and viruses.

Recommendations About Docking Space for Relay

(1) All boats should unload in one place. With multiple landing areas too many enforcement personnel are needed.

(2) The number of landing sites should be adjusted to minimize problems of crowding. Flexibility is necessary in this and other matters. When the site used for relaying turns out to be exceptionally productive, larger numbers of men are likely to participate, resulting in lengthy waits to unload the clams under supervision of enforcement officers.

(3) A boat ramp is desirable to facilitate transferring clams from boats to trucks.

(4) Sites should be selected to minimize problems of vandalism.

(5) Truck parking space should be available.

(6) Boat slip rental should be available nearby at a reasonable cost.

Recommendations About Design of Relay Lots and Relay to Minimize Cheating

There are many opportunities to cheat on a relay, as in other shellfishing and fishing activities, and the amount of cheating is roughly a function of how easy it is. Cheating must be prevented to minimize the chance of a serious epidemic of disease traced to the clams, and to minimize the number of arrests that may raise doubts about the efficacy of the program. However, clammers have few ways of enforcing regulations among themselves, since this is, within licensing limits, a common property resource. Clammers are, however, the best sources of information on how a relay can be designed to minimize cheating. Therefore, they should be used to assist in designing a program. The following recommendations, by William Jenks, come from his experience on the New Jersey relays and trying to work with the State to improve it.

(1) Convince the clammer of the danger of polluted clams. A lot of clammers do not really believe that clams can make one sick; few have read about the evidence for shellfish-borne diseases. This is very important before a relay program is undertaken to impress on the participants the seriousness of the potential for shellfish-borne diseases.

(2) Help clammers find loans or other sources of money to live on for the 45 days it takes from the beginning of an annual relay, in the spring, to the first opening of a relay lease lot. Most baymen live a hand-to-mouth existence, and are thus tempted to find ways to sell relay clams before they have gone through the 30-45 day cleansing period.

(3) Locate lease sites for easy surveillance.

(4) Buffer areas should be established between A,B,C sections of lots. There is a fine line otherwise between relay clams ready for harvest and those dumped later on the lease lot in the adjacent section. In the absence of buffer zones it is very difficult to determine the boundaries between A and B or B and C. A buffer area of at least 100 feet between each of the sections of the lot makes surveillance easier.

(5) Close monitoring is required to document how many clams are taken from the relay harvesting sites, how many are dumped onto the relay lease lots to ensure that relay clams are not sold somewhere in between. Bags need to be counted and trucks need to be sealed.

(6) Signs should be installed on appropriate corners of A,B,C, designating lease number or owner. The leases are staked but not at a specified corner. On rough days it is difficult even for the clammers to know which lease lots are their's and which sections they are in. If the regulations do not specify at which corner of a lease the permit signs should be, signs do not help. One corner should be specified for the signs.

CONCLUDING REMARKS

The above recommendations are based on the details of the New Jersey hard clam relay system and thus not all may be relevant to Suffolk County. However, the basic principles do apply.

(1) Educate the clammers in the public health aspects of the business.

Unless there has been a recent shellfish-associated epidemic and full news coverage of it, clammers are unlikely to appreciate the dangers of eating clams from waters polluted with viruses and bacteria. Even then, they are likely to see only the effects of the epidemic on their market. State or local governments should take more care to educate the clammers, who are the critical epidemiological links.

(2) Design the harvesting and dumping areas for maximum ease of surveillance and law enforcement, balanced against the needs of the relay clammers for flexibility in relation to weather conditions, harvesting techniques, competition, independence, and other factors.

This is not always easy. For example, in the New Jersey program in northern Monmouth County the State initially specified relatively small areas within which the relay clammers could work, to make law enforcement easier. This resulted in a high concentration of clammer, at times over 80, and clearly worked against the grain of most clammers, who prefer keeping information about the "spots" they find, whether "hot" or "cold," to themselves. This year the State has expanded the harvesting areas.

It also took awhile before the State responded to baymen's complaints that the areas selected were inappropriate for typical weather conditions, and that a better mechanism for making changes in the approved areas was needed. The starting and stopping times are another problem; to make enforcement easier they are uniform, with seasonal adjustments according to changing day length. However, if a storm comes up the diggers may wish to come in early, and then are forced to wait until 1:30 p.m. for the enforcement officer to arrive, to check the bags, and to seal the trucks.

Enforcement constraints may lead the state or other governmental unit to limit relay clammers to only a few days a week, as they did in New Jersey in 1983. When the northern Monmouth County relay began, in June 1983, the relay clammers were allowed to work there only two days a week. Through a great deal of political pressure, the relayers persuaded the State to increase this to three days, and eventually, by 1984, to five days a week. While this kind of limitation may make sense from the enforcement standpoint, it may not from the clammers' perspective. If the relay is a long distance from the usual clamming sites of many participants, they must move their clamming boats to the relay site, pay dockage and moorage fees to marina owners, and incur other expenses, which are magnified if they must divide their week up between relay clamming and other clamming in a different area relatively far away.

Another basis for the New Jersey relay clammers' objection to the two or three day limit was more complex, having to do with the fact that, in this particular relay, the shellfish grounds used were also worked by other clammers, those who harvested hard clams for the new hard clam depuration plant and those, to some extent the same, who harvested soft clams for the local soft clam depuration plants. The depuration clamming system has an entirely different organizational basis, and enforcement methods are somewhat different, justifying as many as seven days a week for the depuration clammers. The relay clammers perceived this as discrimination--and often pointed to the statement at the bottom of official state stationery that New Jersey "does not discriminate...." at the meetings where the issue was raised.

What bothered relay clammers most was that on the days they were not allowed to relay, the depuration clammers were working the same beds. In response to political action on the part of the relay clammers, the method of enforcement was changed somewhat to enable relay clammers to work five days a week. Clamming is an extremely competitive, as well as "independent" business, and this economic and social fact should be recognized in the design of management programs.

(3) Involve baymen in the design, implementation, evaluation, and modification of the program.

The general principle behind this is that people whose livelihoods are most at stake and who know the resource, environment, and industry from experience are not only valuable sources of knowledge and advice but invaluable allies of the various branches of government involved in any complex management program. In New Jersey's northern Monmouth County relay program the relationship between baymen and the State (DEP and its water resources, shellfisheries, and marine enforcement divisions; the Department of Health; the State police's marine law enforcement division) frequently was adversarial. The involvement of baymen was forced upon the State, rather than encouraged by it. This was costly for everyone involved and worked against rational planning. It also tended to pit groups of baymen against each other, making it difficult for them to recognize and work upon their common interests.

The State's management style was to develop its own plans first, without official involvement of baymen and present the plans to the advisory shellfish council or to implement them on the water, generating almost ritualistic hostility and allegations of favoritism and hidden political agendas on one side or another. If the state agencies had formally involved a few of the respected baymen in the program at an early stage, some of this could have been prevented. This is a general principle of planning: structure the process for optimal participation by those most affected by the program.

THE OUTLOOK FOR SUFFOLK COUNTY

Although State run relays to public grounds have been conducted in Suffolk County there has not been a program similar to New Jersey's. The major barrier to such a program seems to be in the attitudes of those involved, rather than logistics. Town officials tend to be very parochial about their resources and are unlikely to cooperate in a program that requires intertown transfer of clams. This problem could be avoided only if suitable certified and uncertified areas could be selected within the waters of one town. There is also very strong antileasing sentiment among baymen which would make it difficult to develop the transfer by individuals to individually leased lots. The lack of trust among baymen of different areas proses a problem although this seems to have been overcome, to some extent, in New Jersey.

The involvement of the New York State Department of Environmental Conservation in a shellfish relay program like that described above would seem to be limited to permitting and enforcement. Provisions would have to be made for special permits to allow harvesting of uncertified areas. The State can issue five acre temporary use assignments in the Peconic Bays which could be used by an individual for relaying. Under current regulations, however, the individual would have to pay the State for the additional enforcement needed ($400/week). Therefore, the stocks in the relay area would have to be sufficiently large to compensate the bayman for this added cost.

The biggest difference between New York and New Jersey, with respect to hard clam programs, is the town ownership of much of New York's clamming areas. This means that a successful relay program would require the agreement among several levels of government rather than decisions at the state level only.

APPENDIX A

THE ECONOMICS OF MANAGEMENT ALTERNATIVES FOR THE HARD CLAM IN GREAT SOUTH BAY, NEW YORK

by

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INTRODUCTION

The objective of this paper is to explore the benefits and costs of five management alternatives for the hard clam resource in Great South Bay. The five alternatives are (1) maximum sustainable yield (MSY), (2) maximum employment subject to a lower bound constraint on net revenue, (3) maximum (static) net revenue, (4) maximum present net value, and (5) maximum recruitment to standing stock. The first four alternatives can be viewed as equilibria; that is, conditions which might be maintained or perpetuated in the fishery for some interval of time. The fifth alternative is really a transition or approach strategy which implicitly begs the question: "If the resource stock is less than some desired (equilibrium) level, how quickly should the stock approach equilibrium?"

The first four alternatives will result in different expected revenues and costs for the baymen participating in the fishery. It will be possible to compare these alternatives on the basis of the present value of net revenues. The larger the present value of net revenues the more valuable the fishery to participating baymen and society at large. There are, however, at least two other aspects that need to be considered in choosing among management alternatives. The first is the cost of implementing the management alternative and the second is its equity or fairness. One would presume that a managed fishery would be more valuable than an unmanaged (open access) fishery. Implementing and enforcing a management plan is not costless and one might legitimately ask if the gains from management outweight the cost, and what management institutions can achieve those gains at least cost.

The second aspect, equity or fairness, is more difficult to assess. If a management alternative requires a limitation on the number of baymen or their catch, former or potential bayman who are denied access to the fishery may view the management plan as unjust. We will return to both these aspects in Section IV of this paper.

In the next section we will develop a simple bioeconomic model and identify the four management alternatives in terms of their associated stock, yield, and effort. In the third section we will estimate parameters for growth and production functions which will permit us to identify the alternative management equilibria for the hard clam resource in Great South Bay. We will also assess the length of time it might take to reach the various equilibria from estimates of current standing stock. The fourth section outlines a management proposal which has considerable appeal from a bioeconomic perspective. It has the flexibility to guide recovery and maintain the fishery at or near a desired stock level. The final section summarizes the major conclusions and reiterates the limitations of the study.

BIOECONOMICS

A bioeconomic model is a model which synthesizes the population dynamics of a commercial species with the revenue and cost to harvest. In its simplest form it would focus on a single species describing or measuring the population by a single variable, $X(t)$, denoting the number of individuals or "biomass" (e.g., metric tons) of the population at instant t. There are four components to the basic bioeconomic model: (1) a growth function describing how the population changes in response to net natural mortality and harvesting, (2) a production function, relating yield (harvest) to "effort" and population size, (3) a cost function, relating cost to harvest and population size, and (4) a demand function relating price to the amount harvested. A discussion of these four components necessarily involves a certain amount of technical detail. We have put some of the more tedious details in the Appendix to this paper and will simply reference other results. It is hoped that the noneconomist can wade through the text of this section without too much trauma.

The growth function of a harvested species may be written as

$$dX(t)/dt = X(t) = F(X(t)) - (t) \qquad (1)$$

where dX(t)/dt = X(t) stands for the time rate of change in the population, which may be positive or negative depending on whether net natural growth, represented by the function F(.), exceeds or fails short of harvest. Thus the population increases (X(t) > 0) if net growth exceeds harvest (F(.)-(t) > 0) or decreases (X(t) < 0) if net growth is less than harvest (F(.)-Y(t) <0). The population is unchanged (X(t) = 0) if net growth equals harvest.

There are many specific forms which might be used for the function (F(.). We will explore the implications of two net growth functions, the logistic and the Gompertz. The logistic function may be written as

$$F(X(t)) = rX(t)\ (1-X(t)/K) \qquad (2)$$

while the Gompertz function takes the form

$$F(X(t)) = rX(t)\ \ell n\ (K/X(t)) \qquad (3)$$

where r and K are positive parameters referred to as the intrinsic growth rate and environmental carrying capacity, respectively, and ℓn is the natural logarithm. Without harvest and starting from a low initial population, X(0), the population would increase and approach a maximum population level K determined by food, habitat, and other environmental factors. As the population approaches its maximum the relative or per capita growth rate F(.)/X(t) declines. This is referred to as (compensatory) density-dependent growth.

The logistic function is symmetric while the Gompertz function is asymmetric, being skewed to the right. Figure A-1 shows a graph of both functions for the parameter values $r = 0.5$, $K = 10.0$.

When net growth equals harvest and the population is unchanging $(X(t) = 0)$ Equation (1) implies

$$Y = F(X) \qquad (4)$$

and yield (Y) is said to be sustainable. Points lying along the logistic or Gompertz growth functions in Figure 1 represent (X,Y) combinations where yield is sustainable. Maximum sustainable yield (MSY) occurs at the peak of the growth curve occurring at $X_{MSY} = K/2$ with $Y_{MSY} = rK/4$ for the logistic function and at $X_{MSY} = K/e$ with $Y_{MSY} = rK/e$ for the Gompertz function. Maximum sustainable yield was often the objective of resource managers. As a management objective, however, it ignores cost, revenue, and present value calculations which are important from an economic perspective.

The production function takes the general form

$$Y(t) = H(X(t), E(t)) \qquad (5)$$

where Y(t) is yield or harvest when effort E(t) is directed at a population of size X(t). Effort may be thought of as an aggregate of economic inputs; for example, the number of fully manned vessels, or as a flow input, such as vessel hours, perhaps adjusted for "fishing power". In theory one would like a definition of effort which most closely relates to fishing mortality. Thus hours of "net tow" may be a better measure of effort than vessels or vessel days because the latter two measures do not account for down time in port or hours steaming (as opposed to fishing).

One of the earliest production functions employed in fisheries economics took the specific form

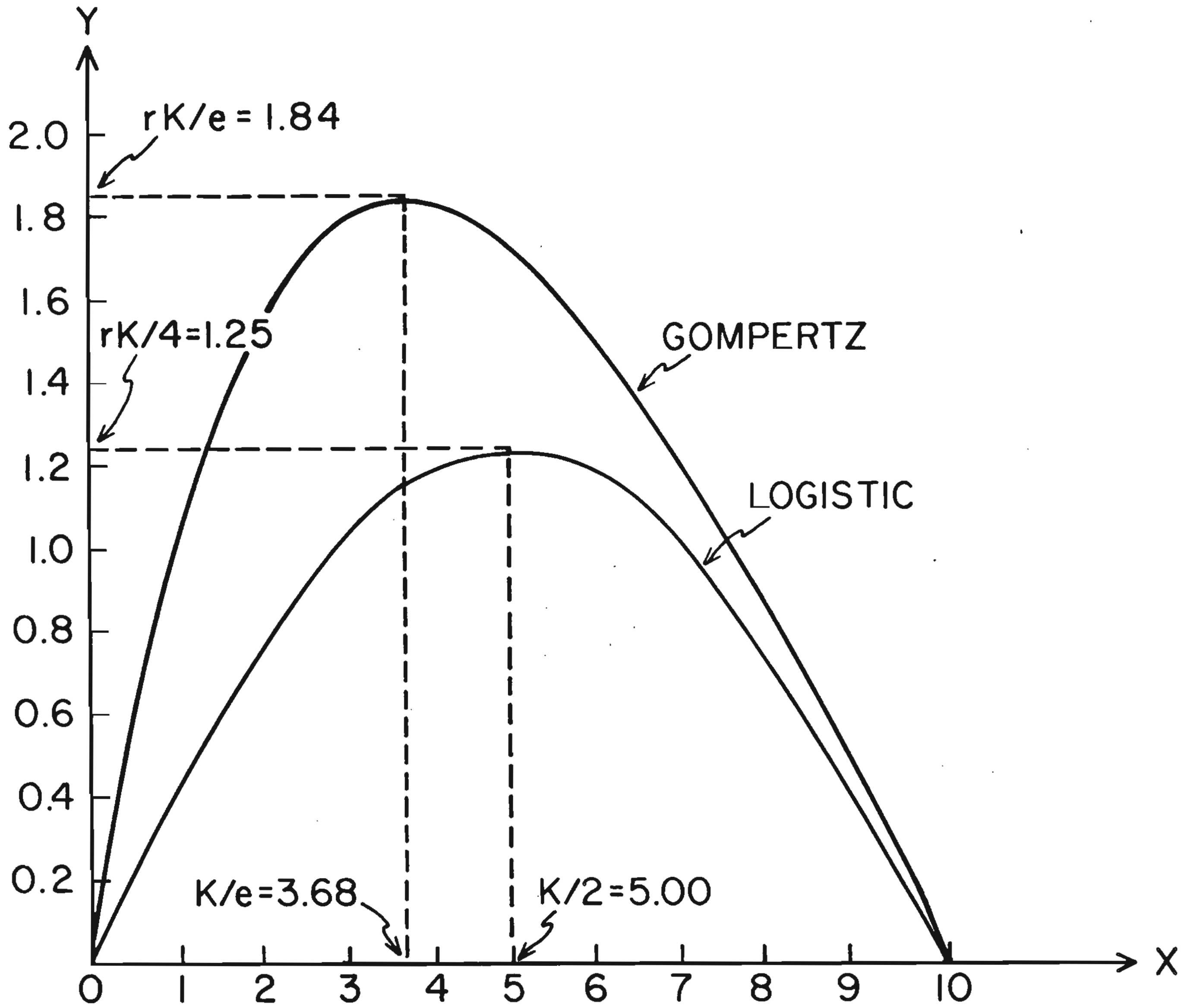

Figure A - 6
The Logistic and Gompertz Growth Functions (r = 0.5, K - 10)

$$Y(t) = qE(t)X(t) \qquad (6)$$

where q is referred to as the catchability coefficient. This production function assumes that catch per unit effort is proportional to the fish stock. Such an assumption, which may not be warranted for schooling fish, would seem reasonable for less mobile, more uniformly distributed species such as shellfish.

The growth function and production function may be used to solve for the yield function. The yield function is an equilibrium relationship relating effort to sustainable yield. In the Appendix we show that the logistic growth function and the catch per unit effort production functions [Equations (2) and (6)] imply the yield function

$$Y = qKE[1-(q/r)E] \qquad (7)$$

The yield function is an important empirical concept because it relates yield to effort, variables which economists and biologists might measure and record through time. By estimating parameters of the yield function one may be able to solve for (identify) the underlying parameters of the growth and production functions. In the case of Equation (7), an ordinary least squares (OLS) regression of (Y/E) on E would produce estimates $\hat{\alpha}$ and qK and $\hat{\beta} = q^2K/r$. If one can come up with an independent estimate of r, K or q one could use $\hat{\alpha}$ and $\hat{\beta}$ to solve for the other two parameters. This approach will be used in the empirical analysis of the hard clam fishery.

For the Gompertz growth function [Equation (3)] and the catch per unit effort production function the yield function takes the form

$$Y = qKEe^{-(q/r)E} \qquad (8)$$

where q, r and K are as before and e is the base of the natural logarithm. By dividing both sides of (8) by E and taking the natural logarithm one will obtain a log linear expression the parameters of which may be estimated by OLS regression of $\ln(Y/E)$ on E. This regression was also run on the hard clam data and will be discussed in the next section.

The third function, the cost function, relates total harvest cost to the rate of harvest and the harvestable population. In our analysis we will assume that an acceptable measure of effort can be defined and that the cost per unit is a constant denoted as c. Total cost is then $C(t) = cE(t)$. Using Equation (6) to solve for E(t) and substituting into the expression for total cost one obtains the cost function

$$C(t) = (c/q)X(t)^{-1}Y(t). \qquad (9)$$

Equation (9) implies that total cost is linear in yield and inversely related to the population size. This makes intuitive sense: a fixed level of harvest will be obtained at a lower cost with a larger fishable population. We will see that this may lead to a situation where it is economic to maintain a population in excess of X_{MSY} if it affords fisherman (baymen) significant cost savings.

The fourth and final component of our simple bioeconomic model is the demand function. This function relates price to the amount harvested. For a resource accounting for a large share of a market (such as hard clams from Great South Bay in Fulton Market) one would expect an inverse relationship; that is, as harvest increases, price decreases. Analysis by Conrad (1980) failed to reveal a significant negative slope term when regressing price p on Y in a single equation or simultaneous equations system. This may be the result of shipments of hard clams from other mid-Atlantic or southern states or from a complex multimarket situation where the price of hard clams in New York's Fulton Market is dependent on the amounts of all other fish and shellfish reaching the market. On the basis of this empirical research, and for mathematical tractability, we will assume a constant price p which is invariant to the amount of harvest Y(t), thus

$$P(t) = p \tag{10}$$

is the presumed demand function.

With these four components of our bioeconomic model we can identify and distinguish between the first four management alternatives listed in section one. We will take each in turn and identify equations that could be used to solve for equilibrium stock, yield and effort if one had estimates of the relevant bioeconomic parameters. We will develop these equations for both the logistic and Gompertz growth function.

Maximum Sustainable Yield (MSY)

From the logistic growth function we saw that (X,Y) satisfying $Y = F(X) = rX(1-X/K)$ were sustainable. Setting the derivative $F'(X)$ equal to zero and checking the second order conditions one can determine that $X_{MSY} = K/2$ and that $Y_{MSY} = rK/4$. Substituting X_{MSY} and Y_{MSY} into Equation (6) or setting the first derivative of the yield function [Equation (7)] equal to zero one can show that the associated level of effort is $E_{MSY} = r/(2q)$.

For the Gompertz growth function the sustainable (X,Y) satisfy $Y = rX\ell n\ (K/X)$ and by similar analysis one can show $X_{MSY} = K/e$, $Y_{MSY} = rK/e$ and $E_{MSY} = r/q$.

Open Access and Constrained Employment

When a renewable resource is regarded as common property there is an incentive to harvest the resource until net revenue is driven to zero (total revenue equals total cost). This has also been referred to as "dissipation of rent" under open access. Open access equilibrium is often characterized by excessive effort and low population (stock) levels capable of supporting only limited harvest. In equilibrium net revenue may be written as

$$N = [p-(c/q)X^{-1}]Y \qquad (11)$$

and if net revenue is driven to zero under open access then the expression in the square brackets goes to zero. Solving for the open access population we obtain $X_\infty = c/(pq)$. If one knows the form of the growth function then open access yield may be calculated as $Y_\infty = F(X_\infty)$. For the logistic and Gompertz growth functions this becomes $Y_\infty = rX_\infty(1-X_\infty/K)$ and $Y_\infty = rX_\infty \ln(K/X_\infty)$, respectively. Open access effort in either case is $E_\infty = Y_\infty/(qX_\infty)$.

Under the second management alternative a regulatory agency might try to restrict effort so that net revenue is positive. Suppose u is the per unit net revenue which the management agency wishes to establish. Then

$$p-(c/q)X^{-1} = u \qquad (12)$$

and the equilibrium stock becomes $X_u - c/[q(p-u)]$. This will typically require the maintenance of a larger stock (i.e. $X_u > X_\infty$). Yield and effort may be calculated according to $Y_u = F(X_u)$ and $E_u = Y_u/(qX_u)$. If effort is measured in terms of the number of part-time baymen then the net income per bayman becomes

$$N_u/E_u = [p-(c/q)X_u^{-1}]Y_u/E_u \qquad (13)$$

Determining the appropriate magnitude for N_u/E_u is subjective decision. If N_u/E_u is regarded as too small (large) one would increase (decrease) u, solve for X_u, Y_{uY} and $_{Eu}$ and recalculate (13) to assess whether the (excess) net revenue per bayman is satisfactory. In general to increase net revenue per bayman one will have to maintain higher stocks and limit access to the resource ($E_u < E_\infty$).

We will see that it is possible to select u so as to achieve what is referred to as the "bioeconomic optimum". At the bioeconomic optimum the present value of net revenues is maximized.

Maximum Net Revenue (Rent)

We have derived a yield function from the growth function and the production function. In general, the yield function in explicit form may be represented as $Y - f(E)$, where $f(.)$ is a single variable function. Using the yield function we may write equilibrium net revenue as

$$N = pf(E)-cE \qquad (14)$$

Economists, when first studying the problem of open access, proposed that a management agency restrict effort so as to maximize (static) net revenue. Setting the first derivative of N equal to zero one obtains the condition

$$pf'(E)-c = 0 \qquad (15)$$

which implies that the management agency will restrict effort so that marginal revenue ($pf'(.)$) equals marginal cost (c). Suppose $E - E_o$ satisfies (15) and the appropriate second order conditions. Figure A-2 shows the relationship of E_o to E_∞ for a yield function derived from a logistic growth curve and catch-per-unit-effort production function when $q = 1$. Note E_∞ is determined at the intersection of revenues ($pf(E)$) and costs (cE) while rent maximizing effort E_o is determined by finding that point on the revenue curve where $pf'(E) = c$.

For the logistic based yield function the rent maximizing level of effort may be solved for explicitly as

$$E_o = r(pqK-c)/(2pq^2K) \qquad (16)$$

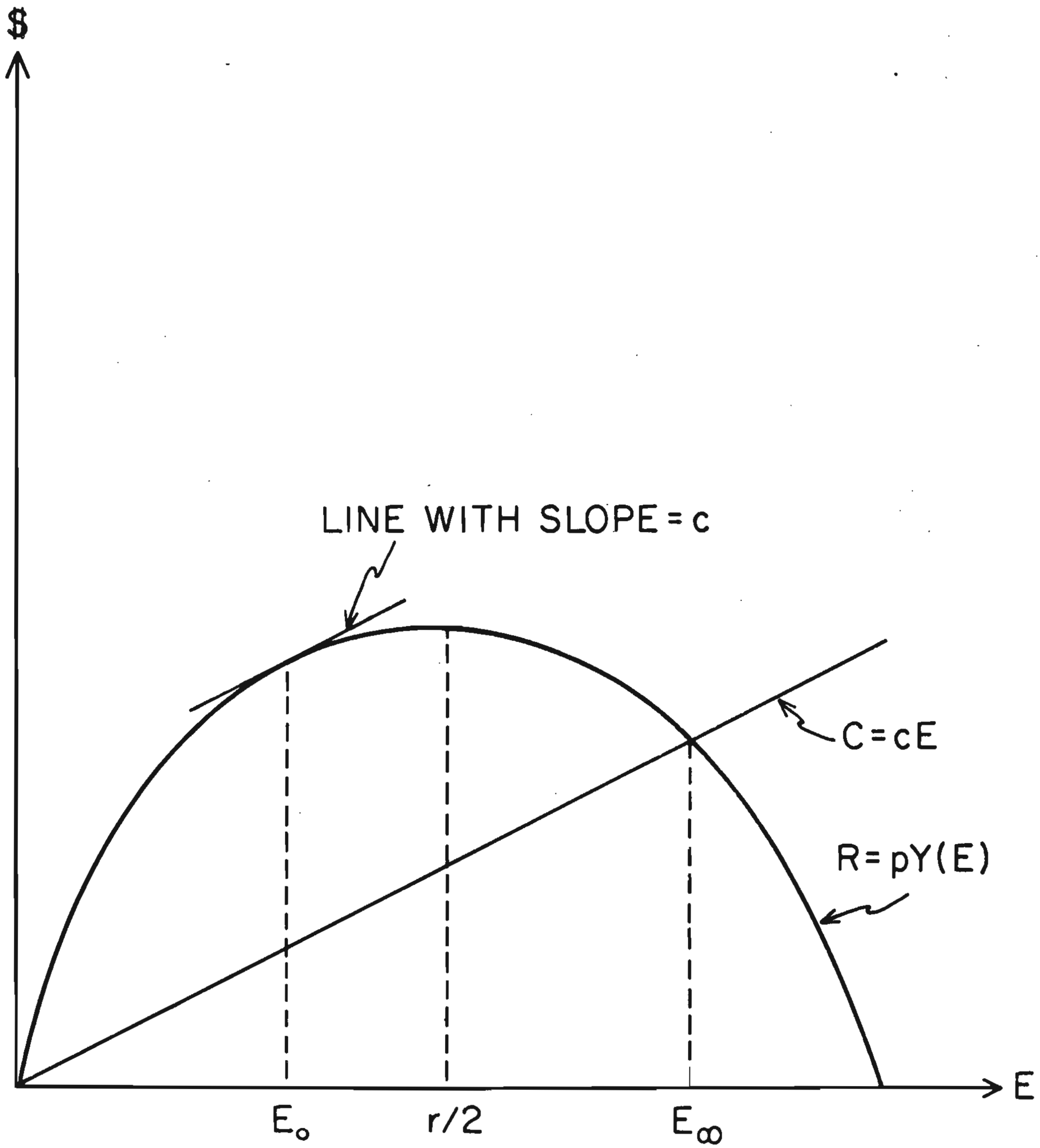

Figure A - 2
Open Access and Rent Maximizing Levels of Effort

for the Gompertz based yield function the rent maximizing level of effort cannot be solved for explicitly but may be solved for numerically according to

$$pqKe^{-(q/r)E}(1-(q/r)E)-c = 0 \qquad (17)$$

Details of the derivations of (16) and (17) may be found in the Mathematical Appendix. After determining E_o one may calculate $Y_o = qKE_o(q/r)E_o)$ for the logistic model and $Y_o = qKE_o e^{-(q/r)E_o}$ for the Gompertz model. In both cases equilibrium stock will be calculated according to $X_o = Y_o/(qE_o)$.

Bioeconomic Optimum

In its modern formulation fisheries management is viewed as a problem of establishing and maintaining the optimal population level, where the fish stock is viewed as a capital asset. From a capital theoretic perspective one would like to maintain the fish stock at a level where its own (internal) rate of return is equal to the rate of return on other forms of capital. This rule is obtained from a dynamic optimization problem which seeks to maximize the present value of net revenues subject to the dynamics of the harvested species. Clark (1976, p. 40) obtains the following equation which can be used to determine the equilibrium stock which maximizes the present value of net revenues

$$F'(X) - \frac{c'(X)F(X)}{[p-C(X)]} = \delta \qquad (18)$$

where F(.) is a growth function, $c(X) = (c/q)X^{-1}$, and δ is the discount rate equal to the rate of return on capital elsewhere in the economy. The resource's own rate of return is comprised of two components, $F'(X)$ representing its marginal growth rate and $-c'(X)F(X)/[p-c(X)] > 0$ which is referred to as the "marginal stock effect" and measures the cost savings from having an additional unit of biomass (e.g., metric ton) in the standing stock.

For the logistic growth function it is possible to solve for the optimal stock, X^*, as an explicit function of the bioeconomic parameters r, K, q, p, c and δ, according to

$$X^* = (K/4) \quad c/(pqK)+1-(\delta/r)+ \quad (c/(pqK)+1-(\delta/r))^2+8c\delta/(pqK). \qquad (19)$$

Optimal yield and effort are $Y^* = rX^*(1-X^*K)$ and $E^* = Y^*/(qX^*)$.

For the Gompertz growth function equation (18) cannot be solved explicitly for the optimal stock. Instead equation (18) implies

$$pqrX\ell n(K/X)-(r+\delta)(pqX-c) = 0 \qquad (20)$$

which may be solved numerically for X^*, and optimal yield and effort may be calculated according to $Y^* = rX^*\ell n(K/X^*)$ and $E^* = Y^*(qX^*)$.

What has been accomplished? If we can obtain estimates of the bioeconomic parameters r, K, q, p, c and δ we can identify (1) maximum sustainable yield, (2) open access and maximum employment subject to any arbitrary net income constraint, (3) maximum net revenue and (4) maximum present net value (the bioeconomic optimum). The yield function provides a possible empirical entry to r, K and q and economic survey or secondary data may lead to estimates of p and c. The appropriate discount rate δ presents some philosophical problems which analysts skirt by solving for the bioeconomic optimum under various discount rates. We now report on attempts to estimate the relevant bioeconomic parameters.

Table A-1 contains estimates of landings, permits and landings per permit for the years 1970-1983 for the towns of Babylon, Islip, and Brookhaven. Precise data on landings is difficult to obtain because of the diffuse nature of the fishery and the incentive to evade income taxation by cash transactions. It is safe to assume that the landings reported in Table A-1 are less than actual landings; how much less is open to speculation.

In our earlier discussion of fishing effort we noted that the ideal measure would be highly correlated with the effective fishing mortality imposed on the resource. Based on this criterion, permit numbers are not a satisfactory measure of effort. A better measure would be the number of hours which baymen spent clamming; or better yet, the number of pulls by tons and rakes. Unfortunately such data are not available and we must make do with permit numbers.

In spite of these limitations the data in Table A-1 would seem to portray a classic case of open access exploitation. Landings and permits generally increased through the early to mid-1970s with both reaching a peak in 1976 and generally declining from 1976 through 1983. Landings per permit, our measure of catch-per-unit-effort, trended downward from a high of 146.4 in 1970 to 64.1 in 1982.

In the previous section we derived yield functions for logistic and Gompertz based bioeconomic models [see Equations (7) and (8)]. Regressing landings per permit or the natural logarithm of landings per permit on permit numbers will produce estimates of slope and intercept terms that are related to r, K and q in the underlying growth and production functions. Specifically

$$Y/E = qK-(q^2K/r)E \qquad (21)$$

Table A-1

Landings of Hard Clams and Commercial Permits in Great South Bay, New York *

Year	Landings Y(t) (bushels)	Commercial Permits E(t)	Landings per Permit Y(t)/E(t)
1970	565,600	3,863	146.4
1971	611,553	4,517	135.4
1972	620,817	4,534	139.9
1973	571,324	4,796	119.1
1974	616,413	5,788	106.5
1975	653,458	6,149	106.3
1976	700,465	6,517	107.5
1977	658,353	5,694	115.6
1978	547,773	4,913	111.5
1979	442,946	4,608	91.8
1980	338,839	4,275	79.3
1981	309,140	3,998	77.3
1982	201,654	3,145	64.1
1983	178,422	2,013	88.6

* Landings and permit numbers are for the towns of Bablyon, Islip and Brookhaven.

and

$$\ell n(Y/E) = \ln(qK)-(q/r)E \qquad (22)$$

for the logistic and Gompertz based models, respectively. Ordinary least squares (OLS) regressions were run with the estimates and supporting statistics given in Table A-2. The null hypothesis of a zero slope coefficient cannot be rejected. The probability of obtaining t and F statistics greater than the observed statistics equals 0.2885 for the regression of (Y/E) on E and 0.1927 for the regression In(Y/E) on E. Thus variations in E alone cannot significantly explain any of the variation in (Y/E) or $\ell n(Y/E)$, using simple OLS regression. This is not surprising given that there are many other factors; such as temperature, salinity and the stock of predators, perhaps acting in a delayed (or lagged) fashion, which may affect catch-per-unit-effort. Time and data precluded a more ambitious econometric investigation and initial estimates of r, K and q were obtained as follows:

(a) Smith (1979) estimates the carrying capacity of certified waters within Great South Bay to be between 3 and 14 million bushels. We opted for a relatively conservative value of 7.5 million bushels.

(b) Using the (suspect) coefficients of the OLS regressions this implied $q = 1.034 \times 10^{-5}$ and $r = 0.129$ for the logistic growth function and $q = 0.981 \times 10^{-5}$ and $r = 0.132$ for the Gompertz growth function.

(c) Assuming $K = 7.5 \times 10^{6}$ and rounding $r = 0.13$ we obtain Y_{MSY} = 243,750 bushels for the logistic model and Y_{MSY} = 358,682 for the Gompertz model. These estimate of Y_{MSY} seemed plausible and consistent with the assumption that the resource was "mined" during the 1970s ($Y(t) > Y_{MSY}$ and stocks declining).

(d) The values of q in step (b) resulted in estimated of E_{MSY} which seemed excessive, approximately twice the number of permits one would have expected with Y_{MSY} between 250,000 and 350,000 bushels.

Table A-2

Results of OLS Regressions of (Y/E) and *In* (Y/E) on E

Dependent Variable	Intercept*	Slope*	R^2**
(Y/E)	77.583564 (2.904)	- 0.006220184 (1.111)	0.0932 (F=1.233)
In(Y/E)	4.297971 (16.770)	- 0.0000741406 (1.380)	0.1370 (F=1.905)

* t-statistics are given in parentheses

** Degrees of freedom: model = 1, error = 12

The value of q was doubled to $q = 2.0x10^{-5}$. This resulted in estimates of $E_{MSY} = 3.250$ for the logistic model and $E_{MSY} = 6,500$ for the Gompertz model. The E_{MSY} value for the Gompertz model, when compared to historical effort (permit) numbers, seemed unrealistically high to be associated with maximum sustainable yield. Overall the logistic-based model seemed a more plausible model for the hard clam resource.

Given the assumptions and adjustments in steps (a) through (d) above, we adopted the initial estimates $K = 7.5x10^6$ bushels, $r = 0.13$ and $q = 2.0x10^{-5}$ for the parameters of the growth and production functions. The remaining parameters p, c and δ were assigned values as follows:

(e) The per unit price p was treated as a weighted average of littleneck, cherrystone, and chowder prices where the weights were 0.6 for the littleneck price, 0.3 for the cherrystone price and 0.1 for the chowder price; based on the composition of a typical day's harvest. During the week July 13-19, 1984 the wholesale price in Fulton Market averaged $13.50/bushel for chowders, $28.50/bushel for cherrystones and $87.50/bushel for littlenecks. Assuming the dockside price to be 10% less than the wholesale price one obtains p = $56.16/bushel. This was rounded to $60/bushel.

(f) The cost parameter c should reflect the opportunity cost (time, boat, gear, fuel and fees) for the average permit holding bayman during the year. Estimate of c is made difficult because of the part-time nature of clamming for many baymen. It was assumed that the average number of eight-hour-days clammed by the average permit holder was 75 days per year. By assuming an opportunity cost of $5.00 per hour and yearly operating costs of $1000.00 per year we obtained an estimate of c = $4,000 for the typical permit holder. Full-time baymen may spend twice as much per year harvesting clams while other permit holders may only clam a few weeks per year.

(g) For calculation of the bioeconomic optimum a discount rate must be specified. The rate should reflect society's real (inflation free) rate of time preference. We will initially adopt a $\delta = 0.05$.

The initial parameter set became $r = 0.13$, $K = 7.5x10^6$ (BU), $q = 2.0x10^{-5}$, $p = \$60$, $c = \$4,000$ and $\delta = 0.05$. Sensitivity analysis was performed on certain parameters and will be reported, where appropriate, in the discussion of each alternative.

Maximum Sustainable Yield

For the logistic-based model we obtained $X_{MSY} = 3.75x10^6$ bushels, $Y_{MSY} = 243,750$ bushels and $E_{MSY} = 3,250$ permits. For the Gompertz-based model the corresponding figures were $X_{MSY} = 2,759,095$, $M_{MSY} = 358,682$ and $E_{MSY} = 6,500$. As noted earlier, observed yields exceeded estimates of Y_{MSY} throughout the 1970s. Using the observed yield data from Table A-1 and assuming a standing stock of $6.0x10^6$ bushels in 1970 the population was simulated using the difference equation

$$X_{t+1} = S_t = 0.13X_t(1-X_t/(7.5x10^6))-Y_t \qquad (23)$$

(Figure A-3). By 1984 the population was driven down to 1,925,625. Starting from 1970 values of $5.0x10^6$ bushels and $7.5x10^6$ bushels led to 1984 standing stocks of 575,481 bushels and 3,148-784 bushels respectively. Thus while the regression coefficients were not statistically significant they led to estimates of X_{MSY}, Y_{MSY} and E_{MSY} which seem plausible and simulations of population dynamics using observed landings which led to plausible estimates for the 1984 standing stock. We will make use of Equation (23) again when we examine the transition policy of maximum recruitment.

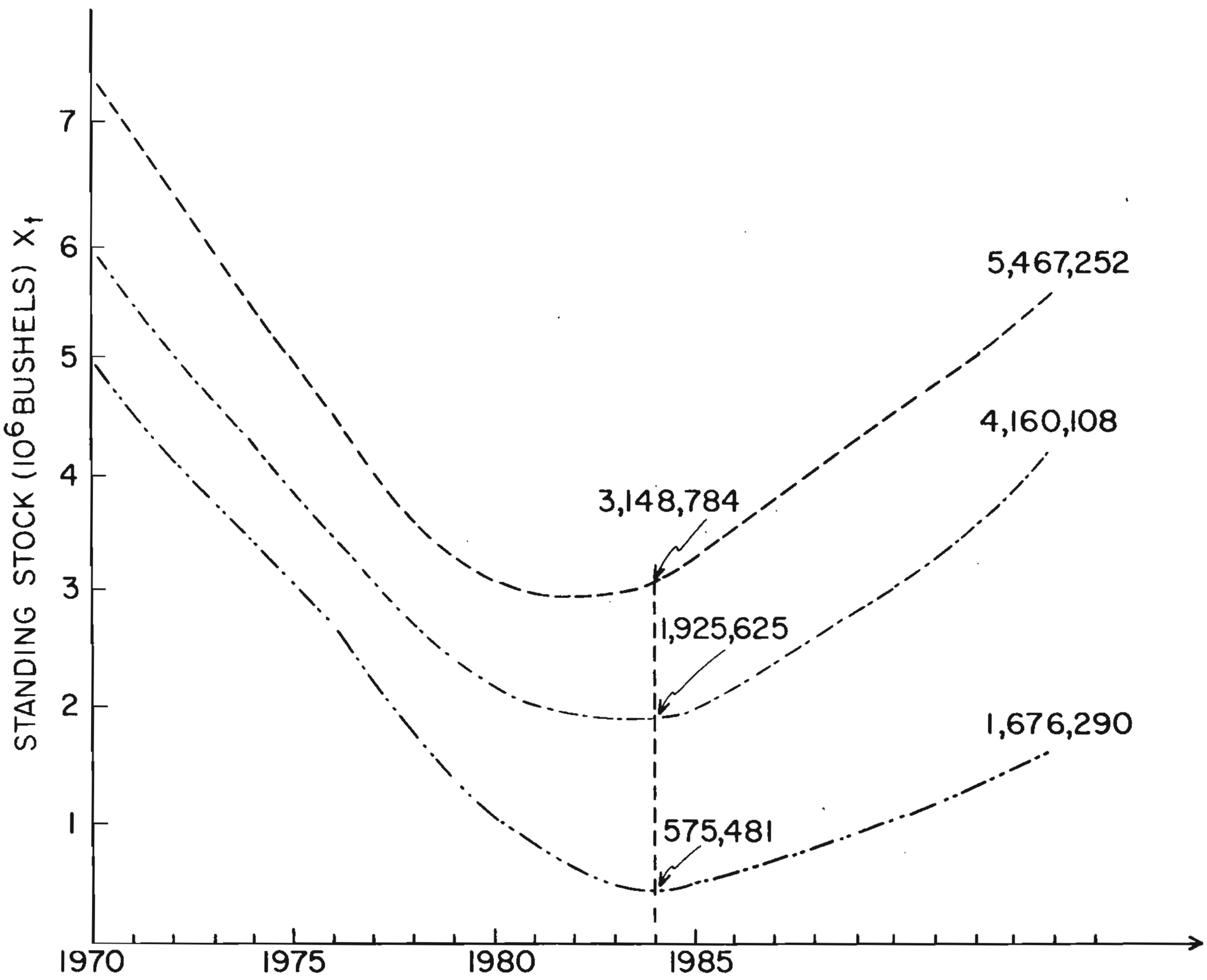

Figure A - 3

Time paths for standing stock

Open Access and Constrained Employment

Open access equilibrium occurred at X_∞ = 3,333,333, Y_∞ = 240,750 and E_∞ = 3,611 in the logistic model and X_∞ = 3,333,333, Y_∞ = 351,403 and E_∞ = 5,271 in the Gompertz. The open access stock is the same in both models ($X_\infty = c/(pq)$) but the different growth functions lead to different yields and effort. The open access stock was higher than expected given the simulations from 1970 stocks of 5.0×10^6 and 6.0×10^6 million bushels and the observed landings. This might be an indication that our cost per average permit holder c = \$4,000 was too high. If our assumption on the number of average days, opportunity cost of labor, or cost of fuel, maintenance, and depreciation were decreased so that the cost per average permit holder were c = \$3,000 we observe X_∞ = 2,500,000 for both logistic and Gompertz with Y_∞ = 216,666 and E_∞ = 4,333 for the logistic and Y_∞ = 357,048 and E_∞ = 7,140 for the Gompertz.

Under open access net revenue is driven to zero. While net revenue is zero baymen are receiving compensation for their time and effort comparable to what they could earn at their next best part-time or full-time occupation. If this were viewed as inadequate a management authority, by restricting the number of baymen and their catch, could increase the compensation to baymen in the fishery. For example, for the initial parameter set and the logistic model, if effort was restricted to 2,213 permit holders harvesting 218,942 bushels each year from an equilibrium stock of 4,946,330 there would be positive next revenues equal to

$$N = [60-(4{,}000/(2.0\times10^{-5}))(4{,}946{,}330)^{-1}](218{,}942) = \$4{,}283{,}815$$

which divided equally among the 2,213 baymen in the fishery would lead to an additional \$1,935 per bayman, per year.

Positive net revenues up to \$4,513,868/yr attained at E_0 = 1,805 are possible (in the logistic model). To augment the opportunity cost payments made under open access, however, a management agency must be able to limit not only entry (into a now profitable fishery) but also limit the catch of those baymen fortunate enough to be included in the fishery.

Industry net revenue of \$4,283,815 for Y = 218,942 bushels implied $u = p-(c/q)X^{-1}$ = \$19.57 per bushel value. This net revenue and yield corresponded to the values obtained at the bioeconomic optimum for the original parameter set. In this instance (X = 4,946,330, Y = 218,942, E = 2,213), u = 19.57 is the "shadow price" or value of and additional unit of the resource "in the water". Thus, in theory, the bioeconomic optimum could be achieved by the appropriate choice of u, and limiting effort and catch to $E^* = 2.213$ and $Y^* =$ 218,942 bu, respectively.

Maximum Net Revenue

For the original parameter set the maximum net revenue equilibrium occurs at $X_0 = 5{,}416{,}666$, $Y_0 = 195{,}601$ and $E_0 = 1{,}805$ for the logistic model and $X_0 = 5{,}222{,}921$, $Y_0 = 245{,}686$ and $E_0 = 2{,}352$ for the Gompertz model. In the logistic model this produces the previously noted maximum net revenue of \$4,513,868/yr. In the Gompertz model maximum net revenue is \$5,333,167.

The Bioeconomic Optimum

Finally, for the original parameter set the bioeconomic optimum in the logistic-based model occurs at $X^* = 4{,}946{,}330$, $Y^* = 218{,}942$, and $E^* = 2{,}213$. In the Gompertz-based model the analogous figures are $X^* = 4{,}857{,}301$, $Y^* = 274{,}314$ and $E^* = 2{,}823$. Note that in each model the optimal stock is in excess of X_{MSY}. In both models it pays to have a higher standing stock than X_{MSY} because of the cost savings it conveys (recall $C = (c/q)X^{-1}Y$).

In each model $X^* < X_0$. Noneconomists often wonder why the bioeconomic optimum, which maximizes present value, is preferable to the equilibrium which maximizes (static) net revenue. By harvesting (X_0-X^*) plus growth, and putting the net revenues in the bank at rate δ one will obtain a higher present value than if one maintained the stock at Y_0.

Increases in the discount rate reduce the bioeconomically optimal stock. Changing δ to 0.10 in the original parameter set leads to a bioeconomic optimum of $X^* = 4,615,384$, $Y^* = 230,769$ and $E^* = 2,500$ in the logistic model and $X^* = 4,603,363$, $Y^* = 292,106$ and $E^* = 3,172$ in the Gompertz-based model. In comparing the δ and 0.05 and $\delta = 0.10$ cases in both models the optimal stock was reduced with $\delta = 0.10$ but because the bioeconomic equilibrium remained to the right of X_{MSY} (i.e. $X^* > X_{MSY}$ for all discount rates) that the optimal effort and yield increased.

The only other comparative static result not mentioned was the effect of an increase in price. Price and cost work in opposite directions in terms of the effect that changes in either will have on resource stock. Clark (1976) has shown that the equilibrium effects can be addressed via the ratio (c/p), with increases (decreases) in (c/p) leading to increases (decreases) in all equilibrium stocks. We have already seen that a decrease in cost from $4,000 to $3,000 led to a reduction in all the equilibrium stocks (save X_{MSY} which only depends on r and K). A decrease in p has the same qualitative effect as an increase in c. If p were to decrease to $50 because of a decline in demand we would observe $X_0 = 5,750,000$, $X^* = 5,380,033$ in the logistic model, $X_0 = 5,620,617$, $X^* = 5,319,684$ in the Gompertz-based model and $X_\infty = 4,000,000$ in both.

Tables A-3 and A-4 summarize the various equilibria discussed in this section. Table A-3 is for the logistic-based model while Table A-4 is for the Gompertz-based model. Equilibria for the initial parameter set and changes in c, δ and p are shown for each model. Tables A-1 and A-2 in the Appendix provide a convenient summary of the relevant formulae.

Table A-3

Equilibria in the Logistic-Based Model

		$r = 0.13$, $k = 7.5\times10^6$, $q = 2.0\times10^{-5}$			
		p=60 c=4,000 δ=0.05	p=60 c=3,000 δ=0.05	p=60 c=4,000 δ=0.10	p=50 c=4,000 δ=0.05
Maximum Sustainable Yield	$X_{MSY}=$	3,750,000	3,750,000	3,750,000	3,750,000
	$Y_{MSY}=$	243,750	243,750	243,750	243,750
	$E_{MSY}=$	3,250	3,250	3,250	3,250
Open Access	$X_\infty=$	3,333,333	2,500,000	3,333,333	4,000,000
	$Y_\infty=$	240,740	216,666	240,740	242,000
	$E_\infty=$	3,611	4,333	3,611	3,033
Maximum Net Revenue	$X_0=$	5,416,666	5,000,000	5,416,666	5,750,000
	$Y_0=$	195,601	216,666	195,601	174,416
	$E_0=$	1,805	2,166	1,805	1,576
Bioeconomic Optimum	$X^*=$	4,946,330	4,380,780	4,615,384	5,380,033
	$Y^*=$	218,942	236,853	230,769	197,695
	$E^*=$	2,213	2,703	2,500	1,837

Table A-4

Equilibria in the Gompertz-Based Model

	$r = 0.13$, $k = 7.5\times10^{6}$, $q = 2.0\times10^{-5}$				
		p=60 c=4,000 δ=0.05	p=60 c=3,000 δ=0.05	p=60 c=4,000 δ=0.10	p=50 c=4,000 δ=0.05
Maximum Sustainable Yield	X_{MSY}=	2,759,095	2,759,095	2,759,095	2,759,095
	Y_{MSY}=	358,682	358,682	358,682	358,682
	E_{MSY}=	6,500	6,500	6,500	6,500
Open Access	X_{∞}=	3,333,333	2,500,000	3,333,333	4,000,000
	Y_{∞}=	351,403	357,048	357,403	326,876
	E_{∞}=	5,271	7,140	5,271	4,085
Maximum Net Revenue	X_0=	5,222,921	4,697,624	5,222,921	5,620,617
	Y_0=	245,686	285,709	245,686	210,773
	E_0=	2,352	3,041	2,352	1,875
Bioeconomic Optimum	X^*=	4,857,301	4,244,964	4,603,363	5,319,684
	Y^*=	274,314	314,093	292,106	237,542
	E^*=	2,823	3,699	3,172	2,232

Maximum Recruitment

If this simple model is reasonably correct the "mining" of the hard clam resource in Great South Bay has left a 1984 standing stock between 575,000 and 3,150,000 bushels. This would put the stock below the level associated with maximum sustainable yield. Such a situation is sometimes referred to as "biological overfishing". For both models and in all cases $X_{MSY} < X^*$; that is the bioeconomically stock (for $\delta = 0.05$ or $\delta = 0.10$) was greater than the level associated with maximum sustainable yield. Because of the reduction in harvest cost it was bioeconomically optimal to have a stock in excess of X_{MSY}.

If maximization of the present value of net revenues is a valid criterion it can be shown that if the stock is not initially at the optimal level, then the "most rapid approach path" (MRAP) is the best way to get there (Spence and Starrett 1975). Suppose yield has some exogenous upper bound Y_{MAX}, then $0 \leq Y(t) \leq Y_{MAX}$. The MRAP decision rule may be stated mathematically as

$$\begin{array}{lll} X(0) < X^* & & Y_{(t)} = 0 \\ X(0) > X^* & , \text{ Then} & Y_{(t)} = Y_{MAX} \\ X(0) = X^* & & Y_{(t)} = Y^* \end{array} \qquad (24)$$

In words, MRAP says that if the stock is less than the optimal stock harvest should be zero, if the stock is in excess of the optimal stock harvest should be at the maximum (Y_{MAX}) and if (or when) stock equals the optimal stock harvest should be set equal to Y^* in perpetuity.

Recall that with $r = 0.13$ and $K = 7.5\text{x}10^6$ bushels, Equation (23) could be used to simulate the effect of the actual (observed) harvest on the stock of hard clams. We can also use Equation (23) to simulate forward in time (from 1984 stock estimates) to determine how quickly the stock will recover if a moratorium (zero harvest) is imposed. If the stock were 1,925,625 in 1984 a moratorium of 10 years would result in a stock of 4,160,108 bushels in 1994 or about 800,000 bushels less than the optimal stock X^* for the initial parameter set in the logistic-based model (Table A-3). If the 1984 stock were lower say at the 575,481 bushels discussed earlier, 1994 standing stock after a 10-year moratorium would be 1,676,290. If the 1984 stock were at 3,148,784 a 10-year moratorium would result in 5,467,252 bushels of hard clams in 1994. Figure 3 depicts the effect of actual harvests from 1970 to 1983 and a 10-year moratorium from 1984-1993 for the three previously discussed initial conditions $X(1970) = 7.0x10^6$, $X(1970) = 5.0x10^6$, and $X(1970) = 7.5x10^6$. In this last case the stock will exceed the bioeconomic optimum for the initial parameters in the logistic-based model in nine years. Thus, even for the high estimate of current stock a period of at least nine years would be required if one wished to reestablish stocks at their theoretical optimum. Harvest at a rate less than net natural growth will allow the population to increase, but the approach to any equilibrium $X^* > X_o$ will be slower than with a complete moratorium.

A PROPOSAL FOR MANAGEMENT OF THE HARD CLAM IN GREAT SOUTH BAY

The preceding analysis would seem to support the argument that the population of hard clams in Great South Bay was "mined" during the 1970s and early 1980s to a level below estimated X_{MSY} and considerably below the optimal level, X^*, based on present value maximization. While a moratorium on harvest would allow stocks to recover "most rapidly" its appeal is probably limited to academic economists who don't carry much political clout. Is there anything of practical relevance in the previous analysis? Two major conclusions emerge: (1) to reestablish stocks some mechanism to limit yield to less than net growth is necessary and (2) once reestablished, a management program must be in place to maintain the resource stock at or near the desired level. The benefits of management, based on the preceding analysis, would appear to be yearly net revenues (at dockside) of $4-$5 million. This is likely to be conservative due to underreporting and the nature of the models employed. Conrad (1982) estimates the net benefits from management using a multiple cohort model to range between $25-$55 million at the wholesale level in 1980 dollars.

The cost of management is a matter of speculation. The major cost component of any serious management program will be enforcement. For a shallow, accessible body of water like Great South Bay, surrounded by thousands of would-be baymen the cost of enforcement is likely to be high. Some would contend that, after netting out management costs, a policy of open access, with its illusion of equity, may be optimal. The cost of enforcement, however, is likely to depend on how current and would-be baymen view the program. If a management program, while limiting access, is seen as fair then it will probably be easier (less costly) to enforce than an alternative program that is viewed as unfair. Thus "economic justice" or equity will affect management cost and, in turn, net social benefits. What program characteristics might prove effective in reestablishing and maintaining the stock of hard clams in an equitable way? The following program would seem to make the most sense from a bioeconomic perspective. Portions of it have been discussed elsewhere (Conrad 1982, 1983).

(1) Establish a lottery where some number of baymen, say 1,000, are selected and given the right to harvest 150 bushels of hard clams during the next year. Baymen admitted to the lottery may be restricted to those who have held permits in four of the previous five years. Those selected in the lottery would pay a fee to cover some of the costs of the management program. The entire quota or unused portion could be sold to any other eligible baymen.

(2) Establish a system of certified collection centers where baymen holding a valid license and quota would record their catch. Spot checks on the sanitary conditions of the harvest would be made, and the centers could, subject to the approval of the bayman, offer to sell his catch at an auction of certified clams.

(3) Establish a records system to keep track of the cumulative harvest of licensed baymen and the sale and transfer of unused quotas.

Points 1-3 sketch a program which has the potential to limit harvest below net growth to allow stocks to rebuild. Over time it may be possible to increase the size of the quota and/or the number of baymen harvesting clams from certified waters. It can be adaptive on a year-to-year basis if recruitment is subject to stochastic fluctuations.

The eligibility requirements and rules on selection via lottery as well as resale can be modified to achieve what would hopefully be regarded as a "fair" system of access. For example, an upper bound on the number of quotas held by a single baymen may be specified to prevent concentration in and manipulation of the quota market.

The public auction of certified clams would actually assist in the enforcement of the management program. If a viable auction of certified clams developed it would create a stigma of suspicion on any illegal, possibly unsanitary, clams harvested by nonlicensed baymen. The lower black market price for suspect clams and the threat of fines or imprisonment for illegal harvest and sale should reduce the level of illegal harvest.

The main obstacle to establishment of a program described by points 1-3 lies in the fractionalized management authority currently practiced by the State and the towns of Babylon, Islip and Brookhaven. On ecological and economic grounds Great South Bay should be managed as a system. While an individual town might institute a program similar to that outlined above, and it may lead to an increase in the population of clams within the town's waters, the greatest chance for success would result if the towns bordering on the bay and New York State could reach agreement on the creation and operation of a baywide hard clam authority.

CONCLUSIONS AND CAVEATS

This paper has attempted to do three things. First, it has briefly reviewed the basic bioeconomic model which allows a synthesis of species dynamics with the economics of commercial harvest. Two specifications, based on the logistic and Gompertz growth functions were presented and five management alternatives were defined and discussed. Four of the alternatives are equilibrium concepts and a set of equations was identified which would allow the calculation of equilibrium stock, yield and effort if certain bioeconomic parameters could be estimated. The alternative equilibria were (1) maximum sustainable yield: X_{MSY}, Y_{MSY}, E_{MSY} (2) open access: X_{∞}, Y_{∞}, E_{∞}, (3) net revenue maximization: X_0, Y_0, E_0, and (4) present value maximization: X^*, Y^*, E^*. The fifth management alternative was actually a transition strategy for encouraging maximum precruitment. It was shown that this strategy was equivalent to the "most rapid approach path" (MRAP), and if the current stock were less than the desired (equilibrium) stock, MRAP would call for a moratorium (zero harvest) for maximum recruitment.

Second, the available data on landings and permits for the three towns bordering on Great South Bay was analyzed by ordinary least squares regression to see if the reduced form parameters of the logistic or Gompertz-based yield function could be estimated. The regression results were not significant. This might indicate that the basic bioeconomic model is an inadequate description of the hard clam fishery or it may mean that the available data inadequately measures the variables of interest. Instead of throwing in the econometric towel the coefficients were used in conjunction with independent estimates of K made by Smith (1979) to obtain estimates of the parameters r and q. Price data (p) is available from the National Marine Fisheries Service via their Market News Report for Fulton Market. Cost estimates (c) for a representative (less than full-time) bayman was constructed based on variable costs for fuel, oil, and gear, yearly depreciation, and an opportunity cost for the bayman's time. In addition to price and cost estimates the bioeconomic optimum, which maximizes the present value of net revenues, requires the specification of a rate of discount, δ. With an initial parameter set assembled it was possible to estimate stock yield and effort for the various equilibria. The following conclusions emerge:

- Maximum sustainable yield was estimated at 243,750 bushels in the logistic model and 358,682 in the Gompertz model. The yields of the 1970s exceeded either estimate and the resource was "mined" during the period.

- Based on simulation using the logistic model and observed yields the 1984 standing stock of legal clams in certified water was estimated to be between 575,481 and 3,148,784 bushels depending on the stock level inherited in 1970 (i.e. the initial conditions).

- It is optimal from a bioeconomic perspective to try to maintain a stock in excess of X_{MSY} because the larger stock conveys cost savings (it's easier and less time-consuming to obtain a given yield from a larger standing stock). Estimates of the optimal stock range between 4.5 and 5.5 million bushels for the logistic and Gompertz-based models. Optimal yield ranged from 190,000 to 237,000 bushels in the logistic model and from 237,000 to 315,000 bushels in the Gompertz-based model. Optimal effort, measured in terms of part-time baymen (75 days per year) ranged from 1,800 to 2,700 in the logistic model and from 2,230 to 3,700 in the Gompertz model. These figures are all equilibrium estimates and the numbers of baymen and bushels of clams would have to be less during a recovery period when stocks are rebuilding.

- Because of the extent of overfishing during the 1970s even the "most rapid approach path", based on zero harvest (a moratorium), would require at least nine years to reestablish stocks near the bioeconomically optimal level. A moratorium is unlikely for political reasons and probably undesirable from the broader perspective of economic well-being. If however, stocks are to be rebuilt using natural recruitment, some mechanism to reduce harvest below net natural growth must be instituted.

Third, a proposal for a management program was outlined which had strong appeal from a bioeconomic perspective. It could limit harvest via a system of transferable quotas awarded to eligible baymen via a lottery. Quotas and the number of baymen could be increased over time if the stocks recover to the point where they can support increased yield. Quotas could be reduced if the rate of recovery where too slow or if environmental factors intervene to make the fishery less productive. The fact that the quotas could be sold (transferred) to other eligible baymen creates an incentive for the aggregate quota to be harvested at least cost. A system of official landing stations where authorized (quota-holding) baymen bring their catch for recording, spot sanitation checks, and possible sale at a certified auction would enhance the price received by authorized baymen and cast a stigma of suspicion on illegally harvested clams. While such a program could be instituted by individual towns it makes more sense ecologically and economically to operate the program bay-wide. This would require the formation of a management compact between the towns of Babylon, Islip and Brookhaven, and New York State. The towns have been reluctant to surrender their local management perogatives. Apparently having some control over an exhausted resource is preferable to risking involvement in a comprehensive institution which, while having a greater chance at rebuilding stocks, may reduce local (town) control.

The models of Section II and the analysis of Section III are based on a highly structured and simplified view of the hard clam fishery. The conclusions, particularly the numerical analysis contained in Tables A-3 and A-4, should be taken with a grain of salt. In particular:

- The models employed are crude biomass models which cannot account for the important age-structured aspects of the hard clam fishery. Spawner sanctuaries and maximum size limits cannot be considered. The interested (and mathematically stalwart) reader is referred to Conrad (1982).

- The models are single species models, incapable of explicit consideration of stocks of predators and competitors.

- No stochastic elements were considered. The effects of storm or wind induced changes in current and salinity were not incorporated in the analysis.

- The statistical insignificance of the regression results raises questions about the logistic and Gompertz specification.

In spite of these shortcomings and limitations a set of parameter values was identified which seemed consistent with our understanding of the dynamics of the fishery during the 1970s and offered some guidelines on both transitional (approach path) yields and targets for resource maintenance. Perhaps more uncertain than the biological and economic underpinnings of the analysis is the ability to create a management institution which would allow economists and biologists a chance at effective management. Without such an institutional gamble the potential gains from management of the hard clam resource will remain the subject of speculation.

Mathematical Appendix

In this appendix we derive yield functions and expressions for stock, yield and effort under open access static rent maximization and at the bioeconomic optimum. This is done for both the logistic and Gompertz growth functions.

Logistic Growth

The equation describing logistic growth is given by the expression

$$dX(t)/dt = \dot{X}(t) = rX(t)(1-X(t)/K) \qquad (A.1)$$

where $dX(t)/dt = \dot{X}(t)$ is the time derivative (change) of the biomass of species X. The parameters r and K are referred to as the intrinsic growth rate and the environmental carrying capacity, respectively. If the species were not subject to harvest it would approach its environmental carrying capacity from any positive initial population level. Mathematically: $X(t) \quad K$ from any $X(0) > 0$, and K is said to be a globally stable equilibrium.

When species X is subject to harvest, equation (A.1) must be modified to become

$$\dot{X}(t) = rX(t)(2-X(t)/K)-Y(t) \qquad (A.2)$$

where Y(t) is the harvest of species X at instant t. Yield is the result of a production process where fishing "effort", denoted E(tr), is directed at the fishable population X(t). One of the earliest forms describing fisheries production was

$$Y(t) = qE(t)X(t) \qquad (A.3)$$

where q is referred to as the catchability coefficient. Implicit in equation (A.3) is the assumption that catch per unit effort (CPUE) is proportional to the fishable population; that is, $Y(t)/E(t) = qX(t)$.

The yield function, or yield-effort curve, is an equilibrium relationship between effort and yield. It indicates the level of yield which could be maintained from a constant level of effort when the system is in equilibrium ($\dot{X}(t) = $)). In such a situation we may dispense with the time notation and

$$rX(1-X/K)-qEX = 0. \tag{A.4}$$

Assuming $X > 0$, dividing the left-hand-side by X and solving for X yields

$$X = K[1-(q/r)E]. \tag{A.5}$$

From (A.3) we note

$$Y = qEX = qKE[1-(q/r)E] \tag{A.6}$$

which is referred to as the yield function or yield-effort curve. It is an empirically important concept because it relates yield to effort, variables which might be measured by biologists or economists.

Equations (A.2) and and (A.3) are sometimes collectively referred to as the Gordon-Schaefer Model after H.S. Gordon and M.B. Schaefer an economist and biologist who did pioneering work in fisheries modelling during the mid-1950s (see References). Gordon (1954) noted that if a fish population were treated as a common property resource that effort would expand or contract until net revenue (or rent) was driven to zero. Let p denote the price received by the fisherman per unit of fish harvested (for example, \$0.50 per pound), and let c denote the per unit cost of effort (cost of a trip or cost of operating a vessel for a year). Assuming c constant we may write total cost as

$$C(t) = cE(t). \tag{A.7}$$

Using (A.7) and (A.3) we can derive a cost function expressing cost as a function of the population X(t) and yield Y(t). Some algebra will reveal

$$C(t) = (c/q)X(t)^{-1}Y(t) \tag{A.8}$$

which permits us to write net revenues, assuming p constant (i.e. the individual fisherman is a "price-taker" as

$$N(t) = pY(t)-(c/q)X(t)^{-1}Y(t) = [p-(c/q)X(t)^{-1}]Y(t). \tag{A.9}$$

If the resource is held as common property and there is no restriction on entry, exit and level of harvest then an open access equilibrium may occur where N = 0 and

$$[p-(c/q)X^{1-}] = 0. \tag{A.10}$$

Assuming Y > 0 (A.10) implies that the population in an open access equilibrium will be

$$Y_\infty = rX_\infty(1-X_\infty/K) \tag{A.11}$$

If one can obtain estimates of long run (equilibrium) values for c, p and q one can obtain an estimate of X_∞. Knowing X_∞ one can solve for open access yield and effort, denoted Y_∞ and E_∞. They are

$$Y_\infty = rX_\infty(1-X\ /K) \tag{A.12}$$

and

$$E_\infty = Y_\infty/qX_\infty). \tag{A.13}$$

As noted in the text, open access equilibrium is often associated with excessive effort, low (depleted) fish stocks capable of supporting relatively low rates of harvest (yield). One of the first recommendations by economists was that effort should be regulated so as to maximize static (equilibrium) rent. Using the yield function (A.6) we may write equilibrium net revenue as

$$N = pqKE[1-(q/r)E]-cE \tag{A.14}$$

Maximization of N requires

$$dN/dE = pqK-(2pq^2K/r)E - c = 0 \tag{A.15}$$

where dN/dE is the first derivative of net revenue with respect to effort. Equation (A.15) may be solved for the static rent maximizing level of effort, denoted E_0, where

$$E_0 = r(pqK-c)/(2pq^2K) \quad . \tag{A.16}$$

The associated levels for yield and stock are

$$Y_0 = qKE_0(1-(q/r)E_0) \tag{A.17}$$

and

$$X_0 = Y_0/(qE_0). \tag{A.18}$$

Static rent maximization may be associated with large stocks, low effort, and relatively high yields. Stocks will typically be in excess of the maximum sustainable yield (MSY) producing stock, which for the logistic growth function (A.1) occurs at $X_{MSY} - K/2$. Clark and others have pointed out that regulating effort to E_0 may not be desirable if society has a legitimate positive rate of discount. Discounting and present value calculations are common business practices. Such practices are a bit more controversial when making public investments or when managing public resources. If some positive rate of discount is justifiable than a reasonably compelling objective for resource management is the maximization of the present value of net revenues. In essence the resource administrator would attempt to regulate harvest so as to maximize the (present) value of the resource to society over time. The present value of net revenues discounted at rate δ over an infinite horizon may be written as

$$V = \int_{0}^{\infty} [p-(c/q)X(t)^{-1}]Y(t)e^{-\delta t}dt \qquad (A.19)$$

where $e^{-\delta t}$ is a continuous time discount factor. Maximization of (A.19) subject to (A.2) becomes a problem in optimal control most easily solved using the maximum principle. The mathematical details of this approach and its application to fisheries management are beyond the scope of this appendix. Clark (1976) has shown that the stock level which maximizes the present value of a single species fishery with r, K, q, c, p, and δ as given constants is

$$X^{*} = (K/4)[(c/(pqK)+q-(\delta/r) = \quad (c/(pqK)+-(\Delta/r))^{2}+8c\delta/(pqKr)) \qquad (A.20)$$

Thus with estimates of the six bioeconomic parameters one can estimate X^{*}. Knowing X^{*} one may calculate Y^{*} and E^{*} as

$$Y^{*} = rX^{*}(1-X^{*}/K) \qquad (A.21)$$

and

$$E^{*} = Y^{*}/(qX^{*}) \qquad (A.22)$$

The relevant equations for the single species model predicated on logistic growth are summarized in Table A-1. We now consider the analagous set of equations for the Gompertz growth function.

Gompertz Growth

The Gompertz growth function takes the form

$$X(t) = rX(t)\ell n(K/X(t)) \qquad (A.23)$$

and as shown in Figure A-1 in the text is an asymmetric function with MSY = Rk/e at X_{MSY} = K/e < K/2. To derive the yield function we note in equilibrium with harvest that

$$rX\ell n(K/X)-qEX = 0$$

$$\ell n(K/X) = (q/r)E \qquad \text{(assuming } X > 0\text{)}$$

$$e^{(q/r)E} = K/X$$

$$X = Ke^{-(q/r)E}$$

$$Y = qEX = qKEe^{-(q/r)E} \qquad (A.24)$$

In open access equilibrium net revenue has been driven to zero thus and as in the logistic case $N = [p-(c/q)X^{-1}]Y = 0$ implying $X_\infty = c/(pq)$. With the Gompertz growth function

$$Y_\infty = rX_\infty \ell n(K/X_\infty) \qquad (A.25)$$

and

$$X_\infty = Y_\infty \ (qX_\infty) \qquad (A.26)$$

The level of effort which maximizes equilibrium (static) rent must maximize $N = pqKEe^{-(q/r)E}-cE$ requiring

$$dN/dE = pqKEe^{-(q/r)E}(-(q/r))+pqKe^{-(q/r)E}-c = 0$$

or

$$pqKe^{-(q/r)E}(1-(q/r)E)-c = 0 \qquad (A.27)$$

Equation (A.27) cannot be explicitly solved for E_0 but can be numerically solved given estimates of p, q, K, r and c. Presuming a unique $E_0 > 0$ will satisfy (A.27) one may solve for

$$Y_0 - qKE_0e^{-(q/r)E_0} \qquad (A.28)$$

and

$$X_0 = Y_0/(qE_0) \qquad (A.29)$$

The derivation of the stock level X^* which maximizes the present value of net revenues subject to Gompertz growth is a tedious exercise in algebra. One obtains an expression which cannot be explicitly solved for X^*, but which can be solved numerically given r, K, q, p, c and δ. It takes the form

$$pqrX\ell n(K/X)-R+\delta)(pqX-c) = 0 \qquad (A.30)$$

Presuming a unique $X^* > 0$ will satisfy (A.30) one may solve for

$$Y^* = rX^*\ell n(K/X^*) \qquad (A.31)$$

and

$$E^* = Y^*/(qX^*) \qquad (A.32)$$

The relevant equations for the single species model predicated on Gompertz growth are summarized in Table A-2. Given the parameter estimates for r, K, q, c, p and δ in the text Tables A-1 and A-2 summarize the equations used to compute open access, equilibrium rent maximizing, and the bioeconomic levels for stock, yield and effort.

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APPENDIX B

GLOSSARY

Advection - The transport of water by currents. Since moving water carries its properties such as, temperature, salinity, and O_2 with it advection can result in a change in these properties at a fixed point.

Astronomical Tides - The rise and fall of sea level that is due to the gravitational attraction of the moon and sun acting upon the rotating earth. Does not include water level changes due to weather.

Benthic - That portion of the marine environment inhabited by organisms which live on or in the bottom.

Certified (Shellfish growing areas) - Having been designated as safe for the harvest of shellfish. Waters are within the allowable limits for coliform bacteria set by the state in accordance with National Shellfish Sanitation Program guidelines.

Cherrystones - A marketing category for hard clams. Defined as between 1 7/16 inches (36.5 mm) and 1 5/8 inches (41.3 mm) thick at the hinge.

Chowders - A marketing category for hard clams. Defined as greater than 1 5/8 inches (41.3 mm) thick at the hinge.

Coliform Bacteria - A large assemblage of related microorganisms which inhabit the alimentary tract of most warm-blooded animals and may occur naturally in the environment. They are excreted in large numbers with the feces. Their presence in food or water may indicate fecal contamination.

Conditionally Certified - Open for shellfishing only after a period of seven or more consecutive days in which no rainfall greater than 0.25 inches has fallen during a 24 hour period.

Diffusion - The spreading or scattering of matter under the influence of a concentration gradient with movement from the stronger to the weaker solution.

Dispersion - The spreading of concentration due to the combined effects of advection and diffusion.

Exchange rate - the volumetric rate of which one body of water is exchanging with another, as Great South Bay with the Atlantic Ocean.

Fecundity - The capability of an organism to produce reproductive units (eggs or sperm).

Fishery Management - Any action or group of actions designed to limit the exploitation of a fishery resource, to obtain long-term optimum or maximum sustainable yield.

Fishing mortality - Death of fish or shellfish resulting from fishing effort.

Growout - Usually the last phase of aquatic husbandry where the organisms are grown to market size, typically in a modified or controlled natural setting.

Larvae - An early life stage of an organism which is morphologically distinct from the adult.

Limited Entry - Any management program that places a limit on the number of fishermen or vessels which may compete in a fishery.

Littlenecks - A marketing category for hard clams. Defined as greater than 1 inch (25.4 mm) thick at the hinge.

Mariculture - Any activity in which the natural life cycle of a marine organism is manipulated to enhance productivity.

Maximum Sustainable Yield - The largest catch that can be taken continuously from a fishery without imparing the capacity of the resource to renew itself.

Metamorphosis (setting) - The process of transformation of larvae from the planktonic to the benthic form.

Meteorological Tides - Tidal anomalies caused by the local effects of wind and weather.

Natural mortality - Death of fish or shellfish resulting from factors other than fishing.

Notata - A genetic variation found infrequently in natural populations of *Mercenaria mercenaria*. It is expressed as variable light and dark banding on the shell.

Nursery - An intermediate culture step where very small hatchery-produced or collected wild seed (where permitted) are grown to a size suitable for growout.

Optimum Sustainable Yield - The rate of harvest which maximizes the value of the catch per unit cost. Usually less than maximum sustainable yield.

Overfishing - Harvesting at a rate which exceeds maximum sustainable yield.

Plankton - Passively swimming or weakly drifting organisms not independent of currents.

Production - Equals harvest or landings of fish or shellfish (such as hard clams).

Productivity - Rate of increase of biomass.

Quota - A limit set, for management purposes, on the level of harvest of a resource. This can be a per harvester limit or a single limit for the entire industry.

Recruitment - The entrance of young fish (or shellfish) of a year class into a fishery; growth and survival to harvestable size.

Relay - Defined in this report as the transfer of clams from uncertified to certified waters for the purpose of allowing the clams to rid themselves of pathogenic substances. Sometimes used interchangeably with "transplant".

Residence Time - The mean time that a substance remains in a reservoir within the ocean. Can be calculated for any subtance (e.g., salt or water).

Salinity - A measure of the quantity of dissolved salts in seawater. Measured in parts per thousand ($^{o}/oo$) by weight.

Seed - Young clams smaller than legally harvestable size.

Setting (metamorphosis) - The process of transformation of larvae from the planktonic to the benthic form.

Spawner Sanctuary - A site which is stocked with large, fecund, adult clams and located such the setting of larvae from the site will be maximized in previously selected areas which have been identified as good for clam development.

Standing stock - The population, of a species of fish or shellfish which is available to be harvested.

Transplant - The transfer of clams between locations for management purposes. Used in this report to indicate specifically the placement of adult, fecund clams in a waterbody to enhance reproduction (i.e., spawner transplant). Sometimes used interchangeably with "relay".

Turbidity - A state of reduced clarity in a fluid, caused by the presence of suspended or dissolved matter.

Turbulent diffusive velocities - random motion of water which results in exchange of water molecules but no net transport.

Uncertified (shellfish growing areas) - Having been designated as closed (unsafe) for the harvest of shellfish. Waters exceed the standard for coliform bacteria set by the State in accordance with National Shellfish Sanitation Program Guidelines.

Velocity - The distance travelled per unit time in a given direction.

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William Wise is Assistant Director for Programs of the New York Sea Grant Institute. He was manager of the Institute's Great South Bay Study, a comprehensive, multidisciplinary research program on the oceanography of Great South Bay and the dynamics of the Bay's hard clam stock. The Study produced much of the information and knowledge used in making the assessments of management alternatives contained in this report.