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The History, Present Condition, and Future of the Molluscan Fisheries of North and Central America and Europe

Volume 1, Atlantic and Gulf Coasts

Edited by

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U.S. Department of Commerce

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Seattle, Washington

On the cover
An early etching of oysters of varying ages attached to a block of wood, circa 1880's, courtesy of W. L. Hobart.

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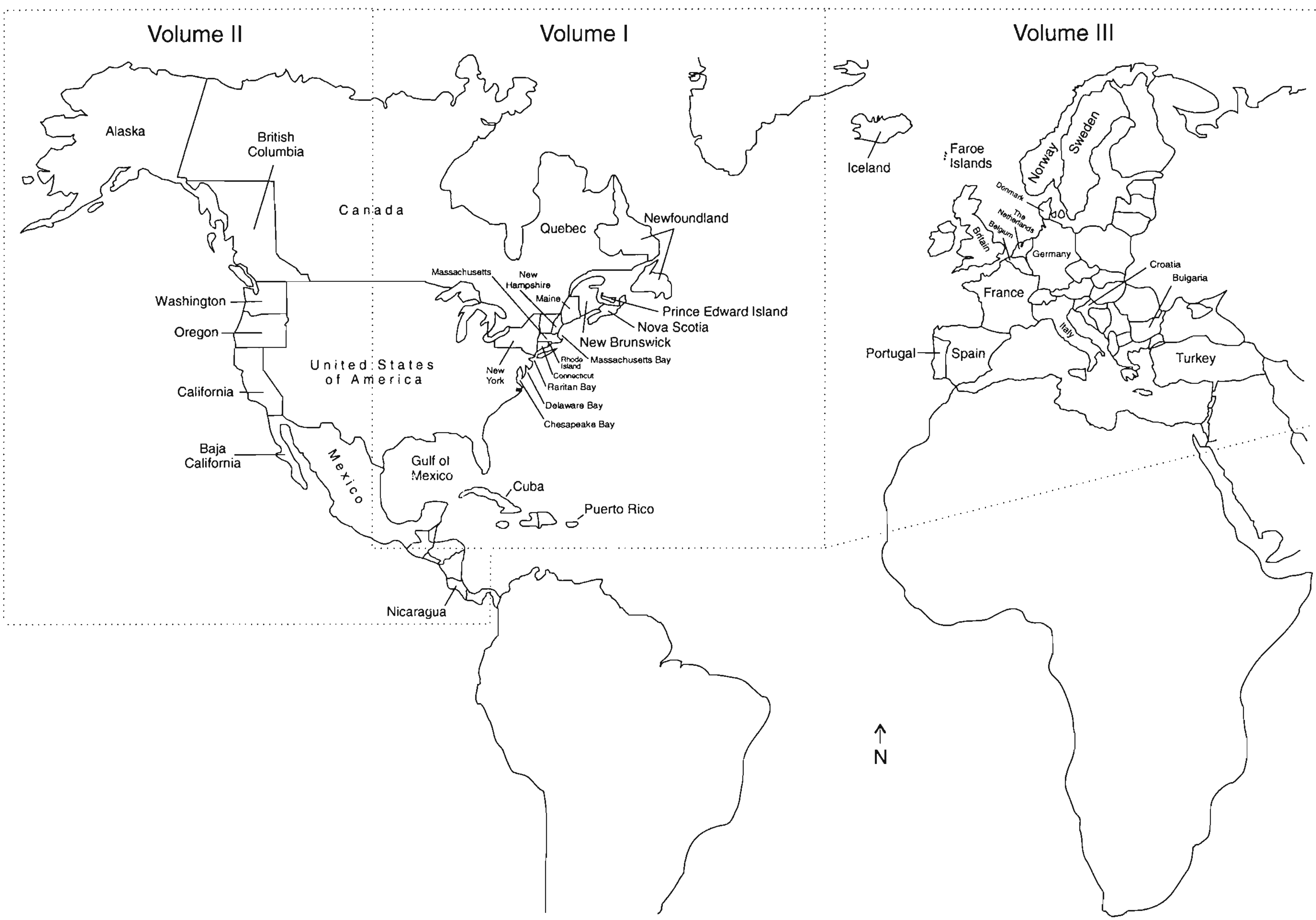

Preface: The Past is Prologue

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This three-volume monograph represents the first major attempt in over a century to provide, on regional bases, broad surveys of the history, present condition, and future of the important shellfisheries of North and Central America and Europe. It was about 100 years ago that Ernest Ingersoll wrote extensively about several molluscan fisheries of North America (1881, 1887) and about 100 years ago that Bashford Dean wrote comprehensively about methods of oyster culture in Europe (1893). Since those were published, several reports, books, and pamphlets have been written about the biology and management of individual species or groups of closely related mollusk species (Galtsoff, 1964; Korringa, 1976 a, b, c; Lutz, 1980; Manzi and Castagna, 1989; Shumway, 1991). However, nothing has been written during the past century that is comparable to the approach used by Ingersoll in describing the molluscan fisheries as they existed in his day in North America or, for that matter, in Europe.

The molluscan fisheries of North America and Europe are changing rapidly, and in many cases, profoundly so. Currently, some fisheries are in long-term decline and some are even at the point of collapse because environments have degraded and stocks have been overharvested. On the other hand, many fisheries have consistently demonstrated fluctuations in productivity or cyclic high-low peaks in product or commodity supply and demand. Natural ecological factors could be involved with resulting harvests that are in accordance to so-called boom or bust, hit or miss, or "luck of the draw" maxims.

Human activities associated with the molluscan fisheries, however, are the dominant influences over landings that enhance or retard shellfish availability through all stages in the sequence from recruitment to final utilization or consumption or both. Many, if not most, descriptions of these human-associated activities and resulting records or compilations of information derived from them are often warehoused, ignored, or otherwise lose accessibility. Consequently, an accurate, detailed, and objectively evaluated documentation of past and current status and projections for the future of molluscan fisheries is long overdue, and this three-volume series is intended to provide such documentation.

As mollusks have high value as food for man, several governments, public and private jurisdictional bodies, industry organizations, cooperatives, tribes, individuals, and even family units over the generations have often developed special propagation strategies and fishing practices for them. For the most part, however, fishing for bivalves and univalves was and still remains largely artisanal, using hunting-gathering approaches, as opposed to some recently developed aquaculture methodologies. As a consequence of the way most commercial fishery operations are now conducted, it is obvious that continuing productivity of the resource, its safe use, and the acceptable quality of commodities or products derived therefrom depend upon production cost encumbrances and on efficient maintenance of environmental quality and intelligent resource management.

It is also important to describe topics closely associated with shellfishing itself. They include the importance of shellfisheries to coastal communities, how shellfish culture affects habitats, the economics associated with shellfisheries, shellfish marketing and trade, and government programs assuring the safe consumption of shellfish and the gathering, processing, and dissemination of landing statistics.

Knowledge of past events affecting molluscan fisheries and the consequences of these events should allow us to avoid repetition of former mistakes and escape the future expense of poor judgment. Furthermore, information about the past, properly interpreted and confirmed, combined with present information, will allow better planning and preparation for the future. These volumes, therefore, bring together the contributions of about 60 distinguished authorities and scientists from many North and Central American states or regions and European nations. Their broad knowledge and experience chronicle important changes or events in molluscan fisheries and discuss the factors that influence productivity, habitat quality, marketing, and trade. Most importantly, and based on the past and present, they describe their views of strategies and actions to be taken in the future if the fisheries are to improve or survive.

This three-volume monograph is based on an international symposium, "The History, Present Condition, and Future of the Molluscan Fisheries of North America and Europe," which was held 25–26 May 1992 in Orlando, Fla. It was sponsored by the National Marine Fisheries Service, Office of Protected Resources; National Ocean Service, Office of Ocean Resources Conservation and Assessment; Shellfish Institute of North America; National Shellfisheries Association; Florida Department of Natural Resources; and the Department of Fisheries and Oceans, Canada. Papers from the symposium were augmented by invited contributions from other authors to cover additional nations, states, provinces, and issues, to make the monograph as complete as possible. The monograph was originally slated for publication in the journal *Marine Fisheries Review*, but, owing to its size, it has been published as three separate volumes in the NOAA Technical Reports NMFS series. Copies of the volumes will be available from the U.S. Government Printing Office and the National Technical Information Service; see page ii for ordering information.

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Trends and Status of Molluscan Fisheries in North and Central America and Europe—A Synopsis

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ABSTRACT

The molluscan fisheries of North and Central America and Europe have fed humans for thousands of years, with various species of oysters, clams, scallops, mussels, and gastropods harvested. In North America and Europe, the initial harvests were made to provide food for the fishermen's families. Later, additional quantities were harvested for local trading and sales, and commercial sales developed slowly. As towns and cities grew, and as harvesting methods, transportation, and refrigeration improved, mollusks could be shipped to population centers for sale, and large-scale commercial industries developed, especially for oysters.

Before the 1940's, harvesting was concentrated in bays and estuaries, but it then began expanding onto the continental shelves. In the United States, the pollution, dredging, and filling that had been weakening sales and damaging mollusk-producing beds in estuaries and bays has slowed in recent years. Due to close government inspections, consumers now have more confidence in mollusks as wholesome and safe and the demand for them is increasing. Hatcheries have been producing some juvenile mollusks where demand has outstripped supply on natural beds. The future of the fisheries appears bright because the demand for mollusks will probably remain high. Many Central American molluscan fisheries are at an early stage of development and somewhat resemble those of early North America. Harvesting by hand, often without implements, prevails, and mollusks are harvested mostly for home use and local sales.

Introduction

Throughout history, mollusks have been harvested from nearly every accessible estuary and bay of North and Central America and Europe. Mainly since the 1940's, the fisheries have extended onto the continental shelves. The Atlantic coast of North and Central America, from the Canadian Maritimes through Panama, including the Caribbean islands, is roughly 9,500 miles or 15,000 km long; shorter than the coast of Europe from northern Norway through Turkey, which is roughly 17,000 miles or 27,000 km. But the two coastal areas are similar in having many estuaries and bays.

The Pacific coast of North America, from the eastern Aleutian Islands in Alaska through Panama, is somewhat longer, roughly 13,000 miles or 21,000 km, than the Atlantic coast (from the Canadian Maritime provinces through Panama, including the Caribbean islands), but has far fewer estuaries and bays and a much narrower continental shelf. Pacific coast mollusks were harvested earlier by Native Americans—before 10,000 B.C.—than on the Atlantic coast, where evidence shows a 7,000 to 10,000 year history. Dutch, English, and French colonists first harvested mollusks on the Atlantic coast in the 1600's, generations before their Pacific coast descendants, and Atlantic coast mollusks have been the subject of more scientific study.

Mollusk fisheries have always been important to coastal communities, often providing employment in the harvesting and processing of shellfish. Communities often have limited daily catches to conserve molluscan resources and spread employment and production over long seasons. Community regulation of stocks is relatively inexpensive because wardens' salaries are often paid for by license fees (although planting seed and cultch can be expensive).

The fisheries are "fluid," in that available stocks, numbers of fishermen, production, and landed prices can be highly variable from year to year. This is especially evident in the short-lived U.S. east coast fishery for the bay scallop, *Argopecten irradians*. The prices fishermen receive fluctuate because supplies come into the market irregularly, and production in one region can strongly influence prices in another. For example, in recent years, prices of softshells, *Mya arenaria*, in Maine were as high as $90/bushel when Maryland's production was low. But, when Maryland's production was high, Maine softshell prices dropped by as much as 50%.

Landed prices of mollusks have had a great affect on fisheries. Eastern oyster, *Crassostrea virginica*, prices (inflation-corrected) along the northeast Atlantic coast have fallen slightly since the 1960's, and efforts to increase production have been sporadic except in Connecticut. On the other hand, landed prices (inflation-corrected) of northern quahogs, *Mercenaria mercenaria*, have risen sharply from about $18/bushel in the late 1960's to $30 (750 count) in the mid-1990's. This has stimulated increased harvests and hatchery construction. The high landed prices of $4–6/pound for sea scallop, *Placopecten magellanicus*, meats, have so spurred harvesting efforts that the Federal government began instituting regulations to curtail effort in order to conserve stocks.

Harvesting gear has changed little over time, mainly because coastal states and communities have not allowed unbridled use of more efficient gear. In Maine, the "hack" (a multi-tined rake with a short handle) used to harvest softshells, has remained about the same since the early 1800's. In the middle Atlantic region, the long-handled rake for northern quahogs has been used since the 1860's when it was first fabricated, although it has undergone some improvement in design and materials. In the Canadian Maritimes, the states of Maryland and Virginia, and in the Gulf of Mexico, hand-held oyster tongs have remained about the same. But patent tongs (for northern quahogs), hydraulic patent tongs (for oysters), and hydraulic escalators (for softshells and northern quahogs), which require little hand labor, have been developed for use in parts of Chesapeake Bay, Long Island, and the South Atlantic.

In the 1800's and most of the 1900's, many fishermen earned their living almost entirely by harvesting from estuaries and bays. In the Canadian Maritimes, they alternated between oystering and lobstering; in southern New England, between bay scalloping and quahoging; in Chesapeake Bay, between oystering and crabbing; and in the Gulf of Mexico, between oystering and shrimping or crabbing. In recent years this has changed because some fishermen, such as those in southern New England and Chesapeake Bay, at least, cannot earn enough from shellfishing full-time as the quantities of mollusks available are too uncertain. Instead, they alternate between shellfishing and working at shore trades.

Preparation of this monograph has revealed that in most areas few details were readily known by biologists about the local mollusk fisheries. Thus, some chapter writers took much extra time to seek out such information as the number of boats and fishermen that were active daily and their typical landings.

The Atlantic Coast of North America

Middens

Shell middens consisting largely of eastern oysters, *C. virginica*, but also of northern quahogs, *M. mercenaria*; mussels, *Mytilus edulis* and *Geukensia demissa*; slipper-snails, *Crepidula* spp.; and gastropods were common throughout the Atlantic coast of North America. Some in Florida are 4,000 years old. Middens of oysters and other mollusks were also common on the larger Caribbean islands.

The sizes and contents of these middens reveal that coastal natives ate and traded mollusks extensively. Shells were also used for ornamentation, scrapers, spoons, knives, fish hooks, and money (northern quahogs).

Historical Production

The dominant mollusks produced from Maine to Texas shifted radically between 1900 and the early 1990's (Fig. 1). Between 1900 and 1902, mollusk landings totaled 164 million pounds of meats. This included 143 million pounds of oysters, 10 million pounds of northern quahogs, 10 million pounds of softshells, and 1 million pounds of bay scallops. No ocean quahogs, *Arctica islandica*, or surfclams, *Spisula solidissima*, were landed, and only 0.63 million pounds of sea scallop meats were taken.

By 1991, oyster landings had fallen by 85%, northern quahog landings remained about the same, and softshell and bay scallop landings each had fallen by 40%. In some areas of the Atlantic coast, persistent low shellfish supplies have placed fishermen's families in poverty or have forced them to search for shore-based employment. This is true of the oyster fisheries in Delaware and Chesapeake bays, the softshell fishery in northeast-

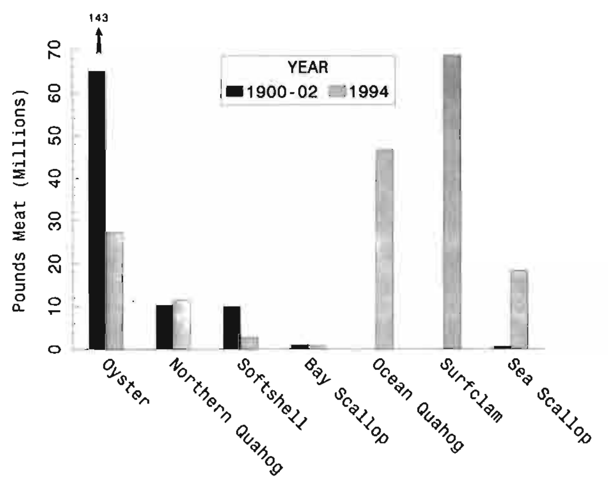

Figure 1
A comparison of mollusk landings (Atlantic coast, Maine-Texas) between 1901–02 and 1994. Sources: Lyles, C. H. 1969. Historical catch statistics (shellfish). U.S. Dep. Inter., Fish and Wildl. Serv., Curr. Fish. Stat. 5007, 116 p.; and Anonymous. 1995. Fisheries of the United States, 1994. Curr. Fish. Statistics No. 9400. NOAA, NMFS, Silver Spring, MD. 113 p.

ern Maine, and the bay scallop fishery in southern New England. By contrast, ocean quahogs, surfclams, and sea scallops now dominate landings. Taken together, 1991 landings of ocean clams and scallops totalled about 113 million pounds of meats (76% of the total), while landings of estuarine and bay oysters, clams, and scallops totalled about 36 million pounds of meats (24% of the total).

Oyster Fisheries

Throughout the 17th and 18th centuries, European colonists on the Atlantic and Gulf coasts found oysters abundant in nearly all estuaries and collected them for food, by hand or with tongs[1]. Dredges were first used for harvesting oysters in the early 1800's. As the immigrant population and food needs grew, many oyster beds were gradually depleted, from Massachusetts to Delaware. Over-harvesting has usually been cited as the cause, but siltation of beds by eroded topsoil from land clearing and farming probably contributed. From the 1820's to the 1840's, when demand for oysters was increasing, oystermen began to transport them on schooners and sloops from Chesapeake Bay to more northern bays, especially to Raritan Bay, Long Island Sound, and Narragansett Bay, for growth and subsequent harvest. This transplantation continued into the early 1900's.

From about 1885 to 1906, oyster production expanded further and attained its historical peak, because oysters, as meats and whole, could be shipped by train to inland population centers especially in the midwest. Markets along the east coast steadily increased as populations grew. More vessels and packing plants were constructed and, in the latter part of the period, oystermen began to install engines in their vessels to make them more efficient.

Oysters were a popular food for all classes of people, costing substantially less than beef, chicken, or fish. Nearly all eating establishments in eastern cities served them. The largest production area was Chesapeake Bay, followed by the Gulf states (especially Louisiana), then Delaware Bay and Long Island Sound. Thousands of people were seasonally employed to harvest and transport them from the beds, and to shuck, can, and serve them.

Steam opening and heat canning of oysters began in the Baltimore area around the 1850's and spread to the south Atlantic states where the intertidal clumped oysters, characteristic of the region, were ideally suited for processing. Oyster canning peaked in the early 1900's, began to decline in the 1940's, and ceased altogether in the 1980's.

From at least the mid-1800's to the early 1900's, dealers were confronted with the problem of oyster meats containing mud and shell particles. One solution was to empty the meats over a grate and run water over them. Another was to hold oysters for up to 24 hours in floats or on river banks, to allow them to flush sediments from their mantle cavities. But the oysters also absorbed brackish water and, in the early 1900's, this practice was largely abandoned for sanitary reasons. Thereafter, all oyster meats were placed in freshwater tanks or "blowers" for cleaning and bloating.

After about 1906, the oyster industry faced a sharply reduced market demand, when a wave of public scares over contaminated food swept the country. Officials and newspapers attacked the ways in which oysters and certain other foods, such as milk, were handled before reaching consumers. They tied numerous cases of typhoid and gastrointestinal disorders to the eating of oysters, and many people switched from eating oysters to beef. Oyster production declined, prices remained level while other food prices increased, and some oyster companies failed or were forced to consolidate with others.

[1] The use of tongs to harvest oysters in North America was first recorded in Virginia in 1701 and in Maryland in the 1730's (A. Witty and P. J. Johnson. 1988. An introduction to the catalog of artifacts. *In* P. J. Johnson (editor), Working the water, the commercial fisheries of Maryland's Patuxent River, p. 53–173. The Calvert Marine Museum and The University Press of Virginia, Charlottesville.), in 1721 in what is now Nova Scotia (P. de Charlevoix. 1744. Journal of a voyage to North America. Vol. 1. March of America Facsimile Series. No. 36. 383 p.), and in New York State in 1748 (P. Kalm. 1937. Peter Kalm's travels in North America: The English version of 1770. Vol. I. Dover Publ., Inc., N.Y., 401 p.).

The oyster industry along the U.S. eastern seaboard was substantially set back again in the mid-1920's, when some people as far inland as Chicago contracted typhoid from eating polluted oysters. Many became severely ill, and some died. Especially subject to adverse publicity were oysters taken from Raritan Bay. Newspaper stories warned of the dangers of eating oysters, and the demand dropped sharply. To help salvage the situation, the industry and government leaders developed a system to classify waters and check the sanitary condition of processing plants and oyster meats, to ensure that meats were safe to eat.

The current system involves several procedures. Shoreline surveys of chemical inputs and toxic contributions from land masses and boats are conducted, and the water undergoes microbiological tests. Open-harvest areas must have less than 70 coliforms/100 ml, or less than 14 fecal coliforms/100 ml, and buffer zones are established around sewer outfalls and marinas. Samples are taken of market shellfish for testing; meats cannot exceed 230 fecal coliforms/100 g of tissue. Problems from rainfall are also examined. Every container of mollusks shipped by a dealer must carry a tag[2] allowing officials to trace the source of the mollusks. This procedure makes it possible to locate a contaminated bed and close it to harvest until the problem is rectified.

Oyster production in the Canadian Maritime provinces sagged from about 1915 to the 1950's because "Malpeque Disease" killed many oysters. They eventually developed resistance to the disease, and production recovered on Prince Edward Island, especially after culture methods were begun in the 1970's.

The mid-Atlantic fishery was badly damaged in the late 1950's, when oysters in Chesapeake and Delaware Bays were infected with a newly identified disease, MSX, or *Haplosporidium nelsoni*. This disease killed over 90% of all oysters on grounds with salinities above 15‰. Additional mortalities were caused by "Dermo," or *Perkinsus marinus*. In the early 1990's, production was at only about 130,000 bushels/year from Chesapeake Bay and near zero from Delaware Bay. Dermo recently has been found in Long Island Sound oysters, but only minor mortalities have so far resulted.

In the early 1960's, several years of small crops of seed oysters enticed companies on Long Island, N.Y., to construct three hatcheries to produce seed. Two were marginal operations that closed after a few years, but the third has remained, producing about 50,000 bushels of market oysters/year, when diseases do not kill juveniles. Since the late 1960's, oyster abundance on natural beds in Connecticut has risen substantially as a result of greatly increased shelling of beds and the control of starfish, *Asterias forbesi*, and oyster drills, *Urosalpinx cinerea*, two important predators. There is now less need for hatcheries, and Connecticut currently produces more oysters—about 750,000 bushels/year—than any other state on the eastern seaboard.

Production in Louisiana, currently the largest source of eastern oysters in the United States, has been limited by market demand because supplies have usually been ample. In the early 1990's, all the Gulf of Mexico states had oyster supplies more than adequate to meet demand.

In recent years, dealers have been selling them year-round, rather than mainly in the fall and winter, as in the past. This has been possible because 1) refrigeration can keep oysters in good condition during warm months at all stages of handling and 2) a summer market has been developed in resort areas.

Overall production of eastern oysters has fallen greatly over the past 30 years, and few are reared in U.S. Atlantic coast hatcheries. This contrasts with production of Pacific oysters, *C. gigas*, which has risen considerably on the Pacific coast and in Europe during the same period.

Clam Fisheries

Clam fisheries have centered around four species: northern quahogs, *M. mercenaria*, and softshells, *M. arenaria*, which occur in bays and estuaries; and surfclams, *Spisula solidissima*, and ocean quahogs, *Arctica islandica*, which are ocean species.

Northern quahogs have been harvested since ancient times, and European colonists first collected them by treading and with rakes at wading depths. The long-handled rake, developed in the 1860's, allowed fishermen to harvest in depths of at least 8 m. Fishermen have also taken quahogs with dredges, but primarily since the 1940's. Production has been highest in bays from Massachusetts through New Jersey and from North Carolina through Florida. Unlike oysters and bay scallops, quahog abundance has remained steady in recent decades, though local fluctuations occur.

Since the mid-1970's, the demand for and consequent prices of "littleneck" quahogs (50–60 mm in length) have risen sharply. Fishing pressure on the littlenecks has increased, and perhaps 20 hatcheries have been constructed to produce them for growout on private and public bottoms. Hatchery-reared seed quahogs are grown to market size in shallow beds covered with screens for protection from predators. Hatcheries operate from Massachusetts to Florida, and seed produced by them resulted in at least 100,000 bushels of

[2] Each tag contains 1) the dealers' address, 2) his certification number and telephone number, 3) date the mollusks were harvested, 4) date they were shipped, 5) harvest location, 6) mollusk species and quantity, 7) identity of buyer, 8) reshipper's certification number, 9) date shipped, and 10) name, address, and telephone number of the company. A tag remains on every container until empty, and it is kept on file for 90 days.

littlenecks in 1993. The increased production of littlenecks by private hatchery-growout farms has cut prices slightly and made it more difficult for fishermen harvesting quahogs on traditional public beds to earn a living. This problem could ease as markets expand.

Softshells have also been harvested since pre-colonial times. The principal harvesting areas were once in the Bay of Fundy and the states of Maine and Massachusetts, where the clams occur intertidally. But since the 1940's, Maryland has produced about the same amount as Maine, harvesting from subtidal bottoms with hydraulic escalator rigs. Throughout the 1800's and until the 1940's, from the Maritime Provinces of Canada southward to Raritan Bay, softshells were shucked in fishermen's homes, with meats peddled locally; the practice has continued on a small scale in a few areas. In the 1990's, pilot hatchery and growout tests with softshells have been made in Maine and New York.

Northern quahogs and softshells currently support large recreational fisheries in the Canadian Maritime provinces, New England, and Long Island, during the warmer months. Sportfishermen tread quahogs and rake both quahogs and softshells on intertidal flats and at wading depths.

Unlike many nearshore mollusk fisheries, the U.S. Atlantic coast offshore fisheries are heavily capitalized, industrial-scale enterprises. They produce far more mollusks than the nearshore fisheries and include surfclams and ocean quahogs as well as sea scallops, *P. magellanicus*.

The surfclam fishery began in the 1930's using power-hauled box dredges. During the 1940's, new hydraulic dredges and mechanical meat washing spurred larger landings. The surfclam's pale, flavorful meat has found good consumer acceptance and, owing to its ocean habitat, it does not have contaminant (coliform bacteria) problems. Surfclams were abundant enough to replace the traditional northern quahog in commercially prepared chowders. They also overtook the market for canned clams on the Pacific coast, and at least one large restaurant chain has used them instead of softshells for fried clams (strips). Improved harvesting efficiency and areal expansion of the fishing grounds have contributed to increased catches.

In 1976, hypoxic water off New Jersey caused a massive surfclam kill, but a large recruiting class the same year rebuilt the stocks. Little recruitment to the stocks has occurred since.

Ocean quahogs live on both sides of the Atlantic Ocean. Off the U.S. coast, they occur mostly in deeper waters than the surfclam. The quahog fishery began off Rhode Island during World War II as a military food source, and in 1976 it expanded to the Mid-Atlantic. The ocean quahog then became a substitute for the increasingly scarce surfclam. U.S. vessels, some of which can hold as many as 90 32-bushel cages of quahogs, harvest them with stern-loaded hydraulic dredges up to 4.25 m wide. Since 1977, the surfclam and ocean quahog fisheries have been managed by the Mid-Atlantic Fishery Management Council, which has established such measures as catch quotas, limited entry of vessels, and effort limitations on fishing time per vessel.

Scallop Fisheries

Bay scallops, *A. irradians*, have supported fisheries from Massachusetts to Long Island and in North Carolina, since the late 1800's. Each fall, quahog fishermen turned their attention to bay scallops and were sometimes joined by local tradesmen. A crop of marketable scallops consists of one year class, and each year abundance varies considerably in every bay. For instance, extensive die-offs were caused by toxic algal blooms in Rhode Island, New York, and North Carolina in the 1980's.

Calico scallops, *A. gibbus*, occur off the south Atlantic states and are similar in size and longevity to bay scallops. A directed fishery for them began in the mid-1960's, when mechanical shucking was developed. Annual yields fluctuate widely.

Sea scallop harvests began in the 1930's in the Bay of Fundy and on Georges Bank. Production expanded sharply in the late 1940's after a market was developed, and demand has remained strong. In eastern Canada, vessels usually tow gang-dredges, whereas in the United States, chain dredges measuring 3–4 m across are used. Total fishing effort increased sharply from the late 1970's into the 1990's, and the current U.S. sea scallop fleet includes at least 400 vessels.

A maritime boundary dispute between the United States and Canada, settled in 1985 by the International Court of Justice in The Hague, restricted Canadian and U.S. vessels to their own waters. The same year, the New England Fishery Management Council adopted a fishery management plan that included a maximum of 30 meats/pound and a minimum shell height of $3^1/_2$ inches. This was not successful in preventing overfishing of the stocks, though, because the U.S. fleet became too large to be profitably supported by the resource. In 1994, the meat count requirement was replaced by rules that restricted the fleet size and number of vessel days at sea. Canada has reduced the size of its scallop fleet, and its landings have increased steadily without the large fluctuations in annual catch experienced in the U.S. fishery.

Mussel Fisheries

Blue mussels, *M. edulis*, locally abundant along the shores of northeastern North America, were infrequently marketed until actively promoted in the 1970's. A directed mussel fishery has since developed in the Canadian Maritime provinces, Maine, and Massachusetts. The mussels are cultured on suspended longlines and sometimes on the bottom, as well as harvested from natural beds.

Gastropod Fisheries

Gastropod fisheries are small, but stocks are probably almost fully utilized. The channeled whelk, *Busycotypus canaliculatus*, fishery, which probably began in Rhode Island in the 1930's, now is a minor pot fishery from Massachusetts through Long Island. A small fishery for the knobbed whelk, *Busycon carica*, and, to a lesser extent for the channeled whelk, has been pursued in lower Chesapeake Bay. They have also been fished by shrimpers in their off-season off the southeastern United States, since about 1980. Other gastropods harvested are the periwinkle, *Littorina littorea*, in the Bay of Fundy and on the northern coast of Maine, and the queen conch, *Strombus gigas*, in the Caribbean area. Florida's queen conch fishery has been closed since the late 1980's.

Atlantic–Gulf Coast Mollusk Culture

Few mollusks were produced from hatchery-reared seed from Canada through Texas in 1994. Less than 1% of oysters, softshells, bay scallops, and no mussels, gastropods, ocean quahogs, surfclams, or sea scallops were hatchery-reared. An exception was the northern quahog; an estimated 10–20% were produced from hatchery seed, and nearly all were sold as "littlenecks" for eating on the half-shell.

Oysters and mussels are the only other mollusks cultured. Perhaps 90% of oysters receive some culture: Many setting beds are planted with oyster or clam shells to collect seed, and seed from shelled and unshelled beds is transplanted to growing beds; predators are controlled in Connecticut. Perhaps 65% of mussels are grown on suspended lines or transplanted as seed to growing beds. On a limited scale during summer, fine mesh nets are laid over softshell beds in Massachusetts to enhance abundances. No bay scallop, gastropod, ocean quahog, surfclam, or sea scallop beds are cultured.

Fishery Statistics

The number of active mollusk boats and fishermen, landings, and value along the Canadian Maritimes and U.S. Atlantic coasts in the early 1990's are listed by region in Table 1. Nearly 21,000 fishermen with 4,800 boats landed about 100,000 t of mollusk meats, or 25,000,000 bushels of shellstock, with a landed value of $470,000,000/year.

The Pacific Coast of North America

Middens

Shell middens of Native Americans were common along the entire Pacific coast. The most abundant shells in them are those of Olympia oysters, *Ostreola conchaphila*; abalones, *Haliotis* spp.; and chitons. In California, middens date from 3,000–4,000 years ago; in Baja California, they date from 6,100–8,890 years ago.

Oyster Fisheries

Olympia oysters are indigenous to the Pacific coast from British Columbia into California. Relatively small (25–40 mm long) and usually inhabiting salinities mostly of 25‰ and above, they occurred in scattered locations in intertidal zones and bays. Small quantities were harvested in the 1800's, especially in the state of Washington where, beginning in about 1900, the oysters were grown in diked grounds, and production was increased. It later declined, especially after the 1940's, mostly owing to pollution. Small-scale Olympia oyster culture also was practiced in California, but they now are grown only in Washington in small quantities.

Completion of the transcontinental railroad in 1869 made it possible to transport eastern oysters, *C. virginica*, to the Pacific coast. Shipments of seed and market-sized oysters were sent to British Columbia, Washington, Oregon, and California for planting and growing. The largest quantities were planted in San Francisco Bay, Calif., and between 1887 and 1900, Atlantic coast dealers shipped an average of 124 carloads of oysters per year for planting there. In 1899, California production peaked at 2.5 million pounds of meats (335,000 bushels). The fishery declined as the bay became polluted, and harvests ended by 1939. Plantings also ended in the other west coast locations by or before the same time.

In the early 1900's, growers from Alaska to California began importing seed of the large, robust, and fast-growing Pacific oyster, *C. gigas*, from Japan. The oysters reproduced naturally only in British Columbia and Washington in the warmest summers, and they became common there intertidally, but seed imports from Japan continued. They have been grown directly on the bottom and on stakes, ropes, and racks.

In the 1960's, several hatcheries were constructed, most of them in Washington and Oregon, to provide a

Table 1

Estimated number of boats and fishermen harvesting on molluscan beds, public and private, during peak seasons, on the Atlantic coast, Canadian Maritimes to Texas, and annual landings and ex-vessel values for either 1990, 1991, 1992, 1993, or 1994. Numbers do not include workers in hatcheries. A dash (—) indicates no data was available.

Location and species harvested	No. of boats	No. of fishermen	Landings		
			Meat wt. (t)	Bushels	Value (US$)
Canadian Maritimes					
Sea scallops	400	1,700	12,276	4,510,295	92,728,000
Arctic surfclams	6	105	1,000	490,370	12,143,000
Blue mussels	—	700	708	155,874	4,929,000
Softshells	0	512	568	96,536	3,099,000
Eastern oysters	780	855	92	50,280	2,479,000
Northern quahogs	15	420	122	23,720	1,015,000
Surfclams	18	36	264	31,104	805,000
Periwinkles	—	35	51	6,260	—
Subtotal	1,219	4,363	15,081	5,364,439	117,198,000
U.S. offshore					
Sea scallops	305	2,205	7,000	2,571,850	105,000,000
Surfclams	53	423	27,277	3,530,000	34,000,000
Ocean quahogs	36	310	22,000	4,800,000	20,800,000
Subtotal	394	2,938	56,277	10,901,850	159,800,000
Maine					
Sea scallops	270	700	710	260,000	9,928,679
Softshells	0	1,200	1,050	154,000	9,158,238
Blue mussels	42	100	150	33,000	1,607,749
Ocean quahogs	45	112	206	45,300	1,357,214
Perwinkles	0	180	93	11,287	356,748
Subtotal	357	2,292	2,209	503,587	22,408,628
No. Massachusetts to Raritan Bay					
Eastern oysters	70	220	2,660	780,000	44,490,000
Northern quahogs	—	2,115	3,028	605,600	33,478,385
Softshells	—	1,000	680	115,000	8,380,648
Surfclams	12	36	3,987	516,000	5,554,545
Bay scallops	350	420	73	26,700	1,644,634
Whelks	30	40	423	62,000	1,635,553
Blue mussels	20	55	804	176,900	1,055,368
Subtotal	482	3,886	11,655	2,282,200	96,239,133
Barnegat Bay to Delaware Bay					
Northern quahogs	130	130	681	136,270	4,400,740
Eastern oysters	59	177	105	32,000	685,000
Whelks	12	36	162	23,800	540,723
Subtotal	201	343	948	192,070	5,626,463
Chesapeake Bay					
Northern quahogs	112	237	597	164,250	4,830,000
Softshells	60	75	359	65,725	3,010,995
Eastern oysters	497	810	285	129,500	1,652,019
Whelks	9	18	409	50,000	1,250,000
Subtotal	678	1,140	1,650	409,475	10,743,014
Southeastern U.S.					
Northern quahogs	—	2,235	992	272,923	11,481,500
Calico scallops	18	54	1,595	877,295	11,209,892
Eastern oysters	—	544	308	173,520	2,246,690
Whelks	80	240	490	59,870	585,710
Bay scallops	200	240	69	25,417	365,274
Subtotal	298	3,313	3,454	1,409,025	25,889,066

continued

Table 1 (continued)

Location and species harvested	No. of boats	No. of fishermen	Landings		
			Meat wt. (t)	Bushels	Value (US$)
U.S. Gulf of Mexico					
Eastern oysters	1,170	2,585	9,926	4,367,446	33,000,000
Subtotal	1,170	2,585	9,926	4,367,446	33,000,000
Grand total[1]	4,799	20,860	101,200	25,430,092	470,903,304
U.S. total only	3,580	16,497	86,119	20,065,653	353,706,304

[1] Total of listed data.

reliable local source of Pacific oyster seed and replace Japanese imports. The hatcheries now supply most of the seed produced from Alaska to California. For a while, nearly all hatchery production was shipped to distant growing sites as larvae, which growers put in tanks containing water and shells, for setting. Recently, some larvae, already set on shells, have been shipped from hatcheries to growing sites. In the last two decades, some triploid Pacific oysters have been produced in hatcheries. They do not develop gonads, so are fat and harvestable in summer, in contrast to normal Pacific oysters. Washington has been, by far, the largest oyster producer on the Pacific coast.

Pacific oysters are also grown in several Mexican estuaries on rafts and longlines. The seed is produced in hatcheries in Mexico and the United States.

Clam fisheries

Several species of clams have been harvested commercially and recreationally on the Pacific coast. They include butter clams, *Saxidomus giganteus*; littlenecks, *Protothaca staminea*; cockles, *Clinocardium nuttallii*; and horse clams or gapers, *Tresus capax* and *T. nuttallii*, in British Columbia, Washington, and Oregon. The introduced softshells, *M. arenaria*, and Japanese littlenecks, *Tapes philippinarum*, also have been harvested commercially in those localities. Another species once important in commercial and recreational landings are razor clams, *Siliqua patula*, found on ocean beaches from Alaska to Oregon. In recent years, harvests have been limited by problems with paralytic shellfish poison, domoic acid, and a new disease known as NIX (Nuclear Inclusion Unknown). Scuba divers and recreational diggers harvest the geoduck, *Panope generosa*, in British Columbia and Washington. The pismo clam, *Tivela stultorum*, once was harvested commercially in California.

Some Pacific coast clam species were canned commercially, but demand fell substantially in the 1960's, when Atlantic coast surfclams, *S. solidissima*, and ocean quahogs, *A. islandica*, took over the canned clam market. Commercial landings continue on a much smaller scale, but in recent decades most clam species have been harvested by recreational fishermen. Several species are harvested commercially in Mexico.

Scallop Fisheries

The weathervane scallop, *Patinopecten caurinus*, has been the most important mollusk landed in Alaska since the mid-1960's; production has comprised about 2.5% of total U.S. scallop production. This species was also harvested on a small scale in British Columbia and Oregon. Small quantities of other scallop species have been harvested commercially in British Columbia and Washington and contribute to the recreational catch in California. Some commercial scalloping takes place in Mexico.

Mussel Fisheries

Small quantities of mussels are produced on the Pacific coast, though they are fairly common from Alaska through Mexico. From Alaska through Oregon, *M. trossulus* is cultured on a small scale, and in Oregon, *M. californianus* also is cultured. California produces the most mussels; both *M. galloprovincialis*, imported from Europe, and *M. trossulus* are cultured. In Mexico, small quantities of wild *M. californianus* and *M. galloprovincialis* are harvested and attempts at culturing them have begun.

Gastropod Fisheries

The most important gastropods harvested are abalones, *Haliotis* spp. In California, which has the largest fishery, commercial harvesting began in the 1850's and peaked in the 1950's and 1960's, with commercial divers using hookah gear to harvest them. Recreational harvesting by sport divers has also become popular. Culturists now are rearing them from hatchery seed. Alaska has a small commercial abalone fishery, and Native Americans in Alaska and British Columbia harvest abalones and chitons on a small scale for personal use. An abalone fishery and hatchery culture are active on the coast of Baja California, Mexico.

Historical Production

A comparison of Alaskan mollusk production in 1927 (when statistics were first available) and 1991 shows that clam production was about twice as high in 1991. Weathervane scallops were not harvested in 1927, whereas nearly 1 million pounds of meats were taken in 1991.

A comparison of early and recent production in Washington, Oregon, and California shows that production of oysters and clams was about six times higher in 1991 than in 1904.

Recent Problems

Mollusk fisheries throughout North America and the Caribbean islands are beset with difficulties. Problems include habitat loss from pollution and the degradation of estuaries and bays by human activities and hurricanes, user conflicts, seed shortages, diseases, intensive fishing that has reduced some stocks, competition with foreign imports, and loss of labor.

Land-based industries use the coastal zone for processing and cooling water, and for transportation, so some mollusk-growing areas have been closed or restricted due to current or potential contamination by toxic chemicals. Channelization for navigation purposes has also altered water and substrate suitability for growth of mollusks.

Since the 1940's, human population density in the coastal zone has increased dramatically and projections are for continued growth. This has led to an increase of anthropogenic wastes, often resulting in closure of mollusk beds and disruption of fisheries. Substantial growth in recreational use of waterways is causing a proliferation of shore-based marinas, golf courses, restaurants, and other developments, impinging on the suitability of some areas as mollusk growing sites. In the past, public officials usually have allowed construction on bays and estuaries if it promised to generate high revenues. Many shellfisheries have suffered as a result. Few shellfish companies have been able or willing to bid against developers for waterfront property to establish landing and processing facilities.

Agriculture and silviculture use chemicals that also can affect the suitability of mollusk beds. Such land-based industries also change runoff patterns which may decrease water retention and allow much silt to enter estuaries, affecting their productivity. Diseases have made it difficult to grow oysters in the traditional areas of Delaware and Chesapeake Bays, and little progress to date has been made in developing disease-resistant stocks.

Competition between commercial and recreational mollusk harvesters; between different sectors of the industry, such as clammers and oystermen; between leaseholders and public grounds fishermen; and between environmentalists and commercial harvesters have resulted in regulatory restrictions that discourage modernization and capital investments in mollusk fisheries. This has prevented some fisheries from being fully exploited. The harvesting and processing segments of the mollusk fisheries are labor intensive and often rigorous pursuits, and many workers are choosing less physically demanding trades.

Mollusks have not been actively marketed, largely because most companies are too small to mount an effective effort. Promotion is usually limited to state agencies' placement of recipes in newspapers and pamphlets and displays of mollusk products at trade shows. Potential health problems, such as those caused by *Vibrio* sp. in the Gulf of Mexico, have not been adequately addressed, and markets have suffered. Paralytic shellfish poison occurs regularly in some areas, causing closures and loss of yields. Other more rare, but publicized, health risks have further contributed to loss of public confidence in shellfish wholesomeness.

On the other hand, there have been at least three positive developments in the past quarter century. First, rulings and activities by government environmental agencies and public interest groups have reduced pollution and halted construction projects that would have destroyed mollusk habitats in many estuaries. Some environmentalists are not sympathetic to the needs of mollusk fishermen, however, so rulings instigated by them do not always benefit fishermen. Environmentalists often oppose proposals to manipulate habitats to enhance mollusk abundances.

Second, assessments of offshore clams and scallops by the Canadian Department of Fisheries and Oceans and the U.S. National Marine Fisheries Service, NOAA, have helped locate stocks for fishermen and determine how rapidly stocks can be harvested without depleting them.

Third, strong market demand, especially for scallops and clams, has increased ex-vessel prices. By 1994, U.S. ex-vessel prices for mollusks were at a near-record high.

For example, "littleneck" northern quahogs were regularly selling for \$0.16/piece (\$120/bushel), Maine softshells for \$80–90/bushel, Connecticut oysters for \$60/bushel, and Canadian Maritimes blue mussels for \$0.55/pound (\$33/bushel). In California, scuba divers harvesting red abalone were selling the largest ones for \$600/dozen. Markets currently prefer farmed or depurated mollusks because they are perceived as safer to eat.

The Future

Much effort is being made on both the Atlantic and Pacific coasts to produce more mollusks, due to good market demand that will undoubtedly grow. For increased production, ways must be found to grow more mollusks in waters that are concurrently becoming more crowded with people using them for recreation and other purposes.

On the U.S. Atlantic coast, officials are attempting to control pollution in bays and estuaries, so that thousands of acres of grounds now condemned for direct mollusk harvests can become available again. Efforts are also being made to increase mollusk abundances in several bays and estuaries using hatchery-produced seed:

1) Northern quahog farms using hatchery-reared seed are expanding in number and size from Massachusetts to Florida. Culturists are trying to develop barriers to prevent whelks and other gastropods from entering the beds of cultured oysters and northern quahogs.
2) Hatchery rearing of softshell seed is being tried in Maine and New York, and has been proposed in Maryland.
3) Hatcheries to produce sea scallops are being constructed in Newfoundland and in Nova Scotia.
4) Proposals have been made to reestablish bay scallops in Niantic Bay, Conn.; Barnegat Bay, N.J.; and Chincoteague Bay, Md. and Va., using hatchery-reared scallops as brood stock. A bay scallop demonstration farm using Chinese lantern nets suspended from longlines has been established in Connecticut.
5) Researchers in New Jersey, Maryland, and Virginia are attempting to develop strains of eastern oysters resistant to the diseases MSX and Dermo and which will survive to market size on beds in Delaware and Chesapeake Bays. The seed would be produced in hatcheries.

The Connecticut oyster industry has been enormously successful in producing oysters by preparing beds to collect wild sets of seed and in otherwise farming the beds to grow oysters to market size. Similarly, farming of such other mollusks as northern quahogs, softshells, bay scallops, and mussels, in bays and estuaries might be successful. Town officials in Maine and Massachusetts recently have had success in enhancing softshell seed abundances by laying ¼-inch mesh screens over clam flats, and field tests are being planned in New Jersey to determine whether a shell-covered bottom will protect wild seed of northern quahogs from predators.

The three U.S. offshore shellfisheries are now managed by fishery management plans implemented under provisions of the U.S. Magnuson Fishery Conservation and Management Act of 1976. At the current rates of recruitment and harvest, the ocean quahog stock will last about 30 years. The plan to restrict surfclam harvests has led to an improved economic situation in the industry. And managers hope that decreased fishing effort on sea scallops will increase its stocks and stabilize yields.

Commercial clams and scallops on the continental shelf could be exploited to a much larger extent. Dense, widespread sets ($>8{,}000/m^2$) of surfclams occur every summer in thousands of acres of coastal bottoms at least off Long Island, N.Y. and New Jersey, but the seed is almost entirely consumed by crabs every autumn. The seed perhaps could be harvested in the late summer and grown on bottoms or in suspended trays in sounds and bays where temperatures are sufficiently low for them to survive and grow to market sizes.

Sea scallop seed could be collected in mesh bags placed in ocean areas. It could possibly be grown in lantern nets, on suspended lines, or on the bottom, in sufficiently cool sounds and bays. This technique is currently being tested on Prince Edward Island.

On the Pacific coast, hatchery culture of oysters is expected to enjoy continued success, and abalone culture is growing in California. Three hatchery-growout farms are producing abalone for food, and about ten similar farms grow them for the aquarist trade. Pacific coast oyster and abalone producers have expanded their markets from North America to Pacific rim countries in Asia, a trend likely to continue.

Researchers on the west coast of Mexico are developing culture methods for scallops, abalone, oysters, pearl oysters, and mussels. The Mexican government is encouraging private companies—domestic and international—to develop mollusk farms. Local officials forecast that Mexico will soon follow Chile, which in the late 1980's and early 1990's developed large salmon and scallop farms. Mexican officials wish to preserve natural environments, but will allow slight alterations where mollusk and shrimp culture is developing.

Video cameras and players make it possible to record effective mollusk culture techniques and share these quickly with other nations. Underwater video cameras enable culturists who cannot scuba dive to view mollusk beds and develop new procedures more effectively, and video cassettes can be mailed to interested aquaculturists almost anywhere.

Considerable research on the biology and ecology of mollusks takes place in many parts of the world. Culturists can scan the published results, seeking ways to increase production.

Central America

Before publication of this monograph, the mollusk fisheries in Central American countries (Belize, Guatemala, Honduras, El Salvador, Nicaragua, Costa Rica, and Panama) had not been described to any extent and little has been written about the biology and ecology of their mollusks. However, at least two species, the Caribbean oyster, *Crassostrea rhizophorae*, and queen conch, *Strombus gigas*, have been described in other parts of their ranges. The Nicaraguan molluscan fisheries described in this monograph may be representative of those in other parts of the region, because the country is centrally located, its mollusks range widely in the region, and habitats are probably similar.

Shell middens left along Nicaragua's Atlantic (Caribbean) coast by indigenous peoples suggest that mollusks have been harvested there for a great many years. In recent times, people on this coast have harvested marshclams, *Polymesoda placans*; coquina clams, *Donax denticulata* and *D. striata*; and Caribbean oysters for personal use. Harvesters paddle or sail dugout canoes to marshclam and oyster beds located 60–90 cm deep at low tide in lagoons, gathering the mollusks by hand. No implements are used. They usually harvest coquina clams with shovels, but also by hand, along Atlantic coast beaches. As was the cultural practice of peoples indigenous to eastern North America, Nicaraguan women and children harvest most of the mollusks, and the women also open and cook them. Adult males harvest finfish, shrimp, turtles, lobsters, and gastropods to sell.

In the Caribbean Sea, gastropods such as queen conchs and whelks are harvested by scuba divers who primarily seek lobsters. Queen conchs are harvested throughout the Caribbean area.

On Nicaragua's Pacific coast, the black ark clam or mangrove cockle, *Anadara tuberculosa*, is harvested in mangrove, *Rhizophora* sp., swamps. Some black ark clams are eaten by the harvesters, but most are sold whole or served in cocktails in the western part of the country. The clams, which range from Baja California to Peru, are harvested in Mexican mangrove swamps and presumably in other Central American countries that border on the Pacific. Mollusks harvested on a lesser scale in western Nicaragua are beanclams, *Donax dentifer*; giant ark clams, *A. grandis*; chitons, *Chiton stokesi*; and giant eastern Pacific conchs, *S. galeatus*. *D. dentifer*, *A. grandis*, and *S. galeatus* range along the entire Pacific coast of Central America. Scuba divers harvest *S. galeatus* in Mexico and Nicaragua.

No studies of water quality have been conducted in Nicaragua, and no sanitary controls over production and marketing are practiced. Because its beds are not certified for marketing, its mollusks cannot be sold in such countries as the United States.

Large-scale commercial harvesting and marketing of mollusks never developed in Nicaragua because supplies are relatively small (no mollusk culturing is done), and refrigerated transport of small quantities of mollusks to distant markets in the warm climate has been impractical. Its mollusk fisheries could expand a little, but substantial increases seem unlikely.

The only commercial scallop fishery along the Central American Pacific coast is in Panama, where Pacific calico scallops, *Argopecten ventricosus*, occur. Harvests apparently peaked in the 1960's, when about 300 t of meats were landed annually. Landings after that have been much smaller. Most scallop meats are flown to the United States for sale.

Europe

Middens

Shells of European flat oysters, *Ostrea edulis*, have been found in ancient (6,000 B.C.) shell piles, from Norway through Portugal. They are also found in inland settlement remains of the Roman Empire. Other species found in the middens are blue mussels, *M. edulis*; cockles, *Cerastoderma edule*; and periwinkles, *L. littorea*.

Oyster Fisheries

In the 17th and 18th centuries, flat oysters were a common food in coastal areas of Europe and were cultivated in the Mediterranean Sea. They became increasingly important during the 1800's in Germany, Denmark, England, the Netherlands, France, Portugal, Italy, Croatia, and other countries. In some nations, they were the most important mollusk landed. Much of the 19th-century expansion in harvesting was due to increased demand created by better transport inland.

By the late 1800's, when oysters were being landed in increasing quantities along the U.S. Atlantic coast, natural stocks of flat oysters had declined sharply in most European countries, although they persisted into the early 1900's in Denmark and Portugal. They have since been replaced by *C. angulata* in Portugal.

Flat oysters have recently been relatively scarce except in the Netherlands, Croatia, and Turkey, where small stocks have persisted. Overfishing was the main cause of decline, but extremely cold winters contributed. In recent years, a disease caused by *Martelia refringens* and

Bonamia ostreae also has killed stocks. *B. ostreae* was introduced when *O. edulis* seed, raised in California hatcheries, was transplanted to Europe for growth.

Several European countries have been growing the robust Pacific oyster, *C. gigas*, a practice begun in the late 1970's. North of the Netherlands, production is entirely from hatchery-produced seed, whereas in the Netherlands and France it is mostly from natural sets. France is Europe's leader in production of *C. gigas*, with 150,000 t (4.13 million bushels)/year. Most French oysters are held in ponds for about two weeks before sale.

Clam Fisheries

The fishery for cockles, *Cerastoderma edulie*, has been important for generations from Germany through Spain. Before the 1960's, fishermen dug them with hand rakes on bare flats and in shallow water at low tide. Since then, they have harvested them with hydraulic dredges and production has increased markedly, especially in the Netherlands, England, and France. A cockle fishery in the Wadden Sea, Germany, began in 1973 and ended in the early 1990's.

In France, Portugal, and Spain, grooved carpet shell clams, *Tapes decussatus*, are harvested from natural areas and also are farmed. Farming consists of collecting seed from natural areas and planting and protecting it in small growing areas (parks). France also produces this species from hatcheries, and Britain produces a small quantity.

The fishery for *T. decussatus* and *Chamelea gallina* is generations old in Italy. *T. decussatus* is also harvested in Croatia. Japanese littlenecks or Manila clams, *T. philippinarum*, were introduced to Europe in the 1980's and are produced in hatcheries in Norway, France, and Italy. Commercial fishing for striped venus, *Venus gallina*, and *T. decussatus* began in Turkey in the 1970's.

Scallop Fisheries

Scalloping in Europe was done on a small scale for fish bait until the early 1900's. It became a large fishery in the 1960's, when fleets began to dredge for *Pecten maximus* off the coasts of Britain and France, for *Chlamys islandica* around Iceland, and for *P. jacobaeus* in the Adriatic Sea in Italy. *P. jacobaeus* is also harvested in French Mediterranean waters. Dredging for *C. opercularis* off the Faroes began in 1970. British boats also have been harvesting *C. opercularis* since the early 1970's, and Norwegian fleets have been harvesting *C. islandica* since the mid-1980's. Belgian boats began landing scallops with trawls in the late 1960's and early 1970's; more than half are taken from the English Channel. European countries import some scallops from outside Europe, with France being the leading importer.

Mussel Fisheries

Mussels are now the most important mollusk landed in Europe. The blue mussel, *M. edulis*, fishery was relatively small until 1900. Although some were consumed, most were used as bait for longline fisheries or as fertilizer. Since then, and especially after the mid-1940's, demand for them as human food has increased. Landings have risen markedly in Germany, Denmark, the Netherlands, France, and to a small extent, Sweden. But Spain is the European leader, with an annual production of 173,000 t (6.3 million bushels) (1990), much as a result of culture. Spanish mussel production exploded with the development of raft culture in the 1940's and 1950's. In other countries, mussel culture involves either dredging seed from natural grounds and planting it on growing grounds, or collecting natural seed on ropes and along the shore and then growing it in suspended plastic mesh socks or, as in France, on bouchots (poles). This method, used on the Atlantic coast of France, is the oldest known method for farming mussels off the bottom and dates from 1235.

The world leader in bottom-farming of mussels is the Netherlands, where about 100,000 t/year are produced in the Wadden Sea. Southeastern France, Italy, Croatia, Turkey, and Bulgaria have historic fisheries for the Mediterranean mussel, *M. galloprovincialis*. Production has increased in some countries since the 1940's, when fishermen began using mesh socks to grow the mussels.

Total mussel production in Europe was at least 590,000 t (about 22 million bushels) in 1990. Wholesalers may rewater the mussels for two weeks or more before selling them to consumers. Freshness is guaranteed by the rewatering, which also serves for depuration. Mussels, commonly distributed from docks and rewatering tanks to wholesalers in various EC countries within 12–36 hours, reach consumers in top condition.

Gastropod Fisheries

Intertidal periwinkles, *L. littorea*, probably have been eaten for centuries along the coast from Norway to France. The largest fisheries apparently were in Britain and the Netherlands. While they continue to be harvested in Britain, this fishery disappeared in the Netherlands in the 1960's, as stocks declined and labor costs escalated.

Whelks, *Buccinum undatum*, also have been harvested for centuries in Britain, and the Netherlands had an important fishery for them from the mid-1800's to the late 1960's, when the whelk populations declined from overfishing. France also has had a large fishery for this species. Countries with small whelk fisheries have been Germany, from the 1950's into the 1970's, and Belgium since the early 1960's. Most whelks are caught with pots.

Fishermen in Bulgaria and Turkey harvest the exotic snail, *Rapana thomassiana*, in the Black Sea. The snail was introduced there accidentally from the Sea of Japan in the 1940's.

European Mollusk Culture

The most important bivalves produced in Europe[3] are mussels, *M. edulis* and *M. galloprovincialis*; Pacific oysters, *C. gigas*; cockles, *C. edule*; flat oysters, *O. edulis*; clams, *T. decussatus*, *T. philippinarum*, *T. pullastra*, and *Venus gallina*; scallops, *P. maximus*, *C. islandica*, and *C. opercularis*; and, recently, hard clams, *Spisula subtruncata* and *S. solida*.

Only oysters; littleneck (Manila) clams, *Tapes* spp.; and scallops, *P. maximus*, are reared in hatcheries. About 20% of the Pacific oysters and less than 10% of the littleneck clams are produced from hatchery seed. More than half of the littleneck clams originated from hatcheries until the mid-1980's, but strong recruitment of natural stocks in Italy has all but eliminated the market for hatchery seed. Hatchery production of flat oysters and scallops is of little consequence because the hatchery seed of both species suffer nearly total mortality during growout in the field.

Production of mussels and oysters depends almost exclusively on culture activities. In the case of mussels, about half of the production is from culture of naturally set spat on ropes or poles (mostly *M. galloprovincialis* in Spain, Italy, and France), and about half is from the relaying of wild seed to subtidal growing beds (*M. edulis* in Denmark, Netherlands, and Germany). Exceptions are Bulgaria and Turkey, where most mussels are harvested from wild beds. In the case of oysters, the seed from spat collectors is usually grown intertidally on reserved plots. Littleneck clam production depends both on fishing for wild stocks and on bottom culture, but it is impossible to say which is more important. Production of cockles, scallops, and hard clams is based on the fishery of natural stocks, mainly offshore dredging with specialized boats.

Public Health Standards for Mollusks

The EC Common Market has been developing uniform standards for the protection of public health. Within the EC regulatory framework, standards are established for the quality of waters in which mollusks are cultivated and fished. Standards currently being being applied in several EC countries include those for: pH, temperature, water-chlorine intensity, suspended solids, salinity, oil, flavor, taste, thermotolerant coliforms, dissolved oxygen, halogenated organic carbons, and a number of metals. The standards provide that their values may not be exceeded under natural conditions, beyond set limits.

Uniform European regulations will be implemented for the waters in which mollusks are fished or kept, as well as for fish and mollusks imported from outside the EC. Criteria apply to processing techniques, hygiene, and facilities. The EC became effective on 1 January 1993.

The Future

The future of mollusk fisheries in Europe appears to be strong, as the new EC public health standards will give consumers increased confidence in the wholesomeness of mollusk products. Demand should continue to be good. The influences of environmental activists may curb mollusk fisheries in some countries since they have been objecting to certain harvesting and culture practices. A few countries with shortages of seed, such as for clam species, cite the need to construct hatcheries.

Interactions between North America and Europe

Nearly all mollusks produced in North America are sold within its boundaries, and nearly all European production is sold within the EC. In recent years there has been little mollusk trade between North America and Europe. Small quantities of North American scallops and oysters have been sold in Europe, and small quantities of pickled European mussels have been sold in the United States. North Americans have copied European methods of growing mussels. Perhaps they could copy the handling of mussels from harvesting to markets. Connecticut methods of farming oysters might be tried in Europe.

Each succeeding chapter in this volume contains:

1) a list of mollusk fisheries in each area
2) a description of mollusk habitats
3) maps showing locations of beds
4) the history of each mollusk fishery including historical landings and gear development
5) historical references relating to mollusk fisheries
6) historical and modern photographs showing aspects of the fisheries.

[3] This section was contributed in 1994 by Matthias Seaman, Institut fur Meereskunde an der Universitat Kiel, Dusternbrooker Weg 20, D-24105 Kiel, Germany; John Bayes, Seasalter Shellfish Ltd., Whitstable, Kent CT5 1AB, U.K.; and Fernando Gutierrez Gomez, Tinamenor S. A., 39594 Pesues, Cantabria, Spain.

In addition, many chapters include local recipes for preparing mollusks, as well as historical numbers of boats and fishermen.

The chapters in the later section (volume 2) on topics associated with mollusk fisheries contain:

1) how fishermen relate to mollusk supplies
2) environmental challenges facing mollusk fisheries and culturists
3) government regulatory strategies to assure the safety of mollusks
4) economic issues relating to mollusk fisheries
5) a description of government collection and processing of mollusk landing statistics
6) mollusk marketing in the United States, and,
7) trade in Europe.

None of the chapters contain descriptions of the anatomy, physiology, or growth of the mollusks, because these aspects have already been described in many papers, books, and reports published over the past century or so. Neither do they provide much information on setting densities of juvenile mollusks. Abundances of juveniles vary among years, and are largely governed by environmental conditions that in turn are influenced by weather. Dense sets can occur even when spawning stocks are relatively low and vice versa. Individual mollusk fisheries can flourish following one or more years in which sets of juveniles are dense and survival is high, or be depressed following a series of poor setting or survival years or both.

Some chapters describe how abundances of mollusks have declined due to habitat degradation. A recent example is the spread of sea lettuce (Chlorophyta, Ulvaceae) on softshell beds in northern New Jersey. The sea lettuce mats over the beds, preventing settlement of larvae and killing adults. Since too little specific information exists about the relationship between habitat condition and mollusk abundances, we recommend that future researchers devote more attention to studying the features of habitats and ways to modify them to enhance abundances.

The Molluscan Fisheries of the Canadian Maritimes

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ABSTRACT

The estuarine and offshore waters of Prince Edward Island, New Brunswick, and Nova Scotia have supported fisheries for nine species of mollusks. Estuarine mollusks have included eastern oysters, *Crassostrea virginica*; softshells, *Mya arenaria*; northern quahogs, *Mercenaria mercenaria*; periwinkles, *Littorina littorea*; and since 1981, blue mussels, *Mytilus edulis*. The offshore mollusks have included sea scallops, *Placopecten magellanicus*, since the early 1900's; surfclams, *Spisula solidissima*, and ocean quahogs, *Arctica islandica*, both since about 1970; and Arctic surfclams, *Mactromeris polynyma*, in the 1980's and 1990's. All except oysters and mussels have been harvested from wild public beds, while oysters have been harvested from public and leased beds and mussels from leased beds. The presence of middens along many shores prove that generations of Native Americans used oysters, softshells, quahogs, mussels, and snails as food and for jewelry. Most shellfisheries are seasonal, with about 50 boats and 920 fishermen employed in the winter, the least active season. About 1,285 boats and 4,090 fishermen are employed in the fall, the most active season. In 1992, 15,191 t of molluscan meats were landed; sea scallops comprised 90% of the landings. The sea scallop fishery has two types of fleets. One with relatively small boats and crews harvests scallops in the southern Gulf of St. Lawrence and the Bay of Fundy and environs, and the other type with large boats and crews harvests mainly on Georges Bank.

Introduction

The estuarine and offshore waters of the Canadian Maritime Provinces (Fig. 1)—Prince Edward Island (P.E.I.), New Brunswick (N.B.), and Nova Scotia (N.S.)—have supported fisheries for nine molluscan species. The estuarine fisheries have been based on harvests of oysters, *Crassostrea virginica*; softshell clams, *Mya arenaria*; and northern quahogs, *Mercenaria mercenaria*, since prehistoric times; blue mussels, *Mytilus edulis*, since the 1940's; and periwinkles, *Littorina littorea*, since at least the early 1950's.

The offshore fisheries have been based on harvests of sea scallops, *Placopecten magellanicus*, since the early 1900's; surfclams, *Spisula solidissima*, since the 1920's and 1930's; and to a small extent, ocean quahogs, *Arctica islandica*, since about 1970; and Arctic surfclams, *Mactromeris polynyma*, in the 1980's and 1990's.

The economies of the Maritimes are based on agriculture, fisheries, forestry, and tourism, with molluscan fisheries important to all three provinces. In 1992, the number of boats ranged from about 50 in winter, the least active season, to 1,286 in fall, the most active season; the number of fishermen ranged from 825 in winter to 4,092

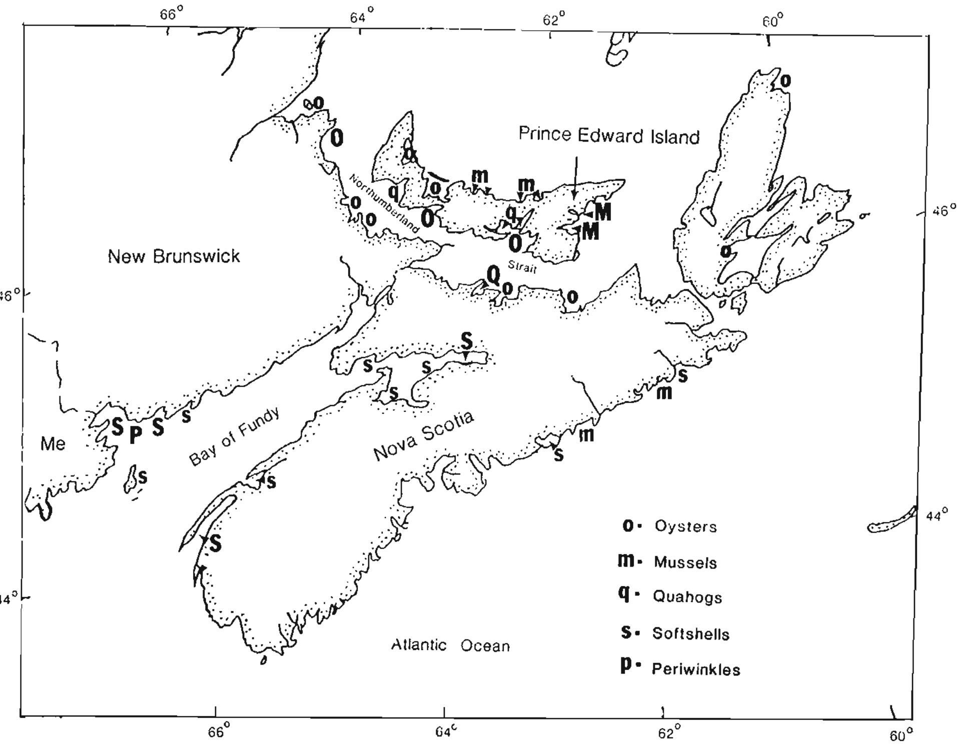

Figure 1
Locations of principal areas for harvesting estuarine shellfish in the Maritime provinces. Letter sizes show relative sizes of the fisheries.

in the fall (Table 1). Total 1992 production of all mollusks was about 112,815 metric tons (t) (whole weight) (4.9 million bushels; 15,191 t of meat) with a landed value of Can$132.2 million (US$104 million); sea scallops comprised about 90% of the landings (Table 2).

Softshells, quahogs, periwinkles, sea scallops, surfclams, ocean quahogs, and Arctic surfclams have been harvested from wild public beds, while oysters have been harvested from public and leased beds and mussels from leased areas. Before the 1970's, the public oyster beds were wild. The only "culturing" was done on private leases, with seed oysters picked by hand and planted on the leases for growth to market size. Since around 1970, production on P.E.I. has come increasingly from cultured public beds, and some oysters are cultured on leases on P.E.I. and in N.B.

The Maritime provinces are at or near the northern end of the ranges of many harvested mollusks. Oysters occur north to Miscou Island in northern N.B. Northern quahogs range to the Gulf of St. Lawrence and ocean quahogs to Newfoundland. Softshells, periwinkles, and sea scallops extend to Labrador while the blue mussels and Arctic surfclams range to the Arctic Ocean (Abbott, 1974).

Habitats

Three main bodies of water border the provinces: the Gulf of St. Lawrence, including Chaleur Bay and Northumberland Strait; the Atlantic Ocean; and the Bay of Fundy. Gulf of St. Lawrence tides range from about 0.6–2.7 m (2–9 feet), while those in the Bay of Fundy have the largest amplitudes in the world, 9 m (30 feet) in most places and as much as 16.5 m (54 feet) in the Minas Basin.

The Gulf of St. Lawrence is called the "Acadian pocket" because its temperatures are warm enough to support species normally found much farther south along the U.S. eastern seaboard. Temperatures in estuaries extending from the Gulf are around –2°C from January into March, but range to 20°–24°C in July and August (Needler, 1931) because the estuaries have extensive shallow zones and broad intertidal flats, many of which are deep orange-red and absorb much radiant energy. In winter, an average of 1 m (3 feet) of ice covers the Gulf, in contrast to the Atlantic Ocean and Bay of Fundy which are nearly ice-free except in estuaries.

Salinities in estuaries range from nearly fresh at headwaters to 32‰ near mouths. Large areas of estuaries

Table 1

Estimated numbers of mollusk fishing boats and fishermen in the Maritime provinces—Prince Edward Island (P.E.I.), New Brunswick (N.B.), and Nova Scotia (N.S.)—during peak fishing times in 1992.

Species	Boats	Fishermen
Oysters		
P.E.I., spring	250	275
P.E.I., fall	230	230
N.B., spring	43	43
N.B., fall	500	575
N.S., fall	50	50
Softshells		
P.E.I., spring–fall	—	42
N.B. (Northumberland St.), spring–fall	—	125
Bay of Fundy, spring–fall	—	300
N.S. (east coast), spring–fall	—	45
Northern quahogs		
P.E.I., spring–summer	15	250
N.B., spring–summer	—	100
N.S., spring–fall	—	70
Periwinkles		
N.B.-N.S., summer–fall	—	35
Mussels		
P.E.I., spring	—	615
P.E.I., summer	5	15
P.E.I., fall	—	615
P.E.I., winter	25	—
Sea scallops		
Gulf St. Lawrence, spring and fall	200	450
Bay of Fundy, spring–fall	150	600
Georges Bank, year-round	50	800
Surfclams		
P.E.I., summer	18	36
Arctic surfclams		
N.S.–Newfoundland, year-round	3	96
N.S., spring–fall	3	9
Totals		
Spring	714	3,870
Summer	94	1,923
Fall	1,286	4,092
Winter	53	921

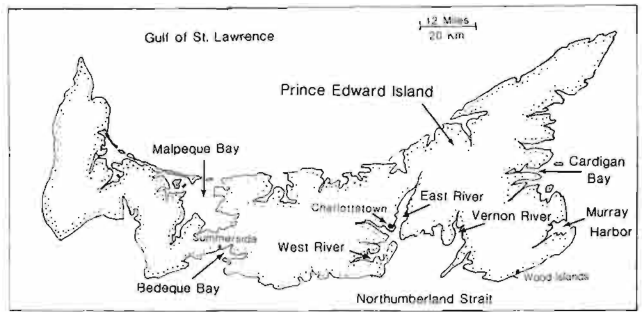

Figure 2
Prince Edward Island showing principal shellfishing areas and three towns.

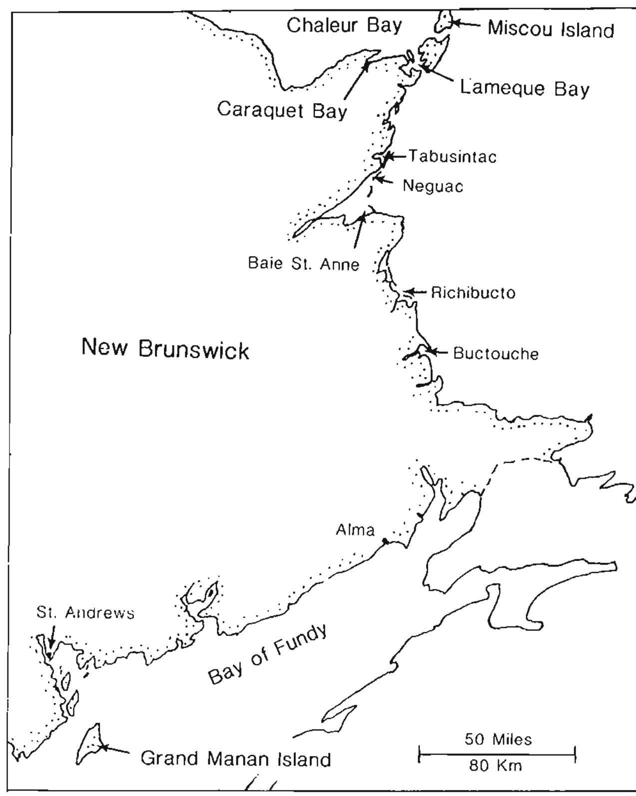

Figure 3
New Brunswick showing principal shellfishing areas and ports.

on P.E.I. (Fig. 2), N.B. (Fig. 3), and N.S. (Fig. 4) have salinities from 7–15‰ at low tide—suitable for oysters, but unsuitable for the predatory starfishes, *Asterias vulgarus* and *A. forbesi*, which cannot tolerate salinities below 15‰. In addition, adult starfish rarely inhabit grounds less than 1.2 m (4 feet) deep at low water. Oysters inhabit many of those grounds even where salinities are above 15‰. (*A. forbesi* has become much more abundant around P.E.I. in the past 20 years.) In mussel-growing areas, salinities range from 23–29‰ (Judson, 1989).

Bottom firmness varies widely. Oysters grow on mud (sometimes so soft it barely supports them), shell deposits, and hard sand. Most quahogs inhabit mud. In the Bay of Fundy and Atlantic Ocean, scallops grow on gravel-sand, gravel-rock, and sand. Surfclams inhabit sand and cobblestone bottoms.

During winters from the 1860's to the early 1940's, farmers destroyed some oyster habitat on P.E.I. and in N.B., particularly close to shores, when they dug deposits of "mussel mud" from the bottoms of estuaries. The mud was dug from the bottom and raised through holes in the ice, using large forks or scoops attached to lines extending to horse-turned capstans. The mud was then transported by horse-drawn sleighs to nearby fields and spread on the soil. While it contained mussel shells, estuary mud was also packed with oyster shells that benefited soils as a fertilizer and conditioner to lower acidity. The shell beds ranged from 60 cm to 3 m (2–10 feet) deep (Ingersoll, 1881; Patton, 1911; Weale, 1978).

Table 2

Commercial landings of mollusks in the Maritime provinces—Prince Edward Island (P.E.I.), New Brunswick (N.B.), and Nova Scotia (N.S.)—in 1992.

				Value (thousands)	
Species and location	Metric tons[1]	Bushels[2]	Meat weight (t)	Can$	US$
Oysters					
P.E.I.	1,179	32,480	60[3]	$2,062	1,623
N.B.	530	14,500	26[3]	1,048	825
N.S.	121	3,300	6[3]	40	31
Softshells					
Gulf of St. Lawrence					
P.E.I.	256	9,404	55	464	365
N.B.	639	23,473	138	893	703
N.S.	0	0	0	0	0
Bay of Fundy					
N.B.	519	19,065	112	638	502
N.S.	1,214	44,594	263	1,943	1,529
Northern quahogs					
P.E.I	560	15,428	77	803	632
N.B.	202	5,565	30	370	291
N.S.	99	2,727	15	117	92
Periwinkles					
N.B.-N.S.	239	6,260	51		
Mussels					
P.E.I.	4,186	154,000	700	4,959	3,903
N.B.	50	1,837	8	33	26
N.S.	1	37	0.17	—	—
Sea scallops					
Gulf of St. Lawrence					
P.E.I.	796	35,264	96	1,076	847
N.B.	832	36,733	100	1,151	906
N.S.	496	22,040	60	723	569
Bay of Fundy and Atlantic Coast					
N.B and N.S.	24,239	1,073,613	2,920	32,107	25,268
Georges Bank					
N.S.	75,528	3,342,645	9,100	82,767	65,138
Surfclams					
P.E.I.	806	22,205	1,306	554	436
N.B.	227	6,254	48	334	263
N.S.	96	2,645	20	134	105
Totals	112,815	4,874,069	15,191	132,216	104,054

[1] Whole weight.
[2] U.S. standard bushels.
[3] Assuming a yield of 4 pounds/bushel.
[4] Data from 1992.

Large deposits of fossil shells remain in the historically oyster-producing estuaries, and on P.E.I. some have been mined and used as cultch for oyster larvae. They have been surveyed in Malpeque and Bedeque Bays and other estuaries on P.E.I. and in Caraquet Bay, N.B.

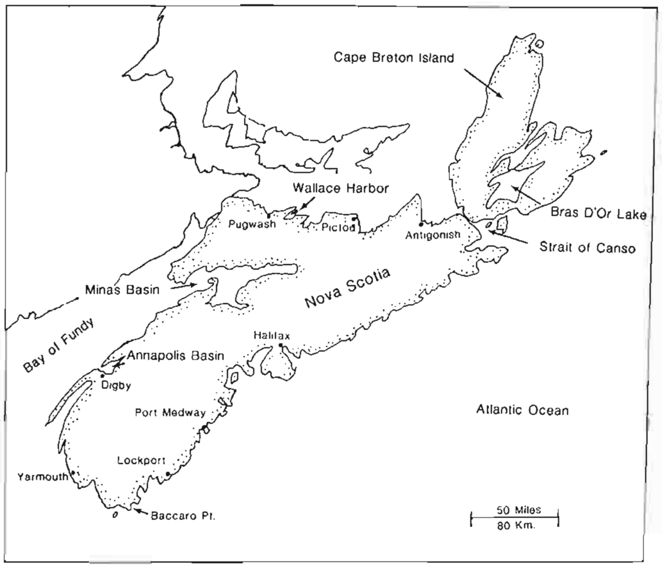

Figure 4
Nova Scotia showing principal shellfishing areas and ports.

Sea scallops, surfclams, and ocean quahogs are harvested on offshore banks (Fig. 5).

Aboriginal Fisheries

In the early 1600's, Pierre Biard, a Jesuit missionary describing life in N.S. (Wells, 1986) said: "In the middle of March, fish begin to spawn . . . from the month of May up to the middle of September, [the Native Americans] are free from all anxiety about their food; for the cod are upon the coast, and all kinds of fish and shellfish [are present] . . ."

The presence of middens along many shores proves that generations of Native Americans used oysters, softshells, quahogs, mussels, and snails as food and for jewelry (Ingersoll, 1881; Baird, 1882). Baird (1882), after finding the ashes in one midden were derived from eelgrass, *Zostera marina,* concluded that the natives cooked mollusks by wrapping them in eelgrass and burning it. The softshell middens are about 60 cm (2 feet) deep and occupy several acres on the coasts of N.B. and N.S. (Newcombe[1]).

[1] Newcombe, C. L. 1933. The softshelled clam fishery of the Bay of Fundy. Manusc. Rep. of the Biol. Stns., Fis. Res. Bd. Can. 288, 38 p.

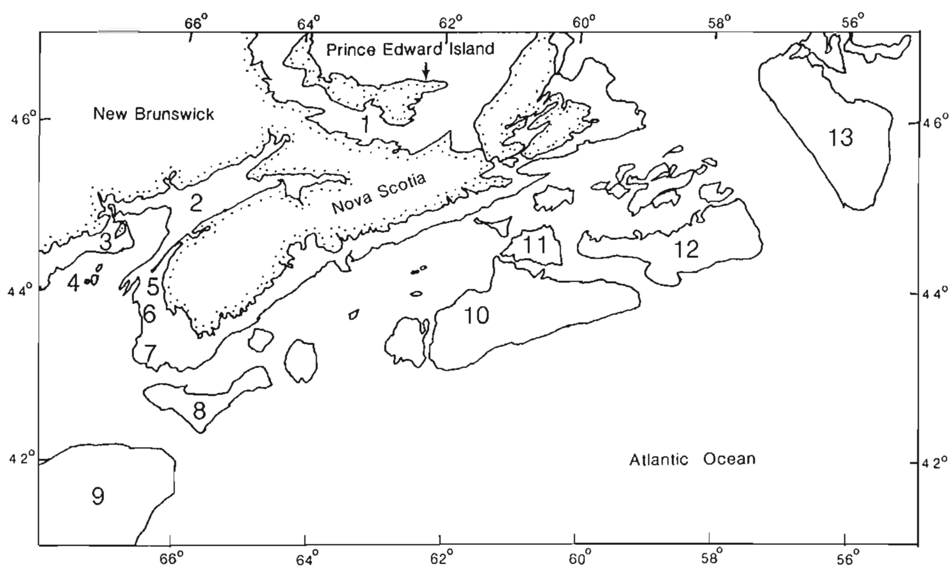

Figure 5
Offshore beds where sea scallops and clams are harvested: 1) Northumberland Strait, 2) Bay of Fundy, 3) Grand Manan, 4) Southwest Bank, 5) Brier Island, 6) Lurcher Shoals, 7) German Bank, 8) Browns Bank, 9) Georges Bank, 10) Western Bank, 11) Middle Bank, 12) Banquereau Bank, and 13) Saint Pierre Bank; the Grand Bank, not shown, lies east of Saint Pierre Bank.

Government Administration of Shellfisheries

The Constitution Act of 1982 assigned legislative authority for Canada's sea coast and inland fisheries to the government of Canada. The Minister of the Federal Department of Fisheries and Oceans (DFO) has constitutional authority over fisheries and direct management authority over fisheries in the Atlantic provinces.

Administrative agreements between the Provincial and Federal governments permit one level of government to act for the other in the daily management of fisheries. In the Maritimes, the DFO regulates public fisheries. Aquaculture, as it applies to private property rights, is regulated and administered by the provinces, except in P.E.I. where it is administered by the DFO on behalf of the province. In P.E.I., an aquaculture zoning system has been developed and implemented, taking into consideration the type of lease (i.e., bottom or surface) and balancing the demands of the various users for marine water resources. This is the first zoning system in North America. Shellfisheries are controlled and administered through DFO regulations governing the licensing of fishermen (the number of licenses in fisheries for most species is limited). Regulations define seasons, size limits, fishing methods and areas, vessel size (if applicable), and other licensing requirements that pertain to governing harvest of public resources.

The Federal government has also entered into international agreements. One of these is the National Shellfish Sanitation Program (known as the International Shellfish Agreement) that outlines specific guidelines for handling and identifying shellfish. To this end, the Federal government has passed Management of Contaminated Fisheries Regulations authorizing the Regional Director General to close any fishery in a contaminated area. Any fishing in such an area can be controlled by licensing and a detailed decontamination plan. Water quality in areas where shellfish are harvested is regulated by the Canadian Department of the Environment.

Fisheries administrators are cognizant of the importance of shellfish to the economic and social fabric of rural communities in the Maritimes, and they try to work closely with fishermen to enhance their employment and earnings. In many areas, estuarine shellfisheries involve people from the lower end of the economic scale, providing almost all of their incomes.

Estuarine Shellfisheries

Oyster Fishery

Nearly all oysters occur in wild public beds of various sizes on P.E.I. and the Gulf of St. Lawrence portion of northern N.B. and N.S., including Bras D'Or Lake. Most occur at depths from 60 cm to 2 m (2–6 feet) at mean low water, but they range from the intertidal zone to a depth of at least 11 m (36 feet). There are very few oysters along the Atlantic coast of N.S. and none in the Bay of Fundy.

Spatfalls of oysters on the public beds occur in commercial densities nearly every year. They subsequently grow in clusters of 3- to 5-year classes, from spat to commercial size (at least 76 mm or 3 inches) (Table 3). Oysters grow relatively slowly, but the rate of growth varies by estuary. On P.E.I., growth is fastest in Bedeque Bay at up to about 37 mm (1.5 inches)/year, medium in the East River at 20 mm (0.75 inches)/year, and slowest in branches of Malpeque Bay at 10 mm (0.4 inches)/year.

Starfish are abundant and eliminate most seed oysters in depths below 1.2 m (4 feet), where salinities are above 15‰. The only other predators are rock crabs, *Cancer* sp., that prey on unattached seed oysters smaller than 25 mm (1 inch), and the Atlantic oyster drill, *Urosalpinx cinerea*, which is scarce and only a minor source of oyster mortality.

Market-size oysters contain less meat than those farther south along the Atlantic coast. In N.S., they yield only about 3.75 pounds of meat/bushel (Morse, 1971),

Table 3

List of minimum legal lengths for harvesting mollusks in the Maritime provinces, 1993. Source: Department of Fisheries and Oceans.

Waters	Species	Minimum in mm (inches)
All provinces	Eastern oyster	76 (3.0)
Prince Edward Island	Northern quahog	50 (2.0)
Inland and tidal	Surf clam	76
waters	Softshell	50
New Brunswick		
Inland and tidal waters	Northern quahog	38 (1.5)
of that portion of New	Surf clam	76
Brunswick that borders	Softshell	44 (1.75)
on the Bay of Fundy		
Inland and tidal waters	Northern quahog	38
of that portion of New	Surf clam	76
Brunswick that borders	Softshell	38
on the Gulf of St. Lawrence and Northumberland Strait		
Nova Scotia		
Inland and tidal waters	Northern quahog	38
	Surf clam	76
	Softshell	44
Bay of Fundy	Sea scallop	76
Georges Bank	Sea scallop	105 (4)

or about half the meat yield of oysters from the State of Connecticut. This makes them less suitable for shucking, but their meat is flavorful and demand for them as fresh oysters on the half-shell is strong. The oysters are unique because, with proper storage, they will remain alive out of water for at least two months.

Before completion of the Intercolonial Railway in 1876, most shellfish and fish products consumed in Montreal, Canada's easternmost large city, were obtained from the United States because of good transportation and a shorter distance from Montreal to the U.S. Atlantic seaboard than to the Maritimes. The railway opened markets in the central provinces, leading to an increased oyster harvest in the Maritimes. Output was highest in the 1880's and 1890's, with P.E.I. the main producer. Maximum recorded output for the three provinces, 162,000 bushels valued at $193,938, was in 1882, but production declined sharply thereafter (Morse, 1971).

Prince Edward Island—The first detailed description of oystering in the Maritimes was written by Ernest Ingersoll (1881) who surveyed the industry in 1879 as part of a wider survey of North American shellfisheries. He found oystering on P.E.I. centered in Malpeque (Richmond) Bay, where each spring (May and June) and fall (September into November) 400–500 local farmers each harvested about 5 bushels of oysters/day from wild beds using tongs. Their boats were square-sterned rowboats and small sailboats. The catches were hauled by wagon to the seaport of Summerside, a distance of 3–16 km (2–10 miles) away, and sold for about $0.40/bushel. The oysters were then transported by boat to the mainland for further sale.

Bedeque Bay then had few oysters, as a consequence of overfishing, and apparently little oystering took place there. But the bay once supported a large oyster supply, and its oysters became famous. Oysters were also scarce in West, North, and East rivers where they had once been abundant. The value of those landed on the island was about $25,000 annually.

In 1880, about the time of Ingersoll's survey, annual oyster production from P.E.I. was about 40,000 boxes (50,000 bushels). The historical peak production year (70,000 boxes (87,500 bushels)) was 1890, after which production fell steadily to only 5,600 boxes (7,000 bushels) by 1920. The decline had four causes:

1) Fishermen retained seed attached to market oysters landed, discarding it on shore (Patton, 1911). (In the 1920's, government regulations required fishermen to break up clusters and return seed to the beds; they could retain only oysters at least 3 inches (76 mm) long (Found, 1927));
2) Mud diggers destroyed many oyster beds;
3) Sediment deposition from land erosion caused by agricultural development (Kemp, 1916) and road construction degraded the beds (deBelle, 1971); and
4) A disease known as "Malpeque disease" infected and killed nearly all oysters in Malpeque Bay beginning in 1915; later, it spread to all oyster-producing areas on the island.

A disease-resistant oyster stock eventually evolved on P.E.I. The last oysters died there from the disease in 1954 (Morse, 1971). As new generations of oysters became resistant to the disease, production rose to reach 30,000 boxes (37,500 bushels) by 1950. The oyster distribution by then had changed. Oysters never became abundant again in Malpeque Bay, probably because the shells of dead oysters became covered with fouling organisms that prevented the larvae from setting. But oysters were abundant in Bedeque Bay which became the island's leading producer, and they were also abundant in the East and West rivers.

A system of leasing barren grounds to individuals for oyster cultivation had begun in 1912 (Patton, 1913), and by 1966, there were about 1,800 leases comprising 4,949 acres, or about 2.75 acres/lease in the three provinces (Morse, 1971). But nearly all had poor bottoms and most were in areas where oyster larvae did not set regularly, so culture was never practiced on most of them aside from growing small quantities of seed gathered along shores.

Some leases have played an important role in oyster production since all oysters harvested from contaminated grounds (such as those in Bedeque Bay and the lower East River) during spring seasons have been held on leases over the summer for depuration then harvested each fall. (Bedeque Bay and the lower part of the East River had become polluted as the towns of Summerside and Charlottetown grew in population.) Termed "relays," contaminated oysters have comprised up to 80% of total production. Fishermen sell most relays to a few dealers who have larger leases of 8–20 acres, planting the remainder on their own leases.

The government established two seasons for public oyster grounds. The spring season, established for relaying oysters at least 3 inches (76 mm) long from contaminated beds, lasts from 1 May to 15 July, while the fall season, for harvesting similar oysters from beds certified for immediate consumption, is from 15 September to 30 November. Harvests tend to remain consistent throughout spring seasons because the oysters are growing, but in the fall seasons they decline after 3–4 weeks[2].

[2] In the Eastern United States, most relayed oysters are small seed transferred from low to high salinity areas. Since seed oysters grow slowly in low salinities and faster in high salinities, the practice works well. A similar management practice cannot be adopted on Prince Edward Island because the oysters grow well in Bedeque Bay and slowly in relayed beds such as those in Malpeque Bay.

Figure 6
Fishermen harvesting oysters with tongs, East River, Prince Edward Island, 1980's. Photograph by A. Morrison.

Figure 7
Trailers used to house fishermen at a temporary site, North River, Prince Edward Island, during the oyster season, 1980's. Photograph courtesy of the Canadian Department of Fisheries and Oceans, Charlottetown, P.E.I.

Many oystermen dig softshells or pick northern quahogs in late July and August. Many once netted smelt, *Osmerus mordax*, in winter, but in the last 25 years or so most have been unemployed in winter and are supported by government unemployment insurance.

Fishermen continue to harvest oysters with tongs during low tides (Fig. 6), in addition to hand-picking small quantities along shores. In the early 1900's, tongs had wooden heads supported by wires. Tonging boats were double-prowed finfishing dories, with tonging (culling) boards in their bows. Since the mid-1940's, fishermen have used square stern boats about 4.4 m (14.5 feet) long, powered by outboard motors (20–25 hp). They are still called "dories," and tonging boards have remained in the bow. In the last 15 years, fishermen have replaced wooden head tongs with wire-head tongs. Fishermen hold oysters in wooden fish boxes containing 4 or 5 pecks (1 to 1.25 bushels), although for the past 25 years, dealers have been shipping oysters in cardboard boxes that hold 3.5 pecks (60 pounds), in place of 5-peck wooden boxes used earlier.

Since the Ingersoll (1881) survey, most island oystermen have continued living on the western end of the island near Malpeque Bay, but since the early 1900's, they have had to travel to other estuaries, mainly Bedeque Bay and the East and West rivers, to harvest oysters. Because the East and West rivers are up to 115 km (72 miles) from their homes, fishermen historically have found it impractical to go to and from home every day. Therefore, they built board and tarpaper shacks in which to sleep and cook, on the estuary shores during oyster seasons. The shacks, which had bunks for one or two men, were improved in the early 1950's and made of plywood. In the late 1950's, axles and wheels from wrecked automobiles were put under them, converting them to trailers that could be towed to estuaries at the beginning of seasons and back home at the end. In the early 1960's, fishermen began buying manufactured trailers, and now nearly all are manufactured (Boylan[3]) (Fig. 7). The fishermen return home on weekends by truck.

Mobile trailers enable fishermen to opt for different estuaries as desired. They simply tow the trailers and

[3] Boylan, F. 1993. Charlottetown, Prince Edward Island, Canada. Personal commun.

Figure 8
Grading oysters for market at Ellerslie, Prince Edward Island, 1920's. The oysters were shipped in barrels. Photograph on display at Department of Fisheries and Oceans Museum, Ellerslie, Prince Edward Island.

dories to chosen sites, usually during the few hours of high tides so as not to lose any fishing time. In recent years, quahog fishermen also have lived in trailers on the shores of estuaries during summer harvesting seasons. The provincial government has established a number of trailer parks with washrooms and electricity which are operated by the Shellfish Association.

Since the late 1800's, the principal market for oysters produced in the Maritimes has been the Province of Quebec, the most important destination being Montreal. Quebec consumers rate the quality of oysters mostly by shell shape. The oysters thus have nearly always been sold in four categories based on shell shape. The top grade, "fancy" oysters (so scarce they have not been marketed for the last 25 years) have a length that is no more than 1.5 times their greatest width. The next, "choice" oysters have a length no more than 1.75 times their width. "Standard" oysters have a length no more than two times their width and in the bottom grade, "commercial" oysters are twice as long as they are wide. The more that oystermen break up clusters of seed while harvesting, the better the grade of market oysters will be in future years. Beds not harvested for a few years produce standards and commercials when harvested. In 1972, the percentages of oysters sold in each of the currently available grades were: choice, 38%; standard, 43%; and commercial, 19%. By the 1990's, the grade and quality had improved because of the cultivation of beds by the government and industry working as partners. The rough percentages of oysters sold in each grade were choice, 65; standard, 25; and commercial, 10 (Boylan[3]). "Fancies" are not included because they so rarely occur as to be statistically irrelevant.

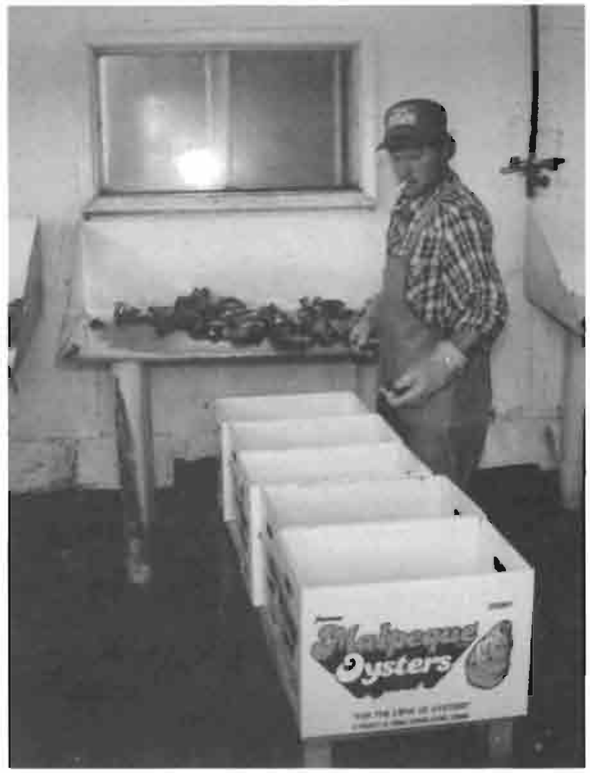

Figure 9
Grading oysters for market at Burleigh Bros. oyster house, Freeland, Prince Edward Island, 1980's. Oysters were shipped in cardboard boxes. Photograph by A. Morrison.

Upon receiving oysters from fishermen, shellfish dealers hire workers to grade them (Fig. 8, 9). A worker can grade about three 3.5-peck boxes of oysters/hour. Dealers pay the fishermen after grading. In 1993, dealers purchased oysters by the peck and paid fishermen Can$16.00 (US$12.30; US$49.20/bushel) for choice, Can$8.00 (US$6.15; US$24.60/bushel) for standards, and only Can$2.00 (US$1.54; US$6.15/bushel) for commercials (Fortune[4]). The fancy and choice grades go mainly to upscale restaurants, the standards to restaurants and grocery stores, and commercials to groups having annual outings. Fishermen often keep one or two boxes of commercials in the basements of their homes for winter eating. In recent years, the demand for commercials has been weak. Less than 1% of all oysters are shucked and sold as fresh meats.

The oyster marketing season has traditionally ended shortly after ice covers the estuaries in early December. But one buyer is selling oysters during winter by hold-

[4] Fortune, B. 1993. Atlantic Aquafarms, Inc., Orwell, Prince Edward Island, Canada. Personal commun.

ing them on racks set on bottoms and raising them as needed through holes cut in the ice.

After 1950, island oyster production fell almost steadily from 30,000 boxes (37,500 bushels) to only 14,000 boxes (17,500 bushels) in 1972. In 1972, the provincial and federal fisheries departments began a program to rehabilitate the fishery (MacKenzie, 1975). Very little had ever been done before then to cultivate or otherwise enhance the productivity of public beds, but since 1972, the government has conducted some enhancement nearly every summer. The actions have involved:

1) Spreading fossil shells mined in Malpeque Bay to collect spat (up to 30,000 bushels/year, a total of about 200,000 bushels from 1976 to 1986 were spread in Bedeque Bay);
2) Transplanting oysters from a 35-acre intertidal flat in Bedeque Bay to good grounds in the bay (24,000 bushels were spread on 38 acres in 1973), and unfished oysters from a channel 6–11 m (20–36 feet) deep in the East River to good grounds 1–2 m deep in the lower river (20,000 bushels were spread on 20 acres in 1992, and a total of some 50,000 bushels on 50 acres in earlier years);
3) Cultivating shells buried under a few centimeters of mud to clean them sufficiently to collect spat (25 acres in Bedeque Bay and the West River were cultivated from 1988 to 1990); and
4) Collecting spat on shells held in plastic mesh stockings (5,000 to 10,000 bushels of shells are spread each year).

The result has been a large increase in oyster abundance, with production rising to 38,000 boxes (48,000 bushels) in 1990 (Fig. 10). (Production in Bedeque Bay increased from 5,000 boxes (7,250 bushels) in 1972 to 30,500 boxes (38,000 bushels) in the late 1980's.) The number of fishermen has also increased. In 1973 about 90 fishermen harvested oysters in Bedeque Bay in the spring, but in 1983 there were about 250, and in 1993 about 200. About 155 men now tong oysters on public grounds each fall: 30–40 in the West River, 60–80 in the East River, and 50 in Cascumpeque Bay (Boylan[3]).

A typical fisherman tongs 5 days/week and harvests from 2 to 5.5 5-peck boxes (2.5–6.9 bushels). The average is 2.5 boxes (3.1 bushels) of market oysters/day, or 12.5 boxes (15.6 bushels)/week. In the spring season, each harvests about 150 boxes (187.5 bushels) of oysters, and in the fall season, 100 boxes (125 bushels), for an annual total of 250 boxes (312.5 bushels). In the early 1990's, fishermen were paid Can$40–50 (US$31–39)/box for oysters harvested in the spring season, and an average of Can$60 (US$47)/box for oysters harvested in the fall season (Boylan[3]). A typical fisherman thus earns Can$6,750 (US$5,312) in the spring season and Can$6,000 (US$4,722) in the fall season, for a total of Can$12,750 (US$10,034)/year while oystering, although the best oystermen land and earn about 50% more.

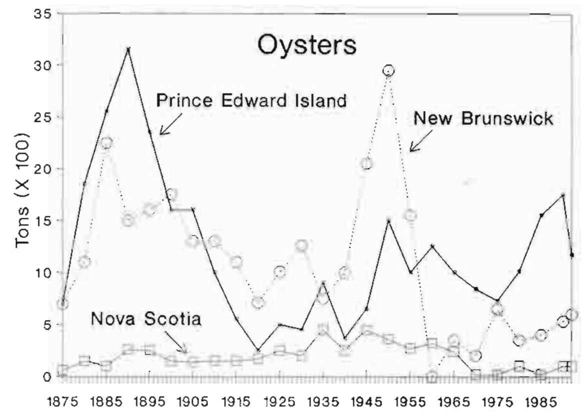

Figure 10
Historical landings of eastern oysters, *Crassostrea virginica*, in Prince Edward Island, New Brunswick, and Nova Scotia, 1875–1990.

In the 1980's, DFO authorities found the enhancement program was not working as well as anticipated. The number of fishermen rose almost in proportion to the growing numbers of oysters. While employment had increased, harvests and earnings per individual did not rise substantially. In 1987, the DFO instituted limited entry to the oyster fishery to improve individual earnings. This should be partially effective, and the fall seasons should last longer. The labor required for the necessary handling of every cluster to separate market from seed oysters prevents individuals from landing much larger quantities in a day, even when oysters are abundant.

Besides oystermen working public grounds, about 75 men harvest from their leased areas. The leases are unique because they have good bottoms and receive regular oyster sets. In recent years, the government has provided assistance to leaseholders to develop their culturing and harvesting methods. Leaseholders harvest with tongs or drags or at low tide by hand picking. When hand picking in Vernon River, they pull wooden sleds to hold the oysters. This group seldom fishes from public grounds.

New Brunswick—In 1953, Malpeque disease caused the first mortalities on the mainland, and by the late 1950's had spread to estuaries along the entire Northumberland Strait coast from Caraquet Bay, N.B., to Pictou, N.S. The result was a 90% decline in N.B. oyster production (Morse, 1971). On the assumption that P.E.I. oysters were resistant to the disease, government authorities transplanted oysters from the island to the affected mainland areas. The government hired P.E.I. fishermen to harvest in the usual way with tongs, but as unculled clusters containing both seed and market oysters. Many, if not all, were taken from Bedeque Bay (Boylan[3]).

In each estuary, a program was implemented to plant oysters on public grounds and on private lease areas that were established to hold them. Large plantings were made on public fishing grounds and government reserve areas, and about 8 bushels of oysters were provided free to each leaseholder to plant. From 1957 to 1962, 22,500 bushels of oysters were transplanted to N.B. and 28,000 bushels to N.S. (Medcof, 1961; Morse, 1971). The seed produced from the imported oysters was resistant to Malpeque disease, and mortalities from it have not been apparent in N.B. and N.S. since then.

N.B. currently produces an official total of about about 12,000 boxes (15,000 bushels) of oysters/year, but unofficial sources claim that actual production is perhaps twice as large. Some 75% of oysters landed are from public beds, and nearly all oystering is done in the fall. In the 1970's, beds in Caraquet Bay produced about 70% of the total, but production there has since declined sharply.

In 1979, DFO biologists implemented a plan for leaseholders to produce more seed by using plastic "Chinese hats" to collect and grow it (Ferguson, 1987). The hats, about 50 cm (20 inches) in diameter, are coated with a mix of cement, lime, and sand, and then assembled in columns of 12. A crew of five workers can prepare 500 columns/day. Leaseholders put the columns in the water when oyster larvae are setting and leave them suspended until October, when the oysters have attained lengths of 5–20 mm (0.2–0.8 inches). They then lay the columns on hard bottoms at a depth of at least 1.5 m (5 feet) to protect them from ice. The columns are resuspended in the spring. When the oysters have grown to at least 25 mm (1 inch), they are removed from the "hats" and most are planted on the bottom at the rate of 300,000 oysters/acre, by hand shovel or mechanical spreader. At this size, oysters are safe from predation by rock crabs. Some oysters are held in plastic mesh bags that are set on racks, as is done in Europe, or placed in "Japanese lanterns."

Ten leaseholders in Caraquet Bay and another ten in Buctouche Bay each set out about 2,500 columns of Chinese hats a year. Use of the hats comprises the only oyster culture in N.B. (Dioron[5]). N.B. oysters require 5–6 years to grow from setting to market size. Dealers grade market oysters similarly to those in P.E.I. and sell most in eastern Canada.

[5] Dioron, S. 1993. Prov. Dep. of Fisheries and Aquaculture of New Brunswick. Shippigan, New Brunswick, Canada. Personal commun.

In the 1990's, the number of men actively oystering in this province has been about 575 each fall and between 40 and 50 each spring. In Caraquet Bay, about 40 fishermen on public beds and 10 on leases tong oysters each fall. The next area southward is Tabusintac where 20 fishermen tong on public grounds and 20 tong on leases. Further south is Neguac where about 150 fishermen tong oysters on public grounds and leases. The government also allows Neguac fishermen to dredge oysters for a week in a deep channel. Each boat is limited to 400 pounds (about 5 bushels) of market oysters/day. Each spring, 35 fishermen drag oysters from contaminated grounds to be spread on their leases; the oysters have to be at least 63.5 mm (2.5 inches) across (Thompson[6]).

Baie St. Anne currently has the largest oyster fishery in the province. About 250 fishermen in 200 dories tong on public grounds, and 15 on leases (Curwin[7]). The next area south is Richibucto, where eight fishermen tong oysters from contaminated areas in the spring to relay onto their leases. The oysters are harvested and sold in the fall and winter (Curwin[7]); in winter, the leaseholders harvest through the ice using quahog rakes. The southernmost oystering area is Buctouche, where about 50 fishermen tong on public grounds and 10 on leases (Dioron[5]).

Nova Scotia—Each spring in N.S., about 50 men tong or rake oysters in 4.25 m (14-foot) boats, locally called "flats." They work from the N.B. border eastward in Pugwash, Wallace Harbor, Caribou-Pictou, and Antigonish, taking oysters of all sizes to plant on their leases. In the past few years, this fishery has become smaller, since the leased grounds are becoming polluted. The other estuary where oysters are harvested is Bras D'Or Lake, where about 20 fishermen tong them every fall.

The Future—Oyster culture in the Maritimes is only about 20 years old and has produced good results, especially on P.E.I. Like many oyster grounds along the Atlantic coast of the United States, a lack of setting surfaces for larvae limits oyster abundances, although large deposits of fossil shells are available to mine as cultch in a few estuaries. Oysters set in commercial abundance nearly every year, disease is not a problem, and predators are nearly absent from vast areas of growing bottoms; therefore, the biological and environmental potential for increasing oyster production is substantial.

The Maritime provinces each have established introduction and transfer committees. Recently, "deadman's

[6] Thompson, W. 1993. Neguac, New Brunswick, Canada. Personal commun.

[7] Curwin, J. 1993. Baie St. Anne, New Brunswick, Canada. Personal commun.

fingers," *Codium fragile*, has been found in several estuaries. This plant is a known pest to the shellfish industry.

Softshell Fishery

Softshells (locally called "clams") are harvested during low tides in all three provinces, but the most important area is the Bay of Fundy bordering N.B. and N.S. The main season is from April to October, but some harvesting continues in the cold months.

Figure 11
Fisherman digging softshells, *Mya arenaria*, in New Brunswick, Bay of Fundy, 1980's. Photograph by M. Therien.

Prince Edward Island—About 35–50 men currently dig softshells on P.E.I. on a daily basis in the warm months. Most use four-tine garden forks, but others use round shovels, plungers, or four- or five-tine hoes, called hacks (Fig. 11), and a few use hydraulic jets. Each digger harvests about 100 pounds (1.7 bushels) of softshells/day Dealers pay Can$1.00–1.40 (US$0.84–1.08)/pound (US$50–64/bushel). The province had one plant. The softshells were shucked by women, each of whom opened 30–50 pounds of meat (3.75–6.25 gallons)/day, and was paid Can$1.00 (US$0.77/pound; US$6.15/gallon) (Can$30–50/day; US$23–38/day). From 1984 to 1992, commercial landings ranged from 71 to 487 t (2,600–17,860 bushels) (Fig. 12).

New Brunswick and Nova Scotia: Northumberland Strait—Commercial and recreational digging of softshells takes place in numerous inlets along the shores of Northumberland Strait in N.B. The most important area is Buctouche where about 100 people dig commercially every day. The total number of people digging in all inlets is about 125. From 1984 to 1992, commercial landings ranged from 590–1,150 t (whole weight) (21,600–42,000 bushels) (Fig. 12). The area has one shucking plant for softshells.

Bay of Fundy—Softshell harvesting in the Bay of Fundy is concentrated in southern N.B. and in the Minas and Annapolis Basins, N.S. Throughout the 1800's, softshells were used as bait by Atlantic cod and haddock fishermen and for local home consumption. The beaches where softshells were dug for bait were near the main finfishing ports, and the bait was preserved in barrels holding mixtures of 2 quarts of salt and 1 pint of molasses. Over the years, increasingly more softshells were eaten, and soon after otter trawls were introduced to catch fish in the 1920's, the need for finfish bait ended (Newcombe[1]).

The harvesting method has remained unchanged through the years. Fishermen dig them on flats with hacks. With about four hours to dig each day, they can harvest about 2 bushels. Dories, sometimes used to transport clams, have been grounded on the flats during ebb tide, loaded with softshells, then floated on the flood tide and either rowed or towed by motorboat to shore (Newcombe[1]).

The softshell fishery became increasingly prominent after about 1890, because laws restricted summer harvesting in the State of Maine. From that time, large quantities of the bay's softshells were marketed in Boston every summer. Diggers sold the softshells to dealers who sold them shucked or whole. Dealers also sold the meats fresh and canned. Canning softshells had begun in the 1880's. In 1900–1905, 14% were canned and by 1925–1930, 70% were canned. Most were exported to the United States. In the 1920's and 1930's, diggers were paid about $1.50/barrel ($0.50/bushel). Canning later became less important as demand for fresh meats and whole softshells rose in New England (Newcombe[1]).

In the 1920's and 1930's, shucked softshell meats usually were packed in 1-gallon cans, but also in 2- and 5-gallon cans. Shuckers, locally called "cutters," received $0.28 for each gallon opened. Dealers shipped the meats by boat to New England in sugar barrels that held twenty 1-gallon cans and in flour barrels that held fourteen 1-gallon cans. The cans were surrounded with ice. The softshells left Yarmouth, N.S., and St. Andrews, New Brunswick, each afternoon and arrived in Boston the following morning. Whole softshells were shipped from St. Andrews to Boston in barrels and boxes (capacity 1/2 barrel weighing about 100 pounds) packed with ice. Whole softshells peddled locally sold for $0.50/peck ($2.00/bushel) (Newcombe[1]).

Softshell landings continued to expand into the late 1940's. But in the 1950's, landings fell sharply when green crabs, *Carcinus maenas*, extended their range northward from Maine, invaded the beds in large numbers, and decimated the softshells (Wallace[8]). The crabs remained abundant and softshell production was low through the 1960's. The number of diggers fell correspondingly. For example, in the Minas Basin the number dropped from 100 diggers in 1948 to 20–70 within those two decades (Anonymous[9]). Since then, the crabs have become much scarcer and the softshells more abundant.

By 1970, softshell canning had nearly ended because New England wanted more whole softshells, and more fresh meats for an expanding market for fried meats. Prices increased as markets grew, and landings of whole softshells and the number of diggers increased in response (Anonymous[9]).

About 300 people currently dig softshells daily throughout the bay in warm months: 100–150 in southern N.B., 100–150 in the Minas Basin, and 40–50 in the Annapolis Basin. In southern N.B., an average of 5 to 6 diggers (range, 0–18) are on each of the local flats. A digger can turn over 1 m^2 of flat bottom every two minutes. In summer, 5–10 tourists and local people in N.B. and a similar number in N.S. also dig softshells daily for home consumption (Robinson[10]).

Besides digging softshells, the commercial fishermen also work on herring seiners, some pick periwinkles and blueberries, and in November many work in the Christmas tree and wreath industry. Some also harvest the red seaweed or dulse, *Rhodymenia palmata*, around the island of Grand Manan, N.B., and a few harvest green sea urchins, *Strongylocentrotus droebachiensis* (Robinson[10]).

In the early 1980's, commercial landings of softshells in the Bay of Fundy were rising, and in 1986 they peaked at 4,517 t (whole wt.) (166,000 bushels), valued at Can$5.6 million (US$4 million). They then fell and averaged about 1,900 t (70,000 bushels) each year from 1988 to 1992 (Fig. 12). Throughout most of the 1980's, of the total landed in the Bay of Fundy and eastern N.S., 28–47% came from southern N.B., 39–60% came from western N.S., and 4–10% came from eastern N.S. (Anonymous[9]).

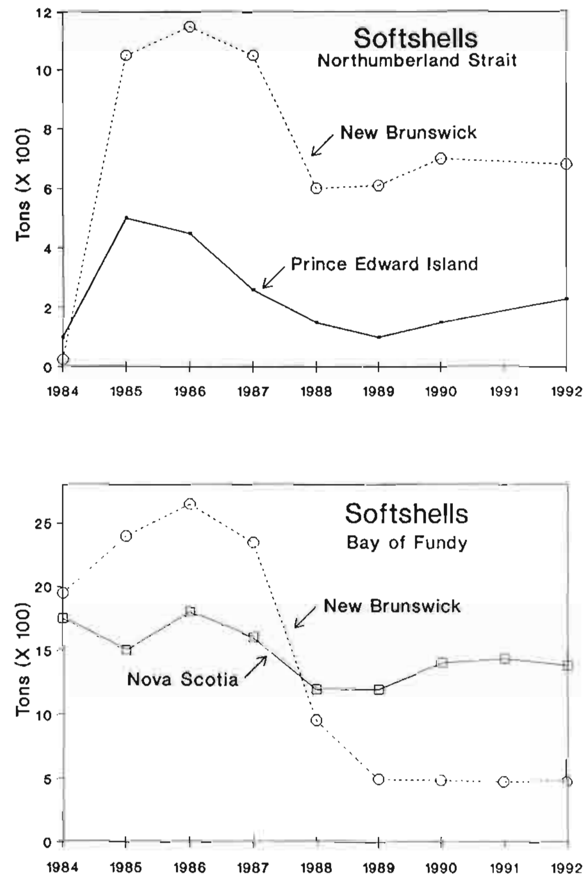

Figure 12
Landings of softshells in Northumberland Strait and Bay of Fundy, 1984–1992.

New England is the primary market for softshells. Fishermen deliver them live to a plant where they are shucked and processed, though some are bought locally and trucked to the Buctouche plant to be shucked by about 100 shuckers. The plant also shucks some softshells trucked in from Maryland, with the meats then sold in New England. The other local plants are at Dipper Harbor, Chamcook, Back Bay, Bocalec, Lepreau, and Welshpool, N.B.; and in Digby and Annapolis counties, N.S. A softshell fishery has recently developed on Grand Manan Island with several plants on the island. Softshells are processed in two forms, fresh (clam meats and in the shell) and frozen (plain and breaded meats). Large quantities of softshells harvested in the Scotia-

[8] Wallace, D. E. 1993. Maine Dep. of Natural Resources, 3081 Mere Point Rd., Brunswick, Maine. Personal commun.

[9] Anonymous. 1989. Softshell clam fishery management plan. Communications Branch, Dep. of Fisheries and Oceans, Scotia-Fundy Region, Halifax, Nova Scotia, Canada.

[10] Robinson, S. 1993. Biological Station, Dep. of Fisheries and Oceans, St. Andrews, New Brunswick, Canada. Personal commun.

Fundy region are trucked to N.B., where they are shucked or packed whole (Anonymous[9]). Each plant hires from 10 to 60 shuckers, nearly all of whom are women.

Some diggers shuck their own softshells at home and sell them to the plants. They harvest each day for about four hours and shuck for another four hours. The plants currently pay home shuckers Can$3.90–4.90 (US$3.00–3.75)/pound for the softshell meats (Doncaster[11]).

Nova Scotia: East Coast—On the east coast of N.S., 40–50 commercial fishermen dig softshells from Halifax to the Strait of Canso. There are no commercial diggers in the area from Yarmouth to Halifax (Doncaster[11]).

[11]Doncaster, D. 1993. Inspection Branch, Dep. of Fisheries and Oceans, Blacks Harbor, New Brunswick, Canada. Personal commun.

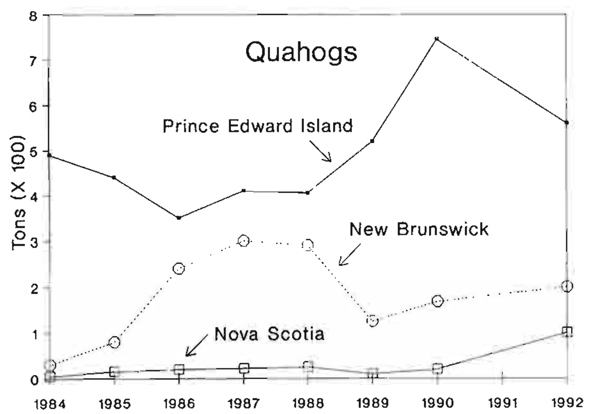

Figure 13
Landings of quahogs in the Maritime provinces, 1984–1990.

Pollution and the Future of Softshelling—The human population along shores has increased in southern N.B. and along with it water pollution. In the past 10 years, about 50% of softshell beds in the area have been closed because of bacterial pollution and the closures are relatively permanent. There are also some temporary closures due to paralytic shellfish poisoning (PSP). The Bay of Fundy area has three depuration plants for softshells, two near St. Andrews and one near Digby. During dry periods, government authorities have conditionally opened some closed flats to digging, but such openings are dependent upon sporadic rain-free periods, so are awkward to manage. As the human population increases, government authorities will attempt to control pollution and use depuration to maintain the softshell fishery (Doncaster[11]).

Northern Quahog Fishery

The fishery for northern quahogs was minor in the Maritimes until about 20 years ago, but it since has been growing in response to rising demand. About 80% are landed in P.E.I. (Fig. 13), where 200–300 fishermen harvest them daily in the warm months. The principal harvesting areas are in the West, East, and Vernon rivers, and Percival and Malpeque Bays. Fishermen get to harvesting locations by outboard motor dory. They generally hand pick the quahogs on bottoms covered by 0–0.75 m (0–2.5 feet) of water at low tide, but also sometimes tong.

To hand pick, which is called “crawling for quahogs” or “hand stomping,” fishermen creep along on their knees while sweeping their hands through the mud surface, feeling for the quahogs. They tow a 1.5-bushel plastic box floated by an inflated rubber tire tube to hold them (Fig. 14). Until several years ago, fishermen wore only pants, shirts, and shoes while hand picking, but recently they have begun wearing rubber scuba diving suits. They also wear rubber dish-washing gloves to protect their hands from sharp oyster shells; a pair of gloves lasts 1–2 days (Campbell[12]).

The best men pick 2–2.5 bushels of quahogs/tide and earn

Figure 14
Fisherman on his knees gathering quahogs with his hands at low tide, East River, Prince Edward Island, 1980's. He holds quahogs in floating box beside him. Photograph by A. Morrison.

[12]Campbell, G. 1993. Fort Augustus, Prince Edward Island, Canada. Personal commun.

Can$80–90 (US$62–69) (Warren[13]); women pick about 1 bushel/tide (Campbell[12]). Dealers purchase quahogs by the pound, and in 1993, paid fishermen Can$1.35 (US$1.04; US$83/bushel) for littlenecks; Can$0.70 (US$0.54; US$43/bushel) for cherrystones; and Can$0.10 (US$0.08; US$6.15/bushel) for chowders. About 90% are shipped to the eastern United States, the rest to Quebec (Warren[13]).

A quahog relay program from contaminated areas recently began on P.E.I. The DFO limits the number of fishermen to 35 (31 men and 4 women were in the program in 1993). The fishermen sell the quahogs by the piece to dealers who depurate them in shallow, clean waters for 14 days. In 1993, dealers paid Can$0.14 (US$0.11) for littlenecks, Can$0.12 (US$0.092) for cherrystones, and Can$0.07 (US$0.054) for chowders. The quahogs were relatively abundant that year in the contaminated areas since they had not been fished before, so the fishermen earned more (about Can$120 (US$90)/day) than those harvesting in clean areas. Dealers pay the Atlantic Veterinary College in Charlottetown Can$60 (US$46) to have each batch of quahogs checked for bacteriological conformity (Sprake[14]).

N.B. and N.S. fishermen also hand pick most quahogs. About 100 fishermen harvest quahogs in N.B. Wallace Harbor, the only uncontaminated bay where quahogs are taken in N.S., is also the largest producing area. Quahogs harvested from a few contaminated bays are relayed by truck to grounds in P.E.I. for depuration. About 70 fishermen harvest quahogs in N.S. (Warren[13]). Most fishermen in the Maritimes trade quahoging for oystering in September.

Periwinkle Fishery

The common periwinkle, *L. littorina*, (called "winkle" or "wrinkle" locally) occurs throughout the Bay of Fundy, but the main fishery is along its south shore in N.B. and a lesser one is on its southeastern shore in N.S., where the periwinkles are smaller than those in New Brunswick (Roach[15]).

L. littorina was introduced to the Atlantic coast of North America from Europe and was first reported in the Bay of Fundy in 1861 (Cook[16]). The yellow periwinkle, *L. obtusa*, and rough periwinkle, *L. saxitilis*, occur farther north in the Maritimes and have been found in prehistoric native aboriginal shell middens, suggesting they are endemic to North America (Caddy et al., 1974). Both are too small for sale.

The periwinkles in N.B. inhabit rocky shores and are largest around offshore islands, probably because of more wave exposure and higher frequency of harvesting by man. They are located in the low intertidal zone and in subtidal waters to depths of at least 9 m (30 feet) at low tide. They are found randomly on boulders that are sometimes 2 m in diameter, and on ledges, but also on rocks as small as 15 cm. They are sparse on sand beaches. The width of the periwinkle range along shores is 10–35 m; the more gradual the shore slope, the wider the range. In most areas, periwinkles track over slimy rocks; in others, they occur in and around Irish moss, *Chondrus crispus*. Periwinkles frequently are covered with the coral, *Lithothamnion* sp. In winter they bunch together in crevices and small tide pools, possibly to prevent freezing (Cook[16]).

Periwinkles are preyed upon by moon snails, *Lunatia* sp.; Atlantic dogwinkles, *Nucella lapillus*; several fishes; gulls and other shore birds; and crabs. The snails do not concentrate PSP (Robinson[10]).

A periwinkle fishery in N.B. has operated for at least 50 years, but landings data were not recorded until the 1950's, when production averaged about 14 t (310 bushels)/year. Landings increased afterward and reached 125 t (2,750 bushels) in 1975; but according to official landings, they fell sharply afterward and almost none were landed in 1980. One dealer reported some landings in 1980, but dealers were not required to report. The main reason for the decline was that most pickers were engaged in the sardine fishery that was booming then (Holland[17]). Periwinkle production again rose sharply and reached 225 t (5,000 bushels) in 1987. It fell to 83 t (1,825 bushels) in 1990 with a landed value of about Can$100,000 (US$77,000), but reached 235 t (5,200 bushels) in 1992 (Fig. 15) .

Periwinkles can be harvested year-round. The busiest period is in the spring after Federal government unemployment funds run out (Cook[16]), but harvesting occurs through summer into fall and even into winter. Winter picking is difficult, however, because periwinkles are located along the low tide line where ice may be present. Most market-size periwinkles measure about 11–13 mm (7/16 to 1/2 inches) in diameter, the largest being 19 mm (3/4 inch). Dealers set a minimum purchase size (Holland[17]).

Fishermen travel to the offshore islands in small boats and pick the periwinkles near the tide line during low

[13]Warren, W. 1993. Bedeque, Prince Edward Island, Canada. Personal commun.

[14]Sprake, D. 1993. Charlottetown, Prince Edward Island, Canada. Personal commun.

[15]Roach, G. 1993. Nova Scotia Dep. of Fisheries, Halifax, Nova Scotia, Canada. Personal commun.

[16]Cook, R. 1976. Periwinkle survey Grand Manan Island. New Brunswick Dep. of Fisheries, Frederickton, New Brunswick, Canada. Unpubl. rep., 31 p.

[17]Holland, R. 1993. RR 4, St. George, New Brunswick, Canada. Personal commun.

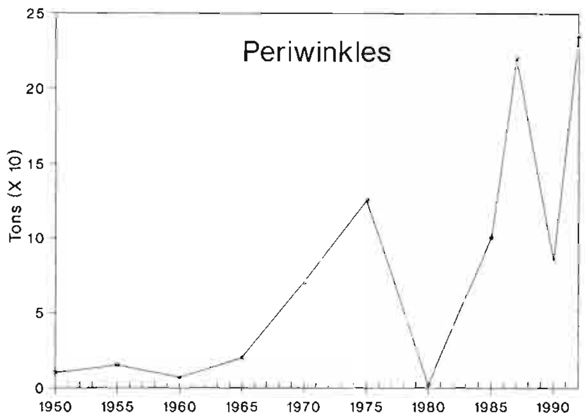

Figure 15
Landings of whole periwinkles in the Bay of Fundy, New Brunswick and Nova Scotia, 1950–1990.

tides. Some wear thin but strong rubber gloves, while others harvest barehanded. The tidal range in southern N.B. is 6–8.5 m (20–28 feet), twice a day. The best picking is during extreme low tides that occur 8–9 days a month when pickers get about four hours of good picking; on neap tides they get only about two hours. The largest and most desirable periwinkles are furthest down the tideline (Holland[17]).

In some areas, a population that has been picked heavily will return to its original abundance by the following set of tides a month later, but most sites similarly picked will require two or three sets of tides (2–3 months) to rebuild with an abundance of periwinkles (Cook[16]).

About 100 people in southern N.B. now engage in the fishery; from 30 to 40 are active daily during warmer months. A typical picker harvests 60–120 pounds (0.6–1.2 bushels) on an extreme low tide and works about five days a week, but working time is dependent upon the tides and weather. In summer, pickers may go for a day with their wives and children and return with several pails of periwinkles (Robinson[10]). Periwinkles are also picked for home use in N.B. and N.S.

N.B. dealers, some of whom also buy sea urchins, pay Can$0.30–0.40 (US$0.23–0.31)/pound for most periwinkles and sell them for Can$0.55–0.60 (US$0.42–0.46)/pound. But for the largest periwinkles they pay Can$0.60/pound and sell them for Can$1.20 (US$0.92)/pound (Holland[17]; Eddy[18]). Typical pickers earn Can$35–40 (US$27–31)/tide, while the best earn Can$60–80 (US$46–62)/tide (Holland[17]).

[18]Eddy, S. B., Fisheries and Oceans, Blacks Harbor, New Brunswick, Canada. Letter dated 22 November 1993.

Upon receiving the periwinkles, dealers weigh them, spread them on a table, wash them, and remove any foreign shells, but they do not grade them. They then pack them in onion bags, 50 pounds to a bag, and submerge them in tanks of running seawater. Each day, the sacks must be turned over and "sloshed" in the water, or otherwise the decomposition of feces will kill the periwinkles at the bottom of the sacks. During warm months, a "large" dealer may have 200–300 bags in tanks ready for shipment (Holland[17]).

Dealers ship the periwinkles in the same bags to Maine or to Canadian destinations such as Ontario and Quebec (Montreal). Many are subsequently shipped to Holland from Maine. One dealer also ships about 200 pounds packed in styrofoam boxes to Hawaii every week (Eddy[18]). The market demand for periwinkles is steady year-round (Holland[17]).

R. Holland, a dealer in St. George, N.B., intends to handle larger quantities of periwinkles because the market is strong. He plans to construct a diver-operated suction device to harvest them at a depth of 9 m (30 feet). Many subtidal periwinkles are 19–22 mm ($^3/_4$–$^7/_8$ inches) in diameter and command top prices.

Mussel Fishery

Wild mussels grow in many Maritime estuaries. During World War II, mussels were harvested and canned on P.E.I., but from then into the 1970's, only small quantities were harvested by hand or with tongs for personal use or sale to a few restaurants. The mussels were heavily laden with pearls and had poor market value. In the 1970's, provincial and DFO biologists developed a system for culturing mussels on suspended longlines, after studying mussel culture in western Europe. Suspended mussels are harvested before pearl formation. Commercial growers began to use this system in 1981, and in the 1990's they filled nearly all suitable estuaries on P.E.I. and several in N.S. with longlines holding mussels. The mussel-growing areas are leased through the DFO on P.E.I., but in N.B. and N.S. they are leased through the provincial governments.

All three Maritime provinces have problems with ducks preying on small cultured mussels. One or more species of scoters, old-squaws, or eiders prey on mussels especially during their fall migrations.

Prince Edward Island—Mussel farms on P.E.I. are located in protected estuaries, 4–8 m (13–26 feet) deep. About 50% of the farms are in the east end of the island, with the remainder in barrier beach lagoons along its north side (Judson, 1989). The farms operate in leased areas, most of which range from 20–61 ha (50–150 acres); the largest lease operates on 465 ha

(1,150 acres). The larger farms contain about 400 lines, of which 200 lines are harvested annually; 200 lines yield 200 t or 7,333 bushels of mussels.

Culture System—The farmed mussels are grown in plastic mesh socks 3 m (10 feet) long, each sock usually strengthened by a strand of polypropylene twine. The socks are suspended from lines of 12 mm (0.5 inch) polypropylene rope, and the lines vary from 100 m (328 feet) to 200 m (656 feet) in length. Buoys support them near the surface and are anchored by 350-kg (770-pound) concrete anchors, or 2-m (6-foot) screw-dish anchors. Each line holds from about 120 to 250 socks. The size of a mussel farm is measured by the number of lines.

In the spring and in October, workers fill the socks with seed mussels 15–20 mm (0.6–0.8 inches) long, at a density of 600–800 mussels/m (500–730/yard) of sock length. Farmers collect seed from ropes or reused socks that they had suspended, and from shorelines. After being suspended in water, the seed work their way through the mesh and attach by their byssuses to the outside of the socks.

In the fall, the longlines are sunk at least 1.5 m (5 feet) below the ice cover that will form. Workers position ice poles that stick about 1 m above the surface to mark the position of each line. The lines are sunk with concrete blocks or sacks filled with beach sand and tied at 3–5 m (10–16 foot) intervals. If socks are not clear of the bottom, the mussels will suffocate in the mud or be destroyed by starfish.

Within 18 to 24 months, the mussels grow to a marketable size of 55–80 mm (2.2–3.3 inches) and each line then contains 1 to 3 t (37 to 110 bushels). Peak mussel quality and market demand occur in winter (November to April), so most mussels are harvested then. Workers use chain saws to cut a 1 × 2 m (3- × 6-foot) hole through the ice at one end of each line. To harvest mussels, a scuba diver enters the hole, ties a line to the longline, swims along the longline and releases its far end from its mooring, and then returns to the hole. Crews use a portable hydraulic winch to haul the longline up through the hole. As the line emerges, workers cut off the mussel socks and stack them in boxes on vehicles (Fig. 16) for shipment to a plant near the shore, where they are declumped, washed, and graded (Fig. 17).

Transportation on the ice depends on its thickness and the snow cover. When the ice is at least 30 cm (1 foot) thick and the snow cover is thin, workers use pickup trucks. In heavy snow, they use snowmobiles, all-terrain vehicles, and farm tractors equipped with chains to tow sleighs. In the spring and fall, when the ice is not sufficiently strong to support vehicles and equipment, workers have used airboats and hauled boxes of mussels ashore with winches. As the industry has developed around P.E.I., harvesting under poor ice conditions has

Figure 16
Crew harvesting blue mussels through hole in the ice at Cardigan Bay, Prince Edward Island, 1980's. Mussel socks are cut off longline, put in plastic crates, and carried to packing house on shore in truck. Photograph by A. Morrison.

Figure 17
Machine that declumps, washes, and grades blue mussels at packing house on shore of Cardigan Bay, Prince Edward Island, 1980's. Photograph by A. Morrison.

become unnecessary because ice formation and breakup varies enough from place to place to cause little interruption in harvesting. Also, the plants have developed long-term (two weeks or more) holding techniques.

The low harvesting season is from June to September. During this open water period, the equipment used is a converted 12 m (40-foot) lobster boat equipped with a boom and hydraulic winch. Many boats have an aluminum chute or conveyor attached to the side or stern to guide the longline and socks aboard and reduce losses due to fall-off.

In 1987, the mussel fishery was threatened when an outbreak of severe food poisoning in humans in eastern Canada was traced to mussels harvested from Cardigan Bay, P.E.I. The name given this illness was amnesic shellfish poisoning. The toxin was identified as domoic acid (Wright et al., 1989), produced by the diatom *Nitzschia pungens* forma *multiseries* (Bates et al., 1989). By 1988, the Federal government had developed a test to monitor mussels for the presence of domoic acid and several insubstantial closures have since occurred. Preselected key shellfishing sites around the Maritimes are monitored year-round for domoic acid and PSP by DFO's Inspection Branch. The domoic acid test uses a high pressure liquid chromatograph with UV monitoring; the PSP test is a mouse bioassay. Samples from several sites are run simultaneously and results usually are available the next day (Gilgan[19]). In 1989, some beds were closed in southern N.B. when the toxin was found in softshells and blue mussels (Richard[20]).

During 1992–93, at least 600 people were seasonally involved in the mussel fishery. In the fall, for about eight weeks, 600 people stripped seed off ropes and socks and put it in new socks. In the winter, at any given time, five five-person crews were harvesting. Each crew harvested its weekly sales in only two days. In the spring, 600 people (most of them the same workers who stripped in the fall) stripped seed and put it in socks. In the summer, five crews of three were harvesting at any given time, each working three days/week (Fortune[4]). An additional 15 fishermen harvested wild mussel seed from shorelines and sold it to mussel farmers in the spring and fall (Warren[13]).

[19]Gilgan, M. Inspection Branch, Dep. of Fisheries and Oceans, Halifax, Nova Scotia, Canada. Personal commun.

[20]Richard, D. 1993. Fisheries and Oceans, Blacks Harbour, New Brunswick, Canada. Personal commun.

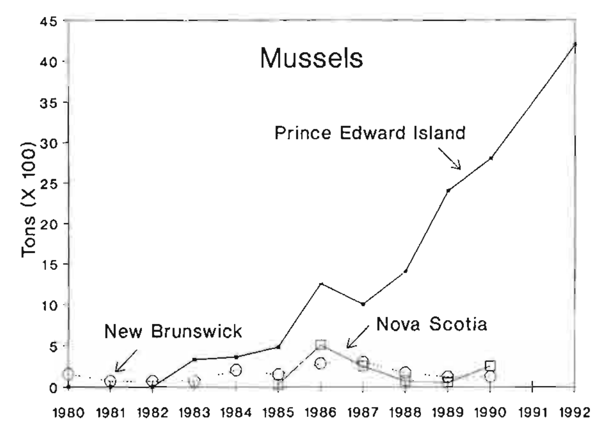

Figure 18
Landings of whole blue mussels in the Maritime provinces, 1980–90.

Marketing—Mussel production on P.E.I. has soared since the early 1980's, reaching 4,200 t (154,000 bushels) (Fig. 18) with a landed value of about Can$5 million (US$3.9 million) in 1992. Dealers sell about 75% in Canada, Quebec being the main market. The rest are shipped to other markets in Canada and the United States. In 1987, the price to growers was about US$0.90/kg (US$0.40/pound) and the export price received by the plants was US$1.66/kg (US$0.75/pound). In 1993, the local retail price was US$2.49/kg (US$1.14/pound).

The Future—The number of operations on P.E.I. has grown rapidly, and the limit of available waters has been nearly reached. Future increases in production will come from more intense use of current production areas and from expansion into shallower waters.

Nova Scotia—In 1993, N.S. licensed 52 leases, but only 12 were producing mussels. All involved growing mussels in socks suspended from longlines, similar to the mussel growing method on P.E.I. The fishery had about 12 year-round employees, besides 50 seasonal employees in the spring and fall. The industry produces about 13% as many mussels as P.E.I. with a landed value of Can$400,000 (US$308,000) (Roach[15]).

New Brunswick—In the early 1990's, mussel culture was just beginning in N.B. A few farmers were growing them on longlines in Lameque Bay and Baie St. Anne.

Shellfish Hatcheries

The Maritime provinces have two shellfish hatcheries. A commercial hatchery in Blandford, N.S., 32 km (20 miles) south of Halifax, has been attempting to produce Belon oysters, *Ostrea edulis*, for oyster bars in cities of Quebec. The bars offer these to provide customers with a wider selection of oyster types. Production has been low, thus far, because of technical problems in producing seed. This hatchery also has reared in test quantities spat of eastern oysters, northern quahogs, and bay scallops, *Argopecten irradians* (Enright[21]). The other hatchery, in Shippegan, N.B., is on a pilot scale. It began operating in 1991, was closed in 1992 because funds were lacking, but produced 3 million northern quahog seed (no oysters) in 1993 (Dioron[5]).

Offshore Fisheries

Sea Scallop Fishery

The sea scallop fishery, by far the largest shellfishery in the Maritimes, has two fleet types. One, with relatively small boats and crews, harvests scallops in the southern Gulf of St. Lawrence and the Bay of Fundy and environs, and the other, with large boats and crews, harvests scallops mainly on Georges Bank.

Recruitment of scallops has been highly variable on all grounds, so periods of good harvests have been followed by periods of low ones. In 1991, landings of scallop meats by the four southern Gulf of St. Lawrence fleets totaled about 270 t, by the four Bay of Fundy fleets about 2,000 t, and by the Georges Banks fleet about 6,000 t. In the past 20 years or so, several management regulations have been imposed to reserve grounds for specific fleets (Fig. 19), and to conserve stocks by limiting entry, restricting meat counts (number of muscles/unit of weight), and setting landings quotas.

Southern Gulf of St. Lawrence—The scallop fishery in the southern Gulf of St. Lawrence, which includes waters from Chaleur Bay to northern Cape Breton Island, N.S., and around P.E.I. is considered a supplement to the lobster fishery, with its seasons and regulations established around lobstering. Most dredging is at depths of from 18–30 m (60–100 feet), and there are large fluctuations in effort and landings (Lanteigne and Davidson[22]).

The fishery is divided into four management areas, each with its own season, gear specifications, and fishermen. Four measures have been taken in each to control effort: 1) fishing seasons, 2) widths of dredges, 3) meat

[21]Enright, C. 1994. Nova Scotia Department of Fisheries, P.O. Box 2223, Halifax, Nova Scotia B3J 3C4, Canada. Personal commun.

[22]Lanteigne, M., and L.-A. Davidson. 1992. Status of the giant scallop (*Placopecten magellanicus*) fishery in the southern Gulf of St. Lawrence (Fisheries and Oceans, Gulf Region) - 1990 update. Canadian Manuscript Rep. Fish and Aquatic Sci. 2148. Dep. Fish. Oceans, Moncton, New Brunswick, Canada, 15 p.

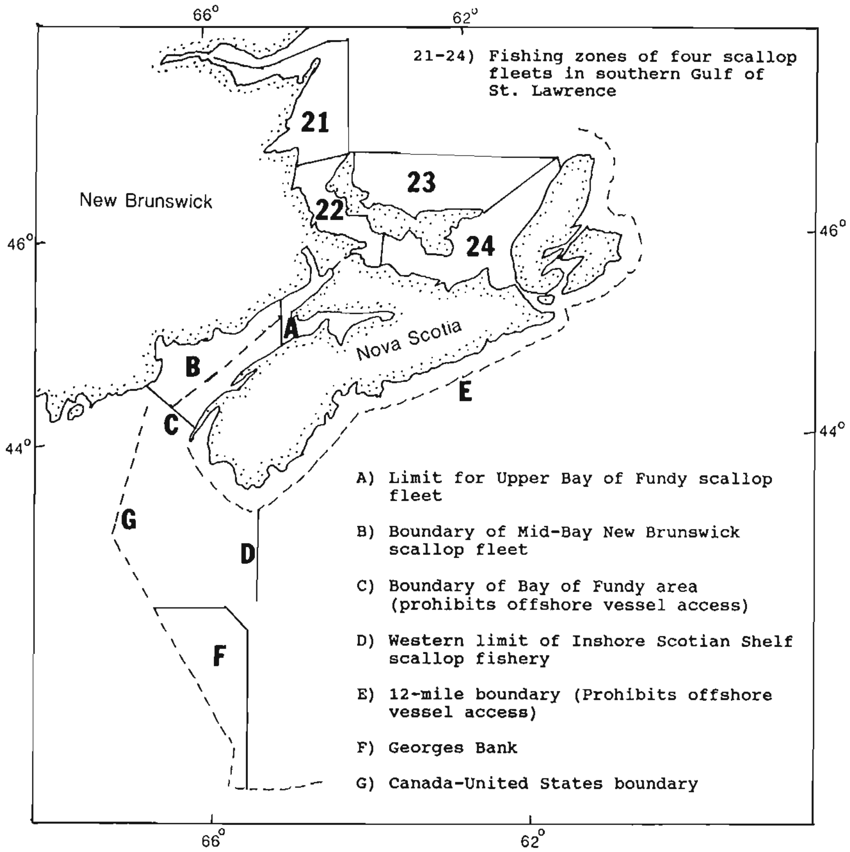

Figure 19
Federal government fishing zones for sea scallop fleets in the Maritime provinces.

count, and 4) number of licenses. The boats used are converted from lobstering (Fig. 20). The dredges are similar to Digby dredges used in the Bay of Fundy, except that the scrapers have teeth and range from 5.1 m (16.5 feet) to 6.6 m (21.5 feet) wide (Lanteigne and Davidson[22]) (Fig. 21).

The beginnings of the scallop fishery in the southern Gulf are unknown, but fishermen harvested scallops in Northumberland Strait as early as the 1930's (Mossman[23]). In all four fishing areas, between 356 and 559 scallop-lobster boats have been active (selling scallops at least once in a year) from 1986 to 1990. The numbers represent between 46% and 72% of license holders (Lanteigne and Davidson[22]). Fishing activity can be intense and localized. For example, during a normal fishing day in Management Area 24, about 150 scallop fishing boats dredge in a 1500 km^2 area (579 mi^2), and perhaps 200 are dredging in all four areas. Two or three men, including the captain, man each boat (Lanteigne[24]).

[23]Mossman, D. 1993. Vernon, Prince Edward Island, Canada. Personal commun.

Each spring off eastern P.E.I. (fishing Area 24), nearly all active scallop fishermen dredge for only 2–3 weeks, then trap lobsters. They start scalloping again in early October and usually continue until a freeze-up in December. Each boat dredges for 10–16 hours/day, getting 10–12 pounds of meats/hour, and returns to port every night. The lobster buyers also purchase scallops. From 1982 to 1992, landings of scallop meats in the southern Gulf of St. Lawrence ranged from 180 to 315 t of meat (Fig. 22). The landings may be underestimated because many private sales are unreported. On occasion, the boats have landed scallop roe; landings ranged from 1,000 kg (2,200 pounds) in 1988 to 11,300 kg (24,860 pounds) in 1981 (Lanteigne and Davidson[22]).

Scallop fishing Area 24 (mainly the Northumberland Strait) historically has had the highest landings and largest number of licenses in the southern Gulf. But landings have declined substantially over the past 20 years, resulting in a high proportion of inactive license

[24]Lanteigne, M. 1994. Science Branch, Dep. of Fisheries and Oceans, P.O. Box C.P. 5030, Moncton, New Brunswick, Canada. Personal commun.

Figure 20
Boats temporarily converted for sea scalloping with A-frames and culling or dredge boards on their sterns, Wood Islands, Prince Edward Island, 1980's. Dredges are partially visible. The boats are also used for catching crustaceans (lobsters, *Homarus americanus*; and rock crabs, *Cancer irroratus*), and fishes (herring, *Clupea harengus*; cod, *Gadus morhua*; hake, *Urophycis tenuis*; and bluefin tuna, *Thunnus thynnus*). Photograph by A. Morrison.

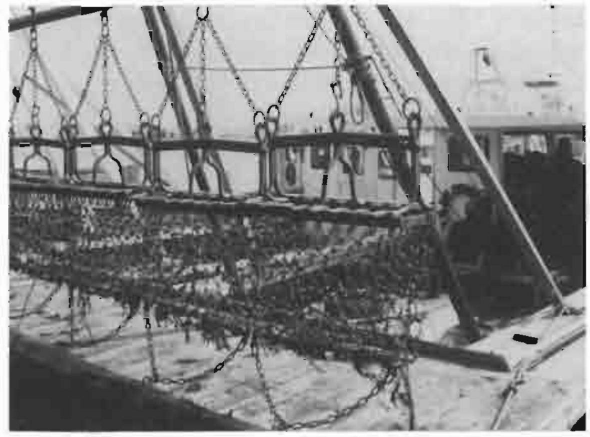

Figure 21
Close-up of part of gang (Digby) dredge used to harvest sea scallops, Wood Islands, Prince Edward Island, 1980's. Photograph by A. Morrison.

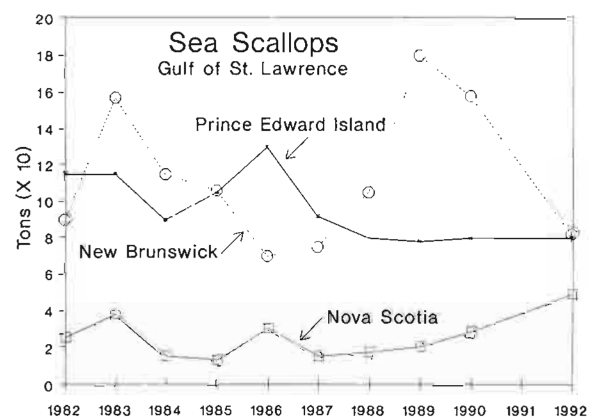

Figure 22
Landings of sea scallop meats in the Gulf of St. Lawrence, 1982–92.

holders. Lobstermen who do not hold scallop licenses do not like to have scallop fishermen dragging over the lobster grounds (Lanteigne and Davidson[22]).

Bay of Fundy—In the Bay of Fundy, which is 160 km (100 miles) long and 50–80 km (32–50 miles) wide, sea scallops have been most plentiful off Digby and Digby Neck and near Grand Manan Island. Scallops probably were first caught on the hooks of trawls and handlines set by cod fishermen, and eaten on the boats or taken home. A directed scallop fishery in the Bay of Fundy area began in 1895, when about 335 bushels of scallops were landed and the meats canned. From then until 1901, steadily increasing quantities were landed and canned during winter season—the offseason for herring fishing. The earliest gear was a rowboat towing a single drag hauled by hand (Stevenson[25]).

In 1902, the scallop fishery started to become sizable when fishermen from Digby, N.S., discovered a large scallop bed in the Annapolis Basin. The bed was dredged regularly for the next few years by a growing fleet consisting of boats powered by gasoline engines and using dredges hoisted by power winches. (Gasoline engines began to be replaced by diesel engines in the late 1930's.) Most boats were about 10.7 m (35 feet) long and 4.3 m (14 feet) wide, with engines of 10–35 hp.

For a long time, single dredges were used, but were eventually replaced by sets of two to four dredges affixed at one end to an iron bar. They were called Digby "drags" or "rakes." The dredges varied in shape, but the design most often adopted had an untoothed scraper on either side so that the dredge could collect scallops with equal efficiency whichever way it landed on the bottom. The dredge bag consisted entirely of wire rings joined by smaller rings. The dredges were about 1 m (3.5 feet) wide, and a set of four weighed about 300

[25]Stevenson, J. A. 1931. The scallop fishery of the Fundy area. Biol. Bd. Can. Manusc. Rep. Biol. Sta. 197, 17 p.

pounds. The Digby scallop fleet was composed of about 48 boats in 1922 and 90 boats in 1926 (Stevenson[25]).

Fishermen considered it unprofitable to dredge on a bed unless at least 180–200 scallops were collected in every haul. The average landed price of whole scallops ranged from $4.48/barrel ($1.80/bushel) in 1922 to $6.93/barrel ($2.77/bushel) in 1926 (Stevenson[25]).

Governmental restrictions have been imposed on the fishery over the years. By 1931, all scallop boats had to be licensed, the dredges had to have rings or twine at least 4 inches in diameter, and a practice of floating scallop meats in freshwater to increase their weight was prohibited (Stevenson[25]). In the 1940's, the scallop season was open from only 1 October to 30 April. Later, it was open year-round, but to save scallop fishing close to shore for the winter months, a zone 9.7 km (6 miles) wide, starting at the N.S. shoreline, and 48 km (30 miles) long into the bay was closed from 1 June to 15 October; later, the width of the zone was extended to 12.8 km (8 miles). A minimum size limit for scallops of 4 inches (102 mm) was also imposed.

The boats and dredges gradually became larger, with more powerful engines and winches. The government imposed a limit on the width of dredges of 18 feet (5.5 m); they now are constructed of seven 0.75 m (2.5 foot) dredges attached to an iron rod (Robinson[26]).

In early years, fishermen landed scallops in the shell, and plant workers were paid $0.25/gallon to shuck them. Through the 1920's, the practice of canning meats gradually ended and meats were sold fresh, mostly to the United States. Packed in ice and sent by train to Yarmouth, they went from there by boat to Boston, New York, and other U.S. ports. Trotline fishermen bought the rims (mantle, viscera, and gills) for $0.125/gallon, as cod and haddock bait. The shells were used for ornaments and ashtrays as well as poultry grit. The poultry industry paid $2.00/t for the shells (Stevenson[25]).

From the 1950's to 1970, only about 25 boats comprised the Digby fleet, but the number later increased (Robinson[26]). By 1970 a fleet of boats was harvesting scallops in N.B., and in 1972 the DFO limited entry to the fleets. Fleet expansion continued, though, because a number of vessel owners provided evidence of historical effort in the fishery; this legally entitled them to obtain licenses (Anonymous[27]).

From 1972 to 1977, the DFO restricted the harvesting area of bay boats to the Bay of Fundy and adjacent waters on the Scotian Shelf. In 1976, the N.B. fleet was given permits that allowed them to harvest scallops only within 7 miles of their coast. Most dredging was on beds near Grand Manan Island (Anonymous[28]). The fleet was then called "the 7-mile fleet." But in 1977–78, depletion of the Bay of Fundy scallop stocks resulted in a request from the inshore fleet for access to Georges Bank. Despite protests by the Georges Bank fleet, in 1978 the DFO gave the Bay of Fundy fleet an annual quota of 2.9% of the catch of the previous year on Georges Bank (Anonymous[27]).

In the late 1970's, the Bay of Fundy fleet continued to expand. Its fishing capacity was sustained by the exploitation of further grounds—first Browns Bank, then German/Lurcher, then the Brier Island area. Almost concurrently (starting in 1981), increased recruitment occurred on the traditional Bay of Fundy beds, and in 1989, landings rose to a peak of about 4,500 t of meats, a total at least ten times the landings in most years from 1955 to 1975 (Anonymous[27]).

In the summers of 1985 and 1986, some vessels violated regulatory and quota restrictions and began to fish on Georges Bank, an action that inflamed relations between the Bay of Fundy and Georges Bank fleets. Following a series of interfleet meetings and seminars hosted by the DFO, an agreement was negotiated in October 1986. It called for the permanent separation of the fleets at the 43°40' latitude line, a phasing out of the effort by inshore boats on Georges Bank by 1989, and an extension of the 7-mile N.B. fleet to mid-bay (Jones[29]). In addition, unused scallop licenses were cancelled (Anonymous[27]).

Four separate inshore scallop fleets currently operate in the bay and along the Atlantic coast of N.S.:

1) The Bay of Fundy Fleet, with 75 active owner-operated vessels 13.7–20 m (45–65 feet) long and 300 fishermen, sails from Digby, N.S., but some Digby boats port in Yarmouth in summer to be nearer the Lurcher Shoals scallop grounds. The fleet is permitted to harvest scallops throughout the bay and approaches, but concentrates on the N.S. side of the bay. Each boat usually has four men—a captain and three shuckers—but when harvesting was good in the 1980's, three or four more shuckers were added. In 1985, the fleet landed 722 t of scallop meats with a landed value of Can$8.7 million (US$6.7 million). Scallops comprise about 70% of its revenue, and other fisheries such as trawling for groundfish account for the rest (Anonymous[27]).
2) The Mid-Bay (formerly 7-Mile) Fleet, composed mostly of vessels <13.7 m (<45 feet) long, dredges

[26]Robinson, H. 1993. Packers Cove, Nova Scotia, Canada. Personal commun.

[27]Anonymous. 1986. *In* G. Griffith (ed.), Final report, 4X+5 Scallop seminar held at Digby, Nova Scotia, Canada.

[28]Anonymous. 1989. Inshore scallop fishery plan. Communications Branch, Scotia-Fundy Region, Halifax, Nova Scotia, Canada, 9 p.

[29]Jones, B. C. Environmental Studies, Prov. Dep. of Fisheries and Aquaculture, P.O. Box 6000, Frederickton, New Brunswick E3B 5H1, Canada. Letter dated 7 January 1994.

scallops on the N.B. side of the bay. It has 124 vessels that do some scalloping, but many fish primarily for lobsters, groundfish, herring, and mackerel. They sail from every N.B. Bay of Fundy port from Alma to St. Andrews including the three islands. Before 1980, N.B. landings comprised only about 5% of the total Fundy landings, but in the 1980's, the large recruitment of scallops in the bay substantially increased landings. In 1985, the vessels landed 189 t of scallop meats worth Can$2.8 million (US$2 million). Scallops comprise about 50% of the total value of all species landed (Anonymous[27]).

3) The Upper Bay of Fundy Fleet, with seven active vessels, is restricted to a small area in the north end of the bay. The vessels range in length from 10.6–13.4 m (35–44 feet) and employ relatively small dredges. The fleet relies on scallops for about 50% of its total revenue and on lobsters for most of the rest. In 1985, it landed 9 t of scallop meats worth Can$115,000 (US$84,120) (Anonymous[27]).
4) The Inshore East of Baccaro Fleet, with 28 active vessels from 5.8–13.4 m (19–44 feet) long, is restricted to coastal areas along the south and eastern shores of mainland N.S. and the outer coast of Cape Breton. It relies on scallops for only a tiny portion (1%) of its landings. In 1985, its vessels landed 8 t of scallop meats worth Can$107,000 (US$78,000) (Anonymous[27]).

In the early 1990's, an estimated 150 boats were scalloping every good summer day in the entire Bay of Fundy and included 100 Bay of Fundy boats and 50 Mid-Bay boats. Price and availability of scallops and problems in other fisheries such as groundfish, all contribute to the use of licenses. In 1993, the number of licenses in each fleet was: Bay of Fundy, 99; Mid-Bay, 209; Upper Bay, 16; Inshore East of Baccaro, 185; and Offshore (Georges Bank), 76. If an owner of a Bay of Fundy boat then desired to sell his license, he would charge Can$125,000–150,000 (US$96,000–115,000) for it (Robinson[26]).

The fleets harvest scallops all year except in restricted areas. Winter weather is often adverse. For instance, in January 1993, the Digby boats were able to make only one trip; they had good weather only after mid-February (Titus[30]).

Boats in the Bay of Fundy fleet leave their ports on Sunday nights and usually return on the following Thursday, but sometimes on Friday or Saturday. Most dredge and shuck continuously 24 hours a day, but some boats return to port every night. Crews are not allowed to shuck at their docks as they once did, and they now can only shuck scallops that are at least 3 inches (76 mm) across (3-inch scallops have a meat count of 60–70/pound). Crew members sleep 4–5 hours out of every 24 (Titus[29]).

With stocks down, each boat in the Bay of Fundy fleet now harvests 200–400 pounds of meats/day. The crews wash the meats aboard, put them in 33- or 40-pound bags and cover them with ice. The boats land 800–1,600 pounds of meats/trip (Titus[30]). In contrast, some Mid-Bay boats often land only 100 pounds/day (Jones[29]).

Over the past 50 years, scallop landings in the bay and its approaches have varied widely, from 12 t in 1974–75 to 4,529 t in 1989 (Fig. 23).

Managing the region's scallop fishery has been vexing for resource managers because the fleet tends to become too large for existing scallop stocks. This has led to instability of the fishery (the fleet increased from 64 boats in 1978 to 98 boats in 1986). Despite efforts to control the size of the fleet, it has grown over the years, and too many scallop boats now are licensed. As a result, the scallop resources in the Bay of Fundy and nearby regions are somewhat depleted, and the economic performance by the participants is not as good as it was.

The fleet has the capacity to overfish any recruitment increase long before it has a chance to reach its growth potential (Anonymous[27]). Fishermen and government authorities now are cooperatively working toward development of further conservation measures that may include new ways to establish a minimum harvestable size, limits on trips or fishing days/week, and closures during spawning periods (Jones[29]).

Georges Bank—Georges Bank is the principal ground for a fleet of large scallop vessels. Scallop beds on the

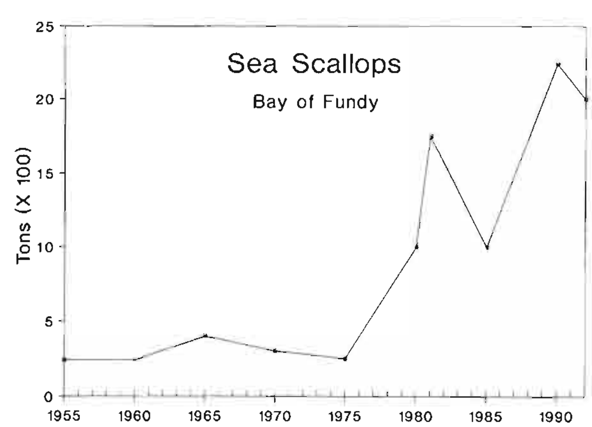

Figure 23
Landings of sea scallop meats in the Bay of Fundy, 1955–92.

[30]Titus, D. 1993. D. B. Kenney Fisheries, Westport, Nova Scotia, Canada. Personal commun.

other offshore banks are smaller, less productive, and have never been regularly exploited, but vessels sometimes harvest scallops on the closer German and Browns Banks during rough winter weather. Only before 1972 were the large vessels allowed to dredge scallops in the Bay of Fundy (Anonymous[27]).

Figure 24
Canadian sea scallop boat on Georges Bank. Photograph by M. Lumdy.

In the early 1980's, this fleet consisted of 72 wooden and steel vessels averaging about 30 m (100 feet) (range, 27–41 m or 89–135 feet) long (Fig. 24) and crewed by about 1,100 fishermen. Seven companies in several ports in southern N.S. owned all the vessels and have exclusive harvesting rights to all sea scallop resources south of the 43°40' line, which includes Georges Bank. The fleet cannot harvest scallops within 19 km (12 miles) of shore (Green[31]) and is wholly dependent on scallops because it has no licenses for other species.

The vessel crews average 16 (range, 11–19) men. Two dredges, 2.4–4.9 m (8–16 feet) wide, are towed off each side of each vessel (Roach[15]). Trips average 10 days, with crews dredging and shucking 24 hours a day. The vessels return to port, unload their catches, and lay over for 24 hours (Green[31]). In 1983, wooden vessels averaged 135 sea days and steel boats 194 sea days. The average crew share on wooden vessels was Can$15,665 (US$12,690) and on steel vessels was Can$32,470 (US$26,300) (Anonymous[27]).

From the 1940's until 1984, Canadian vessels harvested sea scallops throughout Georges Bank (Anonymous[27]). But in October 1984, the "Hague Line" was established by the World Court in The Hague, the Netherlands, to divide Canadian and U.S. waters on the east coast.This gave Canada exclusive rights to the fish and shellfish of the "Northern Edge" of Georges Bank (with the United States getting the remainder). The Northern Edge, 55–90 m (180–300 feet) deep, usually has the highest abundance of sea scallops of any ground in the western Atlantic Ocean.

In 1972, the DFO imposed a maximum number of 60 meats/pound, but that has been gradually lowered to 30. DFO inspectors check the meat count on vessels as they land, and violations are rare (Green[31]). In 1977 the government restricted the fleet by limiting the duration of each trip, the catch of a single trip, and the total catch over a 4-month period, to reduce effort (Anonymous[27]), but the restrictions have since been rescinded.

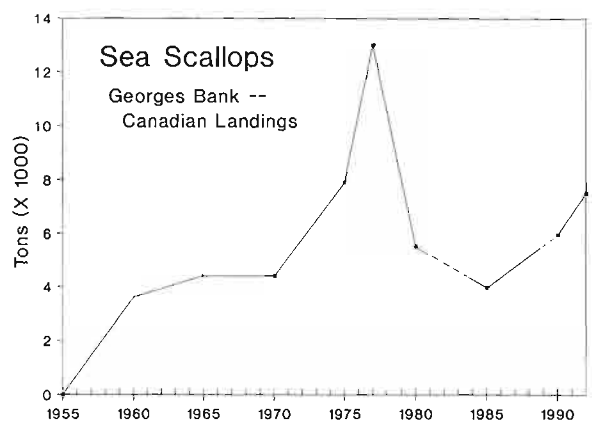

Figure 25
Landings of sea scallop meats from Georges Bank by Canadian boats, 1955–90.

Scallop abundances and landings from Georges Bank have varied, as in the Bay of Fundy (Fig. 25). Over the past 10 years, the total quota allotted to the fleet has risen because the scallops have become more abundant. Less than 2,000 t were landed in 1984, 3,800 t in 1985, 4,300 t in 1986 (Anonymous[27]), 6,000 t in 1991, and 6,200 t in 1993. Vessels in the early 1990's landed up to 30,000 pounds of scallop meats/trip, but 1993 was exceptional and a few vessels landed up to 60,000 pounds of meats/trip (Green[31]). Each of the seven companies is allotted a set portion of the quota, under a system called Enterprise Allocation. The quota is not divided equally; some can land more than others, based on historic landings. A company can also purchase a portion of another company's share. The number of annual trips each boat makes varies with the quantity of scallops its company can land (Green[31]). About 36 vessels are dredging scallops at any given time; the others

[31]Green, S. 1993. Lockport, Nova Scotia, Canada. Personal commun.

Table 4

Canadian exports of frozen scallops by country, 1985–1988. (Quantities [Q] in metric tons, values [V] in Canadian dollars × 1,000).[1] Source: text footnote 8.

	1985		1986		1987		1988	
Country	Q	V	Q	V	Q	V	Q	V
United States	4,068	59,153	4,213	64,837	4,251	63,844	4,199	49,015
France	20	129	—	—	177	2,704	89	1,062
Japan	7	54	8	44	35	486	—	—
Switzerland	—	—	10	68	5	86	28	382
West Germany	29	290	—	—	—	—	—	—
Bermuda	—	1	—	—	2	31	—	—
Others	3	53	16	271	189	1,149	26	285
Totals	4,127	59,677	4,247	65,220	4,659	68,300	4,342	50,744

[1] Total value in U.S. currency: 1985, $43,564; 1986, $46,958; 1987, $51,225, 1988, $41,103.

Table 5

Canadian exports of fresh/chilled scallops to the United States and other countries combined in 1985–1988. (Quantities [Q] in metric tons, values [V] in Canadian dollars × 1,000).[1] Source: Footnote 7.

	1985		1986		1987		1988	
Country	Q	V	Q	V	Q	V	Q	V
United States	1,510	21,597	1,853	27,736	2,548	36,134	3,373	37,473
Other	—	1	1	28	27	415	16	183
Totals	1,510	21,598	1,854	27,764	2,575	36,549	3,389	37,656

[1] Total value in U.S. currency (× 1,000): 1985, $15,766; 1986, $19,990; 1987, $27,412; 1988, $30,501.

are in transition or unloading during mid-season, from March to though July (Matthews[32]).

The Georges Bank fishery has been able to keep the size of its fleet under better control than have scallop fisheries in the inshore areas. And in 1986, the companies decided to reduce their 72-vessel fleet; by 1993, it numbered 42 (Matthews[32]).

Sales of Canadian Scallops—Dealers keep the scallop meats in the same cotton bags in which fishermen land or repack them, and then ship them frozen or fresh (Titus[30]). They sell 95% of frozen (Table 4) and fresh (Table 5) scallops to the United States, shipping them by truck from N.S. and N.B. In the 1980's, Canada's share of the U.S. sea scallop market was about 25% (Anonymous[28]).

[32]Matthews, P. 1994. Deep Sea Trawlers, 152 Monteque St., Lunenberg, Nova Scotia BOJ 2CO, Canada. Personal commun.

Surfclam Fishery

The surfclam (called "bar clam" locally) has a limited distribution in the Maritimes. It is most abundant along the shores of P.E.I. and the Northumberland Strait shores of N.B. and N.S., becoming scarcer with increasing depth. Substantial concentrations do not occur in offshore bottoms as they do off the middle Atlantic coast of the United States (Medcof and McPhail, 1955; Rowell and Chaisson, 1983; Chaisson and Rowell, 1985).

Commercial harvesting of surfclams with hydraulic dredges in Northumberland Strait began in 1969 when the dredges became available and were fitted to lobster boats 12–13.7 m (40–45 feet) long. A typical boat has one hydraulic dredge whose blade is 84 cm (33 in) wide, a heavy duty winch, haul back cables, a pump and motor, intake and outlet hoses, an A-frame, and blocks. Water is fed through the hose to the dredge at 40–50 p.s.i. Of 29 licensed boats, only about 18, each with a crew of two, are active on any day outside of their 2-month lobster season (Warren[13]).

Most surfclamming is done in the summer. Boats dredge the clams from small scattered beds at depths averaging about 4.6 m deep (15 feet) (range, 1–15 m) (3–50 feet) for 10–12 hours/day. Tow times range from 5–25 minutes. Each boat lands 3,000–5,000 pounds of whole clams (35–62 bushels)/day from a new bed, and 700–1,000 pounds (9–12.5 bushels)/day from an old one. Between 1984 and 1990, total landings on P.E.I. ranged from 290 t (whole weight) (7,500 bushels) to 1,000 t (26,000 bushels), in N.B. from 100 t (2,600 bushels) to 800 t (20,750 bushels), while N.S. had minor landings (Fig. 26). In 1992, fishermen were paid Can$0.38 (US$0.29)/pound (US$23/bushel), but in 1993 the price had fallen to Can$0.25 (US$0.19)/pound (US$15/bushel) (Warren[13]).

Workers in local canneries shuck the clams live, discard their viscera, wash the meats, chop them, and put them in cans with shell liquor and brine. The cans are sealed, retorted for 90 minutes, and labelled.

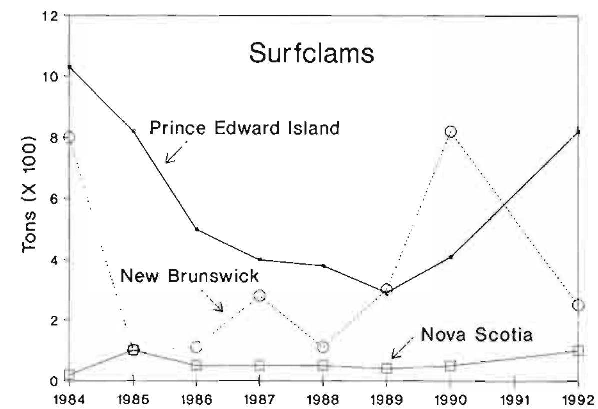

Figure 26
Landings of surfclam meats in the Maritime provinces, 1984–90.

Ocean Quahog Fishery

A large resource of ocean quahogs (called "mahogany quahogs" locally) is present on the Scotian Shelf, Georges Bank (Rowell and Chaisson, 1983; Chaisson and Rowell, 1985), and in the east part of Northumberland Strait. The market for quahogs is weak because of their high iodine content, and the fishery is small. When retorted, the meats turn dark on the surface, which spoils them for market.

In 1970, Triton Sea Products[33] in Port Medway, N.S., began harvesting ocean quahogs. It shipped live ones, about 50 mm (2 inches) long, to the United States for the half-shell trade (Hiltz, 1977). Larger quahogs that had been shucked, minced, and frozen were also shipped to the United States for use in canned chowder and stuffed clams. In 1970 the company landed 907 tons (25,000 bushels), and in 1971, 1,361 t (37,000 bushels) (Caddy et al., 1974); after 1971, operations were halted (Rowell and Chaisson, 1983).

In 1979, 37 t (1,000 bushels) of ocean quahogs were landed in P.E.I., and less than 0.5 t (15 bushels) were landed in either N.B. or N.S. Landings varied little in the next two years. The landings in N.B. and N.S. were for domestic consumption only. In 1982, the only substantial harvests were near Murray Harbour, P.E.I., where two vessels landed 77 t (2,100 bushels), all of which were canned for local markets (Rowell and Chaisson, 1983). A small inshore fishery currently operates in N.S. (Roddick[34]).

Arctic Surfclam Fishery

The Arctic surfclam (called "Stimson's surfclam" locally) supports a fishery that began in the 1980's. In 1980, the DFO had initiated a series of development surveys for underutilized clam species on offshore banks and found commercial concentrations of Arctic surfclams on Banquereau Bank. A commercially exploitable biomass of 561,000 t and an MSY of 16,821 t (whole weights) were estimated for the stock (Rowell and Amaratunga, 1986). This species was found in much smaller quantities on the Grand Bank, Sable Island Bank, and Western Bank at typical depths of 30–50 m (100–165 feet), and also off the coasts of P.E.I. and northern N.B. (Rowell and Amaratunga, 1986). Fishermen later found commercial concentrations on the Grand Bank.

Starting in the late 1980's, three offshore vessels, about 61 m (200 feet) long, two of them processor-freezers, were harvesting Arctic surfclams on Banquereau Bank. The vessels were converted from supplying oil rigs. The processor-freezers have crews of 32 men (16 operated the vessel and 16 processed clams). The vessels tow two hydraulic dredges 4.5 m (14.75 feet) wide from outrigger booms; pumps supply water under pressure to the dredges, which are retrieved and emptied together. The vessels operate 24 hours/day with the two processor-freezers remaining at sea for a month at a time. The vessel landing live clams makes trips of about five days duration (Roddick[34]).

Most clams harvested are about 120 mm (4.7 inches) long (Roddick and Lemon, 1992). In shucking them

[33]Mention of commercial firms and products does not imply endorsement by the National Marine Fisheries Service.

[34]Roddick, D. 1993. Fisheries and Oceans, Halifax, Nova Scotia, Canada. Personal commun.

aboard, the tongues (feet) are removed separately, the mantles frozen into blocks (to be used in soups), and the viscera discarded. In 1989, a converted Norwegian scallop vessel started fishing on Grand Bank, and by 1992 all processor-freezer vessels were fishing on there because its product was more acceptable to the Japanese market. (The foot of the clams on Banquereau Bank has a purple tinge that consumers found objectionable, whereas the foot of clams on the Grand Bank has a more acceptable red tinge.) Typical vessel landings from one trip are 130–140 t of tongues and mantles (800 t or 22,000 bushels whole weight) (Roddick[34]).

In addition, three vessels 13.7–20 m (45–65 feet) long have been dredging for Arctic surfclams and ocean quahogs in inshore waters 30 m (100 feet) deep, off Lockport, N.S. They make day trips, harvesting on orders from dealers. Catches range from 500 to 4,000 pounds (6 to 48 bushels). They land most of the clams in Lockport and ship them whole. Offshore and inshore vessels dredge for Arctic surfclams year-round, but the inshore boats now mainly fish for ocean quahogs (Roddick[33]).

In 1992, catches of Arctic surfclams were 11,000 t (whole weight) (about 300,000 bushels) (2/3 of the MSY calculated by DFO); the value of the landed, processed, packaged meats was Can$12,402,000 (US$9,500,000). If sold by the bushel, whole clams would be worth Can$0.44/kg (US$14.50/bushel). In 1993, an effort was begun to start a fishery for Arctic surfclams in the Gulf of St. Lawrence. A small-scale fishery has been established and currently is operating with two boats. There is a small U.S. fishery for them on Stellwagen Bank in Massachusetts Bay (Roddick[34]).

The long-term future of this fishery is unclear. Clam stocks are holding up well, but the market is mostly limited to Japan and constrains the fishery (Roddick and Kenchington, 1990). The high-value strip clam market in the United States requires clams at least 139 mm (5.4 inches) long. Since less than 1% of Arctic surfclams are longer than 139 mm, they cannot be sold to this market (Chaisson and Rowell, 1985).

Shellfish Buyers

The Maritime provinces have about 128 licensed shellstock or processing plants. P.E.I. has 23 shellstock plants and 10 plants that handle scallop meats. The entire Scotia-Fundy region has about 50 licensed softshell buyers. N.B. has 50 shellstock plants; from 7 to 10 plants also handle scallop meats, and five others handle only scallop meats. N.S. has 30 facilities registered for exporting softshell products to the United States, 10 provincially licensed facilities selling softshells only in N.S., and 20 plants that handle sea scallop meats (FDA, 1993).

Figure 27
Shucking softshells at a plant in Chamcook, New Brunswick, 1994. Photograph by C. MacKenzie, Jr.

The following details were obtained from a softshell shucking plant in Chamcook, N.B., in June 1993. Softshells were delivered to the plant by 20 diggers and shucked by 12 female employees. Each shucked from about 7 to 11 a.m., three days a week. They would work longer hours later in the summer when more softshells were brought into the plant. Shucking continued into winter, but on a smaller scale.

The manager of the plant first hot-dipped the softshells, a bushel basketful at a time, in a tank of near-boiling freshwater for a few seconds to free the muscles from the shells. After being cooled in a tank of ambient-temperature freshwater, the softshells were piled on tables in front of the shuckers, each of whom removed the meat, dropped the shells into a barrel, and cut the end off the neck, removing its skin. The shucker put the meat into a gallon can on the table (Fig. 27), and it took about one hour to fill the can. Full cans of meats were taken to the manager, who washed the meats with a spray of freshwater and packed them in 1-gallon plastic bags that he then sealed and stored in a cold room for later shipment. Shells and skins were discarded in local woods or onto driveways.

When harvesters deliver mussels to one of the five P.E.I. processing plants, shore workers strip the mussels from the socks and put them in polyethylene tanks containing running seawater. The mussels then go through a processing system that consists of a receiving hopper/conveyer, a declumper/grader, an elevating conveyer, a debyssing machine, and a grading/packing table (Fig. 17). They are packed in 12.5 kg (27.5 pound) polymesh bags; two bags are placed with an ice pack in a waterproof carton. The mussels are shipped to markets within 1,000 km (600 miles) by insulated truck and to more distant markets by airfreight. Cultured P.E.I. mussels are sold fresh in the shell with some producers using the name "Island Blues."

The plants ship most shellfish to cities in Canada (such as Montreal), the eastern United States, and California, in refrigerated trucks. Driving time for trucks carrying shellfish from P.E.I. to Montreal is about 14 hours. The drive to New York City takes 25 hours. A shipment that leaves P.E.I. on Saturday for either New York or Cleveland will arrive the following Monday morning. Shipments to California first go by truck to Boston (a 12-hour trip) and then go by plane to California, arriving 24–36 hours later (MacWilliams[35]).

Figure 28
Digging softshells for a home meal in West River, P.E.I., 1994. Photograph by C. MacKenzie, Jr.

Recreational Shellfisheries

Tourists and locals in the Maritimes harvest softshells and surfclams recreationally along many shores, digging with shovels (Fig. 28) and garden forks during low tides; others use snorkels and fins to search for surfclams. Few people go after quahogs or mussels. The DFO and provincial fisheries departments have few statistics on the numbers of recreational fishermen or their catches.

Shellfish as Local Foods

Maritime residents eat shellfish on only a limited scale. Oysters usually are eaten raw on the half-shell. Northern quahogs are eaten raw on the half-shell and in chowders containing milk, potatoes, onions, butter, salt, and pepper. Scallops are eaten fried, steamed, or creamed, while mussels are steamed and then eaten. Most people steam surfclams in their shells, shuck them and remove the viscera, chop the meat into chunks, put it in quart jars, and then boil it for 2–3 hours to tenderize it.

The Future

Use of molluscan resources in the Maritimes can be maximized in two ways. The first is through regulations and policies to 1) control harvests to ensure conservation and promulgate good economic performance by fishermen, 2) minimize damage to the environment by pollution, and 3) if the will exists, partially reverse anthropomorphic damage to the environment.

The second mechanism is enhancement. Oyster and mussel abundances have already been increased substantially by culture and can be increased further. Techniques can be devised for other estuarine mollusks, including softshells, northern quahogs, and perhaps surfclams and periwinkles. The fishermen in the southern Gulf of St. Lawrence currently are experimenting with enhancing natural scallop recruitment. They set out onion bags filled with polyethylene netting to collect seed scallops, which are then released on the bottom or grown in lantern nets. Fisheries authorities will guard against importing non-native species of mollusks because of the possibility of diseases.

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[35]MacWilliams, K. 1993. Fort Augustus, Prince Edward Island, Canada. Personal commun.

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The Offshore Molluscan Resources of the Northeastern Coast of the United States: Surfclams, Ocean Quahogs, and Sea Scallops

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ABSTRACT

The offshore fisheries for Atlantic surfclams, *Spisula solidissima*; ocean quahogs, *Arctica islandica*; and sea scallops, *Placopecten magellanicus*, off the northeastern coast of the United States are among the most valuable shellfisheries in the world. In 1993, U.S. commercial landings of the three species totalled 65,200 metric tons (t) of meats and generated $160 million in ex-vessel revenues. These fisheries are heavily capitalized industrial-scale enterprises. The resulting food products are distributed nationally and internationally. All three fisheries are controlled by Fishery Management Plans (FMP's) implemented under provisions of the Magnuson Fishery Conservation and Management Act of 1976. The modern fishery for surfclams developed in the 1930's, when power dredging was introduced. During the 1940's, technological developments, including hydraulic dredges, stimulated a rapid expansion of the fishery. Catches increased as technological developments continued and fleet size increased. Landings peaked at 44,000 t of meats in 1974. Mid-Atlantic surfclam populations are now dominated by a single year class >15 years old. Ocean quahogs were first harvested commercially during World War II. This mid-Atlantic fishery developed rapidly during the late 1970's and early 1980's. Total landings peaked at 23,000 t in 1985 and have since fluctuated between 21,000 and 23,000 t. The New England sea scallop fishery is centered in New Bedford, Mass. Harvesting methods with heavy dredges have changed little since the inception of the fishery in the 1930's. Total fishing effort by the fleet increased from 11,500 days/year in the late 1970's to 43,000 days/year in 1991. In 1985, the International Court of Justice in The Hague settled the maritime boundary between the U.S. and Canada. The U.S. received fishing rights to grounds south of the Northern Edge of Georges Bank while Canada received rights to the Northern Edge and grounds to the north. In 1982, a Fishery Management Plan adopted by the New England Fishery Management Council included a 30-meat count per pound maximum and a 3½-inch shell minimum for the fishery, but the meat count and other regulations were not effective in controlling overfishing. Amendment #4 to the FMP is designed to lower fishing effort and result in higher, more stable yields. The current fleet of over 400 vessels is far larger than can be profitably supported by the resource.

Introduction

The fisheries for Atlantic surfclams, *Spisula solidissima*, ocean quahogs, *Arctica islandica*, and sea scallops, *Placopecten magellanicus*, off the northeastern coast of the United States are among the most valuable shellfisheries in the world. In 1993, U.S. commercial landings of all three species totaled 65,200 metric tons of meats (down from the record 71,200 t (Fig. 1) set in 1990) and generated $160 million in ex-vessel revenues (Fig. 2). The 1993 combined harvest accounted for 23% of the total ex-vessel value ($707 million) of all commercial finfish and shellfish landings in the New England and Middle Atlantic regions, and for 5% of the ex-vessel value ($3.5 billion) of all U.S. domestic fishery landings (USDOC, 1994).

Unlike many fisheries for nearshore bivalve resources, these offshore molluscan fisheries are heavily capital-

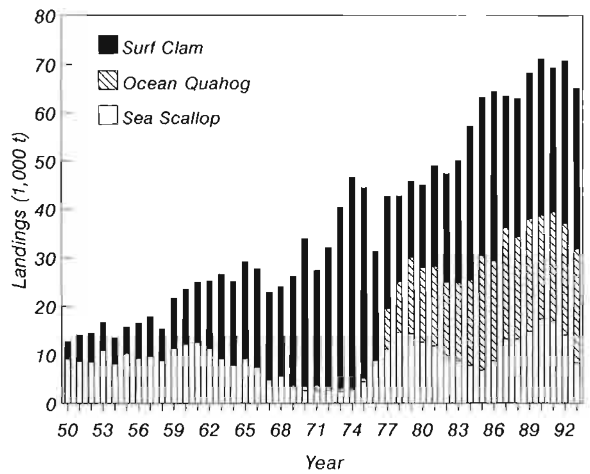

Figure 1
U.S. landings (thousands of metric tons, meat weight) of sea scallop, ocean quahog, and surfclam, 1950–93. Data are for all regions fished by U.S. vessels.

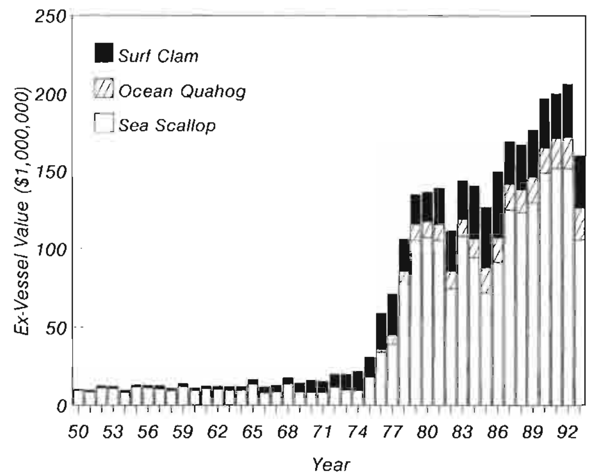

Figure 2
Ex-vessel value (millions of U.S. dollars) of sea scallop, ocean quahog, and surfclam landings, 1950–93. Data are not deflated (i.e. current values).

ized industrial-scale enterprises (Murawski and Serchuk, 1989). The value added through shoreside processing is substantial, and the resulting food products are distributed nationally and internationally. The offshore fisheries also generate significant employment, not just in the harvesting sector, but in the seafood processing, marketing, and retailing sectors as well. Fisheries for surfclams are conducted in waters between 9 and 36 m, while the ocean quahog and sea scallop fisheries are prosecuted at much greater depths, usually 73–110 m. Thus, the harvesting equipment is very different from that used for estuarine and nearshore bivalve fisheries.

All three offshore shellfisheries are controlled by Fishery Management Plans (FMP's) implemented under provisions of the U.S. Magnuson Fishery Conservation and Management Act of 1976 (Mid-Atlantic Fishery Management Council, 1994; New England Fishery Management Council, 1994). Exploitation of the three species dates back to the last century, although it was not until after World War I that the modern offshore fisheries developed.

In this overview, we summarize the biology, management, resource status, and future outlook for the surfclam, ocean quahog, and sea scallop stocks in U.S. waters of the Northwest Atlantic continental shelf.

Surfclam

Biology

Surfclams are distributed in the western North Atlantic from the southern Gulf of St. Lawrence to Cape Hatteras, N.C. (Merrill and Ropes, 1969; Murawski and Serchuk, 1989). In U.S. waters, commercial concentrations are found primarily in the Middle Atlantic region—off the New Jersey coast and the Delmarva (Delaware, Maryland, Virginia) Peninsula—although fishable quantities also exist off southern New England, on Georges Bank, and off Chesapeake Bay (Fig. 3). In the Middle Atlantic, surfclams are found from the beach zone to depths of about 60 m, although abundance sharply declines beyond 40 m. Surfclams are active burrowers and most commonly occur in medium- and coarse-grained sandy sediments. Local clam bed distributions are influenced by both temperature and salinity; upper lethal temperatures for adults run 26°–30° C, and salinities less than 14‰ cannot be tolerated. Water temperature also affects gonadal development and time of spawning (Ropes, 1968).

Surfclams are the largest bivalves in the western North Atlantic (Fig. 4). Maximum size is 22.6 cm shell length, although individuals larger than 20 cm are rare. Growth is relatively rapid; on average, Mid-Atlantic surfclams reach 70 mm by age 2, 11 cm by age 4, and harvestable size (13 cm) by age 6–7. Growth rates, however, can be affected by clam density, with growth significantly reduced in heavily populated beds (Fogarty and Murawski, 1986). Meat yields double between ages 4 and 7, and average meat weight of harvestable-size animals generally exceeds 100 g (Fig. 4). Virtually all of the visceral mass is used commercially, with minced clams, dips, juices, and fried clams made from various body parts. The most valuable portion of the surfclam is the foot muscle, which is generally sliced into thin strips and fried.

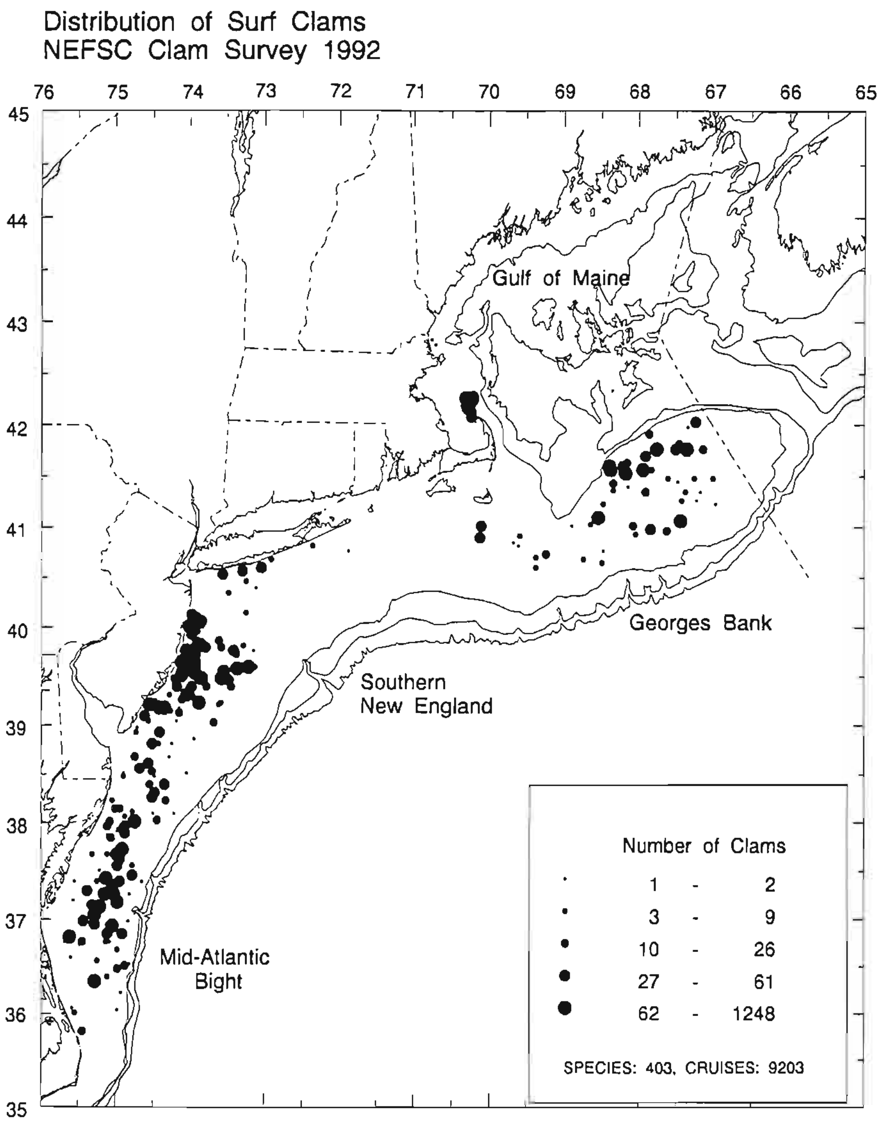

Figure 3

Geographic distribution of surfclam populations sampled in hydraulic dredging surveys off the northeast U.S. during summer, 1992. Data are numbers of clams caught in each 5-minute tow with a hydraulic clam dredge. Survey stations are primarily located in the Mid-Atlantic, southern New England, and Georges Bank. The U.S.-Canada maritime boundary (the "Hague Line") is plotted as a dashed line.

Sexes are separate, although hermaphrodites occasionally occur (Ropes, 1968). Sexual maturity is generally reached by age 2, although some individuals spawn at the end of their first year of life (USDOC, 1993). Spawning can occur either during a single time interval or over multiple time periods, between mid-July and early November. Eggs and sperm are broadcast into the water column, where fertilization occurs. Within a bed of clams, spawning is probably annually synchronous. The buoyant surfclam eggs and larvae remain planktonic for about 3 weeks (at 22°C). Prior to settlement, the larvae may be dispersed great distances by prevailing water currents.

Commercial Fishery

Although surfclams cast ashore during storms were harvested by Native Americans, the U.S. commercial fishery did not begin until the late 1870's off Cape Cod,

Figure 4
Valves (shells) of the Atlantic surfclam. Note the presence of a broad hinge (chondrophore) on the inner surface. This structure is sectioned radially to reveal growth lines that have proved to be reliable indicators of age.

where surfclams were harvested for bait in the handline fishery for Atlantic cod (Yancey and Welch, 1968). The modern food fishery developed in the 1930's, when power dredging techniques were introduced. The fishery was initially centered off Long Island, N.Y., but soon spread southward into the Mid-Atlantic Bight, in particular off New Jersey. During the 1940's, technological developments (e.g. mechanical washers to remove sand forced into the mantle cavity and viscera during dredging, and hydraulic dredges to replace the dry or scrape dredges) and wartime protein demands stimulated rapid expansion of the fishery, and landings quadrupled between 1944 and 1945.

Extensive surfclam beds discovered off New Jersey in 1950 subsequently supported the fishery until the early 1970's. Between 1950 and 1970, surfclam landings increased nearly tenfold, from 3,500 to 30,500 t of meats (Fig. 1). Improved harvesting efficiency, increases in vessel size and the total number of fishing vessels, areal expansion of the fishing grounds, and new technologies and equipment (e.g. shoreside automatic shucking equipment, stern-rigged steel vessels, improved dredge designs, and dredge handling systems) all contributed to increased catches (Murawski and Serchuk, 1989; Figs. 5–7). However, by the early 1970's, commercial catch rates on the New Jersey grounds were declining because abundance (in both northern and southern New Jersey waters) had become much reduced. In 1971, large beds of surfclams were discovered off Chesapeake Bay, and the highly mobile and greatly expanded offshore fleet (about 100 vessels, compared to 54 vessels in 1965) quickly shifted southward to Virginia. During the next 3 years, annual landings rose to unprecedented levels, peaking in 1974 at a record-high 44,000 t (Fig. 1). However, the Chesapeake resource was quickly overfished, and annual landings then steeply declined, falling in 1976 to an 8-year low of 22,000 t, 50% of the 1974 peak. In the summer of 1976, hypoxic water conditions off New Jersey devastated the state's clam stocks, generating a massive reduction in surfclam biomass over a 2,600 mi^2 area (USDOC, 1995[1]).

Since 1977, a restrictive FMP aimed at rebuilding and conserving Mid-Atlantic surfclam stocks and stabilizing annual harvest rates has regulated offshore landings by quotas. Large recruiting year classes produced off New Jersey in 1976 (after the anoxic event) and off the Delmarva Peninsula in 1977 have rebuilt the stocks, although there has been little new recruitment in the past 15 years. Total surfclam landings increased from 17,000 t in 1980 to 35,000 t in 1986, but have since

[1] USDOC. 1995. Report of the 19th Northeast Regional Stock Assessment Workshop (19th SAW). Natl. Mar. Fish. Serv., NOAA, Northeast Fisheries Science Center Ref. Doc. 95-08.

Figure 5
Hand shucking surfclams c.a. 1965. This method was replaced by automated heat shucking methods in the 1970's, which allowed greater volumes of clams to be processed at much lower cost.

stabilized at about 30,000 t. Landings from waters under Federal jurisdiction (the Exclusive Economic Zone, or EEZ, from 3 to 200 n.mi from the coast) have generally accounted for 70-80% of annual U.S. harvests. In 1993, most EEZ landings occurred off of northern New Jersey (75%), with the remainder in the Delmarva (16%) and southern New Jersey areas (9%; Fig. 3; USDOC, 1995[1]).

Landings from the southern New England and Georges Bank fisheries have always been a rather small component of the U.S. harvest. Their combined catches have never exceeded the 3,000 t of 1986, and no landings occurred from either region in 1993 or 1994. The Georges Bank fishery has been closed since 1989, due to the presence of toxins causing paralytic shellfish poisoning (PSP).

Management

Beginning in November 1977, EEZ surfclam fisheries have been managed under the Surf Clam and Ocean Quahog FMP prepared by the Mid-Atlantic Fishery Management Council (Mid-Atlantic Fishery Management Council, 1994). Management measures initially included annual and quarterly catch quotas, a moratorium on vessel entry into the fishery, a mandatory logbook reporting system for both harvesters and processors, effort limitations on fishing time per vessel, and closed areas to protect small clams. In the early 1980's, minimum size limits and target discard rates were also implemented.

The FMP can be credited with restoring the depleted surfclam stocks and contributing to an improved economic situation in the industry. Under the FMP, fishing effort by the surfclam fleet was markedly reduced, and the strong 1976 and 1977 year classes were effectively husbanded. Stock biomass, as indicated by standardized research vessel surveys and fishery catch rates, increased dramatically in the early 1980's. As the 1976 and 1977 cohorts attained harvestable size, annual quotas were adjusted upwards and surfclam landings doubled between 1980 and 1986 (Fig. 1). However, the harvesting capacity of the fleet still greatly exceeded that necessary to catch the annual quota. To space out the quota over the entire year and maintain a steady supply of surfclams for the market, vessels were restricted (beginning in 1985) to only 6 hours of fishing time every 2 weeks (i.e. 36 fishing hours per calendar quarter).

This overcapitalization persisted until 1990 when, under Amendment #8 to the FMP, an Individual Transferable Quota (ITQ) system was enacted to redress the economic inefficiencies created by the FMP in harvesting the resource. Under this system, percentages of the annual quota were allocated among individual vessels, based on performance history and vessel size. Allocated

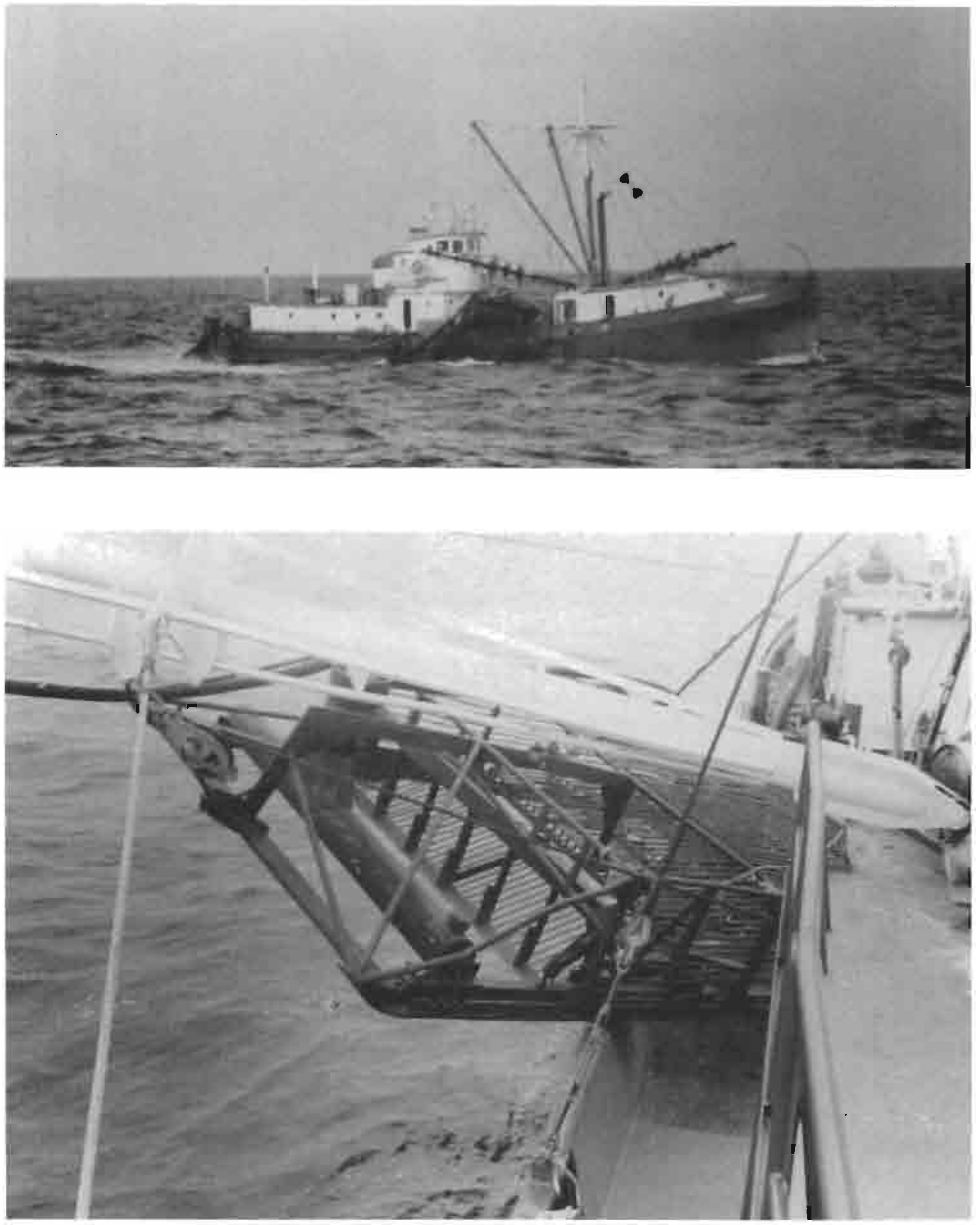

Figure 6
A surfclam-ocean quahog dredge vessel (above), and hydraulic clam dredge (below). Typically, these vessels will tow two dredges, one off each side of the vessel. Dredges are up to 20 ft wide and use high pressure water jets to slurry the substrata and clams before the dredge knife lifts the clams into the rear portion of the dredge.

quota percentages are allowed to be bought and sold and, if desired, combined on fewer vessels. With enactment of the ITQ scheme, restrictions on vessel fishing times and the vessel moratorium were eliminated from the FMP because the trading of allocations was believed to be the means by which rationalization of harvesting capacity and fishing effort would occur (Mid-Atlantic Fishery Management Council, 1994).

This has indeed been the case; under the ITQ system, the number of vessels participating in the Mid-Atlantic EEZ fishery declined by 41% between 1990 and 1991 (from 128 to 75 vessels). Current vessel numbers and their characteristics are given in Table 1. Fishermen are now concentrating on reducing harvesting costs via improvements in efficiency, rather than racing against one another to catch the quota.

Figure 7
Two methods for handling clams onboard the fishing vessel. In the upper picture, a crewman loads bags by hand. This method was used until the early 1970's, when the 32-bushel cage was introduced (lower photograph). The cages are loaded onboard by hand or conveyors. They are off-loaded by crane and transported directly to the shucking plant.

Resource Status

Trends in distribution, relative abundance and biomass, size composition, and recruitment patterns of Mid-Atlantic surfclams have been monitored and evaluated in standardized research vessel surveys performed by the NMFS Northeast Fisheries Science Center since 1965 (USDOC, 1995[1]). Prior to 1976, these surveys were conducted on an intermittent basis, but they were performed annually between 1976 and 1984, and trien-

Table 1
Mid-Atlantic surfclam–ocean quahog vessel characteristics for 1993.

Characteristic	Vessel size class 1-50 GRT	51-150 GRT	151+ GRT
No. of vessels	9	54	25
Mean crew size	3.4	4.0	10.0
Mean age (years)	18	22	18
Mean trips/year	24	59	111
Mean days absent[1]/year	25	75	169
Mean $/day absent[1]	2,959	7,318	4,887
Mean lb/day absent[1]	35,376	97,927	86,752

[1] Days absent from dock.

nially from 1986 on. Surveys use a stratified random sampling design, with a commercial-type hydraulic clam dredge as the sampling gear. Indices of abundance and biomass (stratified mean number and weight per 5-minute tow) and size frequency distributions (shell length in 1 cm intervals) are derived for each assessment area (i.e. northern New Jersey, southern New Jersey, Delmarva). In toto, between 1965 and 1994, 20 separate surveys of the Mid-Atlantic EEZ surfclam resources were done. Surveys were also conducted of surfclam populations off Long Island (1986, 1989, 1992, 1994), in southern New England waters (1986, 1989, 1992, 1994), and on Georges Bank (1984, 1986, 1989, 1992, 1994).

In the Mid-Atlantic region, survey indices have documented significant changes in the abundance and size composition of surfclams during the past three decades. In northern New Jersey, stock biomass (and landings) declined gradually between 1965 and 1974, but plummeted in 1977 due to the 1976 hypoxic clam kill. Outstanding recruitment from the 1976 year class, however, resulted in a marked recovery of the northern New Jersey resource between 1978 and 1982. Since 1982, biomass has declined by about 50% because the growth potential of the 1976 cohort has diminished and no new significant recruitment has occurred. Concomitant with this biomass reduction, commercial catch rates have fallen sharply.

In southern New Jersey, survey indices of relative abundance were high during the late 1960's and early 1970's, but have remained at relatively low levels since the 1976 clam kill. Although there was some modest recruitment of the 1976 cohort in the southern New Jersey area, it was much less than in northern New Jersey, and resource recovery was much more limited. Similar to northern New Jersey, southern catch rates have generally declined since the late 1980's. Survey results indicate that the abundance of surfclams off southern New Jersey is substantially lower than in the northern New Jersey and Delmarva areas.

Off the Delmarva Peninsula, biomass levels of surfclams were relatively high and stable between 1965 and 1975. However, sharp declines occurred during 1976 and 1977 as a result of intensive fishing by the surfclam fleet, which had recently returned to Delmarva after depleting the Chesapeake Bay beds. Despite the extremely low abundance of the Delmarva surfclam resource in 1977, recruitment of the 1977 year class proved excellent. Between 1978 and 1986, indices of survey biomass showed an increase to record levels, however, survey biomass declined in 1989 and 1992 due to lack of additional strong recruitment.

Survey indices of density from the southern New England and Long Island areas are much lower than those in the Mid-Atlantic, suggesting that surfclam resources in these areas are rather limited. Densities are higher on Georges Bank, but have still generally been only about half as large as those for northern New Jersey or Delmarva. Given the continued closure of the Georges Bank fishery, however, surfclam biomass will continue to accumulate there.

The Future

Mid-Atlantic surfclam populations are dominated by single large year classes that are now more than 15 years old (USDOC, 1995[1]). Good recruitment has not followed the strong 1976 cohort in Northern New Jersey or the strong 1977 cohort in Delmarva. Although fishing mortality rates are low and annual catches have stabilized, the overall biomass of Mid-Atlantic surfclams is declining, after peaking in the mid-1980's. Although present resource levels are sufficient to sustain annual catches of between 16,000 and 19,500 t for about 7–10 years in the Mid-Atlantic region, the supply of adult clams will eventually become exhausted unless major new recruitment occurs. Even if such recruitment does occur, it will take about 5–6 years before the clams from this cohort reach harvestable size.

The northern New Jersey and Delmarva areas currently account for about 90% of annual landings of EEZ (offshore) surfclams. While over 60% of the total biomass is located within these two regions, maintaining present harvest levels will result in increased fishing mortality as populations decline. However, it is unlikely that the fishery will soon shift to other regions since clam densities elsewhere are lower.

Clearly, continuing the long-term strategy adopted by managers to husband the extant surfclam resources seems prudent, at least until significant improvement in recruitment is evident.

Ocean Quahog

Biology

Unlike the surfclam, the ocean quahog ranges on both sides of the Atlantic, from the Bay of Cadiz in southwest Spain through northern Europe to Iceland, and westward to the Canadian Maritimes and New England, south to Cape Hatteras (Merrill and Ropes, 1969). Throughout its range, the ocean quahog inhabits relatively cold waters, at shallower depths in the north but progressively deeper at the southern end of its range. In U.S. waters, the species lives at depths of 8–256 m in the Gulf of Maine, on Georges Bank, and in offshore areas of the Middle Atlantic shelf. It rarely occurs where bottom water temperatures exceed 16°C for more than brief periods during the year.

The highest quahog densities in U.S. waters occur on the southern flanks of Georges Bank and in the New York Bight (USDOC, 1995[1]). Highest densities in the Mid-Atlantic Bight occur in 40–60 m depths. In the Gulf of Maine, ocean quahogs occur near shore, owing to cool summer bottom water temperatures. The species inhabits a variety of substrata, from mud to coarse sand and shell hash. Fishable concentrations of large quahogs (>80 mm shell length) are found off New Jersey, Long Island, and the Delmarva Peninsula (Fig. 8). Off Maine, a small-boat fishery for 40–60 mm quahogs occurs (USDOC, 1995[1]).

Ocean quahogs are among the slowest growing and longest lived fishery resources anywhere (Thompson et al., 1980; Murawski et al., 1982). In the Mid-Atlantic Bight, maximum size is 132 mm, although quahogs larger than 110 mm are rare (Ropes and Murawski, 1983). Extensive analyses of growth rate and onset of sexual maturity have been conducted on a population off Long Island. Average shell length at age 5 is 25 mm; at age 10, 47 mm; at age 20, 65 mm; at age 50, 86 mm; and at age 100, 97 mm (Murawski et al., 1982). The oldest known specimen is 221 years old, with a 107 mm shell, sampled from off southern New England (Ropes and Pyoas, 1982). Recent growth studies conducted on natural populations off Machias, Maine, indicate slower growth rates and smaller maximum sizes than in more southern waters (Kraus et al., 1992). When cultured, however, the species is capable of relatively rapid growth during the first several years of life (Kraus et al., 1992).

The bulk of the commercial catch in the Mid-Atlantic Bight consists of animals with shell lengths of 70–100 mm (USDOC, 1995[1]). Average viscera weight for 90 mm shell length is about 30 g (Murawski and Serchuk, 1979). Because of the relatively short foot muscle (unlike surfclams), most large ocean quahogs are processed into chowder, minced clams, juices, dips, and other products. The fishery off Maine primarily targets small animals which are sold live at the retail level. The average ex-vessel value of large clams caught in the Mid-Atlantic is about $4/bushel, whereas off Maine the value of the landings exceeds $40/bushel for small quahogs (Mid-Atlantic Fishery Management Council, 1994).

As with the surfclam, ocean quahog sexes are separate. Eggs and sperm are shed into the water column, where the eggs are fertilized (Lutz et al., 1982). In the Mid-Atlantic, 50% of females are mature at 50 mm shell length, or about 11 years of age. Males mature slightly earlier. Spawning generally occurs in the Mid-Atlantic region from summer through early autumn. The larvae float in the plankton for an extended period, as development time in cold waters of winter is protracted. They may drift for 2 months or more and may thus settle far from their point of origin (Lutz et al., 1982).

Commercial Fishery

Ocean quahogs were first harvested commercially off Rhode Island during World War II, owing to increased protein demands of that time (Murawski and Serchuk, 1989). War-time landings reached about 600 t (meat weight), but declined to less than 200 t for the period of 1947–69. During this same period, the surfclam fishery expanded greatly. Prior to 1976, virtually all quahog landings were from nearshore Rhode Island waters, when a fishery was developed off the Mid-Atlantic area (Delaware, Maryland, and New Jersey). Food processing advancements made the species an effective substitute for the increasingly scarce surfclam during the late 1970's (Fig. 1). This Mid-Atlantic fishery developed rapidly during the late 1970's and early 1980's (Figs. 1, 2), with total landings increasing from 588 t in 1975 to 2,540 t in 1976, and 15,300 t in 1980. Landings peaked in 1985 at 23,600 t and have since fluctuated between 20,000 and 23,000 t (USDOC, 1995[1]).

The Mid-Atlantic ocean quahog fishery has usually taken advantage of the existing surfclam fishery infrastructure, and processing plants in New Jersey, Maryland, Virginia, and Delaware process the bulk of both species. Not surprisingly, the quahog fishery developed first near the existing port and processing facilities, but local resource depletions close to the ports caused a general northward development of the fishery during 15 years of intensified fishing in the region. Initially, fishing was concentrated off southern New Jersey and Maryland, but now the area between Maryland and Long Island is intensively fished, as vessels seek high-density concentrations to maximize catch rates for this high-volume, low unit-value fishery. Total ocean quahog harvests from the Mid-Atlantic fishery have exceeded 300,000 t of meats—more than 2.5 million t of "shell-on" resource.

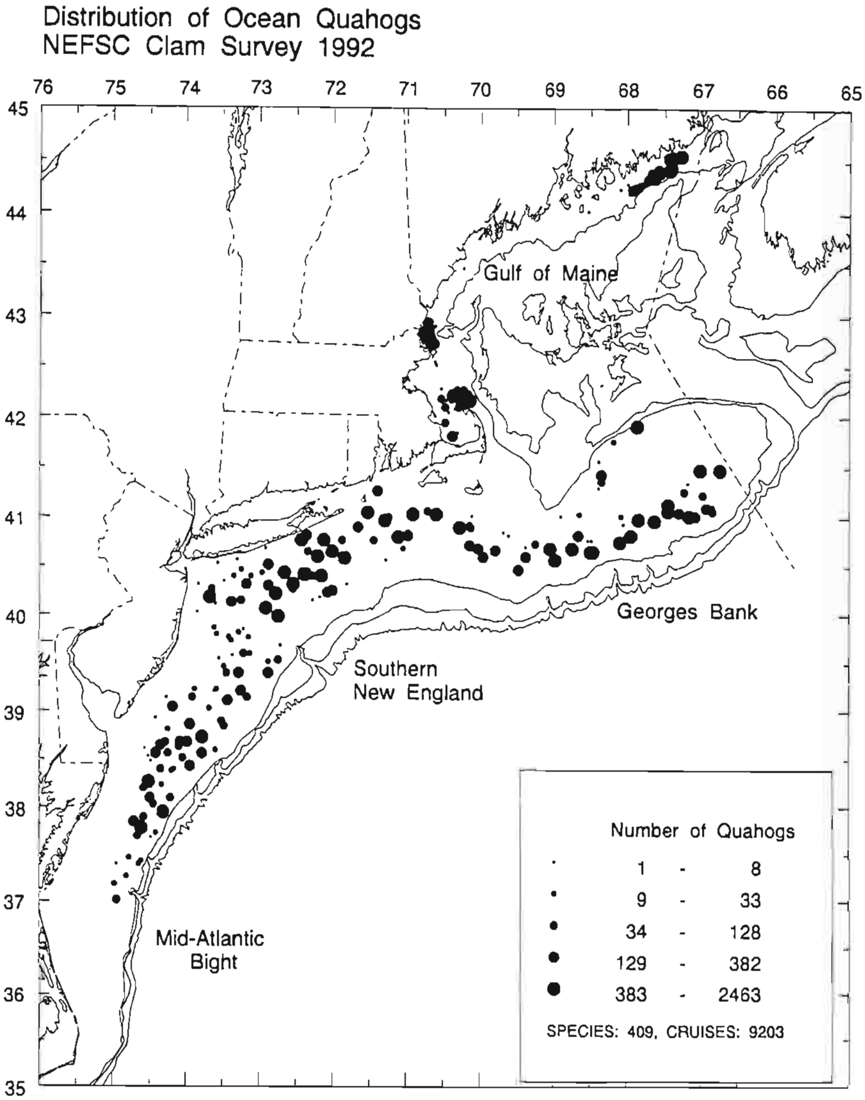

Figure 8

Geographic distribution of ocean quahog populations sampled in hydraulic dredging surveys off the northeast U.S. during summer, 1992. Data are numbers of quahogs caught in each 5-minute tow with a hydraulic clam dredge. The U.S.-Canada maritime boundary (the "Hague Line") is plotted as a dashed line.

The fishery off eastern Maine is a rather recent development. Unlike the highly mechanized, industrial-scale fishery of the Mid-Atlantic, fishing off Maine is small-scale. Most Maine vessels are converted lobster boats (about 30 ft in length and <5 GRT) harvesting less than 20 bushels per day. In contrast, typical landings for large vessels in the Mid-Atlantic fishery (typically >80 ft and >150 GRT) are about 1,000 bushels per trip (USDOC, 1995[1]; Mid-Atlantic Fishery Management Council, 1994). Annual landings from the Maine fishery average about 100 t. The fishery is seasonal (May–August), and many of the boats pursue other species during the remainder of the year. The portion of the Maine coast where harvesting occurs is small because, although the ocean quahog occurs intermittently along the entire Maine coast, most areas are closed to harvest due to lack of routine monitoring for paralytic shellfish poisoning (PSP).

Management

As with the surfclam, formal management of the EEZ resource was initiated in 1977 with the adoption of the Mid-Atlantic Council's Surf Clam and Ocean Quahog

FMP. Specific quahog management provisions initially included an annual quota, logbook recordkeeping requirements, and a moratorium on new vessel entrants into the fishery. No minimum shell size requirement was imposed, owing to the dearth of small quahogs in the heavily fished Mid-Atlantic region.

More recently, Amendment #8 to the FMP established an ITQ plan and eliminated fishing time restrictions (Mid-Atlantic Fishery Management Council, 1994). The current (e.g. 1993 and 1994) annual quahog quota is 24,500 t of meats. The fishery in recent years has not been constrained by the quota and, in fact, total landings are slightly below the quota. The species' extremely slow growth rate and very poor recruitment in the Mid-Atlantic region threaten development of a "sustainable" fishery there. Given the unique population dynamics of the species, managers have pursued a policy of ensuring adequate resource to yield approximately stable catches for a 30-year period. This implies a maximum harvest rate of about 3% per year. Under this scenario, unless recruitment improves, the stock will essentially be fished out by the end of the period (USDOC, 1995[1]).

Current ocean quahog harvests in the Mid-Atlantic region are not proportional to resource abundance in various sub-regions. Most of the catch currently comes from off New Jersey, whereas most of the stock occurs off Long Island, southern New England, and on Georges Bank. The Georges Bank stock cannot currently be harvested due to PSP. Although current resources are sufficient to support annual harvests of 20,000 t into the early part of the next century, it is unlikely that a large-volume fishery for large quahogs can be sustained in the Mid-Atlantic, even if recruitment improves; 20–30-year-old quahogs would be only about 65–72 mm in shell length, far below the current average size in Mid-Atlantic landings. It is not known if harvest rates and recruitment levels are sufficient to sustain present annual catches in the Maine fishery.

Resource Status

Abundance, size composition, and biomass of the ocean quahog resource have been monitored both by standardized hydraulic dredge surveys and by samples of the commercial fishery (the surfclam section describes survey procedures). Abundance and distribution of the resource in the Mid-Atlantic area was well documented by surveys at least a decade before the initiation of large-scale fishing. Additionally, the entire history of the fishery has been monitored by logbook catch and effort data (Murawski and Serchuk, 1989; USDOC, 1995[1]). Except during 1976, all trips have been monitored through mandatory logbook submissions.

Population biomass estimates for areas currently being fished were made by regressing annual catch rates on the cumulative catch from an area. With this formula, the x-intercept of the regression becomes the initial population, and the slope is an estimate of total mortality rate. The formula also accounts for natural mortality and any recruitment to the population. It indicates that the population of quahogs in fished areas is between 200,000 and 300,000 t of meats, with a substantial additional resource located in deep, unfished waters off Long Island, as well as in southern New England and Georges Bank (USDOC, 1995[1]).

Analysis of commercial catch rates indicates a trend of general decline since inception of the fishery. In heavily fished areas off the Delmarva Peninsula and New Jersey, rates have declined substantially. About 45% of the Delmarva resource available in the mid-1970's has probably been harvested. There is no indication from research vessel surveys that these areas are being repopulated with large numbers of juveniles. The Georges Bank resource, currently unfished, represents the largest biomass component and is comprised of relatively large quahogs. The long-term harvest potential of Maine's ocean quahog resource is not known, but total landings have declined in this as yet unregulated fishery.

The Future

The fishery has expanded from two locations, off southern New Jersey and Maryland, to include northern New Jersey, Long Island, and southern New England. On average, vessels steam farther from ports, particularly in cooler months, when the clams are not apt to spoil from the heat. In the future, the focus of the fishery will shift to more northern grounds, and processing plants are already being relocated to New England ports, including New Bedford, Mass. Dense beds off southern New England and Long Island are likely to support the bulk of the fishery after the year 2000. Access to the resource on Georges Bank presupposes a reduction in the incidence of PSP or more aggressive monitoring for its presence and prevalence. Ultimately, sustainability of the fishery will depend on occurrence of new recruitment and its growth to harvestable size. Large-scale recruitment events have not yet been seen in intensively fished Mid-Atlantic areas. Experiments in Maine indicate the species can be grown intertidally and the growth rate accelerated over that occurring under natural conditions. Thus, ocean quahogs may have potential for aquaculture.

Sea Scallop

Biology

Sea scallops occur on the Northwest Atlantic continental shelf from the Strait of Belle Isle, Newfoundland, to Cape

Hatteras, North Carolina. North of Cape Cod, concentrations can often be found just below the low tide mark in waters shallower than 20 m; farther to the south, sea scallops are restricted to cooler offshore waters deeper than 40 m (Serchuk et al., 1979). Sea scallops are intolerant of water temperatures above 20°–22°C and, accordingly, their southern and shoreward distributions are likely limited by temperature (Fig. 9). They prefer cold waters with oceanic salinities; optimum water temperature is about 10°C.

Commercially important aggregations occur from Port au Port Bay, Nfd., to the Virginia Capes, usually at depths of between 40 and 100 m on sand and gravel substrates (Serchuk et al., 1979). In U.S. waters, principal offshore fishing grounds are in the Middle Atlantic from Hudson Canyon, south to off the mouth of Chesapeake Bay, and on Georges Bank. Fishing also occurs in the Gulf of Maine, but that fishery is generally dependent on inshore beds (USDOC, 1993).

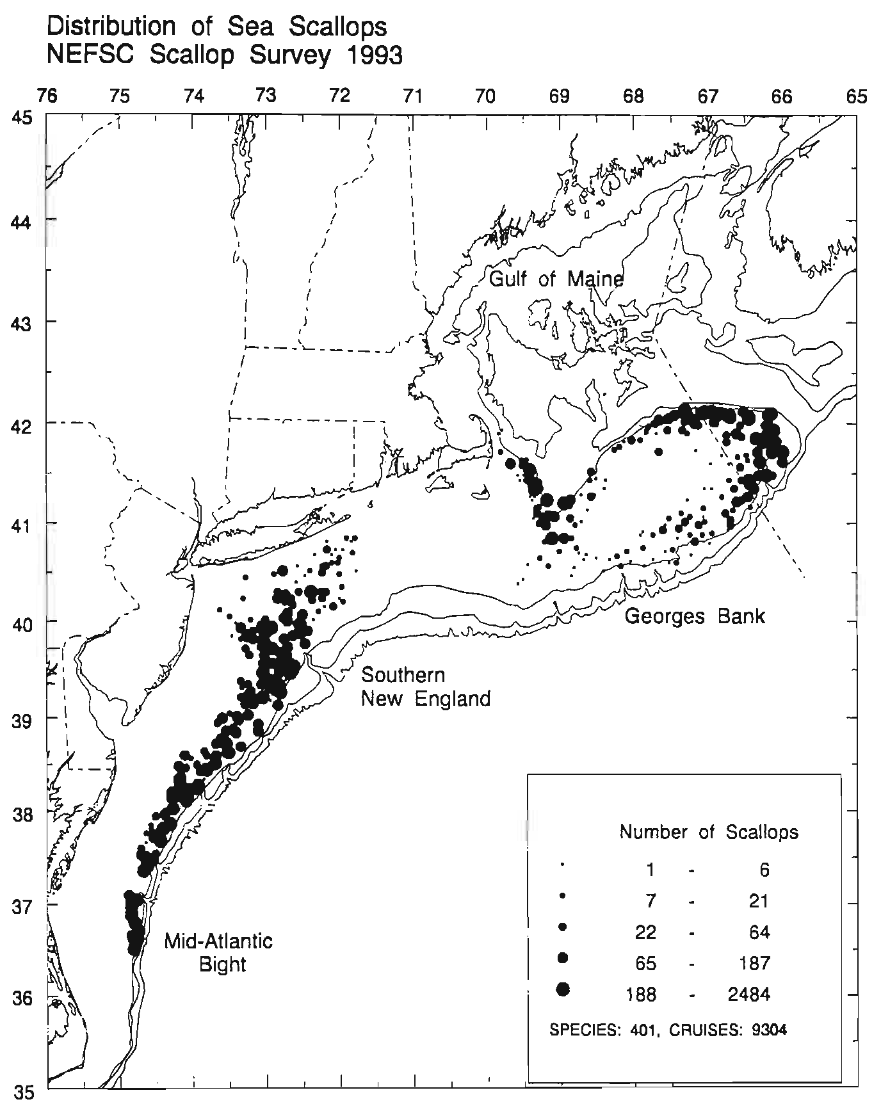

Figure 9
Geographic distribution of sea scallop populations sampled in dredging surveys off the northeast U.S. during summer, 1993. Data are numbers of scallops caught in each 15-minute tow with a scallop dredge. No stations are sampled off Southern New England, owing to the historic dearth of scallops there. No stations were sampled in the Gulf of Maine, although small quantities do exist there. The U.S.-Canada maritime boundary (the "Hague Line") is plotted as a dashed line.

Scallops grow rapidly during their first several years of life. Between ages 3 and 5, scallops commonly increase 50–80% in shell height and quadruple in adductor muscle meat weight (Serchuk et al., 1979). During this time span, the number of meats per pound is reduced from greater than 100 to about 23. Maximum shell size is about 23 cm, but scallops larger than 17 cm are rare. Longevity is not known conclusively, but is thought to be in excess of 15 years (MacKenzie, 1979).

Spawning occurs in late summer or early autumn, beginning in the Mid-Atlantic area in July, and proceeding northward until mid-October in the northern part of the range (MacKenzie et al., 1978). There is some evidence for two spawning periods in the Mid-Atlantic region (Schmitzer et al., 1991), but it is unlikely that individual scallops spawn more than once per year. The sexes are separate. Fertilized eggs are buoyant, and larvae remain in the water column for 4–6 weeks before settling to the bottom (Posgay, 1979; McGarvey et al., 1992, 1993).

Commercial Fishery

An organized fishery for sea scallops dates from 1887, although landings never exceeded 2 million pounds of meats until the early 1930's when harvest of the extensive Georges Bank populations began (Doherty et al., 1964). The New England scallop fishery, centered at New Bedford, Mass., developed rapidly in the 1930's, with peak landings of 10 million pounds by 1939. Landings declined sharply during World War II but increased afterward to 20 million pounds (Premetz and Snow, 1953). Harvesting methods have changed little since the inception of the fishery (Royce, 1946; Posgay, 1957; Smolowitz and Serchuk, 1989). Most catches are still made with heavy dredges, although dredge size and vessel power have increased significantly (Figs. 10-12). Most dredge catches are shucked at sea, with shells and viscera discarded. Only the adductor muscles are marketed in the United States, although there is increased interest in marketing "roe-on" scallops in Europe and elsewhere. In the Mid-Atlantic, some vessels use trawl nets to catch scallops, and these catches are generally landed in the shell ("shell stocked") for shucking ashore.

Between 1951 and 1958, landings remained relatively stable, fluctuating between 8,500 and 10,700 t of meats (Fig. 1), with Georges Bank catches comprising over 80% of all U.S. landings. In 1959, an exceptionally large year class (probably the 1955 cohort) recruited to the Georges Bank fishery, and landings increased to more than 11,200 t annually between 1959 and 1962 (Posgay, 1968; Serchuk et al., 1979). Canadian participation in the Georges Bank fishery also increased then. The percentage of Georges Bank scallop landings taken by Canada rose from 9% in 1957 to 37% in 1962 and to 50% by 1964.

Figure 10
Unsorted catch of sea scallops and other benthic invertebrates and debris (above). Catches are still sorted by hand as they were in the early days of the fishery. Scallops are generally opened by hand (below) at sea, but in some cases they are landed live in the shell and shucked ashore.

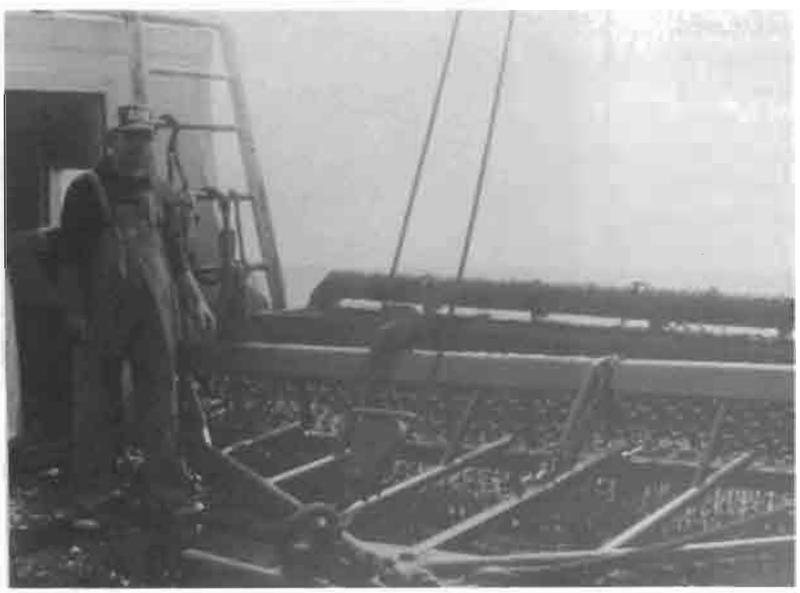

Figure 11
Sea scallop dredges used in the fishery in the early 1960's (above) and the early 1990's (below). Although the design of the dredges has remained similar, the most notable development is that dredges used now are much larger.

By the mid-1960's, abundance had declined on Georges Bank, but increased in the Mid-Atlantic, so U.S. and Canadian fleets shifted their focus accordingly. However, reduced recruitment in the late 1960's and early 1970's resulted in significant declines in landings. From 1967 to 1974, annual U.S. landings did not exceed 5,500 t and during 1970–74 averaged just 2,600 t.

Recruitment of the strong 1972 year class was highly successful on both Georges Bank and in the Mid-Atlantic. As a result, U.S. harvests rapidly increased from 2,700 t in 1974 to 8,700 t in 1976, peaking at 14,500 t in 1978. Thereafter, they decreased steadily, falling to 6,700 t in 1985, as a result of lower region-wide recruitment levels. U.S. catches subsequently increased to a record 17,400 t in 1990, but fell again to 8,200 t in 1993 (Fig. 1; USDOC, 1993).

Total effort in the U.S. scallop fishery increased significantly from the late 1970's until 1993. From 11,500 days fished by the fleet in 1978, effort increased to 43,000 days in 1991 (USDOC, 1992[2]). The greatest increase in effort occurred for the largest vessels (>150 GRT)—nearly a tenfold in increase in effort since the late 1970's. Currently, more than 400 vessels are licensed to participate in the scallop fishery (New England Fishery Management Council, 1994).

Management

Prior to the early 1980's, management advice was formulated through the ICNAF (International Commission for the Northwest Atlantic Fisheries) with participation by U.S. and Canadian science and industry advisors. The ICNAF limited the harvest of sea scallops in waters under its jurisdiction to the two coastal nations. No formal rules were adopted by the United

[2] USDOC. 1992. Report of the 14th Northeast Regional Stock Assessment Workshop (14th SAW). Natl. Mar. Fish. Serv., NOAA, Northeast Fisheries Science Center Ref. Doc. 92-07.

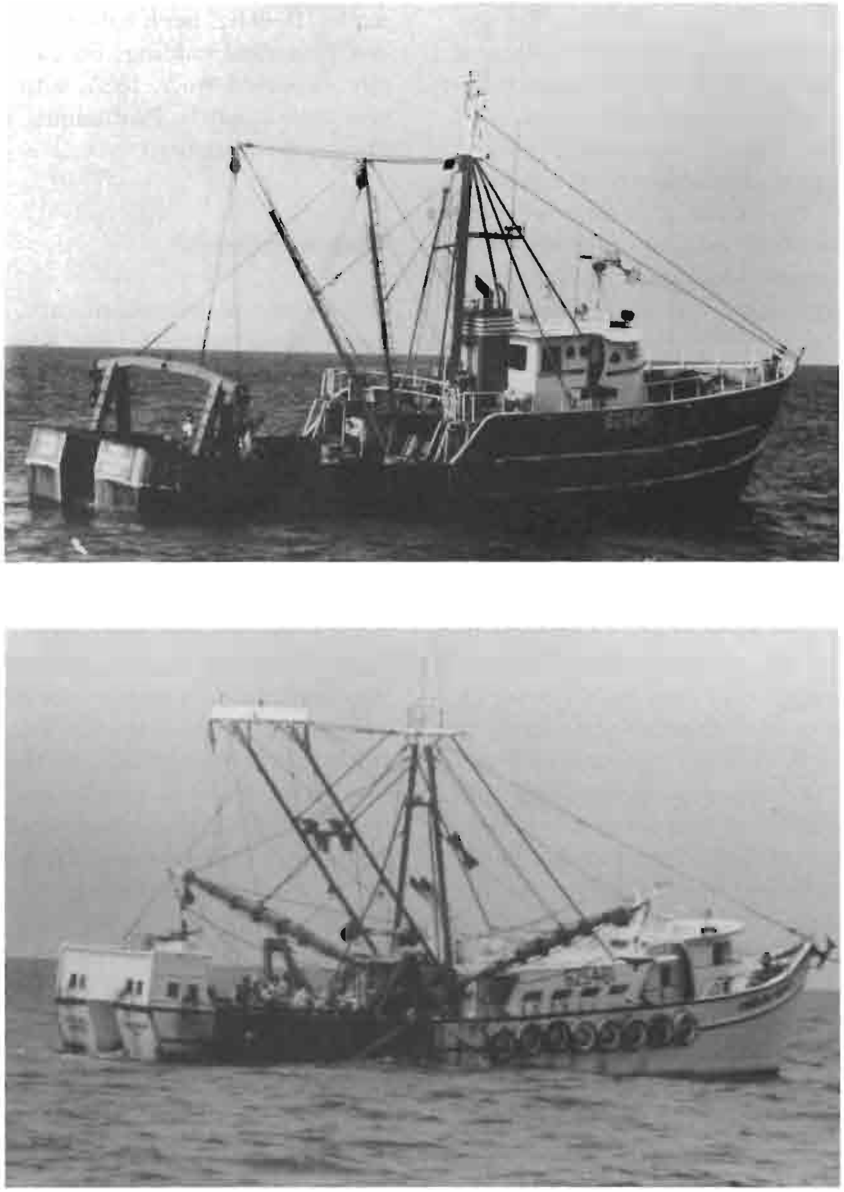

Figure 12
Two typical sea scallop fishing vessels used off the northeast U.S. coast during the 1990's. The vessel above is typical of those hailing from northern ports, such as New Bedford, Massachusetts, whereas the vessel below is typical of southern vessels from North Carolina and Virginia. Note on the vessel below the presence of a "shucking house" on the stern, where the crew separates scallop meats from shells.

States to regulate its fishermen, although union and industry practices limited time at sea and crew sizes (Serchuk et al., 1979). During the ICNAF era, Canada enacted total catch limits (which were not restrictive) and a maximum count of 40 meats per pound. Following extension of territorial jurisdictions to 200 miles by the United States and Canada in 1977, sea scallops became a major bilateral fishery issue. Ultimately, the U.S.-Canada maritime boundary (the "Hague Line") was established by the International Court of Justice in October 1994 (Fig. 9), forcing both countries to abandon grounds that they had historically shared.

Even prior to settlement of the boundary question, the need for restrictive regulations to conserve U.S.

scallop resources was recognized, and a sea scallop FMP was implemented by the New England Fishery Management Council in 1982. Provisions included a 30-meat per pound maximum and a 3½-inch shell height minimum (Smolowitz et al., 1989). A one-year phase-in of the meat count regulation allowed 40 meats per pound to be landed. Subsequent amendments to the plan included tolerances in the count to reflect seasonal variation, and a 12-hour daily "window" during which all scallops had to be landed, to enhance enforcement of the meat-count regulations. But meat count and other regulations were not effective in controlling growth or recruitment overfishing (Smolowitz and Serchuk, 1987; 1989). Consequently, amendment #4 to the sea scallop FMP (enacted in 1994) established a series of direct controls with the goals of 1) restoring adult abundance and age distribution, 2) increasing yield per recruit, 3) evaluating costs of management, and 4) minimizing adverse environmental impacts on stocks (New England Fishery Management Council, 1994).

Amendment #4 replaced meat count requirements with 1) a moratorium on new vessel entrants (Table 2), 2) effort reduction through fewer days at sea per vessel, 3) increase in the ring sizes of dredges (eventually to 3½-inch diameter), 4) mandatory dealer and vessel logbooks, and 5) other provisions to limit gear size and effectiveness. It is estimated that days at sea may have to be reduced 35–70% to lower fishing mortality below the level at which recruitment overfishing occurs. Reductions in effort will occur over a seven-year period, to minimize short-term economic impacts of regulation on the fleet. It is hoped that by decreasing fishing mortality, total yields will increase and become more stable, thereby avoiding the cycle of boom and bust that has characterized this fishery in recent years (Fig. 1).

Subsequent to settlement of the boundary dispute with the United States, Canada implemented a restrictive ITQ scheme to regulate its Georges Bank fishery.

Table 2
Sea scallop vessel characteristics for 1993.

	Vessel size class		
Characteristic	1-50 GRT	51-150 GRT	151+ GRT
No. of vessels	69	100	136
Mean crew size	3.0	7.7	9.5
Mean age (years)	25	18	15
Mean trips/year	36	19	19
Mean days absent[1]/year	53	162	215
Mean $/day absent[1]	1,118	1,854	2,323
Mean lbs/day absent[1]	2,250	2,664	3,389

[1] Days absent from dock.

Since this program was initiated, the Canadian offshore scallop fleet has been halved from about 80 to 40 licensees. Canadian landings on Georges Bank have gradually increased since 1985, without large variations in year-to-year catch. Profitability of this fleet is considered to be quite high.

Resource Status

Trends in resource abundance, size composition, and recruitment strength have been monitored annually since 1975 (Serchuk et al., 1979; USDOC, 1992[2]). Research vessel surveys conducted by the National Marine Fisheries Service sample areas of offshore abundance from Cape Hatteras northward, including all areas on Georges Bank (Serchuk and Wigley, 1986). Periodic Canadian surveys also provide information useful to both countries. Survey abundance indices are provided for both prerecruit (<70 mm shell height), and recruit-sized animals. Given the current high fishing mortality rates, prerecruit indices generally correlate with landings in the subsequent year or two.

Research vessel abundance indices generally follow the pattern of landings. In the Mid-Atlantic region, prerecruit abundance indices peaked in 1989, declined in 1990–92, but increased in 1993–94. Currently, the abundance of harvestable-size scallops is high throughout the Mid-Atlantic region. In contrast, abundance in the U.S. sector of Georges Bank is at an historic low; it peaked in 1991, but recruitment has been poor in all areas of Georges Bank since then. Due to the dearth of prerecruits on Georges Bank, the focus of the U.S. fishery will be primarily in the Mid-Atlantic area for the next few years.

Fishing mortality rates for sea scallops have been estimated based on the ratio of ages 2 to 3 and older in research vessel surveys (USDOC, 1992[2]). Average mortality increased from about 0.6 (43% annual exploitation rate) in 1985 to 1.7 (79% annual exploitation rate) in 1989–90. Recruitment overfishing is defined as occurring when the harvest rate results in spawning stock biomass per recruit that is less than 5% of an unfished population. Under current population circumstances, harvest occurs at a mortality rate of 0.71 (49% annual exploitation rate). Therefore, fishing mortality needs to be reduced by nearly 60% just to reach the overfishing threshold. Growth overfishing occurs at mortality rates in excess of 0.23 (20% annual exploitation rate).

The Future

Consistent with cycles of boom and bust in this fishery, the next few years are likely to see declining yields and concomitant low profits for the fleet. The effort reduction scheme imposed under Amendment #4 should eventually result in lower fishing mortality rates, and thus higher and more stable yields (New England Fishery Management Council, 1994). Replacing maximum meat count regulation with minimum ring sizes for dredges will result in increased harvests of very small scallops, even smaller than those landed under the meat count regulations.

The fishery will likely focus in the New York Bight and off the Delmarva Peninsula during 1994–96, as the abundance on the U.S. portion of Georges Bank is at a record-low and recruitment indices are poor. If the management program is successful in significantly reducing mortality rates, then the pressure to target beds of very small scallops will be reduced.

As of 1994, scallops in excess of 40 and 50 count were being landed. These small scallops compete with lower-priced imported bay scallops from a number of sources. Larger size (e.g. 15–30 count) sea scallops are worth at least double the per-pound value of small ones. If successful, the management program should reestablish the sea scallop as a premium value product and provide nearly $200 million of ex-vessel value annually. The current fleet of over 400 vessels is far larger than can be profitably supported by the resource. Pressure will increase to enact measures that will allow fleet consolidation to occur.

Summary

The ocean clam and sea scallop fisheries are among the nation's most valuable, producing nearly $200 million in ex-vessel value and supporting thousands of jobs in the harvesting, processing, and support industries. These fisheries are typical of those conducted on sedentary animals, in that they are particularly vulnerable to both growth and recruitment overfishing. The example of the surfclam fishery proves that stable fisheries can be achieved even for those species that exhibit aperiodic recruitment events. Despite the virtual absence of good recruitment for more than a decade, the low natural mortality rates on the stock have allowed a stockpiling of the resource and a gradual fishing down of the population. Development of the ocean quahog fishery should proceed cautiously, given the very limited annual productivity of the stock and its extreme longevity.

The Canadian experience in sea scallop fishery regulation on Georges Bank shows that this species can also be stockpiled. Reduced fishing mortality rates under amendment #4 to the U.S. scallop fishery should result in higher overall yields of larger, more valuable scallops, with lower year-to-year variability. The short-term trade off for establishing the fishery on a more sustainable basis will be substantially less fishing time per vessel. If the surfclam fishery is an appropriate example, there should be increased pressure to reduce the size of the scallop fleet, thereby allowing the remaining vessels and crews to be fully utilized.

The U.S. scallop industry is less vertically integrated than either the ocean clam fishery or the Canadian sea scallop industry. It remains to be seen how effort reductions in the U.S. fleet will affect patterns of ownership and employment. At one time, the sea scallop fishery propelled the port of New Bedford, Mass., to the number one fishery producer, by value, among all U.S. ports. It may be so again if prudent management policies are instituted to conserve the resource and enhance the value of the fishery.

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The Molluscan Fisheries of Maine

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ABSTRACT

Maine has been the largest producer of softshell clams, *Mya arenaria*, in eastern North America throughout the 1800's and most of this century. The state also produces blue mussels, *Mytilus edulis*; sea scallops, *Placopecten magellanicus*; mahogany quahogs, *Arctica islandica*; Eastern oysters, *Crassostrea virginica*; European oysters, *Ostrea edulis*; northern quahogs, *Mercenaria mercenaria*; and periwinkles, *Littorina littorea*. Native Americans ate softshells, as the early colonists did later. Fishermen usually have used multi-tined hoes (hacks) to dig them. In the late 1800's and early 1900's, finfishermen used softshells as bait as well as for food. In recent years, they have been sold in the shell as "steamers" and as meats for frying. Production has ranged between 150,000 and 400,000 bushels since 1940. The mussel fishery has grown after markets were found in the 1970's. The mussels are harvested from wild beds and are farmed by transplanting seed to bottom leases for growth. Total landings of sea scallops from Maine's combined inshore and offshore fisheries ranged between 602,000 and 1,530,000 pounds of meats between 1979 and 1990; landings within 4.8 km comprised 32–89% of the catch. The maximum number of boats harvesting them varied from 217 to 271. The fishery for mahogany quahogs, mainly with a shell length of 40-60 mm, has existed since 1976; in 1991, 39,000 bushels were landed. Since 1988, oyster production has been about 3,000 bushels/year. Landings of European oysters and northern quahogs have been relatively low. The periwinkle has been harvested for many years, with as many as 180 fishermen harvesting in any one day, each landing about 100 pounds/day.

Introduction

Maine has been one of the largest producers of softshell clams, *Mya arenaria*, in the United States (Fig. 1). In addition, the state has substantial fisheries for blue mussels, *Mytilus edulis*; sea scallops, *Placopecten magellanicus*; and mahogany quahogs, *Arctica islandica*, and small fisheries for eastern oysters, *Crassostrea virginica*; European oysters, *Ostrea edulis*; northern quahogs, *Mercenaria mercenaria*; and periwinkles, *Littorina littorea* (Table 1).

Table 1
Landings of molluscan shellfish in Maine, 1991.

Species	Bushels (U.S. std.)	Source
Softshell	103,000	Natural beds
Mussels	40,000	Natural beds
Sea scallops	263,000	Natural beds
Mahogany quahogs	39,000	Natural beds
Eastern oysters	3,000	Natural beds
Eastern oysters	5,000	Hatchery-reared
European oysters	880	Hatchery-reared
Northern quahogs	500	Natural beds
Periwinkles	17,500	Natural beds

Softshell Fishery

Fossils dated by carbon-14 methods indicate softshells (called "clams" in Maine), have been present in Maine for 11,800±240 years (Bradley[1]), and kitchen middens left by Native Americans have been aged at 1,710±160 years (Bradley, 1957). They probably dug for softshells in firm sediments with sticks or with tools made from bones, and with their hands in softer sediments. Besides

[1] Bradley, W. H. 1958. Chief Geologist, U.S. Geological Survey, Wash., D.C. Personal commun.

making softshells part of their diet, natives south of the Kennebec River attached large *Mya* shells to sticks to use as hoes for tilling their corn, beans, and squash.

The early colonists from Europe ate softshells but only in times of great need. In his "Journal of Maine History," Sprague (1913) wrote: "In 1781 food was scarce with many at the Kennebec. Mr. Bailey knew families without bread for three months at a time. Many even 20 miles (32 km) inland sought the clam banks."

In considering the softshell flats as a "food bank," the colonists were well within their legal rights. The Massachusetts Bay Colony's Colonial Ordinances of 1641–1647 protected the rights of "every householder for free fishing and fowling as far as the tide doth ebb and flow within the town where they dwell unless the free men of the same town or the general court have otherwise appropriated them." It was then determined that proprietors of adjoining lands "shall have property to the low water mark where the sea doth ebb above 100 rods [1 rod = about 5 m or 16.4 feet] and no more wheresoever it ebbs further." However, they could not prevent "free fishing and fowling" (Anonymous, 1970).

These rights became important about 260 years later in the early 1900's, when the state attempted to encourage the owners of riparian property to farm softshells (Nickerson, 1905). This approach may also be important in the future of aquaculture.

Upon becoming a state in 1820, Maine embraced the tenets of the colonial ordinance as part of its common law. The first legislature (1821) gave the responsibility for regulating local softshell harvesting to municipal governments. Local inhabitants were assured that they could take shellfish at any time for personal and family use (P.L. 1821, chapt. 179).

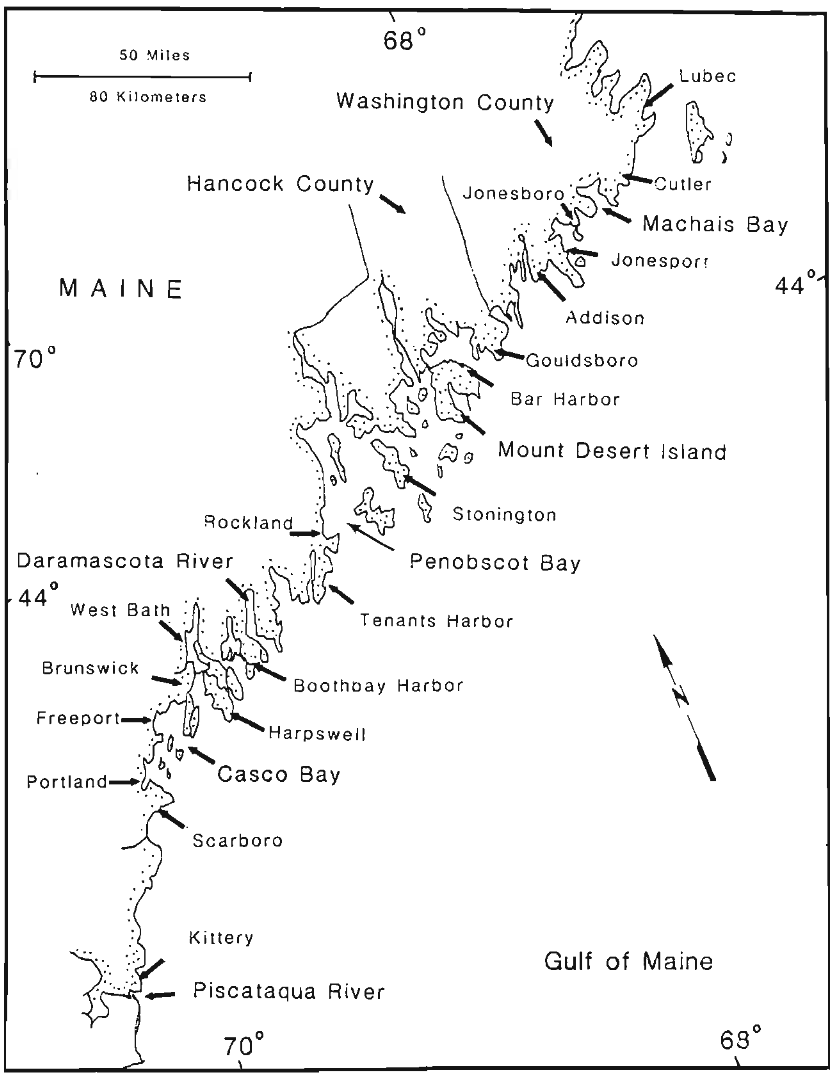

Figure 1
The coastline of Maine.

Softshell Habitat

The Maine tideline coast, about 8,366 km (5,200 miles) long and with many small embayments, has about 20,000 ha (50,000 acres) of intertidal flats. Depending on location, the tidal range varies from 2.4–6 m (8–20 feet), and exposed flats at low tide vary in width from a few meters to at least 1.5 km (1 mile). The exposure time of flats varies with gradient and tidal range (Dow and Wallace, 1961).

Softshells usually grow in sand, but sediments vary from silt and marine blue clay to sand-cobble mixtures, in a zone extending from below extreme low water to nearly mean high water. Commonly occupying the same habitat are polychaete worms, including *Nereis virens* and *Glycera dibranchiata*; other bivalves, such as the baltic macoma, *Macoma balthica*, and amethyst gemclam, *Gemma gemma*; and such gastropods as the threeline mudsnail, *Ilyanassa trivittata*, and periwinkle, *Littorina littorea*.

The Diggers

Softshell diggers have always harvested only during low tides and usually with hoes. They normally have had about 4 hours in which to harvest, but could dig longer and harvest more softshells

Table 2
Data profile of the Maine softshell, *Mya arenaria*, industry in various years.

Years	Mean annual landings (1,000 bushels)	Mean annual no. diggers	Mean price per bushel ($)	Mean landed value ($1,000)
1887	500	Unknown	$0.81	$409
1888	693	500	0.54	374
1917–1941	420	Unknown	0.72	302
1942–1945	353	1,385	1.74	614
1946–1949	573	2,615	2.78	1,593
1950–1959	240	2,105	5.04	1,210
1960–1969	167	1,559	6.67	1,133
1970–1972	420	4,494	13.32	5,594
1973	487	5,927	11.78	5,737
1977	507	5,291	17.70	8,974
1980–1989	293	3,540	40.80	11,954
1990	167	1,748	52.80	8,818
1991	100	1,786	48.55	4,855
1992	147	1,683	52.02	7,647

during a full moon or minus tide. In the long days of spring and summer, fishermen often worked two tides/day, but in the short days of winter they could work only one.

Traditionally, diggers did not harvest year-round, but worked at other manual jobs such as various types of finfishing, lumbering, blueberry picking, or potato digging. From 1947 to 1956, 87% of diggers harvested softshells for only 2–9 months a year.

Before 1942, records of the number of softshell diggers did not exist, with one exception: In 1898, 550 men were counted digging for 8 months of the year, producing 577,935 bushels of softshells or about 6 bushels/man/day (Nickerson, 1898). They were paid an average of $0.69/bushel. This effort and yield is considered to be somewhat representative before World War II. Although softshells comprised only 13% of all commercial fisheries products in 1907–08, Commissioner A. R. Nickerson (1906) said, "The success of the softshell industry directly or indirectly affects more people of this state than that of any other of the fisheries." Numerous commissioners commented on the swings in softshell abundance and expressed concerns for the welfare of people dependent upon the softshell harvest.

The number of diggers has varied through the years. In 1942, the state issued 1,350 softshell licenses, but the number rose in 1948 to 3,326. It then declined, ranging from only 1,000–1,200 from 1958 until 1964, when it increased sharply afterward. From 1972 to 1985 it ranged from 3,500–5,927, but has since fallen, and in 1992 was only 1,683 (Table 2). The number of diggers active in any one day is less than the number possessing licenses. With fewer diggers and less production in recent years, a larger proportion works full time, with about half harvesting nearly 6 months a year and half harvesting 10–12 months, depending on winter ice and availability of open flats.

Legal Intervention

During the late 1880's, the softshell resource and industry gained increasing attention from the state legislature and institutions. In 1894 the Sea and Shore Fisheries Department (SSFD) was established as a permanent state cabinet level agency (Whitten, 1894). Its commissioner was appointed by the governor.

In the early period, the legislature was active in dealing with the ways of improving the fishery and dealing with town concerns. There were no state licenses, but in 1901, towns were authorized to license their diggers and fix times for harvesting (P.L. 1901, chapt. 284). In 1905, the SSFD Commissioner was authorized to set aside flats where small softshells could be planted, to enhance production (Nickerson, 1905).

In 1911 the legislature authorized each town to lease as much as one-fourth of its flats for private softshell reservations. This provision is still a part of Maine's Fisheries Laws (MRSA chapt. 623, 6673). In 1917 a law was enacted enabling upland owners to give consent to have a state softshell reservation located on their flats for a period of 3 years (P.L. 1917, chapt. 281). When the flats opened, only licensed diggers could dig softshells, and it was advocated that only softshells >2½ inches (>63.6 mm) long could be taken (Sanborn, 1918). The attributes of a reservation, as stated by Commissioner Edwin W. Gould in 1920, were: "sandy soil, free from rocks, good currents, located within view of the riparian owner, so that trespassers may be warned or prosecuted." In 1920, a state boat planted softshells on 12 reservations as demonstration farms. In 1922, 22 reservations were licensed for 10 years (Gould, 1919–22). Because local people have wanted the flats open for public digging, attempts to privatize or control even limited areas of flats have failed to gain momentum. Therefore, few people have ever tried to establish leases since that time, despite valid laws (Anonymous, 1970). Tradition and customs of public use have continued, with great resistance to change.

Town Control of Flats

From 1895 to World War II, town control and exclusive use of flats was strengthened by succeeding legislatures, which passed private and special laws giving municipalities the power to license diggers and restrict commercial digging to residents. The SSFD was responsible for enforcement.

Municipal controls, growing stronger each year, were not without court challenge. Constitutional rights were claimed and discrimination charged, but in a 1909 case involving the town of Scarboro, the Maine Supreme Judicial Court upheld the right of towns to discriminate between resident and nonresident diggers (State vs. Leavitt, 1909). By this time, the traditional view of local public ownership set by municipal boundaries had been firmly established. Nevertheless, legal challenges to the rights of towns to restrict softshell harvesting to residents continued after World War II. *State vs. Alley* (1970) challenged Jonesboro, and *State vs. Norton and Mahonen* (1975) challenged North Haven, but the courts upheld the municipal rights when actions were based on the towns' conservation and management programs.

Softshell Uses

Softshells have traditionally been used for both food and bait. For nearly 250 years after the first European settlement, softshells were dug almost entirely for local subsistence. Commercial sales began around 1850, when a market for steamer softshells in the shell was developed locally and in Boston. In addition, inshore fishermen used fresh softshells for bait. After 1880, new markets opened for steamed-out salted meats for use as bait by offshore cod fishermen from North America and Europe. In winter, softshells were dug and steamed open in large vats on shores, and then salted and stored in barrels. As late as 1912, Portuguese boats purchased them from villages along the coast (Dow and Wallace, 1961). Shell mounds from these operations are often mistaken for Native American middens.

Canning Softshell Meats

In the late 1800's, most softshells for eating were canned. Maine cannery workers cut off and discarded the black tissues and siphons, canning the remaining meat and juice. In 1904, the canneries packed 65,116 cases of softshell meat and 5,113 cases of juice (a bushel of softshells produces a case of 48 cans, each containing 5 ounces of meat). That year, fishermen were paid an average of $0.77/bushel (Nickerson, 1905). Before World War II, cannery-owned vessels normally carrying sardines in Maine's Washington County occasionally transported Canadian softshells to the canneries for processing.

From 1901 until the depression years of the 1930's, the state limited the canning season to 15 September–1 June to conserve the softshells, and did not allow softshells to be shipped out of state during that period (P.L. 1901 chapt. 248). Canning dominated the fishery from 1900 to 1940 when up to 18 factories operated. In 1935, at the industry's peak, 63% of softshells harvested were canned, and factories employed from 30–200 workers each (Look[2]). Factory employees canned softshells in winter and packed sardines in summer. When summer markets developed for fried softshells and steamers, arguments began within the state legislature between the canning interests who wanted the season closed in summer and those in the fresh softshell industry who wanted it opened in summer and closed in winter.

Those who wanted softshells for canning argued that summer digging would kill too many softshells by exposing them to excessive heat, while the fresh softshell industry maintained that freezing in winter killed too many. The ban on summer digging in the state's three southwestern counties was lifted in 1937 (P.L. chapt. 241) because the market demand for whole and shucked softshells was increasing in Maine and Massachusetts. Softshells were shucked in local homes, commonly by the diggers and their families. However, the law was maintained year-round in the four northeastern counties, because of a perceived economic need for winter canning. In 1935, the state had passed a 2-inch (50.8 mm) minimum-size law to prevent smaller softshells from going into the "steamer" market (P.L. chapt. 120, 1935).

In 1941, Lincoln County was allowed to ship softshells out of state in summer to meet a growing demand, as fried softshells were becoming popular at "take-out"

[2] Look, A. 1992. Former owner, A.M. Look Canning Co., East Machais, Maine. Personal commun.

Figure 2
Shucking softshells at A. M. Look Canning Co., East Machais, Maine, 1965. Photograph by L. Varney.

Figure 3
Washing softshell meats after shucking, at A. M. Look Canning Co., East Machais, Maine, 1965. Photograph by L. Varney.

stands and restaurants in both Massachusetts and Maine. Development of improved equipment and frying techniques was largely responsible for this popularization.

During World War II, there were far fewer men to dig softshells, but after the war, production reached its second all-time high—653,000 bushels—owing to 1) high demand for protein foods, 2) large labor supply, and 3) accumulation of softshells in flats during the war years. Finally, in 1949, all counties removed restrictions on summer digging and on transporting softshells out of state (Dow and Wallace, 1961).

The industry gradually shifted from home shucking to shucking plants for local and out-of-state distribution of meats for frying. Plants were built at inland sites as they did not need to be on the shore. Shells went into landfills. Ten plants were built in southwestern Maine and three in northeastern Maine. By this time, the will of the canning industry no longer dominated the Maine Legislature, and by 1958, canned softshells declined to less than 10% of the total production. Over the next 10 years canning was practically phased out, and now, only one small plant remains; the A. M. Look Canning Co.[3] in northeastern Maine cans softshells as it has since 1917 (Fig. 2, 3, 4) (Look[2]). The fried and steamed markets have claimed almost the entire harvest.

By 1964, Maine had 27 certified dealers handling shucked and whole softshells, and the number increased to 184 by 1977. Many were handling various other marine fishes and shellfishes also (Varney[4]). From 1986 to 1992, the number of shellstock shippers was constant at about 100, while the number of shucker-packers decreased by 50% to 29 (Interstate Certified Shellfish Shipping Lists, U S. Food and Drug Admin., Wash., D.C.). Current high prices of whole softshells, along with the availability of low-priced shucked softshells from Maryland and Canada, discourage shucking in Maine.

Softshell Management

Commitments made by the Maine Sea and Shore Fisheries Department before World War II to aid towns in managing their softshell fisheries were reactivated in 1946. A program of close cooperation with individual towns and regions was instituted to gain information about their softshell flats and develop management techniques to enhance productivity.

It soon became apparent that survey techniques and analysis methods to determine softshell flat productiv-

[3] Mention of commercial firms or products does not imply endorsement by the National Marine Fisheries Service, NOAA.

[4] Varney, L. 1991. Maine Shellfish Certification Program, Dep. Marine Resources, Augusta, Maine (Retired). Personal commun.

Figure 4
Packing juice of softshells at A. M. Look Canning Co., East Machais, Maine, 1965. Photograph by L. Varney.

ity had to be developed to conserve and manage the fishery. SSFD research director Robert L. Dow conducted such an experimental survey and analysis program from 1947 to 1951 (Dow, 1952), using softshell volume tables developed by David L. Belding (1930) in Massachusetts.

Critical to managing each flat was knowledge of softshell size, composition, and density (Dow, 1952). Verification of the accuracy of the methods came from daily records kept of commercial production from flats that were surveyed and then harvested (Dow[5]). Later, new tables were developed from Maine coast data (Stevenson et al.[6]). Early management efforts included transplanting small softshells by hand digging, measuring growth rates, and rotating the opening of flats to allow small softshells time to grow for increased harvests (Dow and Wallace, 1961).

In 1948, a U.S. Bureau of Commercial Fisheries softshell investigation directed by John B. Glude was established at Boothbay Harbor. Among the findings of cooperative state-federal research was that fishermen kill about 50% of undersized softshells, mainly by burial, when they harvest market softshells (at least 2 inches long) (Glude, 1954). Breakage of harvestable size softshells averaged about 20% (Dow and Wallace, 1961; Taxiarchis et al, 1954). That information, along with experimental data on destruction of small softshells, was valuable in making decisions about closing flats to protect undersized softshells.

After 1959, the towns were responsible for enforcing private and special laws (Maine P.L. 1959). In 1963, the statewide 2-inch softshell law was repealed, and towns were given rights by the Maine legislature to establish ordinances, with Department of Marine Resources approval (Maine P.L. 1963). By ordinance, towns can now: 1) license resident and nonresident diggers, 2) establish fees, 3) control digger numbers, 4) close and open conservation areas, 5) determine size, quantity, timing, and permitted locations for softshell harvest, and 6) enter into agreements with other towns to adopt joint programs with reciprocal harvesting privileges, such as under the Brunswick-Harpswell-West Bath Regional Commission (12 MRSA Chapt. 623, Sec 6671).

To assist towns in management, the DMR divided the state into four regions, each with an area biologist whose primary function was to help community shellfish committees and town officials develop and maintain conservation and management programs. Enforcement of ordinance provisions by local officers was an integral part of effective programs.

Towns can now control their softshell resources. Limiting entry by restricting the license numbers is an effective tool to control digger numbers and digging pressures on the flats. Some towns have limited entry. Brunswick, for example, issues a limited number of softshell licenses to its residents on a "first come first served" basis, and also a limited number to nonresidents by lottery. Some towns place no restriction on the number of licenses to local and Maine residents.

An economic evaluation of restricted entry in the Maine softshell industry showed a 15% larger yield from towns with managed flats (Townsend, 1985). By 1979, 59 communities had ordinances—more than 50% of the total with shellfish-producing potential. In 1984, the 2-inch softshell law was restored to control harvesting of small softshells (MRSA Chapt. 623, Sec. 6676). In 1991 only 41 towns in the town management program had ordinances and authorization for a total of 1,305 municipal resident diggers with each community selling an additional 10% of its allotment to nonresidents. Annual fees for commercial resident diggers ranged from $13–$150. Nonresident fees cannot be more than twice the resident fees, or a maximum of $400 (12 MRSA 6671, para 3b, 1991). Resident recreational fees

[5] Dow, R. 1955. Additional notes on shellfish surveys. Fifth Conf. on Clam Res. U.S. Dep. Inter., Fish Wildl. Serv., Boothbay Harbor, Maine, March 1–3. Unpubl. rep., p. 18–19.

[6] Stevenson, D. K., D. B. Sampson, and W. S. Foster. 1981. A method of improving mean density estimates obtained from intertidal clam census surveys. Maine Dep. Mar. Resour., rep. pres. at 1981 Boothbay Harbor Clam Conference.

range from $0–$25, and non-resident recreational fees range from $0–$75. Where ordinances do not exist, anyone may dig softshells commercially with a state commercial license, in "open areas." In 1993 a state commercial shellfish license cost $63.

Transplanting Softshells

Transplants of small softshells by towns that used hand labor were not cost-effective because labor costs were high and production low. Therefore, the U.S. Bureau of Commercial Fisheries and State of Maine Department of Marine Resources (DMR) developed a mechanical transplanting method using hydraulic water jets. In the most productive day, about 400,000 softshells 5–25 mm long (20,000/bushel) could be transplanted in this way. When planted in sand substrates, the softshells did well in southern Maine, where 13–25 mm (0.5–1 inch) softshells grow to 50.8 mm (2 inches) within two growing seasons.

Green Crab Predation

In the 1950's, green crabs, *Carcinus maenas*, began decimating softshell populations. They had appeared first in southern Maine in the early 1900's and by 1950 were abundant along the entire Maine coast (Scattergood, 1952). Rising water temperatures enabled them to extend their range (Welch, 1969). The crabs feed mostly at night, are highly mobile, hide under seaweed or burrow into coastal banks during the day, and can survive several hours of air exposure. They can crush and consume softshells of almost any size and can consume northern quahogs up to about 50 mm (2 inches) long. The decrease in softshell production from 1950 to 1970 was caused by green crab predation (Fig. 5).

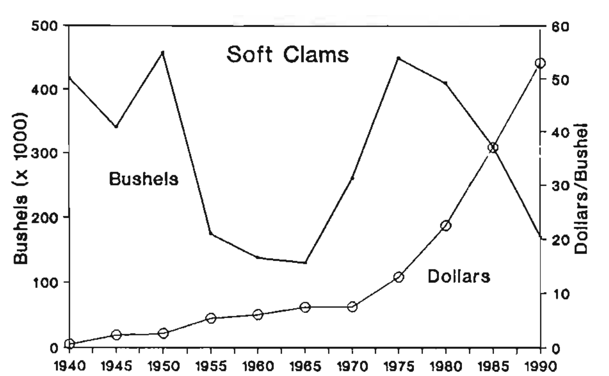

Figure 5
Maine production and price/bushel of softshells, 1940–1990.

In the 1950's, state management efforts shifted from transplanting softshells to developing fences to keep crabs out of beds. Fences were constructed of 13 mm (½-inch) wire mesh, 46 cm (18 inches) high with a 15 cm (6-inch) wide flange on top, and a 15 cm deep skirt that was buried. By law, anti-green crab fencing was made a part of the mandated program of the DMR, which had discretionary authority to take money from the shellfish fund to match town proposals (P.L., 1963 Chapt. 277). But in the late 1960's and early 1970's, lower temperatures and heavy ice covers resulted in a sharp reduction in crab numbers. Softshells became more abundant, production increased, and communities quit building fences. Attention shifted to renewed attempts to transplant small softshells.

Pollution Effects

Pollution has been an ever-present problem for the softshell industry and the DMR. As a marine resource agency, the SSFD was responsible for protecting and enhancing the resources. In 1946, four state agencies began field and laboratory research to identify polluted waters that had to be closed under the National Shellfish Sanitation Program. The SSFD enforced softshell flat closures. Some closures had been initiated before World War II, but were not generally enforced during the war. In 1946–47, 58 classified areas were closed. In 1949, DMR laboratory facilities were constructed to help the Department of Agriculture process water samples and classify waters and flats. In 1963, the SSFD replaced the Department of Agriculture, becoming totally responsible for the state-federal industry certification program. Current regulations are found in 12 MRSA Chapt. 607, 6172, and in DMR Regulations, Chapt. 7.

Some abatement programs have been implemented to curb the spread of pollution. In 1974, Maine had 15 municipal treatment plants and 3,420 residential direct discharges on its coast. Currently it has 59 municipal plants and 2,446 residential treated discharges (Purington[7]).

Since 1963, softshells harvested from restricted flats and waters under control of the DMR and the Food and Drug Administration (FDA) have been depurated in plants. They are held for at least 48 hours in flowing salt water purified by ultraviolet light (Stearl, 1964). As many as five private plants have operated at a time, depurating from 8,000 to 25,000 bushels of softshells annually. Currently, only one plant depurates softshells and one depurates quahogs and oysters as specialty products (Lewis[8]).

[7] Purrington, D. 1992. Dep. Environmental Protection, Augusta, Maine. Personal commun.

[8] Lewis, R. 1991. Dep. Marine Resources, Augusta, Maine. Personal commun.

Tight controls and restricted entry are exercised by the state from harvest to transport to operation of depuration plants. The number of restricted flats has varied over time, as pollution has changed seasonally or annually. The holder of a certificate for a depuration plant must offer digging privileges to a town resident for each nonresident employed. The plant owner must also pay $0.50 for each bushel dug in the town (12 MRSA 6856, para 8, 1992).

Recent Fishery

In recent years, the softshell fishery has been carried on all year. Diggers harvest only during low tides, obtaining about 2 bushels/tide. By law, softshells can be dug only with hand instruments (12 MRSA chapt. 621, 6623). Softshell diggers need little equipment besides hip boots. They normally use hoes to turn over the sediments and then pick out the softshells. The hoes have four or five tines, 15 cm (6 inches) long, and handles 30 cm (12 inches) long (Fig. 6). In extremely soft, fine silt-clay flats, however, diggers pick out the softshells with their gloved hands and put them in various containers, such as ½-bushel hand-made "hods" or "rollers," pails, or burlap and onion bags. Many have small boats to carry the softshells ashore. From the 1940's into the 1970's, softshell dealers drove their trucks to shores near the beds, competing with one another to purchase softshells. Most diggers now have small trucks or automobiles to take their softshells to dealers.

Figure 6
Commercial softshell digger, Brunswick, Maine. Photograph by D. E. Wallace.

Production Decline

In the 1980's, production declined mainly because light sets caused softshells to become scarce in Maine's two northeastern counties, Washington and Hancock. Historically the two counties produced 50–70% of the state's total, but in 1991, this dropped to only 29%, and in 1992, to only 24%. Many citizens had relied on the softshells for employment. For example, in 1979, the town of Addison, Washington County, had 920 residents, of which 231 were commercial softshell diggers (Foster and Wallace, 1979). But only 100 licenses were issued in 1991.

In sharp contrast, Cumberland County in southwestern Maine has received regular abundant softshell sets, and the towns of Brunswick, Freeport, West Bath, and Harpswell in upper Casco Bay have been big soft-shell producers and maintained active management programs.

State Production

Annual softshell production was about 400,000 bushels from 1940 to 1950, but fell to around 150,000 bushels from 1955 to 1965. Thereafter, it increased to over 400,000 bushels again from 1975 to 1980, but has since fallen (Fig. 5).

In 1991, 103,000 bushels of softshells were produced (Table 1), with a landed value of $4,784,000. In 1992, several previously polluted areas were opened after abatement programs were implemented, and production from open areas in southwestern Maine increased. Preliminary 1992 data showed that landings increased 47% to 151,000 bushels with a value of $7,863,000. The landed price/bushel was $52.07, a 7% increase over 1991.

Currently, about 60% of Maine softshells are shipped out of state as shellstock to markets centered in Boston (Lewis[8]). In recent years, shucked softshells from Maryland and Canada have dominated the Maine restaurant trade (Markos[9]).

[9] Markos, J. 1992. Manager, Maine Shellfish Company, Ellsworth, Maine. Personal commun.

Softshell Hatchery

In 1987 the first regional public shellfish hatchery was built on Beals Island in northeastern Maine, producing seed softshells to enhance productivity on Maine's public flats. The hatchery was part of a public aquaculture program developed by private individuals, foundations, 10 participating communities, and academic leaders and centered at the University of Maine in Machias. An education center was also located on Beals Island.

Each year, about 1 million softshells have been produced in the hatchery for each town, which spreads the seed on its local flats. Production has not increased much as yet as a result of this, but the future is bright. At the Dana E. Wallace Educational Center, visitors may watch a series of videos showing all aspects of the hatchery program, including softshell spawning, algal production, nursery rearing, research, and transplanting, and see historical photographs of the industry (Beal and White[10]).

Sanitary Classification of Flats and Waters

Since 1986, increased adherence to Interstate Shellfish Sanitation Conference (ISSC) and FDA guidelines for classification of shellfish producing areas has led to a decline in commercial production in many Maine softshell flats, because shellfish areas have been reclassified and closed. From about 1950 to the late 1980's, from 17–20% of the flats were closed owing to pollution. Now, the percentages are unknown, but new criteria of encompassing water areas has expanded the classified acreage. There are 240 inshore beds classified as prohibited, approved, conditionally approved, restricted, or conditionally restricted (Foster[11]). The National Shellfish Register of 1990 credits Maine with 33,600 ha (83,000 acres) of prohibited beds and waters (Leonard et al., 1991).

The Future

It will be important for the state government and local communities to look upon the softshell resource as a valuable part of Maine's economy and food production. Positive responses are needed to maintain research and management enhancement efforts. Public confidence must be kept high regarding the safety and wholesomeness of the shellfish. A more realistic indicator of dangers to human health by pathogens and viruses must be developed by the Federal government to supplant the non-scientific fecal coliform standard.

In the future, our marine environments must not only be protected from fecal pollution, but from excessive nutrients that produce harmful algal blooms. As an example, in September 1988, a bloom of the dinoflagellate *Gyrodinium aureolum,* combined with hydrographic and meteorological conditions during a period of high nutrient and abnormally low oxygen concentrations, may have killed about 30% of the shellfish in Maquoit Bay (Heinig and Campbell, 1992).

Initiatives important to future protection and development of Maine's softshell resources are:

1) research work must continue on predator control, e.g. screening and fencing, to increase productivity on intertidal flats;
2) expanded use of seed from hatchery and natural stocks;
3) development of more efficient equipment to harvest and transplant small softshells from dense concentrations;
4) research on ways to encourage natural sets and shellfish survival in depleted flats;
5) a close working relationship between the DMR and each town or group of cooperating towns having ordinances, with all possible DMR technical assistance to programs;
6) research and full management demonstrations of public and private, community, regional, or cooperative softshell aquaculture supported by the DMR and University of Maine Aquaculture Association and other organizations, for optimum yield and quality;
7) expansion of enforcement of ordinances and flat management, for efficiency and effectiveness (action taken must be based on seasonal industry needs and knowledge of abundance, size distribution, and growth of softshell populations on a flat-by-flat basis); and
8) better care of softshells and greater assurances of seafood safety to keep demand and prices for softshells high.

Recently, towns lacking ordinances and limitations on diggers or entry have experienced a resurgence of interest in ordinances and regional management programs. In such situations, the "tragedy of the commons" (Hardin, 1968) has prevailed in the past, with softshell beds seriously depleted. Towns with new ordinances and regional programs have been aware of successful management programs, e.g., opening and closing of flats and transplanting shellfish to depleted areas like Brunswick, Harpswell, West Bath, Phippsburg, Freeport, and Scarboro. This increase in management

[10]Beal, B., and S. White. 1991. The Beals Island shellfish hatchery. Maine/New Hampshire Sea Grant College Program, University of Maine, Machias, 8 p.

[11]Foster, W. 1991. Dep. Marine Resources, Augusta, Maine. Personal commun.

effort should continue as softshell supplies in clean waters fall behind the increasing human populations and demand for seafoods.

Mussel Fishery

Mussels are common on intertidal flats and in subtidal zones, usually to about 3 m below low water, all along the Maine coast. In northeastern Maine, however, they are found as deep as 20 m (Newell[12]).

Early Uses

Native Americans used mussels for subsistence, as evidenced by their kitchen middens (Bradley, 1957). European colonists used them for subsistence and fish bait (Dow and Wallace, 1954a). Maine residents have traditionally considered mussels inferior to softshells and oysters, and before World War II did not eat them to any extent, although limited attempts were made to promote and publicize them. They were harvested in small quantities from Long Island, N.Y., to Maine (Miller, 1980), with most sent to Fulton Market in New York City (Lutz et al., 1977). A considerable share came from Casco Bay via Portland by regular steamship service through the 1930's, until the onset of World War II suspended this commercial link (Smith[13]).

In 1942, Maine whole mussel production was only 21 tons (t) (about 767 bushels). During 1943–46, however, production jumped to an average of 1,140 t (41,767 bushels)/year, spurred by the wartime need to produce protein foods (Dow and Wallace, 1954). The mussels were canned, most by four small factories employing a total of 400 people. One factory at Bar Harbor had 200 employees (Kinney[14]). Mussels were sold as a nonrationed food. Maine led the United States with about 70% of total production—a lead that continued into the early 1980's (DMR Files, 1991).

The potential for expanding mussel production was good because a large supply, relatively free of pearls, was available from mid-state to the Canadian border. However, six areas along the coast were unsuitable for canning purposes because the mussels contained a high number of pearls (Scattergood and Taylor, 1949).

In 1947, production fell to only 18 t (667 bushels), because demand declined with the return of other protein foods to markets. Again, attempts to publicize mussels as a desirable seafood were not effective because many mussels were of poor quality (containing pearls and were ungraded and of mixed sizes), consumers were unfamiliar with them, and handling and refrigeration were poor. Therefore, dealers shipped them only to restaurants that served European foods or to ethnic markets in large cities (Varney[4]). From 1947 to 1967, production ranged from 1–203 t (Avg. 62.7 t, or 2,300 bushels)/year (Lyles, 1969).

[12]Newell, C. 1992. Great Eastern Mussel Co., Tenants Harbor, Maine. Personal commun.

[13]Smith, W. 1992. Fisherman, Brunswick, Maine. Personal commun.

[14]Kinney, R. E. 1992. Former owner, North Atlantic Packing Co., Bar Harbor, Maine. Personal commun.

Fishery Development

Gradually, technological changes improved mussel harvesting and processing. In 1965, fishermen in the Casco Bay and Stonington areas modified sea scallop drags (the local term for dredges) to harvest mussels during high tides. A fisherman in Casco Bay used his 112 cm (44-inch) wide twin drags, towed with a bridle, to harvest mussels. Previously, fishermen had harvested mussels at low tide by hand picking, raking, or forking from intertidal mussel bars or pitchforking the mussels into small flat-bottomed boats partially filled with water during low water. To prepare mussels for market, fishermen walked on them to break the clumps apart, then washed them on the shore. Later, steel-ribbed rotating drums were developed and installed on boats to mechanize washing.

In 1969, the Department of Sea and Shore Fisheries began again to promote mussel sales, with some success. The emphasis was on mussel preparation for markets, home use, and restaurants (Bouchard[15]).

Slabyj and Hickle (1976) found that 1) pearl incidence was a function of age (no pearls more than 1 mm in diameter occurred in mussels <5 years old), 2) pearls undetectable to the consumer (under 1 mm) grew more slowly in mussels held in water and in beds where mussels were not in dense concentrations, and 3) suspended cultured mussels became a high quality marketable product in 12–13 months (Lutz, 1980a). They also found that mussels kept twice as long on ice (near 0°C) than at normal refrigeration temperatures (5°C), and that reimmersion in water after mechanical sorting on boats substantially improved shelf life (Newell[12]).

Fishermen were becoming more interested in harvesting mussels, as demand rose due to persistent and well-focused state promotions (Bouchard[15]). State authorities believed that granting leases to individuals or companies would provide sufficient incentive to develop the best growing techniques and get mussels to market in top condition.

A 1973 state law permitted the lease of designated producing areas from the state, and the DMR became

[15]Bouchard, R. 1992. Dep. Natural Resources, Augusta, Maine (Retired). Personal commun.

the leasing state agency (MRSA, Chapt. 12, Sec. 6072–6073). This meant that seafood companies and individuals could venture into new operations with hope of developing markets supplied by their own cultured products.

When people began to lease bottoms from the state, the first ventures were confined to suspended culture (Myers, 1980). One company, Abandoned Farms, is still functioning with lease permit #1. In subsequent years, most growers found that the method was too labor-intensive and costly and abandoned it for bottom culture.

Expanded Mussel Promotion

On 1–7 April 1973, a national boycott on beef, supported by politicians (including President Richard M. Nixon), the Maine legislature, housewives, and consumer groups, was aimed at bringing down beef prices. The marketing specialist of the SSFD seized upon this event to answer the question: "If not beef, what should we eat?" A campaign was quickly launched emphasizing the relative low cost, tastiness, and wholesomeness of Maine mussels. Newspapers were receptive to boycott-related stories. Tasting opportunities and cooking demonstrations accompanied by free recipes were promoted in grocery stores, retail outlets, and a variety of food service facilities. Just before the boycott, and continuing into late spring, radios and newspapers ran the stories throughout much of the United States. Special articles and photographs appeared in regional and national newspapers. Typical was a big cartoon in the Detroit *Free Press* in 1973, entitled "Mussels Muscle in on Meats." The shellfish were served and appreciated at the National Restaurant Convention in New York and at regional conventions in Boston, Chicago, and New Orleans, as well as in New England supermarkets and other retail outlets. Soon, demand for more information came from housewives, restaurants, and seafood markets (Bouchard, 1973).

With this enthusiastic response from the restaurant trade and consumers, the demand was so large that, initially, the Maine harvesting and distribution system was not ready to meet it. As problems of quality and availability were being solved, mussel acceptance increased, as shown by landings data and prices. A number of dealers launched promotions and quality enhancement programs. Especially aggressive was Great Eastern Mussel Farms, Inc., of Tenants Harbor, which invested at least $1 million in mussel promotion.

In 1977 the demand for quality mussels increased sharply, and harvesting became a year-round industry. Maine mussels had good meat yields, lacked grit, and had no pearls. Throughout the 1980's, the region from Casco Bay to Penobscot Bay was the largest production area (Chenowith[16]). From 1980 to 1991, the catches from leased beds ranged from 8–20% (avg., 12%) of the total.

By 1979 the state had issued 30 leases totalling at least 700 acres (283 ha) to individuals and companies, many of which formed partnerships with Great Eastern Mussel Farms. The company marketed mussels in the shell and as fresh and frozen meats packaged in quantities ranging from 2–50 pounds (Davison[17]). It used modern equipment and established rigid standards for pearl control, self-cleansing, debyssusing, grading, packaging, and distribution. It also ran a research program to study growth and meat quality in relation to the density of mussel patches, patch sizes, and mussel locations relative to current velocity on its leases (Newell, 1990a).

With its 18-m (60-foot) boat, Great Eastern Mussel Farms dredges about 40,000 bushels of seed mussels each year from beds with dense concentrations and plants them on 61 ha (150 acres) of leased beds. An additional 11 fishermen, using their own 10.5–12 m (35–40 foot) boats, harvest mussels from the company's leased beds and public beds year-round (Davison[17]) (Fig. 7). The state has seven other mussel dealers and 13 boats; mussel shipments are made from many ports (Lewis[8]).

Leases and Licenses

With private leases of mussel bottoms came problems associated with leasing public property for private use and involving conflicting rights to the resource (Flatbo, 1986). However, due to the lesser amount of exclusive use required by bottom leases and their being out of sight, their acceptance has been greater than for leases where suspension culture of mussels was practiced.

The DMR has jurisdiction over all fish and shellfish leases (12 MRSA-6072, 1991. DMR Rules Chapt II). Adjudicatory hearings are held and site reviews made to determine effects on commercially and ecologically important flora and fauna, and to settle conflicts with traditional fisheries. Any conditions imposed are intended to insure multiple compatible uses of lease tracts. The highlights are 1) leases are in 5-acre (2-ha) tracts, 2) there is an application and site review, 3) rents are not less than $50/acre ($123.50/ha), 4) leases are limited to 10 years, and 5) only 100 acres (40.5 ha) may be granted per lease, with no person holding an aggregate of more than 150 acres (60.7 ha).

Since the program's inception in 1973, the largest number of mussel leases has been 32 sites that com-

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[16]Chenoweth, S. 1992. The blue mussel in Maine. Maine Dep. Marine Resources Leaflet, 4 p. West Boothbay Harbor, Maine.

[17]Davison, E. 1991. Great Eastern Mussel Co., Tenants Harbor, Maine. Personal commun.

Figure 7
Blue mussel dredge boat. The drags, washer, and bags of mussels are visible, 1985. Photograph by P. Blais.

prised 686.9 acres (278 ha) in 1988. A sharp decline followed, however, and in 1992, there were only eight remaining leases, totalling 149.2 acres (36.8 ha) (Honey and Churchill, 1992).

In 1988, mussel boats and hand operations were licensed. That year, Maine had 39 boats; in 1989, 32; in 1990, 38; and in 1991, 25 harvesting wild mussels in coastal waters, dredging in depths from 2 to 9 m. The boats are Nova Scotia-style, 12–15 m long. Operating with a captain and crew of two, each boat harvests about 200 bushels of mussels a day. Since the 1970's, the boats have increasingly been outfitted with hydraulic mussel washers. The washers have spaces of 16–19 mm (0.6–0.75 inches) that allow mussel shells and seed to return to the bottom as "cultch" for catching new mussel sets. Meanwhile, hand operators had decreased, from 76 in 1988 to 49 in 1989, to 29 in 1990, and to 22 in 1991 (Lewis[8]). Noncommercial harvests were limited to 2 bushels/day (PL 1988, Chapt. 626).

Seed Areas

Since the 1970's, the industry has gained increasing knowledge of high quality seed mussel areas. Seed mussels have been a major concern because of a large demand for seed 32–50 mm (1¼–2 inches) long, to replenish depleted farms and supply the public fishery. But because wild mussels are available in large concentrations, pressure on seed beds is low and many beds "go by", i.e., reach 5–6 years old, become blue, and develop pearls before use by the industry (Newell[12]).

In 1988, the DMR promulgated rules to 1) limit the width of drags to 6.5 feet (2 m), 2) prevent nighttime harvesting, and 3) set seed mussel counts and tolerances. Four seed areas were established in northeastern Maine as conservation areas from which leaseholders could take seed for planting. The DMR conducts surveys of mussel abundances and size distributions in the four areas and grants permits for controlled harvesting. A seed removal system monitors harvest activities and ensures maintenance of 40–50% of the initial standing crop. The controls are intended to allow for consistent, long-term availability of seed mussels (Thayer[18]). The beds were used during the first 2 years, but not since, because demand for seed for aquaculture sites declined when high quality wild mussels became available in large quantities in Massachusetts (Chenowith[16]).

[18]Thayer, P. E. 1988. Maine seed mussel conservation areas—mussel count/volume/standing crop. Unpubl. data file. Dep. Marine Resources, West Boothbay Harbor, Maine, 4 p.

In a report on economic issues in the mussel fishery, Wilson and Flemming[19] stated, "The cultured mussel industry has been very beneficial to the wild fishery in terms of marketing, prices, income, and employment. The leasehold arrangements in the mussel fishery have transformed the private incentives and abilities for the development of new seafood markets. The economic effects have been extremely positive for both the cultured and wild segments of the industry and for the state as a whole. Discontinuation of the leasehold arrangement or even the insertion of considerable uncertainty about its continuation would seriously undermine the positive incentives and the economic growth that have occurred to date. A new and valuable industry has been created within the state. There are strong indications that its growth will continue well into the next decade or beyond."

Paralytic Shellfish Poisoning (PSP) and Domoic Acid

Blooms of the toxic dynoflagellate, *Protogonyaulax tamarens*, are a common seasonal occurrence in the Gulf of Maine. They are a health hazard because shellfish accumulate their toxin, i.e., PSP. This prevents optimal use of shellfish resources (Shumway et al., 1988). PSP was identified in Maine in 1957, when waters were sampled in Washington County following years of closure in the adjoining Canadian waters to the north (Medcof et al., 1947). In 1958, a section of the waters in the nearby Town of Lubec, near the Canadian border, was closed to the taking of clams and mussels because PSP concentrations were too high. The mussel is used as the indicator organism for concentrations of poisons, as it accumulates them faster than most other bivalves.

The DMR has developed an extensive monitoring program along the entire coast to manage the closing and opening of flats and waters to harvest of affected species. It follows FDA and ISSC guidelines, and works closely with authorities in Canada, New Hampshire, Massachusetts, and other states as a part of the National Shellfish Sanitation Program. From May into September, southwestern Maine is usually closed to the taking of mussels and frequently other mollusks. At times the impact of PSP can be great on shellfisheries. Closure of the entire Maine coast during September 1980 was considered an economic disaster, with a loss to the economy of at least $4 million (Lewis[8]).

Another feared toxin is amnesic shellfish poison, or domoic acid. Associated with the diatom *Nitschiapurgens* F multiseries (Marcot, 1990), it has caused illness and death in eastern Canada and on the west coast of North America. However, it has not been found in Maine mussel harvesting areas.

[19]Wilson, J., and D. Flemming. 1989. The economics of the Maine mussel industry. Rep. to Maine Legislature Marine Resources Committee, Dep. Econ., Univ. Maine, Orono, 15 p.

Mussel Production

The 1983 production of cultured mussels totalled 1,855 t (68,000 bushels), and in 1985, cultured mussels, most of them produced by Great Eastern Mussel Farms and associates, contributed 20% of Maine's total. After 1989, production of cultured mussels fell and stabilized at about 900 t (33,000 bushels)/year and, in 1991, comprised 7% of the total landings. Since the late 1980's, when a huge bed of high-quality wild mussels was discovered near Nantucket, Massachusetts, there has been a large increase in Massachusetts mussel production. This has led to a concurrent major decline in demand for wild and cultured Maine mussels (Fig. 8), and the state's production dropped 56% between 1988 and 1990.

The Future

The availability of good quality Maine mussels appears to be excellent, although an immediate bottleneck to production is limited markets. As wider markets are developed and aquaculture ventures are enlarged, however, private leases will require more tolerance from coastal residents.

In the wild fishery, harvesting and handling practices must continue to improve and more attention must be given to identifying fast-growing beds for good meat quality and freedom from detectable pearls. Suspended culture may prove economically feasible for supplying

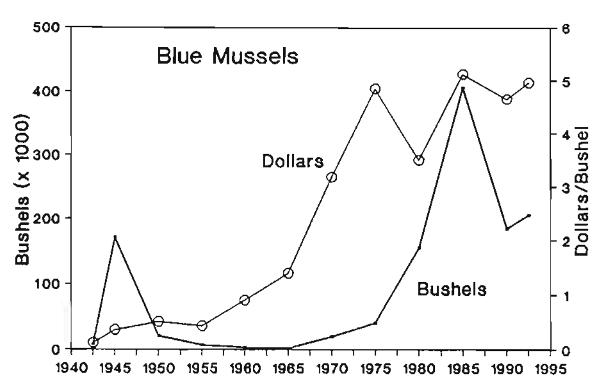

Figure 8
Maine production and price/bushel of blue mussels, 1945–1991.

high quality markets, as improvements in grow-out techniques continue. Price will also be a big factor, spurring or suppressing initiatives.

Inshore Sea Scallop Fishery

Sea scallops occur along the entire Maine coast. Although a fishery for them probably began along coastal Maine in the mid-1880's, landings were not recorded until 1887 (Lyles, 1969). Inshore Maine scallop landings refer to those made from within Maine's territorial zone of 4.8 km (3 miles), while offshore landings are from outside this zone.

Initially, inshore scallops were harvested with scoop nets attached to long poles. After that, small triangular drags hauled astern of rowboats or sailing craft were used (Ingersoll, 1887). Eventually, heavy drags were constructed, the first made from frames of Model T Fords. Currently, at least three types of scallop drags are used: 1) chain sweeps on relatively flat and hard bottoms (Fig. 9), 2) rock drags on rough rocky bottom (Fig. 10), and (3) the much less common Icelandic drag, a hybrid between a chain sweep and a rock drag (Creaser[20]). Scallops are harvested both by dredge boats and scuba divers (Table 3).

Figure 9
Chain sweep drag on sea scallop boat, Harpswell, Maine, 1993. Photograph by D. E. Wallace.

The boats average slightly over 11 m (36 feet) long and usually have a crew of two. Inshore boats usually tow one chain sweep drag measuring 175–182 cm (6.75–7 feet) wide or three rock drags measuring 213–229 cm (8.4–9 feet) wide, with chain sweeps being a little more efficient. Dredging scallops in an average depth of 27–28 m (90–92 feet), each boat makes 28 or 29 tows/day of 12–13 minutes each. The total bottom time for the tows is 5.2–5.5 hours/day. Boats make $26–42/m of drag width/hour towed (Creaser[20]). A limited number (4–5) of boats >21 m (70 feet) long have Federal permits to dredge scallops in offshore waters and sell their catch in Portland.

[20]Creaser, E. 1992. Dep. Marine Resources Laboratory, West Boothbay Harbor, Maine. Personal commun.

Table 3
Number of boats and divers in the inshore fishery for the sea scallop, *Placopecten megellanicus*, in the Gulf of Maine, 1948–1990[1].

Year	Boats	Year	Boats	Divers
1948	160	1970	225	
1949	245	1971	300	
1950	300	1972	500	
1951	220	1973	592	
1952	120	1974	542	
1953	115	1975	583	
1954	100	1976	600	
1955	108	1977	442	
1956	100	1978	N/A[2]	
1957	90	1979	N/A	
1958	60	1980	N/A	
1959	62	1981	N/A	
1960	63	1982	N/A	
1961	63	1983	N/A	
1962	70	1984	N/A	
1963	80	1985	698	267
1964	105	1986	529	170
1965	135	1987	525	224
1966	120	1988	574	247
1967	105	1989	676	244
1968	225	1990	478	133
1969	190			

[1] Sources: R. L. Dow, 1948–1977; DMR License Statistics 1985–1990
[2] 1978–1984—(N/A) Fleet composition relatively static.

Between 1979 and 1990, the maximum number of scallop boats fishing was 217–271 (Morrill[21]). Total landings and value of Maine's combined inshore and offshore fisheries ranged from 100,000–255,000 bushels (602,000–1,530,000 pounds of meats), and inshore landings comprised 32–89% of the catch (Table 3). Most meats weighed from 10–30 g each, and few exceeded 100 g (Creaser[20]). Recorded landings do not show the total inshore catch because direct sales to local markets are not included.

Inshore scallop fishing is limited by law to the colder months of 1 November–15 April. This fishery provides off-season employment for lobstermen and small finfish draggers. Commercial fishing boats pay an annual license fee of $89. The license fee for scuba divers and recreational fishermen is $8.00, and they are permitted to take up to 4 quarts of meats or 2 bushels of whole scallops/day (12 MRSA, 1991, sec. 6701, 6702, 6703). During 1–30 November, drags or combinations in excess of 5.5 feet (1.7 m) in width are prohibited, and during 1 December–15 April, drags may not be wider than 10.5 feet (3.2 m). Fishing times and areas can be controlled by DMR Rules Chapter 11. Established fishing zones are subject to change to protect the scallopers and lobster fishermen from gear conflicts. This is necessary where and when fishing seasons overlap and where restrictions for scuba harvesters may differ from scallop dragging.

Scallop abundances and catches have fluctuated widely, with production peaks in 1910, 1933, 1953, and 1961. In 1980, inshore landings were triple than those of 1979, the result of a scallop population explosion 32–48 km (20–30 miles) offshore of the Rockland-Kittery area; 68% of Maine's landings were taken from that zone (Schick[22]). But by 1985, inshore landings comprised 89% of the total. In 1991, scallop landings were 263,000 bushels (1,579,000 pounds of meats) (Table 4).

Federal regulations govern fishing for sea scallops within that portion of the Atlantic Ocean over which the U.S. exercises fishery management authority (50 CFR ch VI Section 650). Primary Federal regulations have been adopted in the past by the DMR such as one specifying that shucked scallop meats must not exceed 30 meats/pound (DMR Rules 1987, Ch. 11).

[21]Morrill, R. 1992. Fisheries Statistics Branch, Natl. Mar. Fish. Serv., NOAA, Portland, Maine. Personal commun.

[22]Schick, D. 1992. Dep. Marine Resources Laboratory, West Boothbay Harbor, Maine. Personal commun.

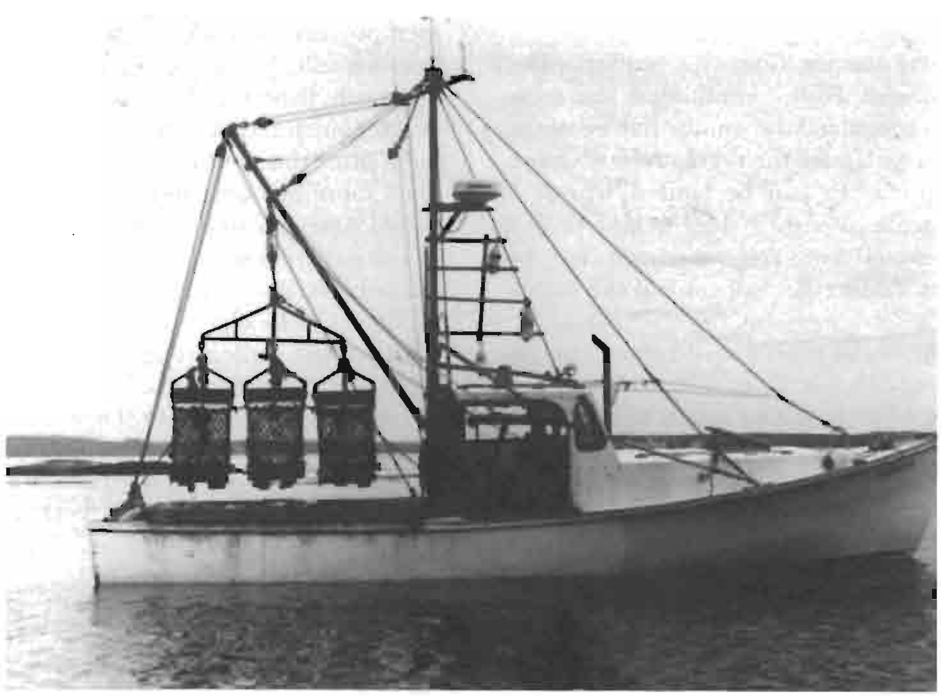

Figure 10
Sea scallop dragger with tooth rock drag, Penobscot Bay, Maine, 1993. Photograph by P. Venno.

Table 4
Maine total landings and inshore landings of sea scallops, *Placopecten megellanicus*, 1979–91[1].

	Total landings of meats (1,000 lb)	Inshore landings of meats	Percent inshore landings
1979	1,163	602	52%
1980	3,213	1,015	32
1981	3,725	1,286	35
1982	1,597	707	44
1983	1,977	1,137	58
1984	1,615	1,145	71
1985	812	721	89
1986	722	541	75
1987	1,239	695	56
1988	1,311	931	71
1989	1,715	1,530	89
1990	1,366	1,112	81
1991	1,579	1,086	69
1992	1,420		

[1] Data are from Annual Maine Landings Bulletins, U.S. National Marine Fisheries Service, and Department of Marine Resources, 1979–91.

The Future

The New England Fisheries Council's scallop plan, known as "Amendment Four," eliminated the meat count/pound and recognized the unique nature of the Maine scallop fisheries.Under the regulations no more than 400 pounds of meats can be landed/trip or 5 bushels of whole scallops with a shell height of 3½ inches or less. Exempted from Federal permits are the small inshore boats. DMR rules will control the Maine fishery (Brennan[23]).

Recent developments in finfish aquaculture may influence the culturing of sea scallops. Since 1985, leases for the pen rearing of salmon have grown from 0 to 36 in Washington and Hancock Counties. Salmon and trout are grown in large moored net pens and, in the future, their net landed value may equal or exceed the combined landed value for Maine lobsters, softshells, and scallops.

More than half of the 70 aquacultural leases currently held along the coast include the sea scallop as a potential species to raise in these privately controlled areas. An experimental program is underway at the Beals Island shellfish hatchery to raise them (Beal and Chapman[24]). Grow-out sites using twine nets and benthic cages, including polyculture under salmon nets, are planned for Cobbscook Bay, Washington County. Scallops may be produced for the wholesale trade and specialty products (Beal[25]).

The prices that Maine dealers pay for inshore scallop meats are important to the incomes of Maine fishermen. Values closely follow the prices paid at the New Bedford, Mass., auction (Plante, 1992a). Therefore, the future scallop plans of the New England Regional Council and implementation of Federal offshore regulations will have impacts on the future economic health of our inshore fisheries.

Harvesting gear needs to be developed to catch adult scallops in ways less destructive to the small scallops and causing less disturbance to the bottom sediments and benthos (Venno[26]).

Mahogany Quahog Fishery

Mahogany quahogs occur along the entire Maine coast (Card et al., 1978). In 1976 a new and profitable fishery for them was founded in the near-shore waters of Machias Bay. Fishermen discovered quahogs that measured about 50 mm (2 inches) long in a bed about 30 m (100 feet) of water. They believed the quahogs could be sold on the half shell, along with littleneck and cherrystone northern quahogs (Clifford[27]). Two fishermen procured a market in southern New England and points south.

Initially, fishermen harvested mahogany quahogs with drags used for that fishery in other states (Averill[28]). Soon after this venture began, other fishermen developed more markets, and the "dry" drag that was introduced. Cheaper to build and easier to use, it consisted of a large wire-framed cage about 120 cm (4 feet) across the bottom, 120 cm high and 180 cm (6 feet) long (Fig. 11, 12). The headgear attached to the front was made of discarded scallop drags. Adjustable teeth 15 cm (6 inches) long were attached along a bar at its mouth.

The boats range from 9.8 to 15.2 m (32–50 feet) long. Most have a captain and one crewman, while a few have two crewmen. One southern dredge boat, used for about 2 years, was 24.4 m (80 feet) long and had a crew

[23]Brennan, W. J. 1993. Maine Dep. Sea and Shore Fisheries. Personal commun.

[24]Beal, B., and S. Chapman. 1987. Raising sea scallop larvae through to metamorphosis. Maine Sea Grant College Program, Orono, unpubl. rep., 6 p.

[25]Beal, B. 1992. University of Maine, Machias, Maine; Consultant, Beals Island Shellfish Hatchery. Personal commun.

[26]Venno, P. 1992. Fisherman, Brooksville, Maine. Personal commun.

[27]Clifford, D. 1992. Dep. Marine Resources, East Machias, Maine. Personal commun.

[28]Averill, P., 1992. Dep. Marine Resources, South Bristol, Maine. Personal commun.

of four. It initially used a converted hydraulic jet-type drag but then switched to a dry drag.

In the peak production years from 1978 to 1988, the fishery consisted of about 120 boats operating full time or part time. Most dredged in 61–91 m (200–300 feet) of water and harvested 60 to 70 bushels of quahogs/day. Early prices ranged from $14–22/bushel. As the quahog beds were depleted in the nearshore areas, the fishermen began to explore and dredge in beds 9.7–12.9 km (6–8 miles) from shore. But such distances were outside practical fishing limits for these small boats, and several capsized and sank while hauling back. Fortunately, no one drowned (Clifford[27]).

Fishermen also found sizable beds east of Jonesport and off Gouldsboro and Bar Harbor. The beds are usually comprised of quahogs of the same year class. Annual recruitment of juveniles is considered excellent in northeastern Maine (McGowan[29]).

About 45 boats are now dredging mahogany quahogs, using ports from Cutler to Gouldsboro. They dredge only 1–3 days/week, as the market is limited. PSP closures also periodically disrupt fishing in some waters. About 15–20 bushels/boat are landed daily in ½-bushel bags. The landed price/bushel is $40–45. Most quahogs are offloaded on the day they are dredged and are shipped south to markets. The remainder are held in cold storage rooms for a day or two, or in wet storage for longer periods (McGowan[29]).

The old age of quahogs caught is of concern to the industry, particularly in the states south of Maine (Ropes and Murawski, 1983). In beds off Machias, the 50 mm (2-inch) quahogs are about 30 years old. Early growth can be as much as 5 mm/year, with a slowing down to only 1 mm/year as the quahogs approach market size (Kraus[30]).

Some beds consist of mixed sizes. Fishermen do not harvest quahogs too big for the half-shell trade. The prices obtained for big quahogs in states to the south are usually lower than for small quahogs from "Down East" Maine. As an example, in 1992, fishermen in New Jersey received $3.74/bushel for large mahogany quahogs to be used for canned products, while fisher-

Figure 11
Boat fitted for dredging mahogany quahogs, Beals Island, Maine, 1993. Photograph by J. McGowan.

Figure 12
Emptying mahogany quahogs from 1.2×1.8-m (4×6-foot) cage dredge, Eastern, Maine, 1993. Photograph by J. McGowan.

[29]McGowan, J. 1993. Biologist, Maine Dep. Marine Resources, Gouldsboro. Personal commun.

[30]Kraus, M. G. 1992. Biology Department, University of Maine, Machias. Personal commun.

men in Maine received $40.37/bushel for small mahogany quahogs for the half-shell market (Morrill[21]).

The fishery is regulated by state licenses, areas fished, gear size, landing tax, and Federal status. The DMR licenses boats to harvest from areas not closed because of pollution or marine toxins, and it restricts the length of the drag's cutting bar with teeth to 36 inches (90 cm) (DMR Rules, Chapt. 10, 1991). The department has a program to protect public health by monitoring the PSP concentration in mahogany quahogs (12 MRSA 6731–6731A, 1991). Producing beds are regularly sampled by department personnel aboard fishing vessels in designated areas (Hurst[31]), a service partially financed by a $1.20/bushel tax paid by quahog dealers (12 MRSA 4712, 1991). Boats dredge with Federal permits issued under the Temporary Exclusion Clause on the east coast allotment program, as established by the National Marine Fisheries Service or the Middle Atlantic Fisheries Management Council (FMC).

The Maine fishery has a unique association with the FMC's. In 1990, the Middle Atlantic Fisheries Management Council learned that Maine had a mahogany quahog fishery and challenged its status in light of Amendment 8 of the Middle Atlantic FMC Surf Clam/Ocean Quahog Plan. The National Marine Fisheries Service considered it a separate stock, and the New England Council sought separate management authority over it. Meanwhile, the fishery operated as an "experimental fishery" with its own logbook requirements (Plante, 1992b).

In 1986 and 1987, respective state landings of mahogany quahogs were 110,000 and 127,000 bushels (1.1 and 1.27 million pounds of meats) with corresponding values of $1.38 and $1.95 million (Table 5). In 1992, the fishery was valued at $1,776,000, when 45,300 bushels (453,000 pounds of meats) were landed (Table 1). Of 36 marine species having values of over $50,000, mahogany quahogs ranked fifteenth in the state (Lewis[8]).

[31]Hurst, J. W. 1992. Maine Dep. Marine Resources, West Boothbay Harbor. Personal commun.

Table 5
Maine landings and value of mahogany quahogs, *Arctica islandica.*

Year	Landings (bushels)	Value ($1,000)	Price/ bushel
1986	111,200	$1,954	$17.60
1987	126,700	1,381	10.30
1988	97,800	1,857	19.00
1989	86,900	2,364	27.20
1990	55,300	1,494	27.00
1991	39,000	1,409	36.10
1992	45,300	1,776	39.20

The Future

The future of this fishery will hinge on how well it is managed and whether 1) littleneck stocks can continue to be found, 2) quality can be maintained, and 3) the fishery has some freedom from PSP closures. Its future also hinges on its relationship with the regional FMC's and its adjustment to Amendment 9. This includes 1) the fishery zone north of 43°50'N, 2) a 3" maximum size limit on the catch, 3) a dredge-bar length of 36", and 4) other qualifications to separate the Maine fishery from the remaining Atlantic quahog fishery.

Eastern Oyster Fishery

Massive middens at the mouth of Salt Bay in the Damariscotta River show that Native Americans ate large quantities of oysters. Considered among the largest in the world, these middens total about 8 million feet^3 (226,629 m^3). The shells are 1,800 ±160 years old as shown by carbon-14 dating (Bradley, 1957). One such oyster shell, 35.6 cm (14 inches) long, is thought to be the largest of the species ever found (Ingersoll, 1881). Smaller middens are present in various other places along the coast. Ingersoll (1881) wrote that, when the Europeans arrived, they found live oysters in the Damariscota River, in Sheepscot and Casco Bays, and at Mount Desert Island. The Damariscota River is now an oyster production center based on aquaculture operations.

Substantial quantities of wild oysters were last harvested from Damariscotta's Salt Bay in the 1840's; few have been found there since. Their habitat was probably destroyed when settlers cleared the forests and constructed sawmills, covering the beds with sawdust and wood debris (Ingersoll, 1887). Some coastal beds did persist for many years, and fishermen took 3,000 bushels from the Sheepscot River over a distance of 4.8–8 km (3–5 miles) in one year (Donahue, 1910).

Small oyster beds were still present in several locations along the coast in the 1960's. The Piscataqua River had the largest quantity, with 23,000 bushels on 25 ha (61 acres) (Harriman and Sterl, 1964). From 1954 to 1968, fishermen harvested about 385 bushels/year from the Sheepscot River using drags from small 3.7–7.3 m (12–24 foot) boats and also with scuba gear (Pearson and Cowger, 1975).

The Piscataqua River beds, closed because of pollution in 1947, are now commercially productive year-round. After being harvested, oysters are depurated in a local plant for 48 hours. Since 1988, production has been about 3,000 bushels/year, with good potential for expansion (Howell[32]).

As oyster prices have increased, lease sites have become more tempting to poachers and a 1992 state law was designed to protect against the poaching of aquacultural products. It states that prior to retail sale, no one can possess cultchless American oysters other than a grower with a license and bill of sale. The license fee is $10.00 (P.L. Chapt. 876, 1992).

The entire oyster industry, from hatcheries to harvesting, is evolving technologically. One project underway aims to identify the causes of intermittent heavy mortalities of juvenile oysters. This will be an expanding industry, as aquaculture becomes more accepted and the high quality of Maine oysters becomes more well-known.

Shellfish Hatcheries

In 1972, the University of Maine, assisted by the Sea Grant Program, began research on culturing oysters. A laboratory and research hatchery were founded at the university's Darling Marine Center in Walpole, on the Damariscotta River (Hidu and Richmond, 1974). Two private hatcheries were also built there.

Since then, this river has become the oyster capital of mid-coast Maine, and the site of an annual oyster festival. There have been about eight different operations on the Damariscotta at one time, but now five companies farm the oysters on six leases totalling 23 ha (55.6 acres) and employ about 30 full-time and 20 part-time people. The leased bottoms are predominantly sand, gravel, and firm clay. They are free from Atlantic oyster drills, *Urosalpinx cinerea*, and relatively free of green crabs, Atlantic rock crabs, *Cancer irroratus*; starfish, *Asterias forbesi*; and flatworms, *Stylochus ellipticus*. About 30% of the oysters reach commercial size in 18 months and 70% in 36 months (Clime[33]).

Since the late 1970's, various methods have been used by the hatcheries in nursery grow-out, predator control, and harvesting, with constant adaption to conditions, as experience and new knowledge have dictated. Bottom culture replaced earlier suspended culture, because cultch fouling by mussels, tunicates, polychaetes, and barnacles were a biological and economic burden. The trend has been toward using more hands-on labor to produce high quality oysters year-round with limited equipment and increased use of wood and non-corrosive materials.

The hatcheries and culturists use upwellers to grow tiny seed and floating screened trays for larger seed (Mook[34]). Periwinkles are held in trays to keep oyster shells clean. Each autumn, after most predators become inactive, workers transfer small oysters from the trays to the bottom, where they overwinter below the ice. The companies use drags from small boats to harvest them and about 5,000 bushels of oysters are produced annually for the half-shell trade (Table 1) (Clime[33]).

The two hatcheries on the river also sell seed of cultchless eastern and European oysters, northern quahogs, softshells, bay scallops, *Argopecten irradians*; and Atlantic surfclams, *Spisula solidissima*, to other U.S. growing areas. Annual production is about 75 million seed (Mook[34]).

European Oyster Fishery

European oysters were introduced to Maine in 1949 by the cooperative efforts of the U.S. Bureau of Commercial Fisheries and the SSFD. The intent was to establish a new commercial fishery in a shallow subtidal zone that did not usually support softshells. The introduction was initiated by Victor L. Loosanoff of the Federal shellfisheries laboratory in Milford, Connecticut, and the stocks came from the Oosterchelde in Holland, as arranged by Peter Korringa of that country. Trays of 3,600 oysters were held in Boothbay Harbor, 1,060 in Basin Cove, Harpswell, and 1,060 in Taunton River, Franklin. The Taunton River oysters did not survive beyond 1953, and no progeny were discovered in that area. But seed oysters from the plantings were discovered in Boothbay Harbor in 1952 (Welch, 1963) and in Harpswell in 1954.

From 1954 to 1961, state biologists made five more introductions in the Damariscotta River and Casco Bay, both from progeny of the Milford Laboratory introductions and also directly from Holland. During this period, the Boothbay Harbor stocks, at water depths of from 0.6–1.3 m (2–4.25 feet), were increasing in abundance. In the early 1960's, individual oysters or small beds were found at a number of sites, primarily in Casco Bay.

Maine's success in introducing European oysters and their progeny stimulated the founding of a succession of small hatcheries to provide seed of this species for prospective growers, and the first of these was built in 1968 (Foster[11]). As both a public service and an incentive for commercial ventures, University of Maine re-

[32]Howell, T. 1991. Spinney Creek Oyster Co., Eliot, Maine. Personal commun.

[33]Clime, R. 1991. Aquaculturalist, Dodge Cove, South Bristol, Maine. Personal commun.

[34]Mook, W. 1991. Mook Shellfish Hatchery, Walpole, Maine. Personal commun.

searchers gave 33 private individuals along the Maine coast, from Cutler to Harpswell, several hundred oysters each, as well as trays to hold them for their own growth and survival tests. Average survival in winter was 61% in 1973–1974 (a warm winter) (Packie et al., 1976).

Suitable sites for culture were identified in Washington and Hancock Counties (Foster, 1976). Interest in culturing grew in more areas, as other hatcheries were built and seed became available. Seed was also purchased from Pacific Mariculture and International Shellfisheries Co., Inc., in California. Five small hatcheries began producing the seed in the 1970's.

Throughout the 1970's, fishermen and others found small beds of European oysters throughout Casco Bay, below –1 foot MLW and primarily on sand, gravel, and shelly bottoms, where currents were strong between islands and ledges (Heinig and Tarbox[35]). Small drags and scuba gear were used to gather them for local sale, and some were harvested as a sport fishery. Oysters set heavily in 1978, and a period of high commercial abundance followed in 1982 and 1983. In the 1980's, fishermen marketed 31,000 bushels of European oysters from Casco Bay, using scuba and drags from small boats year-round.

In 1984, the DMR became concerned that the harvests would lead to depletion of the oysters, so prohibited harvesting each year during the oyster's main spawning period, from 15 June to 15 September. It also established a minimum marketing size (longest diameter) of 5 cm (2 inches) (DMR Rules, Chapter 14, 1985).

In the last few years, stocks have not fared well, as natural events have had devastating effects. For example, in December, 1989, temperatures were below average (Smith, 1991), and the next spring fishermen and residents observed many dead oysters (Waddle[36]). In the subsequent summer, Casco Bay and adjacent waters experienced massive mortalities of menhaden, *Brevoortia tyrannus*, that had been driven into shallow waters by bluefish, *Pomatomus saltatrix*; oxygen concentrations fell to nearly zero. Since then, live oysters have been virtually nonexistent in one section of the bay, and spat has not been seen in it.

As European oyster culture expanded in the Damariscotta River during the late 1970's and 1980's, 800–1,600 bushels of oysters were marketed annually (Clime[33]). But the 1990's have seen mortalities, slow growth, and poor sets in Damariscotta and Casco Bays, probably due to infection by the parasite *Bonamie ostreae* (Davis[37]).

[35]Heinig, C., and B. Tarbox. 1984. A range and distribution study of the natural European oyster, *Ostrea edulis* population, in Casco Bay, Maine. Unpubl. Rep. Dep. Marine Resources.

[36]Waddle, R. 1990. Shellfish dealer, Quahog Bay, Harpswell, Maine. Personal commun.

[37]Davis, C. 1992. University of Maine Research Center, Walpole. Personal commun.

In 1991, landings of European oysters, all from hatchery-produced seed, totalled about 880 bushels (Table 1). The species was filling an important nitch in our fishery, and we hope it can recover to its former status and be further developed.

Northern Quahog Fishery

Northern quahogs have occasionally been a "feast," but usually a "famine" resource in Maine. In relatively cool Maine waters, big natural sets concentrated in the upper portion of Casco Bay occurred in 1939, 1947, and 1952 (Dow and Wallace, 1954a). After the quahogs grew to market size, 50 mm (2 inches), they supported fisheries. In beds in that area, the quahogs set too densely for adequate growth and survival. One 3.2 ha (8-acre) bed had 433 quahogs 1.2 mm in diameter per cm^2 ($279/inch^2$), or about 168 billion. Noncommercial quantities also grew in the Daramiscotta Estuary, Madomac River, Union River Estuary, the west side of Mount Desert Island, and Piscataqua River.

Quahogs occur in sand, silt, marine blue clay, and sand-cobble mixtures, in a zone extending from below low water to mean high water. Occupying the same habitats are polychaete worms, including *N. virens* and *G. dibranchiata*; and other mollusks, such as the baltic macoma, amethyst gemclam, threeline mudsnail, and periwinkle. Green crabs are predators, as are herring gulls, *Larus argentatus*, which drop the quahogs on rocks and ledges to break them.

Fishermen harvested Casco Bay quahogs in intertidal flats, using short-handle rakes with 75 mm (3-inch) tines. In the 1930's, annual production from the upper bay was about 13,000 bushels; in 1945, 20,000 bushels; and in 1949, 39,000 bushels. In 1961, it fell to less than 100 bushels and has since been about 500 bushels annually (Table 1).

In 1950, fishermen and local residents transplanted stunted quahogs to save them from winter mortalities and to give them growing space. Initially, they were raked up by hand and transplanted with harvesters' boats. Finally, an old World War II personnel carrier 10 m (33 feet) long was rigged with a herring sucker pump and a 15-cm (6-inch) diameter hose (Dow and Wallace, 1951) to collect seed and spread it thinly in commercially depleted areas. About 38,000 bushels of seed were transplanted by hand and hydraulic dredging gear between 1950 and 1959.

As a result of the transplantings, more quahogs were available. The average number of harvesters holding licenses in the region was 357 during the highest production years of the 1950's; only about 20% were part-time diggers. Quahogs have not set in commercial quantities since 1952.

Periwinkle Fishery

The common periwinkle[38], which occurs mostly on rocky shores, has been harvested commercially for many years. The fishery is centered in Washington County in northeastern Maine, where the "winkles," as they are called, are largest and most abundant. They have shaped the rocky coast by controlling the algal community and the substrate on which it grows. Their foraging action removes large quantities of algae and loosens the sediment, leaving exposed rocky shores. Periwinkles are not filter feeders and therefore do not accumulate paralytic shellfish poison.

Nearly all harvesters are part-timers who also work in other fisheries or land-based jobs. They also harvest softshells or marine worms and seasonally pick blueberries, make Christmas wreaths, and cut wood. People can enter the fishery with minimal investment in equipment. This is important in coastal towns where employment opportunities are limited. Periwinkles are harvested by hand at low tide, sometimes with the aid of a dip net squared off at the end, in intertidal and shallow subtidal bottoms consisting of ledge, rock, or sand. Many easily accessible areas have been depleted, and fishermen now routinely harvest on offshore ledges and islands. Some fishermen tow lightweight dredges from small outboard-motor boats to harvest in slightly deeper waters.

During peak periods, about 150–180 people harvest periwinkles on any given day. A typical fisherman harvests about 100 pounds of rough-culled periwinkles a day. The dealer then culls them and pays the fisherman for those that are salable, usually about 60–80 pounds.

The state has no management regulations for the fishery other than a requirement that fishermen have commercial fishing licenses. Estimates have not been made of the amount of fishing the resource can sustain and still remain productive in the future.

Landings data date back to 1969, but before 1987, landings were vastly under-reported. For 1969–86, average annual landings of meat totalled 22,412 pounds (range in pounds, 3,000 in 1986 to 81,000 in 1981); 4 pounds of shellstock yields 1 pound of meat. The fishery peaked in 1989, when nearly 1 million pounds of meats were landed at a value of $1,343,000. Since 1987, landings have been stable, between 330,000 and 360,000 pounds. The landed price per pound of shellstock has increased considerably: In 1969, it was $0.06; in the 1970's, $0.25; in the 1980's, $0.34; and in the 1990's, $0.41.

In 1992, 11 dealers purchased periwinkles in Washington County. Most also handled softshells, blue mussels, ocean quahogs, whelks, sea urchins, crabs, lobsters, and seaweeds. Dealers do not process periwinkles beyond culling and bagging.

Maine periwinkles have supplied ethnic markets across the United States and also are shipped to Europe and Asia. The foreign markets are relatively new and have created more demand. In retail markets, periwinkles frequently are prepared by cutting off the tip of the shell's spire and removing the operculum from the meat. They then are cooked in sauce or lightly boiled in seawater. Periwinkles are served in the shell; the consumer removes the meat with a small pick or sucks it out.

Shellfish as Food in Maine

Due to an aggressive marketing program initiated by the Maine Department of Marine resources, mollusks are sold all year in supermarkets and fish markets. Softshells, scallops, and oysters are traditional favorites and are usually fried. An exception is the European oyster, eaten raw on the half shell (Fig. 13). Next in

Figure 13
Packing European oysters in Damariscota River, Maine, 1982. Photograph by R. Howard.

[38]This section is summarized from Chenoweth, S., and J. McGowan. 1995. Periwinkles in Maine, fishery and biology. Maine Dep. Mar. Res., West Boothbay Harbor, Res. Ref. Doc. 95-2, 14 p.

popularity are stews and chowders. Oyster and scallop stews consist mostly of milk, cream, shell liquor, butter, potatoes, and onions; no herbs are added. Steamed softshells, cooked in a little saltwater and served hot with a side dish of melted butter and cup of clam bouillon (broth from the kettle) are also popular, as are pan-fried clam cakes made of chopped softshells or quahogs, cracker crumbs, and eggs.

Until recently, mussels were not eaten by Maine residents, except those with European ethnic backgrounds. Nearly all mussels were shipped out of state. However, due to population mobility of recent decades, mussels are now found on local restaurant menus, especially steamed with wine, olive oil, and garlic, and they are also consumed at home. Few ocean quahogs are eaten fresh in Maine; they are shipped with northern quahogs to inland states. They are competitively priced and find good markets when served on the half-shell (Wallace[39]).

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The U. S. Molluscan Fisheries From Massachusetts Bay Through Raritan Bay, N.Y. and N.J.

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ABSTRACT

The region from Massachusetts Bay through Raritan Bay has long been an important producer of mollusks. The oyster, *Crassostrea virginica*; northern quahog, *Mercenaria mercenaria*; and softshell clam, *Mya arenaria*, have been harvested since pre-colonial times. The bay scallop, *Pecten irradians*, has been harvested since the 1800's, the smooth conch, *Busycotypus canaliculatus*, since the 1930's, and since the 1980's and 1990's, the surfclam, *Spisula solidissima*, and blue mussel, *Mytilus edulis*. The oyster industry expanded during and after the 1820's when immense quantities of oysters were imported from Chesapeake Bay to Long Island Sound and Raritan Bay for planting. Owing to the imports and shelling of the seed beds, the industry grew to a production peak of 4,250,000 bushels a year in the 1890's and early 1900's. After 1900, the oyster industry declined because of poor demand and small supplies. The oyster industry in Connecticut has recently grown substantially.

From the 1700's to the early 1900's, fishermen developed tongs and various types of rakes to harvest northern quahogs, mostly from boats, and, since about 1940, dredges also have been used. Softshells have been harvested in several areas of the region with multi-tined diggers and churning hoes used with scoop nets. From the 1800's into the 1940's, the clams were commonly shucked in fishermen's homes and peddled locally. Surfclams have traditionally been harvested on the north shore of Massachusetts, and recently with hydraulic dredges in Long Island Sound, where production ranged between 41,000 to 516,000 bushels/year from 1985–91. Bay scallops have traditionally been harvested mostly in bays and ponds from Massachusetts through Long Island, N.Y., in the fall and winter. The blue mussel fishery developed, especially in Massachusetts, in the last 10 years or so, when a market demand for them developed. They were harvested in coastal bays and from an ocean bed. Conchs have been harvested with pots. In 1990, the number of active fishermen on the molluscan beds was about 3,350 in the summer and 2,336 in the fall. A comparison of landings in the past with those in 1990 shows that several species have declined in abundance. Total production has declined from 3,712,000 bushels in 1901–02 to 2,380,000 bushels in 1990, when about 6% of landings were from hatchery-produced seed.

Introduction

The estuaries and bays of the U.S. northwest Atlantic coast, which extend from Massachusetts Bay through Raritan Bay, include the states of Massachusetts, Rhode Island, Connecticut, New York, and northern New Jersey (Fig. 1). They have been and remain important producers of molluscan shellfish. Since the days of the Native Americans and European colonists, the oyster, *Crassostrea virginica*; northern quahog, *Mercenaria mercenaria*; and softshell, *Mya arenaria*, have supported valuable fisheries. In the late 1800's the bay scallop, *Argopecten irradians*, began to be harvested, by the 1930's the fishery expanded to include the smooth conch, *Busycotypus canaliculatus*, and, mainly in the 1980's and 1990's it has included the Atlantic surfclam, *Spisula solidissima*, and the blue mussel, *Mytilus edulis*.

Most northern quahogs and all softshells, bay scallops, conchs, surfclams, and blue mussels have been harvested from public beds, whereas in the past, large areas in Wellfleet Harbor, Mass., Narragansett Bay, R.I., the Connecticut coast, bays around Long Island, N.Y.,

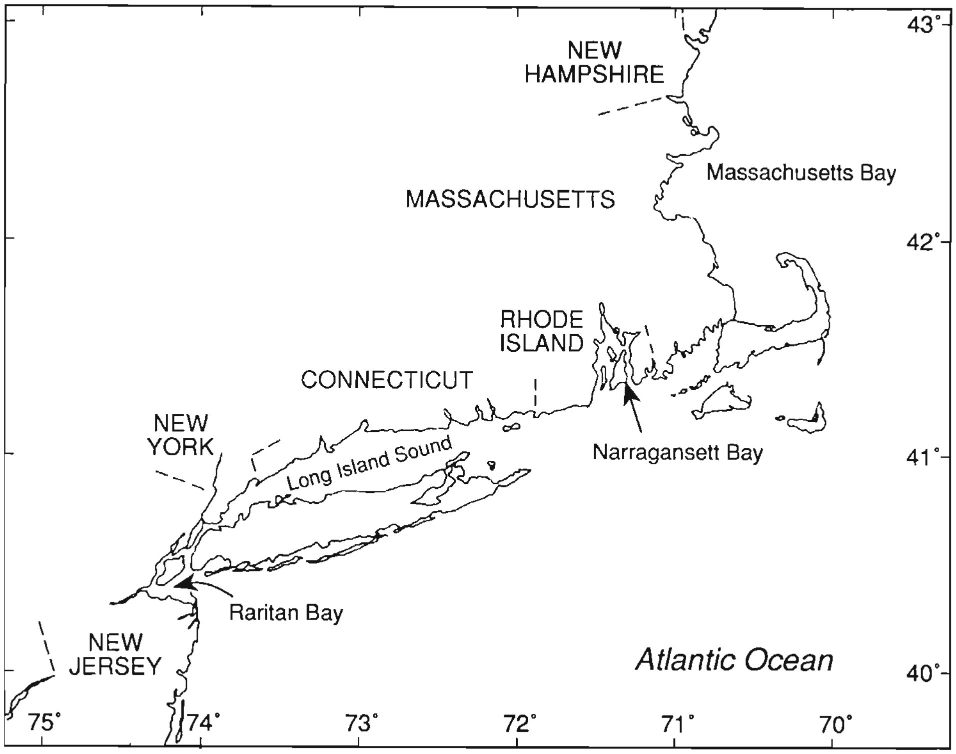

Figure 1
The region from Massachusetts Bay to Raritan Bay.

and Raritan Bay, N.Y. and N.J., have been privately leased for growing oysters. Some leased bottoms including all those in Narragansett and Raritan Bays have since reverted to public use. Management of public beds in the region has been generally controlled by the states, but some towns, especially those in Massachusetts, have considerable control over their local shellfisheries. The states and towns collect license fees, establish seasons, and set limits on daily catches.

In oyster, northern quahog, softshell, and bay scallop fisheries, the fishermen have included "regulars" who worked in them year-round, as well as "part-timers" who took time off from other jobs or were temporarily unemployed. Since the 1940's, the part-timers have also included students working during summer vacations. The number of fishermen has expanded during depressed economic periods.

Habitat

The bottoms of estuaries and bays in the region (Fig. 2, 3) consist mostly of mixtures of fine and coarse sand or gravel, or sand and mud; some bottoms are mud and some are covered with oyster shells (Sanders, 1956; McMaster, 1960; Reid et al., 1979). Salinity ranges from 21–34‰ in Plum Island Sound, Mass. (Jerome et al., 1986), 18–32‰ in Narragansett Bay (Pilson, 1985), 25–28‰ along the Connecticut coast (MacKenzie, 1981), and 18–32‰ in Raritan Bay (MacKenzie, 1990, 1992b). Water temperatures generally range from about 0.2°C in winter to 24°C in summer (Riley, 1955), although in Great South Bay, Long Island, and the Navesink River, N.J., they may reach about 27°C in summer. The region is the most heavily urbanized in North America resulting in physical damage and pollution in some shellfish growing areas.

Oyster Industry

Oysters have occurred in all five states of the region (Fig. 2, 3). In prehistoric and colonial times, oyster beds were present in river and estuarine areas where the salinity ran from about 7–15‰, and most were at depths of about 0.6–5 m (2–16 feet). Oyster predators included bay anemones, *Diadumene leucolena* (common only in Raritan Bay), xanthid crabs, and blue crabs, *Callinectes sapidus*. Other associates were sponges, bryozoans, polychaete worms, blue mussels, *Mytilus edulis*; and barnacles.

When the oyster industry expanded to zones of higher salinity, mostly 20–27‰, associated animals also included Atlantic oyster drills, *Urosalpinx cinera*; starfish, *Asterias forbesi*; and Atlantic rock crabs, *Cancer irroratus*, all predators.

Native Americans ate oysters extensively, as shown by their middens along various river banks, and by accounts of early explorers (Bakeless, 1961). For instance, in the 1740's, Peter Kalm (1937), a Swedish naturalist, observed them gathering oysters near New York City and noted their middens of oyster and mussel shells.

In the 1600's and 1700's, coastal European colonists gathered oysters with tongs from rowboats and dugout canoes. The colonists shucked the oysters in their homes and in shanties on the river banks, and peddled the meats in coastal and inland communities (Ingersoll, 1881).

In the late 1700's, oysters were becoming much scarcer because fishing was heavy and siltation from soil erosion degraded their habitats. States passed laws to conserve them by restricting catches. By the early 1800's, sloops with dredges were used to harvest oysters, which then declined sharply in abundance throughout the region while demand for them was strong.

In the 1820's, the oyster industry expanded beyond the 7–15‰ zones to areas where salinity was mostly >20‰, when oystermen imported immense quantities of seed oysters each spring from Chesapeake Bay (Virginia and Maryland) for planting on beds they had leased. Oysters became abundant again thereafter. They were usually left to grow only one summer and were marketed in the fall and early winter (Ingersoll, 1881). Oyster drills were not controlled on any grounds, and they caused large losses of seed oysters thereafter. (In the late 1940's some Connecticut grounds began to be cleared of the drills by a suction dredge, and now most are cleared of drills by suction dredges.) Some control of starfish was achieved with mops in the 1800's (Ingersoll, 1881); mops remain in use in the 1990's.

Despite predation on seed (mainly by drills and starfish), the region's oyster industry grew large and reached a production peak in the 1890's and early 1900's; in 1910, 6.25 million bushels of oysters (21,000 metric tons of meats) were produced (Fig. 4). By then, scores of companies had shucking and packing houses throughout the region, and they employed hundreds of men, women, and children. Peripheral industries dependent on the oyster industry were freight boats, boat yards, blacksmith shops, basket factories, hardware and can manufacturers, lime kilns, and railroads. Since then, the oyster industry has declined markedly.

From at least 1900 to 1938 and again from 1988 to 1996, oyster production was limited by demand, rather than supply. From at least 1950 to the mid-1980's, oyster production was usually limited by inadequate supplies.

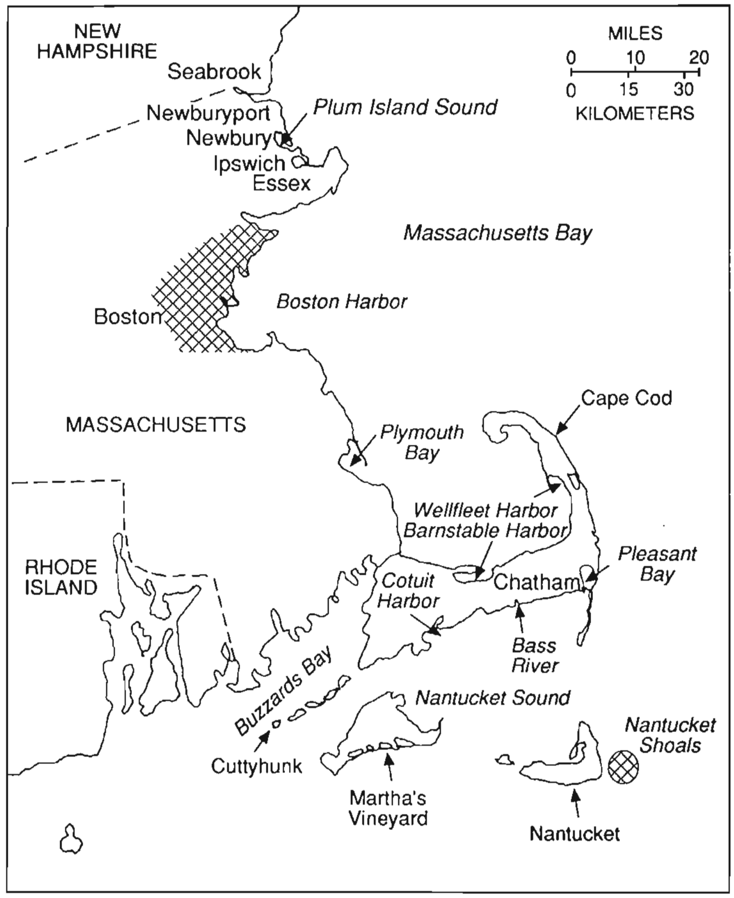

Figure 2
Shellfishing areas of Massachusetts. Hatched area east of Nantucket represents a mussel bed.

Massachusetts

Oysters occurred in various bays and brackish ponds in Massachusetts, but in far smaller quantities than in other states in the region (Fig. 4). Wellfleet Harbor had the only substantial oyster industry. After the harbor's native oysters were depleted by the early 1800's, the local fishermen imported seed oysters for bedding, first from neighboring states to the south and then from Virginia. In the mid-1800's, as many as 100,000 bushels of Virginia seed were laid down each year (Ingersoll, 1881). Although the industry declined soon after the turn of the century, the trade in southern oysters continued until shortly after World War I.

In the early part of this century, Connecticut growers leased bottoms in Wellfleet Harbor and planted seed oysters imported from their own state. But the oyster

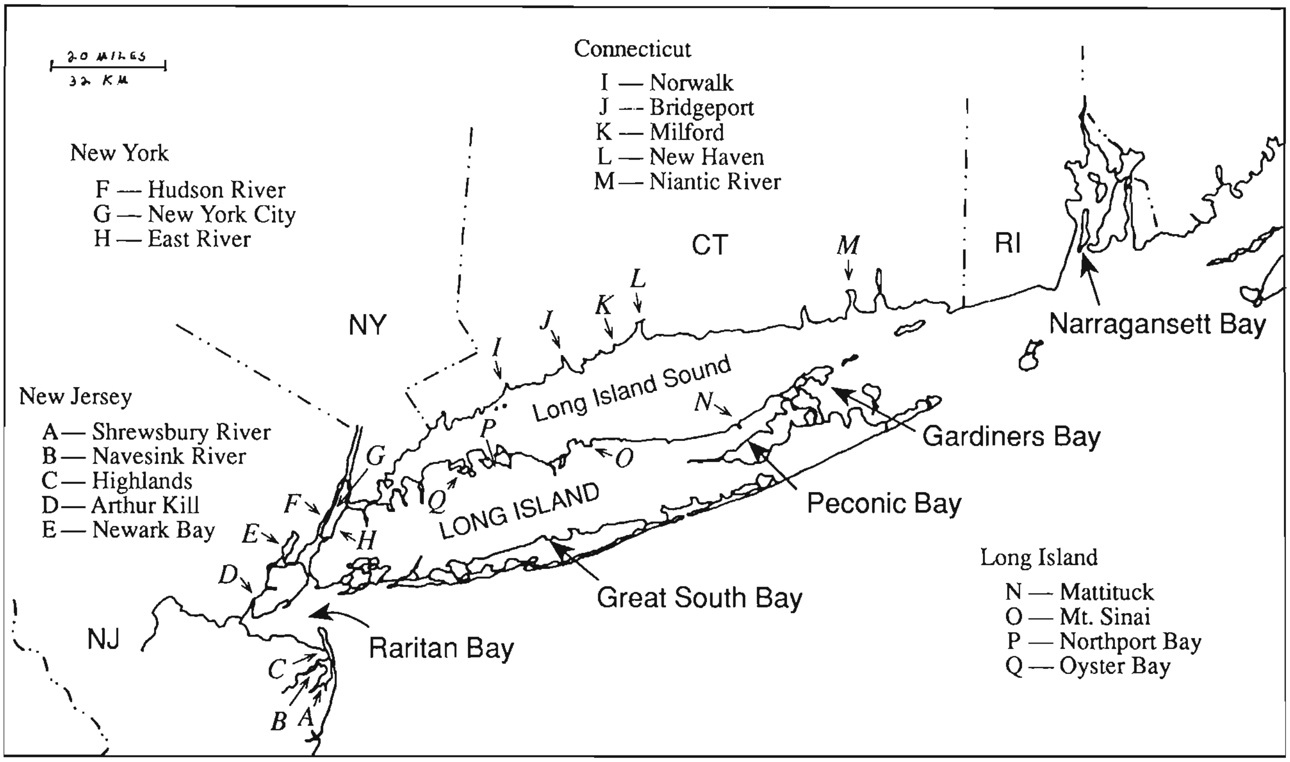

Figure 3
Shellfishing areas from Narragansett Bay to Raritan Bay.

industry declined throughout the region after a severe hurricane struck the northeast coast of the United States in 1938. By 1973, only 26 hectares (65 acres) of ground were leased for oystering in this harbor (Kochiss, 1974). Small- scale oyster culture continued in the 1990's.

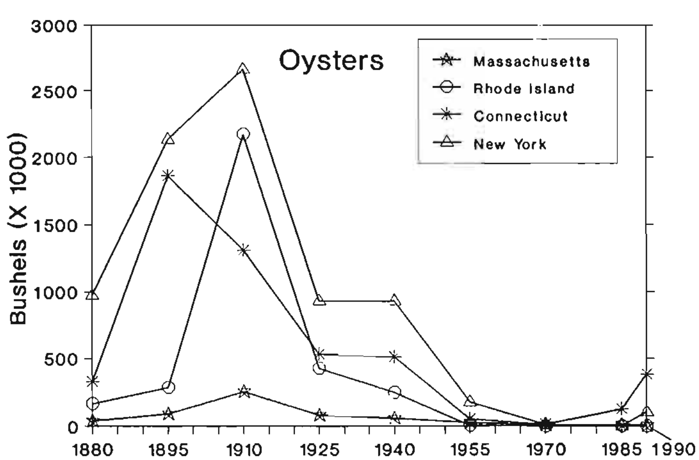

Figure 4
Landings of oysters from Massachusetts, Rhode Island, Connecticut, and New York, 1880 to 1991 (Lyles, 1969; Statistics Division, National Marine Fisheries Service, NOAA, Wash., D.C.).

Rhode Island

The granting of bottom leases to Rhode Island fishermen began in 1822, when authorities sought to encourage development of the oyster industry in Narragansett Bay. Fishermen imported seed oysters from Chesapeake Bay and Great South Bay for planting on leases in the upper part of the bay; the oysters were marketed after one season of growth (Kochiss, 1974). Seed imports continued every year, and by 1878 the industry had grown to a substantial size with about 500 men, 100 boats, and annual production of 660,000 bushels (Table 1).

After 1880, Connecticut growers gradually took over oystering in Narragansett Bay, as they did in Wellfleet Harbor. They planted the beds with oysters, 2–4 years old, in the spring and marketed them during the subsequent fall after one growing season. By 1908, at least 100 large motor-propelled oyster boats were working in the bay (Kochiss, 1974). The companies had leased about 9,000 hectares (22,000 acres) for growing oysters, and in a few ports they constructed large plants in which their oysters were shucked and packed and boat equipment

Table 1
Size of the oyster industry in Rhode Island in the late 1870's (Ingersoll, 1881).

Item	Amount
Planters (no.)	100
Area planted	
Hectares	390
Acres	962
Boats (no.)	100
Men hired all year (no.)	150
Men hired half year (no.)	350
Production	
Native oysters (bushels)	148,000
Southern imports (bushels)	512,000
Value of oysters produced	$600,000
Price/bushel or gallon	$0.90–1.50

was repaired. Oyster shells were saved for spreading as cultch on the Connecticut seed beds (Usinger[1]).

The industry continued at a substantial size until the 1938 hurricane buried most of the oysters, destroyed many oyster boats, and damaged much shore property. A sharp decline followed, in part because little Connecticut seed was available to plant (Kochiss, 1974). Since the 1960's, few oysters have been planted and harvested in Narragansett Bay (Fig. 4). But in 1993 and 1994, oyster sets occurred on public beds around the bay, and in 1996, commercial fishermen harvested an estimated 30,000 bushels of market-sized oysters (Ganz[2]).

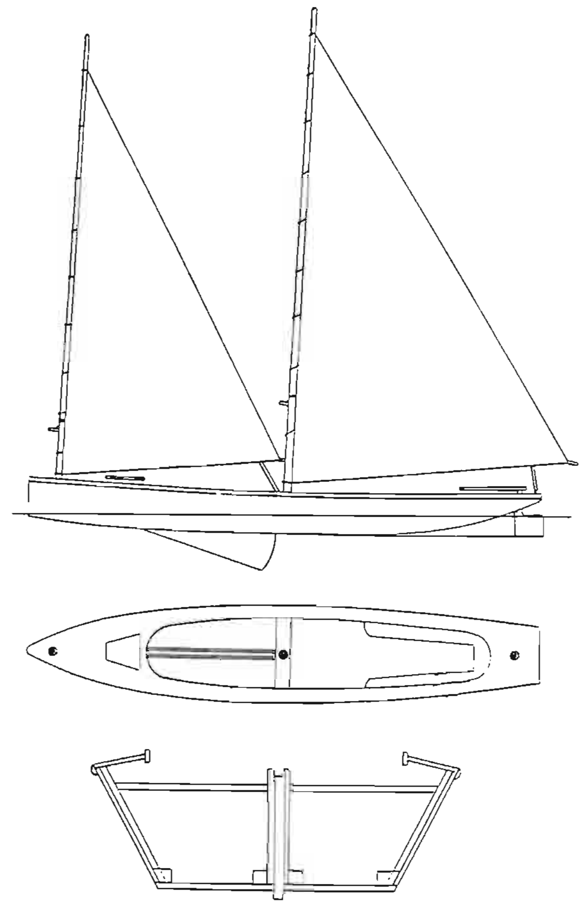

Figure 5
A "sharpie" used to harvest oysters in Connecticut from the mid-1800's to early 1900's. From Collins, 1891.

Connecticut

New Haven has been the main oyster center in Connecticut, with most beds being 3–12 m deep. In the 1800's and most of the 1900's, its beds were farmed more intensively than any others in the nation, involving spreading shells, transplanting seed among beds usually every year, and controlling starfish. It was also the region's largest producer of seed oysters. Other prominent oystering areas were beds off Bridgeport and Norwalk.

From the mid-1800's to early 1900's, the "sharpie" was the prominent Connecticut boat for tonging and dredging oysters (Fig. 5). Sharpies were 6.7–10.7 m (22–35 feet) long with drafts of only 60 cm (2 feet), and had sharp bows, flat bottoms, 1–2 masts, and carried up to 125 bushels. Fishermen also used dugout canoes, sloops, 9–12 m (30–40 feet) long, and schooners for oystering. Small dredges were hauled by hand and larger dredges by hand winches (Collins, 1891).

The importation of Chesapeake oysters to Connecticut probably began in the 1830's. In the 1850's, about 80 schooners carrying 2,000–4,500 bushels apiece were supplying New Haven with 500,000–750,000 bushels of those oysters each year; the Chesapeake imports continued afterward and, in 1879, 450,000 bushels were imported (Ingersoll, 1881). About 75% were opened immediately and distributed to customers throughout the state and in New York City. The remainder were spread on beds in the spring and harvested the subsequent fall, after having increased about one-third in size (Collins, 1891).

From observing sets of local spat on the imported Chesapeake oysters, growers learned that local seed could be produced by spreading shells over their beds,

[1] Usinger, E. 1991. President (ret.), Bluepoints Company, West Sayville, N.Y. Personal commun.

[2] Ganz, A. 1992, 1997. Department of Environmental Management, Division of Fish and Wildlife, Wakefield, R.I. Personal commun.

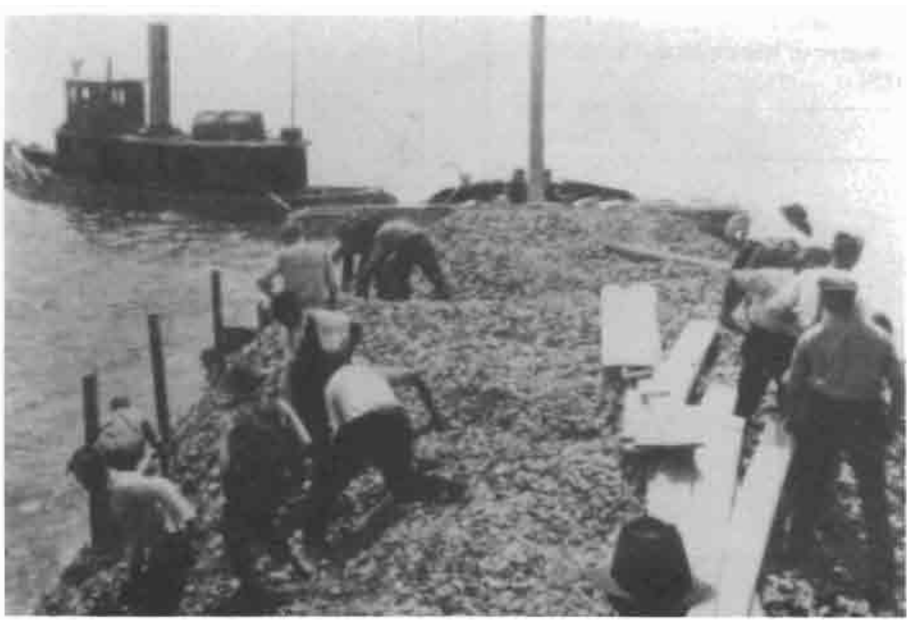

Figure 6
Spreading shells on an oyster setting bed in New Haven, Connecticut, ca. 1910. From Churchill, 1921.

and by 1900 they were spreading large quantities of shells (Fig. 6). They towed 3 m wide "mops" of cotton bundles to control starfish. Seed cultivation eventually encompassed all available inshore bottoms (Kochiss, 1974). With local seed available in increasing amounts, companies imported far less from Chesapeake Bay but they continued importing some into the 1930's.

In the 1870's, oystermen installed steam plants consisting of a boiler and an engine in some of their oyster sloops and schooners. The engines propelled the vessels and retrieved the dredges, which were towed from each side of the boat and held 10–12 bushels each. Dredges were hauled over rollers on the gunwales. Six deckhands, three on each side of each boat, emptied oysters from the dredges and shoveled them onto a pile amidships (Kochiss, 1974). By the late 1800's, the Connecticut oyster industry had grown to a substantial size with about 1,244 persons working on the beds and ashore, 662 boats of all sizes, and a production of nearly 1.5 million bushels of oysters/year (Table 2).

Table 2
Size of the oyster industry in Connecticut in 1889 (Collins 1891).

Item	Amount
Oystermen on water (no.)	593
Shoremen and women preparing oysters for market (no.)	651
Steam vessels (no.)	54
Sail vessels (no.)	59
Small boats (no.)	549
Bushels of shells spread per year on setting beds	1,914,000
Bushels of southern seed spread	115,000
Area planted with oysters or shells	
Hectares	6,200
Acres	15,400
Bushels of oysters produced	1,486,000
Value of oysters produced	$1,055,807

Vessels thereafter increased in size and were from 12–24 m (40–80 feet) long, while engines and hoisting machinery underwent steady refinement. Oystermen tested gasoline, naphtha, electric, oil, and kerosene engines. They chose gasoline engines because of their reliability, power, performance, and lower cost. In converting sloops and schooners to motor boats, workers removed the sails and mainmast, shortened the bowsprit and foremast, built a pilot house over the aft trunk cabin, and installed an engine; to haul the dredges, they added hoisters, a post, and rollers. Soon after 1900, most oyster vessels had the same general layout: A clear deck forward and a cabin and pilothouse aft (Kochiss, 1974). The vessels held from 1,000 to 2,400 bushels of oysters.

From the early 1800's (Ingersoll, 1881) to the early 1900's, after fishermen harvested oysters from the beds for marketing, they put them in brackish water areas for about 18 hours. The oysters were spread on creek bottoms, on planks covering soft shorelines, or in floats measuring 3×6 m (10×20 feet) and 0.5 m (1.5 feet) deep. The practice allowed the oysters to clear their mantle cavities of any mud and sand and caused their meats to bloat nearly 30% in volume from osmotic absorption of brackish water.

Shortly after 1900, state health authorities forbade the practice because some brackish waters had become polluted. To accomplish the cleaning and bloating of meats, planters have since held shucked oyster meats in "blowers" (tanks holding 100–200 gallons of freshwater agitated with bubbling air) for about 10 minutes before packing them in cans.

The Connecticut oyster industry declined after 1906, when the Federal government passed several food laws. Before then, companies handled oysters without any government restrictions. The new laws required that every condition surrounding oyster production, from bed to consumer, be sanitary (Anonymous, 1910). Some illnesses associated with eating oysters had been highly publicized in newspapers. People began to eat fewer oysters and more meat (Kochiss, 1974). As demand for oysters fell, so did their relative prices, and the companies made only small profits (Anonymous, 1917).

By the 1920's, Connecticut had about 24 oyster companies, half of which were sizeable operations. Each of the latter had 6–8 dredge boats with crews of 6–8 men who lived aboard during the week. The companies also had blacksmith shops to make and repair boat equipment (Usinger[1]). There were 16 shucking and packing houses in New Haven, 1 in Milford, 1 in Bridgeport, and 6 in Norwalk (Churchill, 1921).

Every year, companies spread 2–3 million bushels of shells on their beds, mainly in New Haven and Bridgeport. The beds usually received light sets of oyster spat, but got heavy sets every few years. At times, at least 4,000 hectares (10,000 acres) of bottom were planted with oysters and shells. The companies usually transplanted seed oysters among beds every April and May to spread them as they grew. The transplanting also broke up the larger clusters of perhaps 4–12 oysters into much smaller ones, enabling the oysters to grow in a desirable oval shape by the time they were market size. Besides, oysters as singles or doubles were less expensive to cull and pack for sale when sold whole. Companies stored some oysters resulting from the heavy sets on deep-water beds (10.5–13.5 m; 35–45 feet) where they grew slowly. When crops would otherwise be small from years of light sets, the stored oysters were transplanted as needed to inshore beds in the spring for fattening and sold in the fall. Thus, companies always had a crop to sell (Usinger[1]).

Another source of seed oysters was the public bed, of about 1,200 hectares (3,000 acres), off Bridgeport. It often supported a fleet of 30–40 sloops, each with a crew of three who hand-pulled five 1-bushel dredges to gather seed from the bed (Kochiss, 1974). State authorities ruled the sloops had to be propelled by sails rather than by engine. After a day of harvesting as many as 200–300 bushels of seed, each crew ran its sloop to company beds and sold them. The public bed was never enhanced by the spreading of shells before the 1980's, but it continued to produce oysters until the mid-1940's when it became barren of shells and oysters. The bed produced oysters again in the 1980's and 1990's when the state of Connecticut spread shells on it (see below).

The Connecticut oyster industry was severely harmed by the 1938 hurricane, which buried most oysters and damaged vessels and shore property. A lack of manpower during World War II further limited it. During the war, companies installed a new dredging and off-loading system on boats, fitting each with 2 boom dredges and a water hose and pump. The system enabled companies to compensate for a labor shortage by reducing the number of deckhands needed from 6 to 2; the captain still handled the controls. After being retrieved from the bottom, each dredge was hoisted to about chest level above the deck at the end of one of the booms. A deckhand unlatched a door at its bottom to dump the oysters on deck. To spread seed oysters on another ground, the deckhands washed them overboard with a strong stream from the water hose rather than shoveling them. A crew could load about 2,400 bushels of oysters from a well-stocked bed onto their boat in about 4 hours and wash them onto another bed in half an hour. Another innovation was the hydraulic suction-dredge system installed on 1 or 2 boats to remove shells and oyster drills from bed surfaces by sucking them through a head and pipe onto their decks (Kochiss, 1974).

Connecticut companies were slowly increasing their oyster production in the 1940's, but a severe storm in November 1950 again buried nearly all the oysters on beds. As a result of various hurricanes and storms, many beds had dense concentrations of shells buried at least 30 cm (1 foot) deep in them. After the 1950 storm, companies had only about 200,000 bushels of shells/year to spread on setting beds and much less seed was produced. Another setback came in 1957, when starfish, scarce for many years, became abundant. From then until the mid-1960's, the starfish destroyed most oyster seed.

In the mid-1970's, the industry had a modest surge in production when companies in South Norwalk and New Haven improved their cultivation methods beginning in the late 1960's, by 1) widespread use of granulated quicklime (CaO) to control starfish, 2) controlling oyster drills with a suction-dredge and a chlorinated benzene poison called Polystream[3], and 3) re-

[3] Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

ducing the suffocation of seed in silt each spring (from 7 to 50% died from this cause each spring) by rescheduling seed transplanting from late April and May (when the oysters had already begun to pump water) to March–early April when they were still inactive. Oyster production in the area rose from about 45,000 bushels in 1967 to 350,000 bushels in 1975 (MacKenzie, 1981). The use of Polystream on shellfish beds was banned by the U.S. Food and Drug Administration in 1967 after 2 years of use on about 100 hectares (250 acres) of beds, but while in use companies observed that controlling oyster drills led to large increases in oyster production.

The disease MSX, *Minchinia nelsoni*, which kills many oysters in some areas of Massachusetts, Great South Bay, and Delaware and Chesapeake Bays, has not killed oysters in Connecticut, probably because water temperatures, which do not rise above 23°C, are too cool. The oysters are not resistant to the disease and most die within a year if they are transplanted to salinities above 15‰ in infected areas, such as Delaware Bay, where summer water temperatures reach as high as 30°C.

Nearly all oysters in the region currently are produced in Connecticut, with much lower quantities in Oyster Bay, and much less than that in Wellfleet, Mass. The Connecticut oyster industry is almost entirely controlled by the Tallmadge Brothers Company[3] of South Norwalk. The company has leased from the state nearly all the good oyster beds previously leased by other companies that have since gone out of business, a total of about 8,000 hectares (20,000 acres) (Fullilove, 1992). It has a fleet of about 25 oyster vessels, mostly 15–20 m (50–65 feet) long, but 3 are slightly over 30 m (100 feet). The boats mine and spread shells as cultch for oyster larvae, clean their beds of starfish and oyster drills, and transplant and harvest oysters.

The company sells some of its oysters and all its northern quahogs from a packing house in South Norwalk, but most oysters are trucked to its plants in Bivalve, N.J., on the shore of Delaware Bay, where they are packed in the shell or shucked and then distributed. The oysters are sold throughout the United States and in Canada. The company employs about 100 people on its boats and ashore in South Norwalk and 50 more as shuckers and packers in Bivalve. In addition, about 60 independent people in 30 boats gather seed oysters in good weather from the public oyster bed off Bridgeport to sell to the Tallmadge Brothers Company or to plant on their own small leases. While the number of oystermen and boats in Connecticut is now much smaller than during most of the 1800's and the early 1900's, nearly all the equipment used is much larger and more efficient.

During the 1980's and 1990's, oysters became relatively abundant on Connecticut beds when the Tallmadge Brothers Company and the State of Connecticut vastly increased the quantities of shells spread on the beds as cultch for oyster larvae. Every year, the company spread from 250,000 to 1 million bushels of shells on its setting beds, while from 1988 to 1991 at least, the Connecticut Division of Aquaculture, headquartered in Milford, spread 1 million bushels/year over the 1,200 hectare (3,000-acre) public oyster bed off Bridgeport. Oyster sets on the shelled beds have ranged from light to heavy, and the beds now contain a few million bushels of oysters, a supply that exceeds demand. Connecticut oyster production has risen sharply (Fig. 4).

The future of the Connecticut oyster industry appears to be bright, but "Dermo" (*Perkinsus marinus*) was found in the oysters in 1992 and small numbers of oysters in well-stocked beds in about 3 m (10 feet) of water died from this disease. The "Dermo" infections have since declined, and the industry should continue to prosper as long as large quantities of shells are spread on the setting beds and starfish and oyster drills are controlled.

New York

Great South Bay, which extends along the south side of Long Island for nearly 50 km (30 miles) and is mostly about 1.8 m (6 feet) deep, was the state's prominent oyster bay. A barrier beach, currently with one inlet, separates the bay's south side from the Atlantic Ocean.

The bay once consisted of two ecological zones. In its eastern part, the salinity was <15‰ and oysters set regularly on scattered natural beds that covered nearly one-tenth of its area; salinity kept the beds free of oyster drills. In its western part, inlets to the Atlantic Ocean kept the salinity above 15‰, few oysters occurred naturally, oyster drills were present, but planted seed oysters grew more rapidly than those in the eastern part. A large oyster industry developed when growers in the western part purchased seed from fishermen in the eastern part and also from those in Newark Bay, the Hudson and East Rivers, and New Haven, Conn., and planted it on beds they had leased (Taylor, 1983).

By the 1870's, about 1,500 men using 500 catboats, sloops, and rowboats were farming oysters in the bay. Each year, western bay growers planted about 100,000 bushels of seed from the eastern part and an additional 100,000–200,000 bushels from the other sources. Afterward, the local seed was steadily supplanted by Connecticut seed (Taylor, 1983). In 1909, production of market oysters from the bay was 450,000 bushels of shell stock and 101,000 gallons of meats (Kochiss, 1974).

The industry continued about as well as Connecticut's oyster industry did with relatively poor prices for oysters in the 1910's, 1920's, and 1930's. The 1938 hurricane also inflicted heavy damage to the beds, boats, and shore property and created wide inlets through the barrier beach. Ocean water intrusion increased overall bay salinity to >15‰ enabling oyster drills to spread throughout the bay and destroy nearly all seed oysters. With the seed supply from Connecticut much reduced after the hurricane, the bay's oyster industry declined sharply. From the 1940's through the 1950's relatively small quantities of seed were planted and grown in the bay. In the 1960's the oyster disease MSX was introduced and killed nearly all planted oysters. The industry has since planted only small trials of oysters.

Other less prominent places on Long Island for growing Connecticut seed to market size were Oyster, Northport, Peconic, and Gardiners Bays. For some undetermined reason, spat sets were sparse in them, at least during most of this century, despite the presence of large numbers of adult oysters at times.

In the 1970's, three hatcheries were producing seed oysters on Long Island, but two have since ceased operations because they were not cost-effective. The remaining one, operated by the F. M. Flower Company, has been producing "cultchless" seed (larvae set on shells about 3–4 mm in diameter and seed appears to be cultchless), growing them in trays until they are 25–50 mm (1–2 inches) long, and then planting them on its leased beds in Oyster Bay. In the 1980's and early 1990's, production of market oysters from the hatchery seed comprised about 90% of New York's oyster production of 30,000–80,000 bushels/year. In addition, oysters have set naturally in Oyster and Northport Bays, and small-scale commercial harvesting has taken place.

Raritan Bay

The northern half of Raritan Bay is under New York jurisdiction, while the southern half is under that of New Jersey. In the 1820's, imports of Chesapeake Bay seed oysters began each spring for planting on leases in the bay, and they rose later to as much as 300,000 bushels/year (Ingersoll 1881). Growers also obtained as many as 100,000 bushels of seed from local areas, such as Newark Bay, Arthur Kill, and Raritan River, for planting (MacKenzie, 1990, 1992a). In the 1800's, workers harvested most market oysters with tongs and rakes, and the remainder with dredges. Their boats were square stern, flat bottom, clinker-built rowboats, the largest of which were 6.7 m (22 feet) long (Hall, 1894). Besides these, about 50 sloops and some schooners and catboats comprised the bay's oyster fleet (Ingersoll, 1881).

In the mid-late 1800's, growers also farmed oysters on about 160 hectares (400 acres) of bottom in the Shrewsbury and Navesink Rivers, that flow into southeastern Raritan Bay (Hall, 1894). About 250 men worked in this industry, relaying seed oysters to the rivers and harvesting market oysters (Ingersoll, 1881). They shipped oysters to New York City in flour and sugar barrels by steamer and rail (Hall, 1894).

In the late 1800's, about 600 oystermen worked on Raritan Bay and ashore, and an additional 200 men tonged oysters in Newark Bay (Lockwood, 1883). Annual oyster production from Raritan Bay was about 300,000 bushels (Lockwood, 1883; Bayles, 1887). Planters shipped the oysters by sloops or passenger-freight steamers to markets in New York City (Ingersoll, 1887). By the early 1900's, planters had converted their sloops to motor boats and installed power hoists to retrieve their 8-bushel dredges for harvesting oysters (MacKenzie, 1990, 1990a).

After 1915, the oyster industry in Raritan Bay declined, when the western part of the bay became polluted. A score or more people contracted typhoid fever from eating oysters harvested from there. By 1925, pollution had worsened, more people had become ill from eating the oysters, and the industry ceased operating. Unfortunately, accusations through radio and newspapers about Raritan Bay's polluted oysters causing illnesses made people so suspicious of eating oysters that demand for them fell throughout the eastern United States (McCarthy, 1925). The question for the remaining oyster industry was how to assure the public that oysters were free of pathogenic bacteria; since inspection programs had not yet been established, consumers had no assurance that any shellfish were safe to eat (Galtsoff, 1958).

In the mid-1920's, meetings initiated by the shellfishing industry and government officials led to the establishment of the National Shellfish Sanitation Program, which set health standards and guidelines for harvesting and marketing shellfish. Every state thereafter developed its own program to inspect the waters and to assure that shellfish were harvested from certified, clean waters. Processing plants were also required to adhere to strict sanitary practices.

Due to pollution also, the oyster industry in the Shrewsbury and Navesink Rivers ended in the 1920's only a few years after the Raritan Bay industry ended. Raritan Bay and the two rivers have since remained too polluted to be used for growing oysters for market.

Northern Quahog Fishery

Northern quahogs (usually called quahogs or hard clams) occur in salinities >15‰, from low tide lines to the deepest bottoms of bays, mostly in sand, sand-shell, and sand-mud, but also in mud. Fishermen have harvested them in all five states in the region (Fig. 2, 3). Shrimps, crabs, boring gastropods, and starfish are the principal known predators of juvenile quahogs (Belding, 1912; Landers, 1954; Carriker, 1951, 1955; MacKenzie, 1977; Vitaliano and MacKenzie, 1989).

Native Americans gathered quahogs by treading at wading depths. They ate the meat and used the shells for money, ornaments, and tools. Quahogs were featured in their "green corn" festival, in which they roasted them with corn and seaweed. The custom, adapted by the European colonists (Ingersoll, 1887), has persisted as the clambake.

From the 1700's to the early 1900's, fishermen and blacksmiths developed four different harvesting gears. The first was the claw-shaped metal rake, about 25 cm (10 inches) wide with a wooden handle 2 m (6 feet) long, which fishermen used at wading depths. The remaining three gears were used from boats. One was tongs, similar to oyster tongs, but with slightly longer teeth. The third gear was the "bull" or Shinnecock rake, 45–60 cm (18–24 inches) wide, with curved metal teeth, and wooden handle 6–7 m (20–23 feet) long (Fig. 7) (Ingersoll, 1887). The first record of the bull rake's use was in Raritan Bay in 1863 (Leonard, 1923). The fourth gear, the basket rake used from anchored boats in Massachusetts, had about 16 teeth 38 mm (1.5 inches) long, a basket 20 cm (8 inches) deep, and a wooden handle 4.25 m (14 feet) long (Belding, 1912).

Figure 7
The first long-handled northern quahog rakes like these were used in Raritan Bay in the 1860's. Drawing (late 1800's) from Archives, NMFS Sandy Hook Laboratory, Highlands, N.J.

From the late 1800's and into the 1900's, people in the northeastern and mid-Atlantic states ate a great many oysters raw on the half-shell during the fall-winter-spring oyster season. Littleneck northern quahogs, nearly always eaten raw on the half-shell, partially substituted for the half-shell oysters during the summer when oysters were not harvested. Hundreds of men were digging the quahogs and many oyster dealers handled them. Some diggers worked as crewmen on oyster dredge boats and as tongers during the oyster seasons. The consumption of littlenecks was far less than that of raw oysters during the colder months (Anonymous, 1897). Belding (1912) believed that popular demand for littlenecks in the 1890's and early 1900's stimulated the development of the quahog fishery.

From the late 1800's through the 1920's, quahog landings were relatively low, but in contrast to oysters and softshells, they rose dramatically afterward until about 1970. They have since declined somewhat (Fig. 8). The cause of the rise was increased demand for the quahogs and improved fishing gear, rather than increased quahog abundance. Since the late 1800's, at least, quahogs have been sold in three principal size categories: 1) littlenecks, $1^1/_2$–$2^1/_4$ inches (38–57 mm); 2) cherrystones, $2^1/_4$–3 inches (58–76 mm); and 3) chowders (also termed "sharps" or "blunts") >3 inches (Belding, 1930). On a bushel basis, littlenecks, whose numbers total about 750/bushel, have brought the highest prices; cherrystones (180–200/bushel), the middle prices; and chowders (100–150/bushel), the lowest prices.

Massachusetts

Bays in southern Massachusetts have long produced northern quahogs, locally termed quahogs, a Native American term. The prominent bays include Wellfleet Harbor, Pleasant Bay, Cotuit Harbor, Bass River, Buzzards Bay, and those on Martha's Vineyard (Fig. 2). In the early 1900's, about 745 fishermen were digging quahogs in the state in the summer. Most of the same fishermen dredged bay scallops in the late fall and winter (Belding, 1912). Quahog production in the state increased from 8,000 bushels in 1880 to 111,000 bushels in 1925; it has since fluctuated from 96,000–219,000 bushels (Fig. 8).

Quahog production from bays on Cape Cod has declined in recent years because 2,000–2,800 hectares (5,000–7,000 acres) of beds have become closed due to pollution. In 1990, commercial diggers in Massachusetts landed about 100,000 bushels of quahogs (Table 3), while sport diggers landed about 36,000 bushels (Anonymous, 1992a).

Table 3

Commercial landings of molluscan shellfish, Massachusetts Bay to Raritan Bay, and percent from hatchery-reared seed, 1990.

Species	Landings (1,000 bushels)	Percent from hatchery seed
Oysters		
Massachusetts[1]	4.5	33
Rhode Island	0	
Connecticut[1]	380[2]	0
New York	106	92
Northern quahogs		
Massachusetts[3]	100	20
Rhode Island[1]	210[4]	0
Connecticut[1]	102[5]	0
New York[1]	225	8
Softshells		
Massachusetts[1]	98[6]	0
Rhode Island[1]	1	0
New York[1]	12[7]	0
Surfclams		
New York[1]	516	0
Bay scallops		
Massachusetts[1]	42	5
New York[1]	2	0
Mussels		
Massachusetts[1]	277	0
Conchs		
Massachusetts[8]	95	0
Rhode Island[1]	3	0
Connecticut[1]	5	0
New York[1]	6	0
Totals	2,184.5	6

[1] Source: NMFS Stat. Div., Wash., D.C.
[2] 1,047,120 bushels in 1994; 654,450 bushels in 1995.
[3] Source: Anonymous, 1992.
[4] 134,410 bushels in 1994.
[5] 100,000 bushels in 1994.
[6] 98,667 bushels in 1993.
[7] 8,178 bushels in 1993; 2,753 bushels in 1994.
[8] Source: MacKenzie, 1992b.

Rhode Island

Since the 1920's, Narragansett Bay has been a major producer of northern quahogs, locally termed quahogs. In the 1870's, about 75 fishermen dug quahogs (Ingersoll, 1887). They rowed to the beds in boats 3–4 m (10–14 feet) long and used tongs for harvesting (Desbonnet and Lee, 1991). They were limited to quahoging depths of 3.7 m (12 feet) or less with the tongs. In the early 1900's, the fishermen were usually towed to the beds by motor boats (Boyd, 1991). By the late 1930's, they had outboard motors of about 7 hp to propel their own boats (Braiton[4]). As the oyster industry declined in the bay in the 1940's, the quahog fishery became more important. Some expansion was related to the opening of new beds where oyster leases had been abandoned and also to increased market demand.

During World War II, about 40 boats, 9–10.6 m (30–35 feet) long, with crews of three, began harvesting quahogs with rocking chair dredges. A state regulation limited each boat to a harvest of 40 bushels/day (Braiton[5]). The dredge fishery ended in 1956, when the state legislature banned it as a result of pressure from fishermen using rakes.

In the 1940's and 1950's, many quahogs being harvested were of chowder size and were sold to a national soup company. Fishermen shipped any littlenecks to New York City by boat (Braiton[4], Manchester[6]).

From the late 1800's to the early 1920's, about 15,000 bushels/year were landed, but afterward production increased and reached 425,000 bushels in 1955. It fell afterward as authorities banned rocking chair dredging and closed some beds to harvesting because of pollution (Boyd, 1991). In 1974, production was 210,000 bushels, but it rose afterward (Fig. 8). Fishermen using bull rakes were able to dig in bottoms as deep as 7.6 m (25 feet), and thus they had nearly twice the area avail-

[4] Braiton, B., Sr. 1991. Fisherman, Kingston, R.I. Personal commun.
[5] Braiton, B., Jr. 1991. Fisherman, Kingston, R.I. Personal commun.

[6] Manchester, F. 1992. Owner (ret.), Manchester Sea Foods, Tiverton, R.I. Personal commun.

able for digging than had they used tongs (Fig. 9) (Pratt, 1988).

Larger raking boats became available through the years, and, by the 1970's, most were about 5.5 m (18 feet) long, 1.6 m (5 feet) wide, and constructed of fiberglass. Many boats currently are equipped with radios, Loran navigational equipment, and depth sounders used to determine depth and bottom type, the latter being an important factor affecting quahog abundances (Smith[7]).

Since the early 1970's, some scuba divers have been gathering quahogs commercially. They loosen the bottom with a small hand rake and then pick up any quahogs in the raked area, fill their mesh bags with them, return to the surface, and empty the bags in their boats. During a day, each can harvest a few bushels, a larger quantity than individual bull rakers obtain (Smith[7]).

In the 1980's, quahog production peaked at about 350,000 bushels (Fig. 8) as more productive beds became available when the state opened areas to quahoging in the northern part of the bay that had been closed previously. In the past 30 years or so, recreational quahoging has become important (Dykstra[8]).

In Narragansett Bay, the regular quahog fishermen now include about 600 bull rakers and 100 tongers, both groups using outboard motor boats, besides some waders using short-handled rakes, and 40 scuba divers. The number of rakers increases when students and others join in the digging in summer, bringing the total number of quahog fishermen to about 1,500 (Smith[7]). The fleet of outboard motor boats used by the Narragansett Bay quahogers is probably the largest such commercial fleet in North America. The typical daily catch/digger is 1,000–2,000 littlenecks (1.3–2.7 bushels) with a landed value of $150–$300. The landed value of quahogs in Rhode Island is $13–$14 million/year. In 1996, the fishermen discovered unusually large quantities of seed in Rhode Island beds (Ganz[2]). Catches are likely to increase in the future.

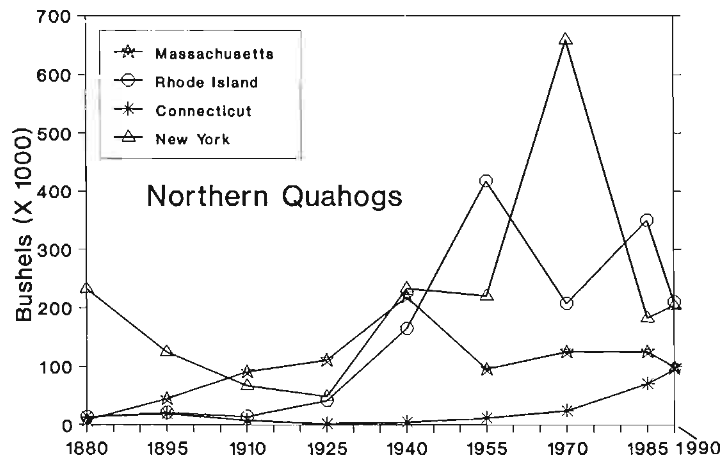

Figure 8
Landings of northern quahogs in Massachusetts, Rhode Island, Connecticut, and New York, 1880 to 1990 (Lyles, 1969; Statistics Division, National Marine Fisheries Service, NOAA, Wash., D.C.).

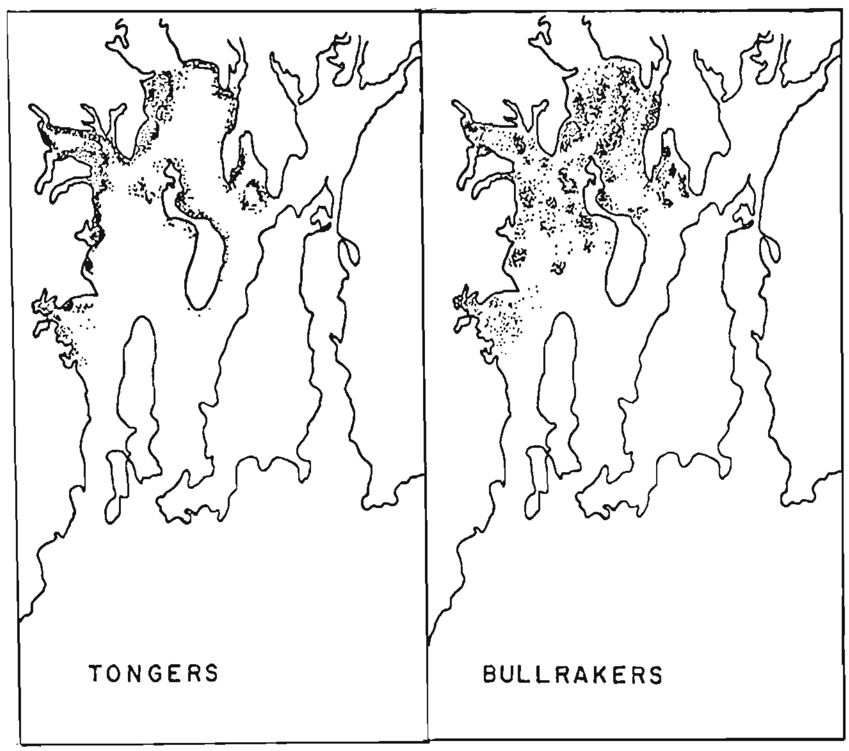

Figure 9
Locations of tong and bullrake fishermen harvesting northern quahogs in Narragansett Bay, September 1959 to August 1960. From Campbell, 1961.

[7] Smith, R. 1991. Fisherman, Charleston, R.I. Personal commun.
[8] Dykstra, J. 1991. Fisherman, Kingston, R.I. Personal commun.

In recent years, on a good summer weekend day, at least 1,000 additional people harvest quahogs for sport in Narragansett Bay and the coastal ponds of Rhode Island. Most are waders using short-handled rakes (Ganz[2]).

About one-third of the quahog grounds in Narragansett Bay, mainly in the north end, contains dense concentrations of quahogs, but the water is polluted (Ganz[2]). While most polluted areas are permanently closed to digging, some portions are open during dry weather. When it rains steadily and at least 12.5 mm (0.5 inches) of rain falls, water runoff from land and overflows from sewers force state authorities to close those portions for at least 7 days. If heavy rain (at least 25 mm [1 inch]) falls, closures extend to 10 days (Smith[7]).

Limited bed access is a critical feature affecting Rhode Island quahoging. Since the 1970's, fishermen have found it difficult and expensive to get dock space for their boats as a result of marina expansion for increasing numbers of pleasure boats. The marina owners do not like to rent space to commercial boats because they have a poor appearance. Many fishermen have had to trailer their boats every day, but even that has become increasingly difficult as roads to the shore and parking spaces have become congested.

Connecticut

Harvesting northern quahogs (locally termed clams) was less important in Connecticut than in other states in the region. In the 1920's and 1930's, perhaps 50 fishermen working from rowboats harvested quahogs with tongs in the entire state (Usinger[1]). In 1946, fishermen brought three rocking chair dredges to Connecticut and deployed them from three motor boats, each about 12 m (40 feet) long. In 1958, two oyster companies replaced the rocking chair dredges with hydraulic dredges and used them on 3–4 boats to harvest quahogs in the late winter and spring when oystering was slow. Since then, a few boats have been harvesting quahogs with hydraulic dredges. Connecticut has few hand rakers or tongers. Production was small (usually <10,000 bushels landed/year) before 1955, but rose sharply to an average of 24,000 bushels/year from 1960 to 1967 (Lyles, 1969), and then to 70,000 bushels in 1985 and 95,000 bushels in 1990[9] (Fig. 8).

Nearly all quahogs are produced by the Tallmadge Brothers Company of Norwalk; its boats gather them year-round with hydraulic dredges. The company lands 125,000–150,000 bushels of quahogs/year[9] (Fullilove, 1992).

A large quantity of quahogs set and survived in the early 1990's in many Connecticut grounds, mainly from Milford through beds east of New Haven—a distance of at least 20 km. In 1996 and 1997, a large littleneck crop was harvested by Tallmadge Brothers and many small leaseholders, all using hydraulic dredges. Some fishermen abandoned lobstering, mounted dredges on their boats, and leased public grounds to harvest the littlenecks. Production will probably increase for the next several years.

New York

Long Island has been a major producer of northern quahogs (locally termed clams) since the 1800's. In the 1870's, fishermen harvested the quahogs in bays on the island's north shore and in Great South Bay, where about 500 men and 200 boys tonged and raked them from boats. Each gathered about 3 bushels of quahogs/day. They sold them in New York City as well as to the many hotels on the island in summer (Ingersoll, 1887). Long Island continued to be a large supplier of quahogs afterward, with the north shore bays producing about as many as Great South Bay.

In the early 1960's, quahogs set densely in 2 years spaced 2–3 years apart in Great South Bay. They grow slowly in the bay, and, after attaining littleneck size in 4–5 years, they take 2–4 years to reach cherrystone size. A huge stock of littlenecks resulted. In the late 1960's and the 1970's the number of fishermen, which included seasonal part-timers (ordinarily school teachers, students, and firemen), increased to a few thousand on good summer days to dig them. Most dug from flat-bottom wooden garveys, about 5.5 m (18 feet) long, propelled by outboard motors, while some also used rowboats and 9.75-m (32-foot) motorized sloops (Usinger[1]). At the peak in the 1970's, most fishermen using bull rakes harvested 7–8 bushels of quahogs/day, and total production was a little above 700,000 bushels in each of the three biggest years (Fig. 8) (Anonymous, 1987).

During the 1940's and 1950's, most fishermen used tongs in Great South Bay and they dug mostly on former oyster beds that had large quantities of surface shells. The quahogs were much more abundant on those beds than on others without the shell cover, probably because the shells hid juvenile quahogs from predators. In the 1960's and 1970's, the fishermen using bull rakes removed most of the shells, and the quahogs became much sparser there (Klaassen[10]). Quahogs now are most abundant in bottoms having large quantities of shell

[9] Some annual landings data for specific species presented in this chapter vary for the same years. The reason is that data from states, the Federal government, and reporters is collected differently. The landings data should be considered as approximations.

[10] Klaassen, J., 1991. Fisherman, West Sayville, N.Y. Personal commun.

fragments mixed with sand (Strong[11]). A similar relationship exists in Wellfleet Harbor, Mass., where, in bottoms with a cover of surfclam shells spread by fishermen as cultch for oyster larvae, quahogs from natural sets are sufficiently abundant for commercial digging. The quahogs are scarce in nearby bottoms with few shells (Rask[12]).

In Great South Bay, about 250 rakers and 50 tongers currently harvest about 1,000 quahogs/raker/day on public bottom. Besides, the Bluepoints Company owns or hires nine hydraulic dredge boats that each gather 10–12 bushels/day from the 94 km^2 (36 $miles^2$) of Great South Bay bottom, or about one-fourth of the bay area, that the company owns.

In the 1980's and 1990's, the abundance of quahogs has remained relatively low in the bay. The recurring presence of dense "brown tide" blooms probably is detrimental to them. The blooms are caused by the microscopic brown alga *Aureococcus anophagefferens.*

In the mid-1990's fishermen discovered and began harvesting a large quantity of littlenecks in grounds along the south shore of Long Island Sound. Since the shelf on which quahogs occur is much narrower than the one in Connecticut, production probably will not increase as much in New York. Long Island currently has three hatcheries producing northern quahog seed.

Raritan Bay

In the 1870's, Raritan Bay fishermen harvested northern quahogs (locally termed clams) by hand raking from rowboats, dredging from sloops, using short-handled rakes while wading, and treading. Production was about 150,000 bushels/year (Ingersoll, 1887). Fishermen with sloops modified bull rakes to dredge for the quahogs in beds 6–9 m (20–30 feet) deep (high tide depth) with mud bottoms. They added four more teeth to the rakes, cut the long handles down to 1.5 m (5 feet), towed each with a rope, and termed them "dredges." The sloops, with crews of two, each towed four such dredges off one side as they drifted in the winds and currents, retrieving them by hand. Their daily catches were from 10–30 bushels of quahogs/sloop. The number of dredging sloops was about 40 in the 1920's but declined to 14 by the 1950's (MacKenzie, 1990, 1992a).

About 12 hand rakers dug quahogs during the 1920's, but their numbers rose to 700 in the 1930's, because the quahogs had set densely in the bay and the nationwide economic depression forced many unemployed men to seek work raking quahogs (MacKenzie, 1990, 1992a). Each hand raker dug 6–10 bushels/day.

In 1946, some Raritan Bay fishermen began using rocking chair dredges to gather quahogs during the colder months. About 20 eventually were in use every day. They were towed from motor boats with crews of 3; each boat harvested about 40 bushels of quahogs/day. From July to October each year, the 60 men switched to otter trawling, purse seining, and gill netting for scup, *Stenotomus chrysops* (MacKenzie, 1990, 1992a).

As pollution increased in Raritan Bay in the 1920's, New York authorities had to prohibit further quahoging in their half of the bay. Pollution continued to increase, and in 1942 New Jersey authorities closed about 60% of their half of the bay; by 1960, they left only a small area in New Jersey's eastern end open for quahoging. In 1961, about 50 people contracted infectious hepatitis from eating quahogs from the bay, and harvesting them was then prohibited. In the 1960's and early 1970's, part of the eastern end was opened briefly again for quahoging. Fishermen harvested quahogs with bull rakes and sail dredges. Thus, the two gears had been employed in the bay for around 100 years at that point. Since the early 1970's, the entire bay has been closed to direct marketing of quahogs.

A quahog depuration plant operated on Staten Island, N.Y., from 1979 until 1983, when it was closed because it was not cost-effective. The year it closed, a new plant opened in Highlands, N.J., but it closed in 1988 for failure to adhere to depuration guidelines. When it reopened in 1992, it was joined by a new plant in nearby Sea Bright, and a second new facility began operating in Highlands in 1994.

Beginning in 1983, New York and New Jersey authorities have permitted fishermen to rake northern quahogs from Raritan Bay, which is uncertified, and relay them to leased areas in certified waters in eastern Long Island and Barnegat Bay, N.J., respectively. In 1990, about 50 diggers in New York waters of the bay dug 48,000 bushels of quahogs, and 15 diggers in New Jersey waters of the bay (Fig. 10) dug 10,000 bushels for relaying (MacKenzie, 1992a); in 1991 and 1992, the number of New Jersey diggers on the water daily had increased to about 30; in 1993, New York had 30 diggers and New Jersey had 40–45 diggers (about one-third of New Jersey's diggers were selling their quahogs to a depuration plant in Sea Bright, N.J.). Most New York boats have two persons, a digger and a culler, while the New Jersey boats have one. Biologists in New York (Fox[13]) and New Jersey (Joseph[14]) estimate that as much as 25%

[11]Strong, C. 1992. Bluepoints Company, Atlantic Avenue, West Sayville, N.Y. Personal commun.

[12]Rask, K. 1993, 1996. University of Massachusetts, Cooperative Extension, Barnstable. Personal commun.

[13]Fox, R. 1992. State of New York, Department of Environmental Conservation, SUNY, Building 40, Stony Brook. Personal commun.

[14]Joseph, J. 1993. State of New Jersey, Division of Shellfisheries, Nacote Creek. Personal commun.

Figure 10
Northern quahog fisherman in his boat in Raritan Bay, ca. 1987. Note rake and aluminum handle. Littlenecks have been separated from the cherrystones and chowders. Photograph by the author.

of their states' production of quahogs is from the relayed transplants from uncertified to certified waters.

Current Regional Overview

Northern quahogs in the region have fared much better than oysters, softshells, and bay scallops. In the past decade or so, competition for the quahogs has been keen. Most quahogs landed have been littlenecks, because nearly all were raked or dredged before they could grow to larger sizes. In Narragansett Bay, rakers have attempted unsuccessfully to ban commercial scuba diving for quahogs, claiming the method is too efficient and depletes the supply (Fleet, 1992). And in Oyster and Northport Bays, rakers have been trying to convince state authorities to force companies to surrender their long-held oyster leases, to provide them with more public ground territory for quahoging.

Since the 1970's, the States of Massachusetts, Rhode Island, and New York have enhanced their public quahog fisheries by transplanting dense concentrations of northern quahogs from uncertified (polluted) to certified (unpolluted) waters (Fox[13], Ganz[2], Merritt[15]). This has served the dual purpose of depleting the quahog stocks in uncertified waters, where they had been a temptation for poachers to dig them for sale, and increasing quahog stocks in certified waters. Authorities in Massachusetts (Merritt[15]) and New York (Fox[13]) hired boats with hydraulic dredges, while those in Rhode Island (Ganz[2]) hired bull rakers to do the transplanting. The quahogs have had to remain at least 21 days on the certified beds before being harvested for market. Rhode Island authorities found such transplanting was much more cost-effective than purchasing hatchery seed for planting (Ganz[2]).

Fishermen who dig northern quahogs on public beds, especially in Narragansett Bay, on Long Island, and in Raritan Bay, strongly oppose the leasing of additional bottoms, and so the future development of hatchery operations using additional private grow-out areas will be slow or unlikely at least in those areas. Instead, hatchery production will be confined to existing leases or would have to be for the benefit of the public fisheries. Two hatcheries on the shores of Great South Bay currently are producing quahog seed and distributing it on beds in the bay without using protective screens. The seed is too large for shrimps but not for crabs to destroy them. Hatchery personnel do not know the survival rates. Quahog production on natural beds might be enhanced by spreading broken shells over them and

[15]Merritt, C. 1992. Shellfish warden, Town of Bourne, Mass. Personal commun.

by developing additional means of enhancing survival of natural and hatchery seed. (A later section describes hatchery-produced seed quahogs in Massachusetts.)

Softshell Fishery

Softshells occur throughout much of the region, but the most important producing areas have been 1) the north shore of Massachusetts from Newburyport to Ipswich and Boston Harbor, 2) bays on the north shore of Long Island, 3) Raritan Bay, and 4) the Navesink and Shrewsbury Rivers. Less important areas have been Barnstable Harbor and bays in southern Massachusetts, Narragansett Bay, the Connecticut coast, and eastern Long Island (Fig. 2, 3). In most areas, fishermen usually dig the clams on bare flats during low tides.

Softshells grow in dense numbers in broad, intertidal flats and narrow beaches as well as subtidally in bottoms at least 3 m deep. The broadest flats are along the shores of Massachusetts north of Boston, where the tide remains sufficiently low for fishermen to dig 4–5 hours each day, and, until the early 1900's, the south shore of Raritan Bay. The depths that softshells burrow vary, apparently according to sediment coarseness. In sandy flats on the north shore of Massachusetts, the softshells are 25–45 cm (10–18 inches) deep. They are shallower in Boston Harbor, and only about 2.5–7.5 cm (1–3 inches) deep in firm mud-sand flats in Raritan Bay, N.J.

The main predators of softshells in northern Massachusetts are the mummichog, *Fundulus heteroclitus*, which preys on softshells 2–11 mm (0.08–0.4 inches) long (Kelso, 1979), and the green crab, *Carcinus maenas*. While softshell predators have hardly been studied in other areas of the region, mummichogs also prey on softshells in New Jersey and crabs may be universal predators. Other invertebrate associates include polychaete worms that are commonly dug in and near the clam flats for fish bait.

Native Americans dug softshells for food, as evidenced by those shells in their middens (Belding, 1930). They probably used sticks and large northern quahog shells as digging tools.

The earliest European colonists dug softshells for food year-round (Pearson, 1972) on bare flats mainly using a "digger," a fork with six thin tines about 30 cm (12 inches) long attached perpendicularly to a wooden handle about 40 cm (15 inches) long (Fig. 11), or with a "drag," which was similar to the digger but with 4–5 teeth each about 15 mm (0.67 inches) wide and 15 cm long (6 inches) (Fig. 12). Each fisherman usually took 2–3 bushels of softshells during a low tide.

The digger and drag have remained in use along with four other gears. One of these, no longer employed, was the "sea horse" used mainly on Martha's Vineyard, Mass., in the early 1900's and probably earlier. It was 35 cm (14 inches) wide and had metal tines 30–35 cm (12–14 inches) long and a wooden handle about 1 m (3 feet) long attached perpendicularly. The handle had a belt that went around the fisherman's waist. Two men were required for the work. In about 30 cm (1 foot) of water, one pushed the tines into the sand at an angle and dragged it along, plowing out the softshells. His partner followed and gathered them (Belding, 1930).

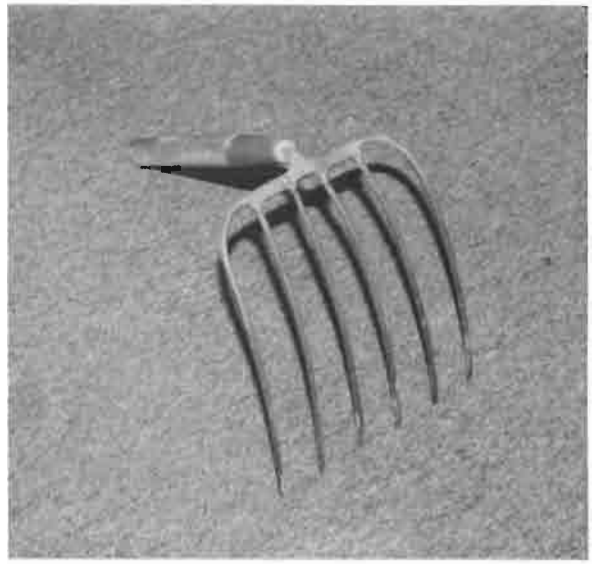

Figure 11
A digger used to harvest softshells in northern Massachusetts, ca. 1992. Photograph by the author.

The second gear is the churning hoe. It has a blade 10×20 cm (4×8 inches) attached perpendicularly to a handle 1.8–2.7 m (6–9 feet) long. The fishermen churn while wading in shallow water or standing in a boat anchored in water 1.1–2.1 m (4–7 feet) deep or standing on ice. By moving the hoe up and down vigorously (churning) just below the sediment surface of a bed, the fishermen lift out the softshells, and gather them with a scoop net or rake. Churning hoes have been used in New Jersey since at least the early 1900's (MacKenzie, 1990, 1992a).

The third gear, currently used around Cape Cod, Mass., is a plumber's plunger on a handle about 1 m (3 feet) long. Used much like the churning hoe, the fishermen work it up and down at the sediment surface to lift out the softshells and then scoop them up with a net attached to the opposite end of the handle (Chadwick and Kennedy[16]).

[16]Chadwick, D., and J. Kennedy. 1992. State of Massachusetts Depuration Facility, Plum Island, Newbury. Personal commun.

Figure 12
A drag (mid, lower) and fork (mid, upper) used for harvesting softshells; the short-handled rake (right) is used for harvesting northern quahogs in eastern Long Island, ca. 1992. Photograph by the author.

The fourth gear, currently used mostly on southern Cape Cod (Kalweit[17]) and Martha's Vineyard where the softshell beds never fall bare, is a water jet from single or multiple nozzles. A pump in the outboard motor boat delivers water at high pressure through a hose with a narrow end. Standing in water knee-to-waist deep, they move the nozzle(s) across the bottom to wash the softshells onto the surface and then gather them with a rake. This gear was first used in the 1940's (MacKenzie, 1992b).

Massachusetts

Early in the 1800's, softshells, locally termed soft clams or softshell clams, were in demand as food as well as bait for offshore finfisheries using hooks on trotlines. As demand for the softshells grew, large numbers of people in towns like Newburyport, Essex, Ipswich, Chatham, and Boston, dug and shucked them for both markets (Fig. 13). Finfishermen in the ports of Gloucester, Boston, and Provincetown bought the meats fresh or salted. In the 1920's, use of softshells as bait probably ended when fishermen substituted otter trawls for trotlines in New England fisheries. For conservation purposes, Massachusetts has not allowed diggers to land softshells <2 inches (50.8 mm) since the early 1900's (Belding, 1930).

Since the early 1900's, fried clams have become a popular food, especially at seashore resorts in summer but also year-round in inland restaurants of the state, and the demand for softshells has risen more. At least 95% of softshells have since been shucked and fried, the remainder steamed. From Newburyport to Ipswich, about 100 fishermen used to shuck softshells in their homes for the frying market, and the practice continues on a small scale. Nowadays, about 95% of the softshells produced, including many of those in other parts of the state, are shucked by hand in about a dozen fish houses on the north shore. In addition, the fish houses purchase softshells from Maine and Maryland for shucking; shucked softshells are imported from Nova Scotia. Each fish house employs as many as 12 shuckers and pays them about $8.00/gallon of meats opened; workers in the plants hot-dip the softshells so they can be opened more easily (Chadwick and Kennedy[16]).

The number of softshells in a gallon varies. At times, the meats of about 1,100 softshells from Massachusetts (Chadwick and Kennedy[16]), 900 softshells from Maine, and 556 softshells from Maryland have constituted a gallon (New Hampshire *Sunday News*, 1992). A person can shuck about 1 gallon of meats/hour of average-size softshells, working 4–6 hours/day. Seabrook, N.H., is another center for shucking Massachusetts and Maine softshells for sale in Massachusetts. The town has about 100 shuckers (50:50 male:female), who open softshells in nine shucking houses. Softshell shucking in Seabrook dates back an estimated 200 years (Health Department, Town of Seabrook, NH[18]). The meats are sold to dealers and restaurants. In 1992, a gallon of softshell meats had a wholesale price of $75–80 (Chadwick and Kennedy[16]).

The softshell beds in Boston Harbor have been polluted with sewage bacteria since the early 1900's and undoubtedly long before then. In 1928, the state constructed a plant at Plum Island in Newbury for depurating the softshells dug in Boston Harbor. From then until 1961, the method used for depuration was holding the softshells in water sterilized with added chlorine for 48 hours. Since then, the plant has held the softshells in water sterilized by ultraviolet light for 48 hours.

[17]Kalweit, D. 1992. Department of Natural Resources, Town of Barnstable, Mass. Personal commun.

[18]Health Department. 1992. Town of Seabrook, N.H. Personal commun.

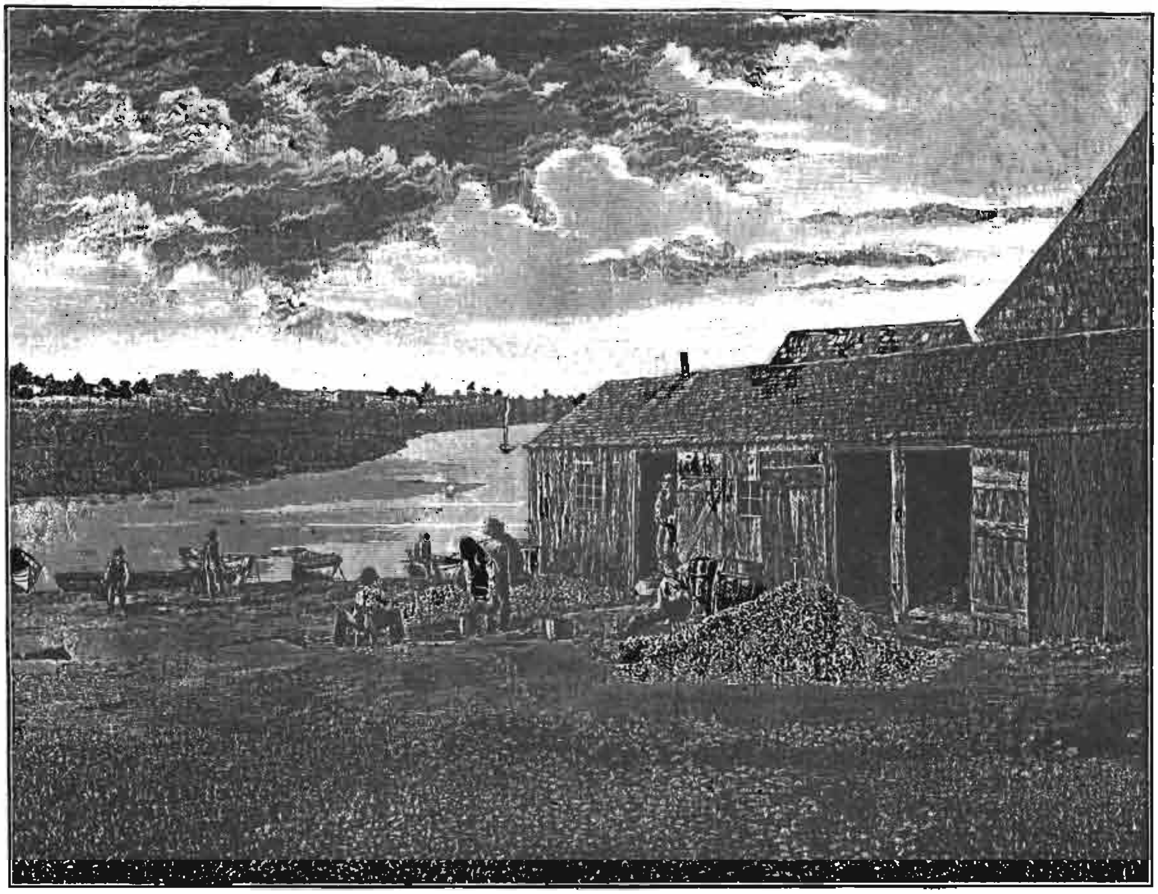

Figure 13
Opening (shucking) softshells at Essex, Mass., ca. 1878. From Ingersoll, 1887.

Softshells are taken by refrigerated truck to the Plum Island Plant, which has a maximum capacity of 850 bushels of softshells every two days. Since the plant cannot handle as much as fishermen could potentially dig, the harbor is divided into three areas. Diggers work on a rotation schedule and are permitted to dig in one or two areas a day. The plant depurates 60,000 bushes of softshells a year, charging the fishery $3.50 a bushel (Chadwick and Kennedy[16]).

The softshell fishery in northern Massachusetts including Boston Harbor now is in good condition. The softshell beds, aside from those in Boston Harbor, are little threatened by pollution or coastal development, the softshells usually are sufficiently abundant for good digging in most areas, and fisherman access to the beds is not limited as in Rhode Island. The local towns conserve softshell stocks by limiting daily catches by fishermen. This includes allowing fishermen to dig on only one low tide each day. In the early 1990's, due to unemployment ashore caused by the national economic recession, more men have been digging, forcing the towns to reduce the limits. One town reduced its limit from 5 to 3 bushels/man/day, and another from 3 to 2 bushels/man/day. Limits are often relaxed in summer, when demand for the softshells is high, and the diggers can land all they can harvest (Chadwick and Kennedy[16]).

The diggers on the north shore travel to the softshell flats in groups of 2–4 in aluminum outboard motor boats, whereas in Boston Harbor they walk out to the softshell flats from shore. The diggers put the softshells in plastic buckets and then into mesh onion bags. They rinse the sand off the softshells so the meats will be sand-free when shucked (Chadwick and Kennedy[16]).

Softshell production in Massachusetts rose from 7,000 bushels in 1880 to 185,000 bushels in 1940. Between then and the late 1980's, it ranged between 62,000 and 91,000 bushels and was consistent from 1989–91 (Fig. 14). Annual landings ranged from 96,000 to 105,000 bushels, the landed price/bushel was from $56 to $61, and the total landed value was from $5.6 million to $6.1 million (Chadwick and Kennedy[16]).

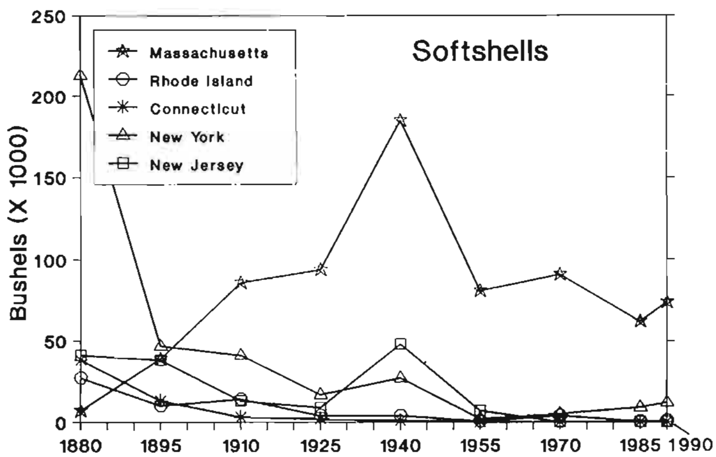

Figure 14
Landings of softshells in Massachusetts, Rhode Island, Connecticut, New York, and New Jersey, 1880 to 1990 (Lyles, 1969; Statistics Division, National Marine Fisheries Service, NOAA, Wash., D.C.).

In 1993 and 1994, softshells set in extremely high abundances in several areas from southern Massachusetts through Raritan Bay. A large area at Monomoy, in southeastern Massachusetts, has a dense stock of softshells, and, during the summer of 1996, at least 200 commercial fishermen dug softshells there daily, using "diggers" on intertidal flats. With larger supplies entering the New England market from Maryland as well as Massachusetts, the market became glutted and landed prices fell in 1996 (New Jersey diggers selling to a depuration plant received $10 less than they did in 1995: $35 vs. $45/bushel).

Rhode Island

In the late 1870's, softshell production in Narragansett Bay was about 35,000 bushels. Most were shipped to New York City where they sold for $0.75–$1.00/bushel (Ingersoll, 1887). After 1895, production was much lower except for a brief increase around 1940 (Fig. 13).

Connecticut

In the late 1870's, Connecticut production of softshells was around 22,000 bushels/year (Ingersoll, 1887). By the 1930's, small numbers of men and boys in some communities were digging them with drags on tidal flats (Usinger[1]), and annual production was only about 2,000 bushels (Lyles, 1969). Most softshells were sold to local restaurants. By the 1940's, most softshell beds had become polluted by effluents from coastal cities, such as Bridgeport and New Haven, and harvesting ended (Usinger[1]).

New York

The principal softshelling areas on Long Island were bays along its north shore; a less important area was Peconic Bay. In the 1880's, annual production of softshells (locally termed soft clams) from the state was about 215,000 bushels, but it fell sharply afterward (Fig. 13), as effluents from the growing towns bordering the north shore bays polluted the softshell beds.

In the 1920's and 1930's, about 25 men using drags and garden forks dug softshells part-time in Peconic Bay, each harvesting 2–3 bushels/day. They shucked some and peddled the meats locally, and shipped the remainder whole to New York City. About 12 fishermen currently dig softshells in the bay (Lester[19]). Softshells occur in bays on the north side of Long Island, but nearly all softshell flats are polluted and the softshells cannot be dug for human consumption.

Raritan Bay

Softshelling was a substantial fishery on the south shore of Raritan Bay and in the Navesink and Shrewsbury Rivers from at least the mid-19th century until the 1940's. Locally, they are simply called clams. In winters during the 1870's (and probably long before), "hundreds" of men and boys dug softshells at low tide on broad flats on the south shore of Raritan Bay (Ingersoll, 1887). Subtidal digging of softshells with churning hoes was also prominent in this area; as many as 100 fishermen from Highlands, N.J., churned them while wading and 50 more churned them from small boats. Each churner gathered from 2–12 bushels/day (MacKenzie, 1990, 1992a).

Most softshells were shucked locally in fishermen's homes or commercial shanties. From sometime in the early 1800's through the 1940's, many softshell fishermen, with the assistance of their wives and children, opened softshells and packed their meats in quart jars in their homes for peddling in local neighborhoods. And in Highlands, from at least as early as the 1850's (Ingersoll, 1887) and also continuing into the 1940's, most softshells were shucked in about 12 shanties along the shore; from 5–10 women shucked the softshells in each one. Those meats were shipped by train to New York City for sale (MacKenzie, 1990, 1992a). The remaining Highlands' softshells were sold whole to seaside resorts and clambakes. From 1897 to 1938, softshell

[19]Lester, F. 1991. Shellfisherman, Amagansett, N.Y. Personal commun.

landings from the bay and the two rivers ranged from 48,000–120,000 bushels/year (Townsend, 1901; Fiedler, 1940), while, from 1885 to 1940, landed prices ranged from $0.35–$2.20/bushel (MacKenzie, 1990, 1992a).

After 1900, an increasing number of softshell beds along with the northern quahog beds were closed to digging because pollution spread. In addition, softshells were scarce in the bay between the late 1930's, following the disappearance of eelgrass, *Zostera marina*, that protected the softshell beds from disturbances by wave action during storms (MacKenzie and Stehlik, 1988), and the 1990's. Digging began again in 1995 when softshells set and survived at Sandy Hook at the eastern end of the bay. The eelgrass and softshells have never returned in any abundance to the main beds of the bay.

In the late 1970's, three private plants began depurating softshells in Highlands. About 30 fishermen dug softshells in the Navesink and Shrewsbury Rivers and sold them to the plants. But by 1988, softshelling ceased because softshells became scarce and New Jersey authorities closed the plants when their operators failed to follow the state's depuration guidelines. In 1995, the depuration plant in Sea Bright became certified to depurate softshells. In the warm months in 1995 and 1996, from 12 to 18 fishermen each dug 5–7 bushels of softshells and sold them to the depuration plant on a daily basis.

Massachusetts and Rhode Island, especially, but also eastern Long Island, have large recreational fisheries for softshells. In 1990, sport diggers in Massachusetts harvested nearly 16,000 bushels (Anonymous, 1992a), or about 15% as many as its commercial fishermen landed.

Surfclam Fishery

Atlantic surfclams in this region (excluding oceanic areas) have been harvested along the shores of northern Massachusetts and in Long Island Sound (Fig. 2, 3). In Massachusetts, recreational fishermen harvest the surfclams along shores barely covered by water during low tides. Local towns have a conservation limit restricting each digger to a few quarts of surfclams/day.

In 1985, commercial fishermen found a bed of surfclams between Mt. Sinai and Mattatuck in Long Island Sound, where the water depth was 3–7.5 m (10–25 feet). The surfclams were comprised of only two year classes, apparently lived only about 10 years, and reached an average asymptotic height of only 71 mm (2.8 inches) (Cerrato and Keith, 1992). Clam predators have not been studied there, but crabs prey heavily on juvenile surfclams on the northwest Atlantic shelf (MacKenzie et al., 1985).

The fishery lasted about 10 years. From 1985 until the early 1990's, about 12 boats, 21–27 m (70–90 feet) long, each with a crew of three, harvested surfclams from the bed using hydraulic dredges (Fig. 15). To conserve the resource, New York authorities limited each boat to 56 cages/week (at 32 bushels/cage). For the first few years, they did not impose limits on total annual landings, but after 1991 they limited them to 450,000 bushels/year. The boat owners had to report their landings each week to the New York Division of Marine Fisheries. Fishermen landed the clams at three ports in northern Long Island, and then they were trucked for processing to Rhode Island, Delaware, and Virginia. As the clams were relatively small, they could not be processed as strips to be fried, and so all were diced or minced (Fox[13]).

The fishery shut down for 3 months each summer when the meat yield/bushel was relatively small. Most surfclam fishermen spent the summer lobster fishing. Surfclam production for 1985 to 1991 ranged from 41,000–550,000 bushels/year (Table 4). But by the mid-1990's, the surfclams became scarce and commercial harvesting ended.

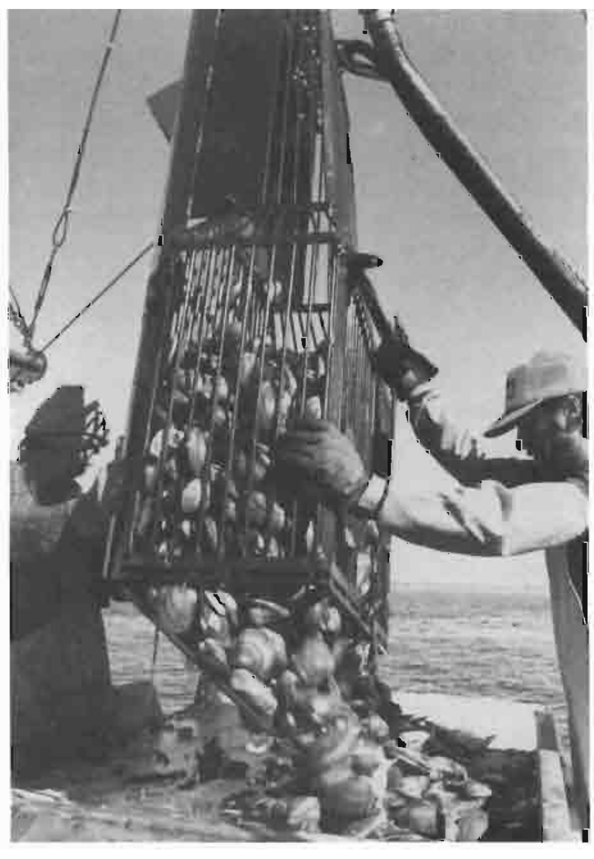

Figure 15
Emptying surfclams from a hydraulic dredge in Long Island Sound, ca. 1986. Photograph by L. Sholz, courtesy of *National Fisherman* magazine.

Bay Scallop Fishery

The largest production of bay scallops in the region came from bays and saltwater ponds in southern Massachusetts, Narragansett Bay and various ponds in Rhode Island, and Peconic Bay on Long Island; smaller quantities were from the Niantic River in eastern Connecticut and Great South Bay on Long Island (Fig. 2, 3). Scallops once occurred sparsely in other areas of Connecticut and Long Island, and in Raritan Bay (Ingersoll, 1887), but are almost nonexistent in those areas now. Bay scallops are most abundant in clear, high-salinity water, in depths of 1–3.5 m (3–12 feet), and in eelgrass meadows. Their life span is 18–24 months, and only two age classes, adult and seed, are present at any time. Fish, such as scup, and crabs prey on the seed. In scallop beds, annual scallop numbers vary widely from near scarcity to highly abundant, and scallop production (Fig. 16) and employment in the fishery has fluctuated accordingly.

Commercial scalloping in the region began in the late 1800's (Belding, 1910). By the early 1900's, most states and towns had decreed that daily scallop catches should be limited. Such limits ranged from 1 to 15 bushels for each boat or fisherman. Only the scallop adductor muscle, termed the "eye," has been sold in retail markets. In recent years, the remaining soft parts, termed "guts," have usually been discarded, but in the late 1800's they were used as fertilizer (Ingersoll, 1887), and, in the early 1900's and probably earlier, some were salted and sold as bait to Atlantic cod, *Gadus morhua*, fishermen in Massachusetts (MacKenzie, 1992b).

Table 4
Landings and value of surfclams from Long Island Sound, N.Y., 1985 to 1991. Source: Fox, text footnote 13.

Year	Bushels	Value
1985	292,000	$1,753,000
1986	550,000	3,300,000
1987	41,000	230,000
1988	58,000	394,218
1990	516,000	3,070,000
1991	460,000	2,720,000

Fishermen and hired help (elderly men, women, and children) opened the scallops in fish markets, shanties, kitchens, cellars, yards, and on benches at the shores; bowls and cans held the muscles. In the 1950's, the help was paid $1.00 for each gallon opened; by the 1990's, the pay had risen to $9.00/gallon. The shells were spread on driveways, discarded in dumps, or used as cultch for oysters in Connecticut (Lester[19]).

In the fall of each year, when adult scallops have nearly completed their seasonal growth, state or town authorities have opened the seasons for commercial harvesting. As the adults will die before the next fall season, fishermen have been allowed to harvest all they can, but they must leave the seed in beds. The scallop crops usually last 1–2 months, but they sometimes continue for an entire season of about 6 months for regular and part-time fishermen.

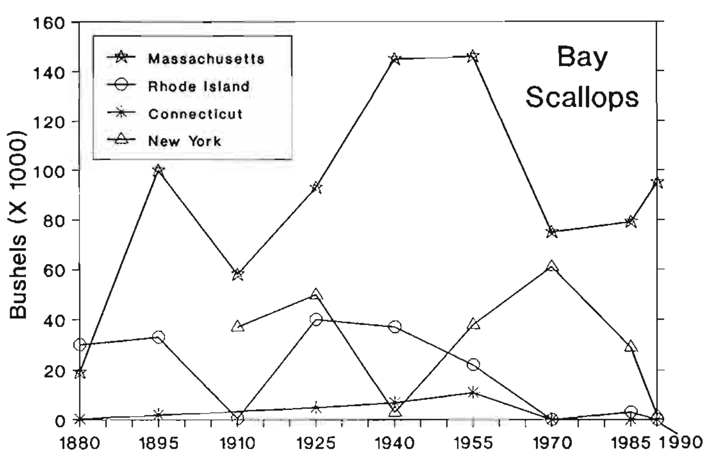

Figure 16
Landings of bay scallops from Massachusetts, Rhode Island, Connecticut, and New York, 1880 to 1990 (Lyles, 1969; Statistics Division, National Marine Fisheries Service, NOAA, Wash., D.C.).

Massachusetts

The bay scallop fishery had little commercial importance in Massachusetts until the 1870's, when the dredge was introduced to Cape Cod for towing from sailing catboats 5.5–7 m (18–23 feet) long. Its net bag held about a bushel. Each boat towed 4–8 dredges. Previously, scallops were harvested only with scoop nets in wading depths, and the demand for them was minimal. In the early 1900's, fishermen installed engines in the catboats and the dredging became more efficient (Belding, 1910).

Another harvesting method, begun in the mid-1920's, is dip-netting. A glass-bottomed viewing box is held in one hand and a scoop net in the other. Nearly always working from a rowboat, but occasionally while wading, the fisherman holds the scoop under water, just above the bottom, as he looks through the viewing box, searching for scallops. Visible at depths of 1–2.5 m (3–8 feet), they can be gathered one at a time with the net, as the boat drifts (Fig. 17). With this method, a fisherman can gather about a bushel of scallops/hour (500 scallops/bushel) from a well-stocked bed. The scallops are held in burlap bags, baskets, or crates (MacKenzie, 1992b).

The number of people fishing for scallops in earlier periods was rarely recorded, but data are available from the three largest areas in the 1950's and 1960's. The numbers harvesting at the beginning of good seasons were: Chatham (Pleasant Bay), 225 (Moore[20]); Martha's Vineyard (several ponds), 400 (MacKenzie, 1992b); and Nantucket, (2–3 bays) 140 (Fronzuto[21]), for a total of about 765. Most were men, but some women culled scallops on 2-person boats. The total number in the state probably did not exceed 1.5 times the number working in these three locations.

Rhode Island

In the late 1870's, the bay scallop fleet in Rhode Island consisted of about 90 boats, mostly sailing catboats but also sharpies and small sloops (Fig. 18). Each boat towed 3–8 bushel-sized dredges that fishermen retrieved by hand (Ingersoll, 1887). By the 1920's and 1930's, a typical scallop boat was about 7 m (23 feet) long, usually driven by a Lathrop engine and propeller. It was capable of towing from 6–8 dredges, that were limited by state law to a width of 30 inches (75 cm). The state imposed a 15-bushel limit for each boat plus one additional bushel for each person aboard besides the operator. By the 1940's, the boats had engines of about 40 hp (Dykstra[8]).

In the 1950's, at the beginning of seasons when scallops were abundant, nearly every fisherman and tradesman with a boat went scalloping. Many took leave from other jobs to harvest scallops for 2–4 weeks (Dykstra[8]). About 600 boats comprised the fleet. Most were single-man skiffs, 4.25–4.9 m (14–16 feet) long, propelled by outboard motors (Smith[7]).

In some Rhode Island ponds, the authorities allowed only dip netting for scallops. Several men dip-netted them commercially, and a few dozen others did it only for home consumption, harvesting 1/4–1 bushel/trip (Smith[7]).

Rhode Island scallops have been relatively scarce since the late 1950's. Loss of eelgrass and other types of environmental degradation, such as low oxygen and elevated nutrients in waters, are believed to be the cause, but no systematic studies have been made to establish this. In 1985 and 1986, brown tide blooms of *A. anophagefferens*, a microscopic brown alga, were so dense they killed nearly all the remaining scallops (Burns, 1991). Attempts have since been made by state personnel to re-establish scallop populations in their former beds by purchasing seed from hatcheries and holding it in cages for growth and spawning (Ganz[2]). Light sets of juveniles have resulted, but few have survived (Smith[7]).

Connecticut

Annual bay scallop production in the Niantic River has fluctuated with changes in eelgrass abundance. The river is about 900 m (3,000 feet) wide and is mostly 2–2.5 m (6–8 feet) deep. When eelgrass was abundant in this confined area, it grew too thickly for scallops and usually inhibited them from attaining commercial densities. After the eelgrass died in the 1930's, scallops were frequently abundant, but after it reappeared in the late 1940's they were less often abundant. In recent years, the two towns managing the river have tried to improve the scallop habitat by cutting paths through dense eelgrass meadows. By local decree, scallops could be gathered only by dip netting with a limit of 1 bushel/man/day. From 1976 to 1987, whenever scallops were generally abundant, the number of boats scalloping each day, with one fisherman in each using a dip net, varied from 10–15 during the week to as many as 50 on weekends (Daboll[22]).

Niantic River scallops currently are scarce. Local authorities are considering purchasing scallop seed from

Figure 17
Fisherman harvesting bay scallops in 1.5 m (5 feet) of water using a glass-bottomed box and scoop net, Sengecontacket Pond, Martha's Vineyard, Massachusetts, ca. 1950. Photograph by the author.

[20]Moore, S., 1992. Shellfish warden, Town of Chatham, Mass. Personal commun.

[21]Fronzuto, D. 1992. Shellfish warden, Town of Nantucket, Mass. Personal commun.

[22]Daboll, R. 1992. River Commission, Town of Niantic, Conn. Personal commun.

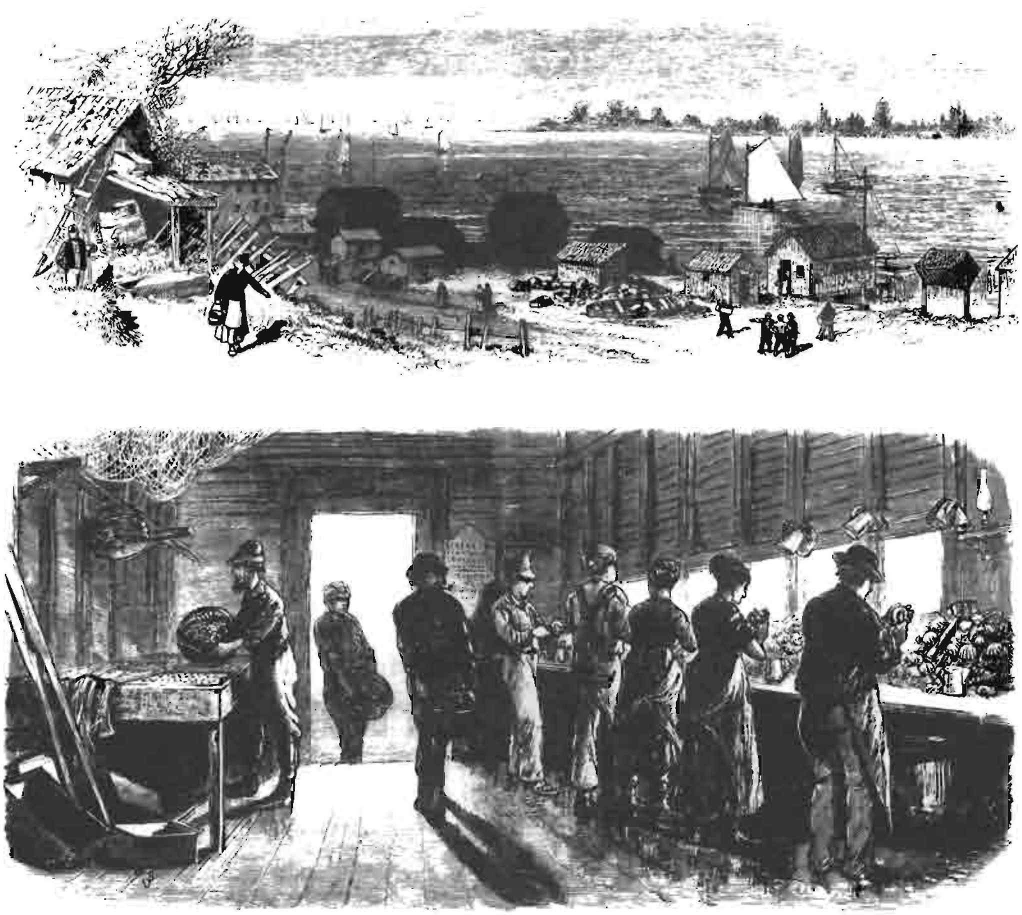

Figure 18
General view of Scalloptown, East Greenwich, Rhode Island, and the fishing beds; interior of scallop shanty, ca. 1877. Illustration from *Leslie's Weekly*, courtesy of the Rhode Island Historical Society, Providence R.I. Negative number Rhi X3 5799.

a hatchery and holding it in cages in the river for growth and spawning (Daboll[22]).

New York

In Peconic Bay, 193 men were engaged in the bay scallop fishery in 1880, and 471 women and children were employed to open them. Scallop production was 54,000 bushels with a landed value of $19,492 (Ingersoll, 1887). Fishermen dredged the scallops using sailing catboats. Around 1900, fishermen still sail-dredged in catboats, but within a few years motors and propellers had been installed in most of them. By the 1950's, as in Massachusetts and Rhode Island, fishermen were dredging scallops mostly from skiffs 4.25–4.9 m (14–16 feet) long, propelled by outboard motors. When scallops were abundant around 1900, about 50 boats sail-dredged for them, while during the motorboat era the number of dredge boats was about 125. Authorities allowed each boat to harvest 10 bushels of scallops/day, but if two people were in a boat, the limit was 15 bushels. In summer, many regular scallopers worked as fin-fishermen; in winter, if scallops were scarce, they dug softshells. The remaining scallop fishermen were part-timers with regular jobs ashore (Lester[19]).

In Great South Bay, the scallop fishery was much smaller than in Peconic Bay. Fishermen usually dug northern quahogs in winter, but if scallops were abundant some harvested them instead. Before the 1960's, state authorities allowed only sail dredging for scallops in this bay and the fishermen's catch was not limited. Afterward, they allowed dredging by motor power and imposed the same limit as for Peconic Bay (Klaassen[10]). The 1960's had a few good scallop years, but the 1970's had fewer. Since then, scallops have been too scarce for commercial fishing.

In Peconic Bay, dense blooms of brown tide have killed nearly all the scallops since the mid-1980's, as they did in Narragansett Bay. Local towns have attempted to restock the beds by planting seed reared in hatcheries. The seed has grown, spawned, and produced other generations of seed, but the results have been marginal because the *A. anophagefferens* blooms have recurred in varying concentrations each summer often killing nearly all the scallops (*New York Times*, 1991). The scallops survived better than usual in 1991 and 1992, and the 1992 scallop season was considered a fair one. About 200 one-man boats began the season, and for a few weeks many harvested the state limit of 5 bushels/boat. While the future of the scallop fishery in Rhode Island and Peconic Bay seems to depend on whether the brown tide blooms persist, the Rhode Island waters would benefit from additional habitat improvement.

Scallop Fragility

The bay scallop is the commercial bivalve most sensitive to environmental adversity in the region, as it nearly disappeared from several areas and has become scarce in others where environments have degraded. It has declined sharply in parts of Massachusetts including Martha's Vineyard Island, where the number of scallopers has declined from about 400 in the 1950's and 1960's to about 100 in the 1990's. One of the areas where scallops remain abundant is Cape Poge Pond, Martha's Vineyard. The pond's opening has remained unchanged, few people live around the pond, and it has little boating. In some areas, habitat degradation was caused by bay or pond inlets becoming much smaller or much enlarged often combined with intense pleasure boating in the summer. But specific causes of declines remain undetermined.

Blue Mussel Fishery

Blue mussels occur in various parts of the region, especially in Massachusetts (Fig. 2). Vast mussel beds were once present in Vineyard and Nantucket Sounds between Cape Cod and Martha's Vineyard and Nantucket Island, in oceanic waters south of the islands, and in Cape Cod Bay. Most were torn up and destroyed when fishermen towed otter trawls across bottoms while catching finfish from the 1920's to 1940's (Jackson[23]; Larsen[24]; MacFarlane[25]). Mussels had little commercial importance until the 1980's because the market for them was negligible. Market demand has since increased sharply and a fishery has developed in Massachusetts.

In the 1980's and 1990's, fishermen have dredged the mussels in at least four locations in Massachusetts, two of which were in the ocean but near land. The major bed with a diameter of about 8 km (5 miles) was on Nantucket Shoals about 10 km (6 miles) east of Nantucket Island and the other was 1.6 km (1 mile) south of Cuttyhunk Island (Rask[12]). The mussels, which ranged up to 10 cm (4 inches) long, were larger than those from bays. A few boats, 18–24 m (60–80 feet) long, harvested mussels from each of the ocean beds year-round. Each towed a single sea scallop, *Placopecten megellanicus*, dredge, 2.4 m (8 feet) wide, which was slightly modified for this use. Two boats each landed about 1,600 bushels/week, while a third boat landed about 3,400 bushels/week from the Nantucket bed (Wheeler[26]). On 11–13 December 1992, a severe easterly storm destroyed nearly all the Nantucket mussel bed, with serious consequences for the state's mussel production.

The other beds are in bays. One is in Pleasant Bay, Chatham, where about 12 boats each dredge about 100 bushels of mussels/day. Another bed is in Barnstable Harbor, where 2–3 boats (2 men/boat) dredge them daily. Town authorities limit the daily catch to 50 bushels/boat. In both areas, the boats are open skiffs about 6.7 m (22 feet) long. They tow bay scallop dredges about 1 m (3 feet) wide with long bags that hold about 5 bushels (Moore[20]). Another area is Plymouth Bay, where fishermen pitchfork intertidal mussels into boats at low tide.

In 1991, Massachusetts mussel landings were 294,467 bushels (8,030 metric tons of whole mussels) with a landed value of $1,442,000 (NMFS Fishery Statistics Division); 90% were from the Nantucket bed. Most mussels were trucked to markets in New York and New Jersey. In 1992, whole mussels usually sold for $0.99–1.29/pound in retail markets.

Conch Fishery

The origins of the region's conch fishery are unknown, except for Massachusetts (Fig. 2, 3); it may have begun as late as the 1930's. Fishermen have caught conchs in wooden slat pots about 50 cm (18 inches) square and 25 cm (9 inches) high with an open top (Fig. 19). The pots are weighed down with two bricks or some cement, baited with parts of horseshoe crabs, *Limulus polyphemus*, usually buoyed separately, set about 90 m (300 feet)

[23]Jackson, R. 1944. Fisherman, Town of Edgartown, Mass. Personal commun.

[24]Larsen, L. 1993. Fisherman, Town of Chilmark, Mass. Personal commun.

[25]MacFarlane, S. 1993. Environmental consultant, Town of Orleans, Mass. Personal commun.

[26]Wheeler, R. 1993. Blue Gold Sea Farms, New Bedford, Mass. Personal commun.

Figure 19
A conch pot made of wood slats and weighted with cement; each pot has a separate buoy, ca. 1991. Photograph by the author.

apart, and lifted every 1–2 days. The season lasts from spring into October, when the conchs are active. About 99% of the catch is the smooth conch. The knobbed conch, *Busycon carica*, present in some grounds, usually avoids pots (Smith[7]). State authorities do not limit catches, because they consider the conch a predator of commercial bivalves.

Massachusetts

The conch fishery began in Massachusetts on Martha's Vineyard island in the 1970's. The main conch grounds are in Nantucket Sound. By the 1980's, the island had about 25 conch boats, most of which had the design of lobster boats and were about 7.6 m (25 feet) long. Each boat crew sets 100–150 pots (MacKenzie, 1992b); daily catches run about 8–35 bushels/boat (Bagnall[27]). The state has few other conch boats. In 1990, Massachusetts landings of whole conchs were about 95,000 bushels (Table 3).

Rhode Island

In the 1930's and 1940's, Narragansett Bay had only 3–4 boats potting conchs because demand was small. But demand began to increase in the mid-1950's when a local company began cooking conch meats. By the 1960's, three plants were processing them and about 18 boats, 7.6–10.7 m (25–35 feet) long, were potting in the bay; none potted outside the bay. Each boat crew set about 100 pots and landed 15–20 bushels of conchs/day (Braiton[4], Amerighi[28]). Plant workers boiled the conchs for about 30 minutes, removed their meats with ice picks, discarded the viscera and opercula, and packed the meats in 5-pound boxes (Braiton[4]). By the 1980's, two companies, Blount Seafoods and Galilean Seafoods in Warren, processed nearly all the conchs. They pressure-steamed them for an hour, picked out their meats by hand, and then washed and trimmed them. In 1986 they processed about 1.2 million pounds (Haring, 1987).

For many years, Rhode Island fishermen gathered horseshoe crabs for conch bait, but the crabs have since become scarce, perhaps because too many were gathered. Fishermen currently purchase and freeze horseshoe crabs from southern New Jersey, where they are abundant in late April and May (Smith[7]).

In the late 1980's, most boats potting conchs were breaking the meat out of the shells on their boats and selling it for $2–3/pound. A bushel of conchs yields about 15 pounds of meat. Conchs in the shell sold for about $9/bushel (Smith[6]). From the 1960's to 1989, annual Rhode Island landings of conchs have ranged from 4,000–23,000 bushels (NMFS Fishery Statistics Division).

Connecticut

The mid-coast of Connecticut is also a conch fishing area. Data on the number of conch boats was not available, but from 1982 to 1991 the number of state licenses issued to land conchs ranged from 9–43. Some fishermen potted conchs and lobsters during the same season. For the 10-year period, total annual Connecticut landings averaged about 8,000 bushels of conchs with an average annual landed value of $168,000 (Volk[29]).

New York

Gardiners Bay in eastern Long Island is another conch fishing area. In the 1930's and 1940's, about five boat crews potted conchs, but the current number is only 3–4 crews. Each sets about 150 pots in depths of 3–9 m (10–30 feet). The fishermen collect horseshoe crabs used for bait along local beaches every spring and keep them in floating cars, that hold up to 400 crabs each. Through time, the conchs have become smaller. In the early 1990's, each boat crew landed 12–15 bushels of conchs/day (Fox[13]).

[27]Bagnall, P. 1992. Shellfish warden, Town of Edgartown, Mass. Personal commun.

[28]Amerighi, A. 1992. Amerighi Seafoods, Johnston, R.I. Personal commun.

[29]Volk, J., 1992. State of Connecticut, Department of Agriculture, Aquaculture Division, Milford. Personal commun.

Great South Bay also has had a small conch fishery; 2–3 fishermen each set about 100 pots for 6 weeks in the spring. Daily catches have been 10–15 bushels/boat (Klaassen[10]).

The Long Island fishermen shipped most of their conchs to Fulton Fish Market for sale and sold the remainder to local restaurants (Klaassen[10]). Annual New York landings rose steadily to 15,000 bushels in 1986 (NMFS Fishery Statistics Division), but fell afterward to 5,700 bushels in 1990 (Table 3).

The conch fishery in Rhode Island will likely continue, but may be smaller than in the past. The conch fisheries will also likely persist in Massachusetts, Connecticut, and eastern Long Island.

Comparison of Early and Recent Landings

A comparison of mollusk landings in the past with those in 1990 shows that production of oysters, softshells, and bay scallops has declined sharply in the region. The peak of oyster landings was from about 1887 to 1911, when an average of about 4,250,000 bushels/year were produced. In 1990, oyster production was about one-ninth as much, 490,000 bushels (but was higher in succeeding years). Massachusetts' highest landings of softshells were during 1937–42, when they averaged about 520,000 bushels/year, but by 1990 they were about one-fifth as much, 98,000 bushels. Nevertheless, its softshell production nearly equalled that of Maine in 1990. Landings of softshells in Rhode Island and Connecticut have fallen from highs of about 15,000 bushels/year in each state, during 1880 to 1905, to almost nothing, while those in New York have declined from slightly over 200,000 bushels in 1880 to one-seventeenth as much, about 12,000 bushels, in 1990. From 1948 to 1962, combined bay scallop landings in Massachusetts, Rhode Island, and Connecticut averaged about 200,000 bushels/year, but they have since fallen to about one-fifth as much, 42,000 bushels in 1990. New York's landings of bay scallops from 1957 to 1966 averaged about 107,000 bushels/year, but only about 2,000 bushels were landed in 1990 (Table 3).

In contrast, northern quahog landings have increased when compared with the early 1900's, but they have declined recently in Rhode Island and New York. In 1990, total quahog landings in the region were 637,000 bushels. Conchs and especially surfclams and blue mussels, both of which comprised sizable landings, 516,000 and 277,000 bushels, respectively, are relatively new to landings. (Landings of surfclams and blue mussels have declined sharply by the mid-1990's.)

Annual landings of all the region's shellfish at the turn of the century, in 1901 or 1902, when statistics were available, were 3,712,000 bushels. In 1990, such landings were about three-fifths as large, 2,184,500 bushels (Table 3).

Current Number of Mollusk Fishermen

In 1990, the total number of mollusk fishermen active on the region's beds on good days during peak seasons was about 3,350 in summer and 2,336 in fall and winter. Perhaps 50% more people held mollusk fishing licenses, but were not active every day. Rhode Island with about 1,500 active fishermen, nearly all of whom were quahog diggers (Smith[7], Dykstra[8]), had the largest number of any state. Massachusetts was second with nearly 1,200 active fishermen, most of whom were softshell diggers: 400 dug on the north shore of Massachusetts, 150 in Boston harbor (Chadwick and Kennedy[16]), 150 in the vicinity of Chatham (Moore[20]), and the remainder in several other towns. New York was the next largest with about 350 in summer and 540 in fall-winter. Most of New York's fishermen were quahog diggers (Klaassen[10], Strong[11]), followed by bay scallopers (Smith[30]) and softshell diggers (Lester[19]). Connecticut had about 150 fishermen, most of whom were oystermen. In the region, about 2,115 fishermen were engaged in quahoging, followed by about 1,000 in softshelling, 420 in bay scalloping, 220 in oystering, 80 in conching, 55 in musseling, and 36 in surfclamming (Table 5).

Landings from Natural and Hatchery Seed

In 1990, 94% of mollusk landings in the region was from natural seed; 6% was from hatchery-produced seed (Table 3). All softshells, surfclams, blue mussels, and conchs, nearly all bay scallops, and most northern quahogs were produced from natural sets. The oyster is the only species in which substantial landings were from hatchery seed, a total of 20%, and they may decline in the near future because mortalities have occurred in hatchery-reared seed throughout the region. The seed died, apparently from disease, in July and August when 15–25 mm (0.6–1 inch) long. Losses were >80% and 95% at two sites in Massachusetts in 1989, and they also occurred at Fishers Island and Oyster Bay, both in New York, where they ranged from 54–75%, 1989 to 1992 (Bricelj et al., 1992). The hatcheries may have to switch to raising northern quahog seed unless the disease can be controlled.

All northern quahogs produced in Narragansett Bay, Connecticut, and Raritan Bay and >90% of those produced on Long Island were from natural seed. But at

[30]Smith, C. 1993. Cornell University Cooperative Extension, Riverhead, N.Y. Personal commun.

Table 5
Estimated numbers of commercial fishermen actively shellfishing during peak seasons, Massachusetts Bay to Raritan Bay, 1990. Many of the same people are included in summer and fall-winter columns.

Activity	Summer	Fall–Winter	Sources[1]
Oystering			
Massachusetts	25	50	12
Connecticut	50	120	29
New York	25	50	—[2]
Quahoging			
Massachusetts	195	165	15,17,20,21,27
Rhode Island	1,500	400	6,7
Connecticut	20	20	29
Long Island, N.Y.	320	275	10,11
Raritan Bay	80	60	—[3]
Softshelling			
Massachusetts	900	600	15,16,20,27
New York	100	5	19
Surfclamming			
New York	0	36	13
Bay scalloping			
Massachusetts	0	220	20,21,27
New York	0	200	30
Blue musseling			
Massachusetts	55	55	12,20,26
Conching			
Massachusetts	50	50[4]	27
Rhode Island	10	10	6,7
Connecticut	10	10	29
New York	10	10	19
Total	3,350	2,336	

[1] Numbers indicate text footnotes.
[2] D. Relyea, F. M. Flower and Sons, Bayville, N.Y. Personal commun.
[3] D. Barnes, State of New York Department of Environmental Conservation, SUNY, Stony Brook. Personal commun.
[4] This fishery ends in late October.

least 20% of quahog landings in Massachusetts came from hatchery seed (Anonymous, 1992a). Overall, about 6% of quahogs were from hatchery seed in the region. The largest hatchery in Massachusetts, Aquacultural Research Corporation (ARC) in Dennis, sells quahog seed to towns and leaseholders. About 80 leaseholders in Massachusetts, each with from 0.2 to 4 hectares (0.5–10 acres) of leased bottom mostly at wading depths at low tide, plant quahog seed to grow. They purchase two common sizes of seed, 5.3–8.0 mm long which cost $0.022 each, and 12–17 mm long which cost $0.035 each in 1996. Some leaseholders plant 300,000–800,000 seed/year and then cover it with a protective plastic screen with mesh openings of 6–9 mm. The quahogs attain littleneck size in about 28 months, selling for $0.15–$0.20 each. They are dug with bull rakes with handles about 2 m long. Massachusetts leaseholders purchase some quahog seed from a hatchery in New Jersey as ARC cannot meet the demand for seed. Several Massachusetts towns also obtain quahog seed from hatcheries to spread on their public beds (Kruczek[31]).

Enhancing Mollusk Fisheries

Mollusk abundances in the region need to be increased in areas where waters are certified for direct marketing. This would reduce the temptation to poach and market abundant mollusks from polluted waters, a practice that has caused some illnesses. If the public can be assured that all mollusks in markets are safe to eat, demand for them will become stronger. Abundances can undoubtedly be increased in some areas by improving their habitats, through use of hatchery seed, and transplanting natural sets from areas where they cannot survive and from polluted areas to good growing and marketing beds.

Habitat improvement includes predator control, eelgrass planting and thinning, and, in oyster areas, spreading of shells and removal of silt and mud from shells to permit oyster larvae to set. But additional research is needed to determine some specifics of the physical, chemical, and biological features of habitats that control mollusk abundances. Such information would allow managers and politicians to manage bays and estuaries more efficiently to sustain and increase mollusk production.

In recent years, environmental groups have assisted mollusk fisheries by working to prevent or reduce the degradation of bays from pollution, dredging, and filling. But they have also objected to some routine industry practices carried out to increase oyster abundances and landings, even though productive mollusk beds support an abundance of many types of biota. For example, Galtsoff (1964), Arve (1960), and I have observed that beds well stocked with oysters have greater biodiversity than nearby bottoms where oysters are absent. As environments are improved for mollusks, they would also improve for many associated invertebrates and fish. Besides, an active mollusk fishery offers one more justification for preserving aquatic habitats.

Mollusk Marketing and Preparation

Simple Marketing

In the past 50 or more years, mollusk marketing in the region has rarely involved much advertising in newspapers or other types of promotion. Instead it usually has

[31]Kruczek, B. R. 1993. Shellfisherman, Orleans, Mass. Personal commun.

consisted of transporting whole mollusks, mostly in bushel baskets or bags, but more recently in cardboard boxes, from boat docks to dealers who distribute them to retail markets and restaurants. If the shellfish, such as oysters, softshells, bay scallops, and surfclams, have been sold as meats, the shellfish company or dealer has had workers shuck and pack them in cans holding 8 ounces (usually only surfclams) or 1 or 5 gallons for sale to the outlets. Retail markets present the mollusks in chilled showcases with a price tag on them.

Oysters

From the 1600's to the early 1900's, oysters were an important protein food for people in coastal communities. They were eaten in a variety of ways, the most common being in stews, casseroles, fried, and raw on the half-shell. Many types of dishes were prepared as described in recipe books.

During the 1800's, dealers in New York City imported large quantities of oysters from Chesapeake Bay, with smaller amounts from northern areas for local sales. This began in the early 1800's, and, by 1853, perhaps as many as 1,000 vessels supplied Chesapeake Bay oysters and 520 vessels supplied northern oysters to New York City. In that year, the oyster quantities handled by the estimated 5,000 retailers in the city were about 1,000,000 bushels in the shell and 600,000 gallons of meats from southern bays, mainly Chesapeake Bay, and 1,600,000 bushels from northern bays, with a total value of $2,760,000 (Ingersoll, 1881).

After development of refrigerated railroad cars in the 1880's and 1890's, dealers in New York City shipped large quantities of oysters to markets in the midwest and far west. Although the railroads opened new markets for oysters, they eventually weakened the oyster industry because the refrigerated cars also enabled the growing meat industry to ship beef and pork from such centers as Chicago and Kansas City to the east coast (Walsh, 1982). With meat available in large quantities, people began to consume more meat and fewer oysters, especially after 1906, when newspapers began reporting that oysters were sometimes unsafe to eat owing to sanitation problems. In the early 1900's, New York City was importing about 1,500,000 bushels of oysters each season. About two-thirds were shipped out of the city and the remainder were eaten by its residents (Fig. 20), an equivalent of two meals of oysters/week for every man, woman, and child in the city (*New York Times*, 1907).

Beginning in about 1870, from 150,000 to 310,000 bushels of oysters/year were shipped to Europe from Connecticut, Great South Bay, and Raritan Bay, with about 95% going to England. The oysters that found favor in England were relatively small and received the trade name "London stock" (Ingersoll, 1881). Some oysters were planted on English beds as the quantity arriving from the U.S. often exceeded the demand. Atlantic oyster drills and Atlantic slippersnails were carried with the oysters and introduced to the English beds, where they became pests. Oyster shipments to England continued into the 1930's (Kochiss, 1974).

From the mid to late 1800's through the 1920's, companies shipped their salable oysters from ports in Narragansett Bay, Connecticut, and Long Island to U.S. markets. The American Railroad Express was the principal company transporting oysters by rail and it was almost as efficient as trucking is currently. The oyster companies carried oysters from their packing houses to the railroad freightyards, initially by horse and wagon and later by truck. Since the 1920's and 1930's, trucks have been delivering oysters to markets (Usinger[1]). In the 1800's and early 1900's, oysters from Raritan Bay were taken to New York City by boat.

A relatively small number of restaurants in New York City currently serve oysters and northern quahogs. At least one, the Oyster Bar and Restaurant[3] in Grand Central Station, serves oysters on the half-shell from about 12 sources on the east and west coasts of North America, besides northern quahogs on the half-shell, stews of oysters, quahogs, and mussels, and steamed mussels. The restaurant serves about 6,500 bushels of oysters on the half-shell each year (Anonymous, 1992b).

The oyster market is strongest during the Thanksgiving and Christmas holidays, when many families use them as an ingredient in stuffing for their turkeys. Otherwise oysters are usually eaten fried, in stews, or on the half-shell.

Oysters are currently being sold year-round, whereas in past decades the main marketing seasons were fall and winter. Companies have also been selling some unshucked oysters by the piece, a major shift from selling them by the bushel. One Connecticut company sells them for $29/100 oysters.

Northern Quahogs

Quahogs were important in the diets of coastal peoples, somewhat like oysters once were, but supplies were less than one-tenth as large as oysters in the 1800's and early 1900's. Most quahogs have been dug in summer. Those dug in winter, especially the largest, have been eaten in chowders. In the New England States, the ingredients of chowders are milk, potatoes, onions, and minced quahogs (New England clam chowder), while in New York State they are water, tomato paste, celery, onions, potatoes, carrots, and minced quahogs (Manhattan clam chowder).

In the late 1870's, about 100 sailing freight boats transported northern quahogs to New York City in sum-

Figure 20
Oyster stands in the Fulton Fish Market, Manhattan, New York City, where oysters were prepared several ways for eating, including on the half-shell (left) and fried (right), ca. 1870. Illustration from *Harper's Weekly*, October 29, 1870, courtesy of the South Street Seaport Museum, New York, N.Y.

mer; they brought oysters to the city in the fall and winter. Nearly all the quahogs came from Long Island, Raritan Bay, and Barnegat Bay. Including the diggers and the retailers and hawkers in the city, 8,000 people worked in this quahog trade during a large part of the year (Ingersoll, 1887). The transport of some quahogs by boat to the city continued into the 1930's; since then, trucks have delivered the quahogs (MacKenzie, 1990, 1992a).

Littlenecks currently are, by far, the most common size of quahogs available. They are purchased in fish and grocery markets and eaten on the half-shell in seafood snack bars, restaurants, and private homes. Like oysters, northern quahogs are now selling by the piece, rather than by the bushel. Wholesalers pay fishermen $0.12–0.20 for each littleneck; in markets they sell for about $0.36 each.

Softshells

In the late 1870's, New York City markets also received whole and shucked softshells, chiefly from Long Island and Raritan Bay. In the spring, particularly, the region around Fulton Fish Market was crowded with street vendors who sold northern quahogs and softshells from baskets and wheelbarrows (Ingersoll, 1887). No record exists of when the street-peddling of the two species of clams began or ended (Brouwer[32]), but it was practiced as late as the 1930's (MacKenzie, 1992a).

Since the late 1800's, Massachusetts has been a large market for softshells, and currently the state is, by far, the largest market in the region for them. Nearly all softshells landed in Massachusetts and Maine and substantial quantities imported from eastern Canada and Maryland are eaten by residents and visitors in Massachusetts (Chadwick and Kennedy[16]). The softshells shucked in fish houses along the north shore of the state and in Seabrook, N.H., have been sold to Massachusetts clam stands at resort beaches that feature fried clams in summer, and to the state's many restaurants that serve fried clams by themselves or with steaks year-

[32]Brouwer, N. 1993. Historian, South Street Seaport Museum, N.Y. Personal commun.

round. Restaurants and especially clam stands often display large signs advertising fried clams for sale.

In other areas of the region, people have eaten softshells in a variety of forms: fried, in pies, and as fritters in their homes, and steamed and served with their broth especially in restaurants and saloons.

Scallops, Surfclams, Mussels, and Conchs

Bay scallop meats have been sold in fish and grocery markets. Restaurants usually serve them fried, while at home they are usually served fried but sometimes in casseroles and stews. The diced and minced meat of surfclams is marketed mostly in 8-ounce cans throughout the northeastern states. Most is served with tomato sauce on spaghetti. Whole blue mussels are frequently boiled in water and their meats are eaten as is, but also in tomato sauces with pasta. Mussels are available in restaurants, and fresh, frozen in prepared pasta dishes, as frozen meats, and smoked in jars in markets. Most conch meat in Rhode Island has been made into snail salad (a mixture of thin slices of conch meat marinated in onions, garlic, vinegar, and lemon juice) for sale in local delicatessens and grocery stores. The remainder is cut into chunks and served as scungilli in pasta dishes or made into fritters. In recent years, Americans of Chinese descent use conchs by cracking live ones, tenderizing them, slicing them thinly, and covering them with brown sauce (Drumm, 1993).

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History and Present Status of Molluscan Shellfisheries From Barnegat Bay to Delaware Bay*

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ABSTRACT

The mollusks produced in this region have included the eastern oyster, *Crassostrea virginica*; northern quahog, *Mercenaria mercenaria*; and bay scallop, *Argopecten irradians*. The practice of planting seed oysters in Barnegat Bay began as early as the 1830's. By 1881, about 1,000 men on 675 vessels were harvesting 330,000 bushels of oysters from the bay. In the early 1900's, the region from Barnegat Bay to Cape May produced 20% of all market oysters in New Jersey, but by 1930 the harvest had declined to 5% of the total. The oyster industry has been concentrated in Delaware Bay with the New Jersey shore producing about four times as many oysters as the Delaware shore. The growth of Philadelphia, the region's largest city, probably fostered the beginning of commercial oyster harvests. Oysters initially were transported directly to Philadelphia by the same boats that harvested them, but later, most of the harvest was transported by train to Philadelphia and other markets. The oyster grounds eventually were divided into up-bay seed grounds maintained by the states of New Jersey and Delaware, and lower bay leased grounds planted with seed from the up-bay grounds. From 1880 to 1930, production of market oysters ranged between 1 and 2 million bushels annually, and between 1930 and 1957 it was fairly steady at 1 million bushels a year. In 1957, the oysters were hit with MSX disease, and by 1959, 90–95% of those on leases had died. The industry recovered somewhat afterward, but in 1990 *Perkinsus marinus* (Dermo) killed many oysters, and the industry faces an uncertain future. Northern quahogs occur in the coastal bays of New Jersey and in lower Delaware Bay. In 1880, 241,000 bushels were harvested. Since 1970, many quahogs have been relayed from polluted grounds to leases in the state. Beginning in the 1970's, hatcheries have been producing seed clams. Their estimated contribution to total harvests is between 15% and 45%. Small quantities of bay scallops once occurred in Barnegat Bay. From 1956 to 1968, scallop harvests ranged from 4,000 to 376,000 pounds of meats, but since then, scallops have been scarce.

Introduction

The shellfish-growing waters from Barnegat Bay along the Atlantic coast of southern New Jersey into Delaware Bay (Fig. 1) support two commercially important molluscan species. Eastern oysters, *Crassostrea virginica*, extend into the less saline creeks and up estuary about 80 km (50 miles) in Delaware Bay, and northern quahogs, *Mercenaria mercenaria* (known locally as hard clams), grow in the higher salinity waters of the region. A third species, the bay scallop, *Argopecten irradians*, inhabits eelgrass beds of the coastal bays, but commercially important sets occur only sporadically.

Ancient kitchen middens attest to the use of these resources by early Native Americans when they settled in the area several thousand years ago (Weslager, 1944, 1972). Tribes migrated from inland villages to the shore during the summer to gather shellfish, which they consumed on site or smoked and stored for winter use. When Europeans first explored, and later settled in, the Delaware Valley, they were amazed by the abundance and size of oysters and quahogs that they found (Ingersoll, 1881).

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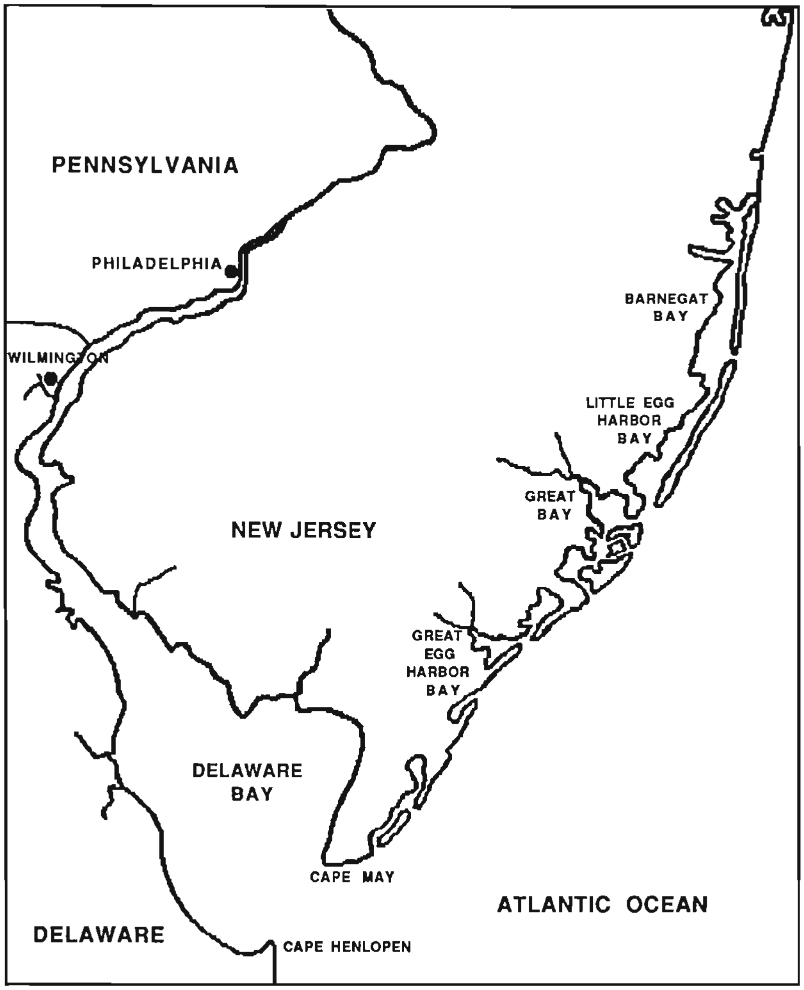

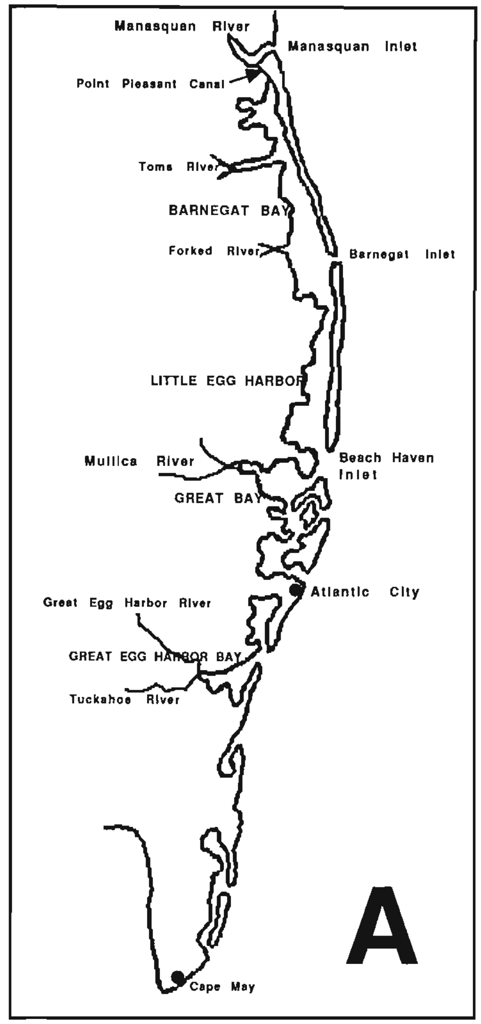

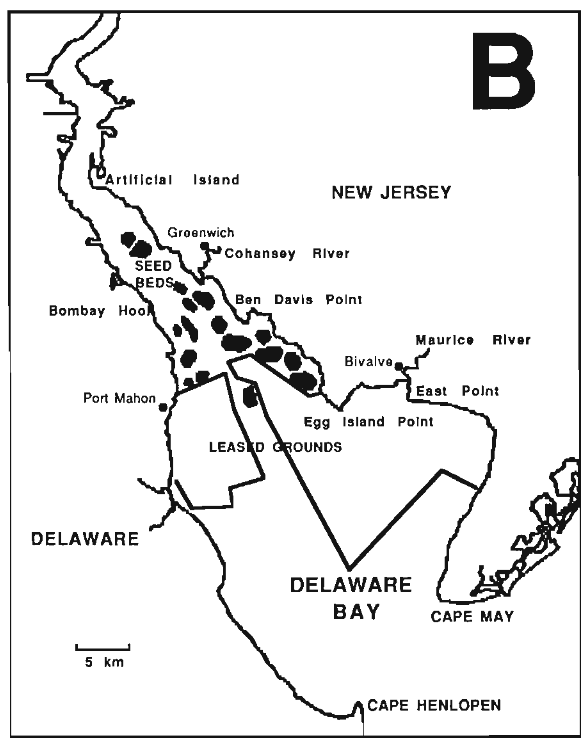

Figure 1
The southern New Jersey shellfish-growing areas with enlargements of the Atlantic coastal estuaries (A) and Delaware Bay (B). Shaded areas in Delaware Bay represent natural seed beds.

The first permanent European settlements in the region, established in the middle 1600's, were near the present cities of Wilmington, Del., and Camden, N.J. Later colonists moved eastward along both shores of Delaware Bay and to the Atlantic coast during the remainder of 17th century and into the 18th century (Weslager, 1967).

Settlers living near the shore initially collected shellfish for their own consumption. Commercial harvesting arose as the growing towns and cities created markets for large quantities of shellfish. Oyster and quahog harvesting accelerated with the expansion of population centers around Wilmington, Philadelphia, and New York, and eventually grew into one of the most potent and influential market forces in the region. Overharvesting and disease have since greatly reduced oyster harvests, whereas the value of the quahog industry remains at a near historic high.

Physical Description of Shellfish Growing Areas

Beginning 50 km (about 30 miles) below New York Harbor, a series of small shallow bays extends for 140 km (85 miles) along the coast of New Jersey, from Barnegat Bay to Cape May Harbor (Fig. 1). Barrier islands broached by occasional inlets separate the bays from the Atlantic Ocean. Inland, they are bordered by extensive saltwater marshes through which small rivers and creeks introduce fresh water.

Barnegat Bay, with its southern extension, Little Egg Harbor, is a narrow lagoon-type estuary about 60 km (37 miles) long, 2–6.5 km (1.2–3.5 miles) wide, and 1–6 m (3–18 ft) deep, lying on a north-south axis (Chizmadia et al., 1984). Salt water enters at the head of the bay through the Point Pleasant Canal from the Manasquan Inlet, at Barnegat Inlet on the east, and through Beach Haven Inlet at the south (Fig. 1A). Freshwater from surface runoff in the Pine Barrens flows in through multiple creeks and rivers, as well as through ground water seepage. Salinity ranges from 12–32‰, with a mean of about 25‰ in the center of the bay. Eelgrass, *Zostera marina*, is the primary benthic macroflora and provides important nursery areas (Chizmadia et al., 1984).

To the south lie two smaller estuaries, Great Bay and Great Egg Harbor Bay (Fig. 1A). In contrast to Barnegat Bay, these lie on east-west axes, are fed by one or two relatively large rivers, and have a single, major opening to the ocean. Along each bay axis is a salt gradient from brackish to near ocean salinity. Each is about 10–11 km by 5–6 km (6 × 3.5 miles) with depths of 1–5 m (3–15 ft). Interspersed among these larger estuaries are shallow, high-salinity lagoons surrounded by salt marsh. Ocean inlets provide saltwater, but the lagoons have little freshwater input and no clear salinity gradient.

West of Cape May lies Delaware Bay, a funnel-shaped estuary covering nearly 2,000 km^2 (750 $miles^2$), bounded on the north by New Jersey and on the south by Delaware (Fig. 1B). Nearly 60% of the gauged fresh water inflow is from the Delaware River (measured at Trenton, N.J.), and the total drainage area for the estuary covers 35,000 km^2 (13,500 $miles^2$) in Delaware, Pennsylvania, New York, and New Jersey. The estuary joins the Atlantic Ocean over a distance of 19 km (12 miles) between Cape May and Cape Henlopen. From the capes, where salinity is 30–31‰, salt content decreases regularly to 0–4‰ at the port of Wilmington.

Delaware Bay is relatively shallow, with an average depth of 5–8 m (15–25 ft), a tidal range of 1.3–1.7 m (4–5 ft), and prevailing winds (northwest in winter and southwest in summer) approximately along its major axis. These factors contribute to high turbidity and prevent the growth of aquatic vegetation such as eelgrass and macroalgae that are common in the coastal lagoons.

Mean water temperatures in the region range from −1.8 to 28°C, with the higher temperatures occurring in the shallower estuaries, such as Barnegat Bay, which also warm faster in the spring and cool more rapidly in autumn than do the deeper bays. Intertidal areas frequently have water temperatures well above 30°C.

Shellfisheries Before 1880

Although few reliable harvest records exist before 1880, the importance of molluscan shellfish to the region's economy can be traced in legislation designed to protect and enhance the resource. The newly established colony of New Jersey passed legislation in 1719 that prohibited residents from taking oysters during the summer spawning season and barred nonresidents entirely (Ingersoll, 1881). Later, in 1775, a second law prohibited

> "a Practice [that] hath prevailed of raking and gathering great Quantities of Oysters with Intent to burn the same for Lime only, whereby great Waste is made, and the Oyster Beds thereby in danger of being entirely destroyed."

In 1846 the state passed much broader legislation entitled "An Act for the preservation of clams and oysters." The law not only protected the natural resource by reiterating the earlier legislation, but it encouraged cultivation of the shellfish by legalizing and protecting the planting of seed oysters in creeks, ditches, and ponds (Bacon, 1903).

The State of Delaware began enacting oyster laws in 1812, when it restricted harvesting to residents of the state (Miller, 1962). Additional legislation in the 1830's sought to conserve the resource by limiting harvests and outlawing oystering during the summer.

By the late 1870's, when Federal and state governments began keeping records, commercial harvesting of both quahogs and oysters was already well developed along the Atlantic coast of southern New Jersey and in Delaware Bay. Within 14 years, from 1879 to 1893, at least four different surveys were made of the resource.

The first was by Ernest Ingersoll, a young journalist/scientist who visited all oyster-growing regions of the United States and Canada and reported on their condition for the 10th Census of the United States (Ingersoll, 1881). He also obtained information on mussels, quahogs, and scallops, which was published later (Ingersoll, 1887). Samuel Lockwood (1882) surveyed the New Jersey oyster interests for the State's Bureau of Labor and Industry in 1882. Six years later, Julius Nelson (1889), a newly hired biologist at the New Jersey College of Agriculture reported on the status of both quahogs and oysters in New Jersey. The final work (Hall, 1894) was a comprehensive report on the state's oyster industry, produced for the U.S. Commission on Fish and Fisheries by Ansley Hall.

Although the reports varied in scope from the largely "best guess" estimates of Nelson to the meticulously detailed descriptions and statistics of Hall, similar conclusions were reached: 1) oysters were an extremely valuable product in the economies of New Jersey and Delaware, as well as the city of Philadelphia; 2) quahogs were considerably less important, being somewhat of an "appendage of the oyster trade" (Ingersoll, 1887); 3) the ever-growing oyster industry had already severely depleted natural beds; and 4) the supply of both quahogs and oysters could be much increased by better husbandry of the resource and a greater reliance on cultivation rather than wild harvest.

Data Sources

Federal landings records for eastern oysters and northern quahogs, collected under the U.S. Departments of Interior and Commerce, are intermittent from 1880 to 1929, after which they become regular (Lyles, 1969; NMFS, 1990). For the most part, the figures are derived from reports of fishermen, dealers, and processors, and can be considered minimal. Exceptions are records of seedbed harvests in New Jersey after 1955, which were obtained by the Oyster (now Haskin Shellfish) Research Laboratory at Rutgers University and the New Jersey Bureau of Shellfisheries, through direct observation of deck loads. Also, Delaware records both seed and market catches by censusing vessel deck loads.

Both Delaware and New Jersey have kept careful records of license and lease revenues, including numbers and sizes of vessels and acreages leased. For consistency in this review, landings figures reported in pounds have been converted to bushels using the following factors obtained from landings records: Northern quahogs—8 pounds/bushel until 1908, 9 from 1921 through 1932, and 10 after 1933; eastern oysters—7.5 pounds/bushel from 1880 to 1929, 8.5–9 in the early 1930's, 6–7 in the 1940's and 1950's, 8 in the early 1960's, and 6 after 1964; bay scallops—6 pounds/bushel.

New Jersey Oyster Biologists

Julius Nelson was a recent graduate of Johns Hopkins University, Baltimore, Md., when he was hired in 1880 as the biologist at the newly established New Jersey Agricultural Experiment Station (Fig. 2). As a former student of the renowned oyster biologist William K. Brooks, Nelson maintained a keen interest in oyster biology, even though his responsibilities included research on all farmed animals. He argued that the planting of seed oysters was a form of agriculture and established the Department of Oyster Culture at Rutgers University in 1888.

Nelson was succeeded by his son, Thurlow Nelson, and eventually by Harold Haskin, a student of the younger Nelson. Together they spanned a nearly 100-year tradition of oyster research in the state. In 1991, the Department of Oyster Culture was merged with the Department of Marine and Coastal Sciences at Rutgers, which still maintains a shellfish research program.

Barnegat Bay to Cape May Oyster Fishery

The Peak Years 1880 to 1925

In 1880 the Barnegat Bay oyster beds extended from the southern end of the bay approximately 16 km (10 miles) northward to the mouth of Forked River. They were a source of seed oysters for planting in the small embayments to the south along the Jersey coast, to the north in Raritan Bay, around Staten Island, and on the south shore of Long Island (Ingersoll, 1881). By then, the beds were already suffering from overharvesting. New Jersey had included a "rough cull" measure in its 1846 legislation, which mandated the separation of shells from oysters aboard ship and their immediate return to the beds as cultch for the attachment of oyster larvae. But, as Ingersoll (1881) lamented, the law was neither obeyed nor enforced, the beds had greatly deteriorated, and seed shipments were declining.

Beds at the mouth of the Mullica River, called the "gravellings" (now Graveling Bed), and those in the Great Egg Harbor and Tuckahoe Rivers also provided seed, mostly to small planters along the coast. When Ingersoll visited them in 1879–80, there appeared to be no lessening in the available quantity "despite great

Figure 2
Dr. Julius Nelson, first director of the New Jersey Oyster Research Laboratory of Rutgers University, at his laboratory at Barnegat, N.J. (ca. 1906). Source: Nelson, J. 1907. Report of the Biological Department, New Jersey Agricultural College Experiment Station for the year 1906. New Brunswick.

amounts removed each year." Within a dozen years, however, Hall (1894) noted that many of those beds were exhausted.

Oyster planting began in Barnegat Bay as early as the 1830's, not long after it started around New York City (Ingersoll, 1881), and it was still employing about 300 persons during 1889–93 (Hall, 1894). It was not entirely successful, however, as planters were resented by men who continued to catch wild seed and considered the planters to have usurped good natural beds for their own use. Poaching was common and diminished enthusiasm for purchasing and planting seed oysters. Also, there was growing competition from quahogers for bay bottom on which both quahogs and oysters would grow (Nelson, 1889).

At the time of the Ingersoll (1881) survey, the Atlantic shore of New Jersey had already become a popular summer retreat, with centers in Atlantic City and Cape May. An oyster growout industry, which developed in the small lagoons near these resort cities, supported hundreds of small planters (Ingersoll, 1881; Hall, 1894).

Seed oysters came from Barnegat and Great Bays, as well as from Chesapeake Bay, and were frequently large enough to be planted in the spring and harvested a few months later for sale in the resort hotels. Not all the oysters were sold locally, however. The same rail lines that brought tourists from Philadelphia to Atlantic City carried oysters in the opposite direction. In 1879–80, about 125,000 bushels were shipped through Pleasantville, just inland from Atlantic City.

Ingersoll (1881), who provided the first solid figures on the industry, estimated that in 1879–80 1,000 tongers were employed in oystering along the Atlantic coast of southern New Jersey. A total of 675 vessels, mostly under 5 tons, harvested 330,000 bushels (about one-fourth of it grown from Chesapeake seed), which represented 11% of the total state production and was worth about $310,000.

Between 1902 and 1905, the state of New Jersey assumed control of most of the oyster industry along the Atlantic coast, and subsequent reports of the New Jersey Bureau of Shellfisheries make frequent note of conflicts between quahogers and oystermen, and between oystermen who wanted all areas open to public harvest and planters who wanted to lease acreage for private cultivation.

Most oystermen operated from small boats because tonging was the only legal harvest method. Seed oysters were in chronic short supply and the cost of importing seed from the Chesapeake and Long Island Sound was prohibitively high for most of the small planters (New Jersey Bureau of Shellfisheries, 1912).

Small-scale oystermen had another problem during the first decade of the century, in that several large grants to underwater lands containing natural oyster beds were sold by the State Riparian Commission (McCay, In press). Private ownership of rich seed areas by a few wealthy individuals threatened to displace hundreds of oystermen who had made their living tonging on what the state legislature itself had deemed public oystering grounds. Scandal and conflict of interest cloaked the riparian purchases and incensed the local baymen. The situation came to a head in 1907 in a violent clash between hundreds of tongers and guards hired by the Sooy Oyster Company, which claimed a riparian grant on the Mullica River seed beds (New Jersey Bureau of Shellfisheries, 1908).

The ensuing legal battles exposed more questionable official conduct: critical testimony as to whether the riparian grants were on natural oyster grounds was not allowed, nor was testimony permitted that the state, to enhance the public resource, had allocated funds for the planting of shell cultch on the disputed lands. In the end, the riparian claims were upheld, although in 1906 the state legislature ordered that no new grants be made in shellfish grounds (McCay, In press). A physical legacy of the Sooy riparian grant in the Mullica is a series of ditches dug across narrow "necks" of marshland at bends in the river[1]. The company planted shells and oysters in the ditches, in an apparent attempt to create oyster bottom from the "high ground" portion of their grant.

The Demise of Oystering in Barnegat Bay After 1925

At the peak of the New Jersey oyster industry, from about 1870 to 1930, the Barnegat Bay-Cape May area produced about 20% of all market oysters harvested in the state. By 1930 this figure was less than 10%. Overfishing of relatively small natural beds, already taking a toll 50 years earlier, was an important reason for the decline. Change in the salinity regime was another factor. In 1919, a major Atlantic storm drastically altered Beach Haven Inlet (see Fig. 1A), increasing salinity in Little Egg Harbor and giving an advantage to oyster predators. The oysters died, but were replaced by quahogs that flourished in the saltier waters (Nelson, 1960).

For a decade after 1925, a series of set failures dealt a major blow to the oyster industry in Barnegat Bay. In annual reports of the New Jersey Agricultural Experiment Station, Thurlow Nelson (1929, 1930, 1933, 1934) chronicled the problem: good broods of larvae were produced but did not survive beyond the early setting stage. By 1929, he had formulated an explanation: oystermen harvested the fastest growing oysters and threw back the stunted ones. It was the latter, he believed, that were now producing the "defective" progeny, a process he called the "selection of the unfit" (Nelson, 1930).

Nelson (1933) apparently abandoned this hypothesis several years later, when he concluded that a major cause of the problem was the Point Pleasant Canal, completed in 1925, which introduced salt water into the head of the Bay, altered circulation patterns, and fostered the spread of predators. By the 1950's, Barnegat Bay was producing only a few thousand bushels of oysters a year, and since then landings have been insignificant.

Current Status of Oystering on the Atlantic Coast of Southern New Jersey

For the last half century, oystering on the New Jersey coast has centered in Great Bay. Fueled by the small (150 acres (McCloy and Joseph, 1985)), but productive Mullica River seed beds, the region supported 60–70 planters and tongers as late as 1990[2]. Most of the river's seed catching area is leased by planters with grounds in Great Bay.

At one time, the state transplanted seed oysters from the public beds in the Mullica to tonger's beds in Great Bay, but this practice was discontinued in 1982 for lack of funds. Oyster diseases, both MSX and Dermo, have limited oyster production on the coast, as they have in Delaware Bay. Because of recent heavy losses to Dermo desease, most growers have left the fishery and there are currently only two active planters left.

Barnegat Bay to Cape May Northern Quahog Fishery

History From 1880 to 1930

Quahogs are scattered over most of the bottom in the coastal bays of New Jersey where salinities of 25–32‰ are high enough to support them (Kennish et al., 1984; McCloy and Joseph, 1985; Joseph, 1989). Although a fishery for quahogs has probably existed along the coast as long as there has been an oyster fishery, it did not command the same attention, nor did it produce comparable revenue, until about 1930.

[1] Maxwell, D. 1993. Leeds Point, N.J. Personal commun.

[2] Joseph, J. 1997. New Jersey Bureau of Shellfisheries, Leeds Point, N.J. Personal commun.

As he did for the oyster, Ernest Ingersoll (1887) provided the first published estimates of quahog production in New Jersey. He calculated that 241,000 bushels were harvested from Barnegat to Cape May in 1880. Most of the quahogs came from just inside Barnegat Inlet, where diggers sold their harvests to boats that came down the coast from New York. Some of the quahogs were salted and pickled for shipment to Europe or to the western United States.

Eight years later, Julius Nelson (1889) estimated the total state production at 333,000 bushels, about one-third of which came from the southern coast. He also noted that there was intense competition between quahogers and oystermen for bay bottom, and that the quahogers were winning. Annual reports of the New Jersey State Oyster Commission and the Bureau of Shellfisheries from 1899 to 1921 describe the oyster industry in glowing terms, but make few references to quahogs. The latter often reflect the frustration of state officials at the refusal of quahogers to support or obey conservation measures or to attempt planting and cultivating seed quahogs.

Rise of Quahoging After 1930

Northern quahog landings for New Jersey declined after reaching a peak of nearly 600,000 bushels around 1900 (Fig. 3). A resurgence of quahoging occurred in the 1930's during the Depression, and the total value of quahog landings approached that of oysters, which declined at the same time. Men were attracted to quahoging, despite a drop in prices, because it required little or no capital investment.

Meat shortages during and after World War II increased the demand for quahog products (Ritchie, 1977) and stimulated a boom in harvests that lasted into the mid 1950's. The proportion of state landings taken from southern New Jersey coastal areas gradually increased as northern beds were exhausted or closed by pollution: 30% in 1888, 40% in 1901, 70% in the early 1930's, and nearly 100% between 1960 and 1990. Relaying of quahogs from condemned northern areas to southern waters, however, contributed a substantial fraction of this harvest after 1983 (see below). It is difficult to break down recent landings data, but the fraction of clams coming from Barnegat Bay south has decreased since 1990 as larger numbers of clams from northern estuaries are depurated rather than relayed south.

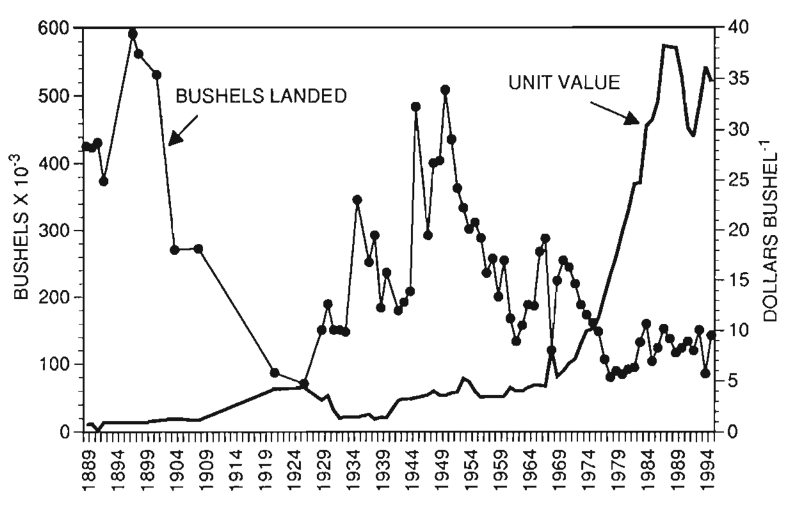

Figure 3
Reported landings of Atlantic quahogs in New Jersey. The proportion coming from Barnegat Bay south was 30% in 1888, 40% in 1901, 70% in the early 1930's, and was nearly 100% between 1960 and 1990.

Surfclams and Pollution Reduce Landings

Many of the quahogs harvested during the 1930's and 1940's were large "chowder" quahogs sold to canning companies. By the late 1950's, however, surfclams, *Spisula solidissima*, were being harvested in increasing numbers from offshore beds (Lyles, 1969). They were cheaper than chowder quahogs, more consistently available, and eventually replaced them in the processed clam market (i.e., clam strips and chowder).

The second important event leading to decreased quahog harvests was pollution. New Jersey is the most densely populated state among the United States and borders New York City, largest in the country. Resorts and year-round developments crowd the Atlantic shore. It is not surprising, therefore, that pollution has affected the state's shellfisheries in those areas.

In the late 19th century, public health officials were already expressing concern that eating shellfish from contaminated waters could be a health risk (Kochiss, 1974), and by 1917 some waters near Atlantic City were closed to shellfishing (Cumming, 1917). More closures occurred in 1924–25, and additional areas were added in the 1930's. However, it was not until the early 1960's, after several cases of infectious hepatitis were traced to the consumption of raw quahogs from Raritan Bay, that large-scale closures of productive quahog grounds began to adversely affect landings (Swanson, 1989; MacKenzie, 1997).

Industry Changes After 1970

The large quantity of quahogs in closed areas was no longer available to the fishery, but it still represented a potentially valuable resource. To utilize it, the state instituted a relay program in 1970. Under supervision of shellfisheries officials, quahogers are allowed to harvest quahogs from contaminated areas and replant them on private grounds in approved areas. The quahogs are marketed after they have been in the clean water at least 30 days while the temperature is above 10°C. Until 1983, transplants were made from southern bays, particularly those behind Atlantic City, into Great Bay[3]. Thereafter, most of the relayed quahogs were moved from northern estuaries, especially Raritan Bay, into Barnegat Bay. As of 1989, 2–30% (mean, 13%) of reported landings were attributed to relay (McCloy and Joseph, 1985; Joseph, 1989). Two depuration plants, newly operating in the state, are processing an increasing share of the quahogs marketed since 1990. Combined relayed and depurated clams now represent about half of the reported quahog landings.

Since the mid-1970's, New Jersey has made a concerted effort to clean up its coastal waters. Recent restrictions on sewage discharge and coastal development, and a decision to shift sewage treatment plant outfalls from the small back bays into the ocean have had promising results. Since 1980, 22,500 acres of formerly condemned waters in the state's southern coastal bays, where the most dense hard quahog populations exist (Joseph, 1989), have been approved for direct harvest of shellfish, and more are added each year[4].

Another substantial change in the industry has been the use of hatchery-produced seed quahogs. A few individuals began experimenting with hatchery techniques in the early 1970's, but their efforts formed only a small proportion of the total harvest until the 1980's. Although accurate figures are difficult to obtain, it is estimated that half of the harvest is now based on hatchery seed[5].

In contrast to oysters, which set and survive predictably in certain areas, quahog setting and survival is highly variable both spatially and temporally[6]. Quahogers follow successful wild sets from one bay to another or from one site within a bay to another, and may harvest from it for as long as 5 years. In recent years, improved water quality has drawn quahogers into bays that were formerly closed to the taking of shellfish and where large populations had developed in the absence of harvesting.

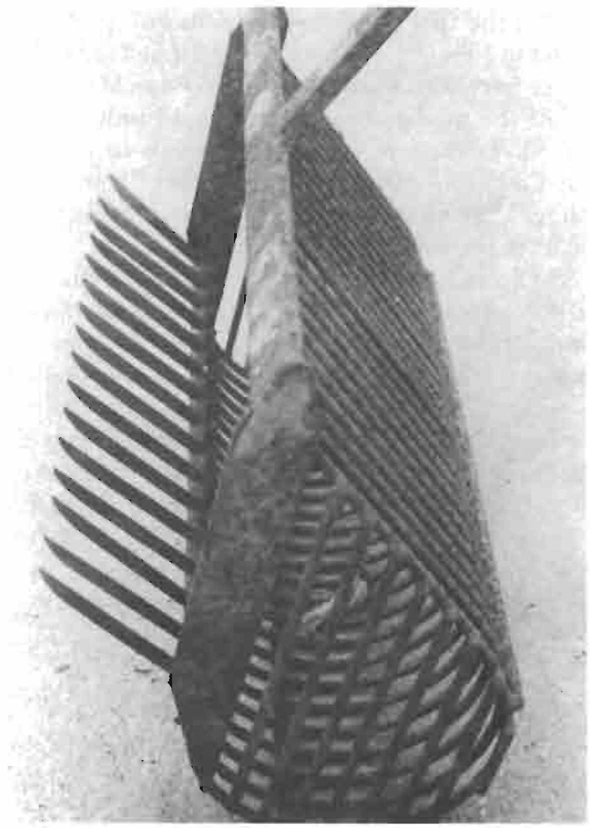

Figure 4
Bull rake, used for Atlantic quahog gathering, showing basket and tooth bar. Photograph by S. E. Ford.

In 1996, 1,354 fishermen were licensed to harvest quahogs commercially in New Jersey, about 20% of them full time; another 7,558 were licensed in the recreational fishery. Although full-time commercial quahogers have comprised only about 3% of license holders during the past decade, they have caught 80% of all quahogs harvested.[7]

Most quahogers use "bull rakes," which have a tooth bar about 50 cm (20 in) wide behind which is a small wire basket (Fig. 4). The rake is jerked through the sediment and the quahogs collect in its basket (Fig. 5). Treading, a process whereby the quahoger, walking in shallow water, feels and extracts quahogs from the sediments with his feet, is popular with older fishermen. Tonging is also practiced, but less so than the other methods[8].

[3] Joseph, J. 1997. New Jersey Bureau of Shellfisheries, Leeds Point, N.J. Personal commun.

[4] Connell, R. 1997. New Jersey Bureau of Marine Water Classification and Analysis, Leeds Point, N.J. Personal commun.

[5] Canzonier, W. J. 1997. Aquarius Associates, Manasquan, N.J. Personal commun.

[6] Fegley, S. R. 1992. Haskin Shellfish Research Laboratory, Port Norris, N.J. Personal commun.

[7] Joseph, J. New Jersey Bureau of Shellfisheries, Leeds Point, N.J. Personal commun.

Minimum legal size is 36 mm (1.5 inches) (greatest dimension), although there is pressure to reduce this to 24 mm (1 inch) for hatchery-produced quahogs.

Commercial quahogers have no restriction on the number of quahogs they can catch or the season in which they can harvest (except when quahogs are in waters seasonally restricted because of pollution). The average daily catch for full-time quahogers in 1990 was about 900 quahogs[9]. Recreational quahogers are permitted to catch up to 150 quahogs per day for personal use. The average number of commercial quahogers typically working in the coastal bays of New Jersey on a given day in autumn and spring is about 45. This figure rises to about 130 in summer when part-time quahogers are more numerous[8].

Figure 5
Bull raking from small boat. The handle shaft of a bull rake is typically 3–8 m (10–18 ft) long, depending on water depth. Use of the bull rake is restricted to water less than 2.5–3 m (8–10 ft) deep. Photograph by S. R. Fegley, Maine Maritime Academy.

The long-term outlook for the quahog industry in New Jersey is good. Prices rose dramatically from 1970 to 1990, and although they were depressed during a brief recession in the early 1990's, they had rebounded by 1994 (Fig. 3). The opening of formerly restricted waters and the increased use of cultured seed provide needed stability for maintaining the markets.

A major impediment to sustained growth is the lack of a clear state policy to support aquaculture[10]. Harvesters of wild quahogs do not wish public areas to be leased for private culture, which limits the expansion of quahog culture because these areas contain some of the best growing grounds. This conflict may be resolved as increasing numbers of quahogers use cultured seed, rather than wild harvests, to satisfy the market for small quahogs ("necks") that have the highest unit value and are generally served raw or steamed; larger quahogs are used for stews and chowders. The newly passed (1997) Aquaculture Development Act offers the potential for change, however. It assigns to the New Jersey Department of Agriculture responsibility for developing policies and regulations to foster all aquaculture in the state. One outcome might be the setting aside of special areas for aquaculture operations only.

Barnegat Bay to Cape May Bay Scallop Fishery

Bay scallops, *Argopecten irradians*, were probably harvested intermittently and in small quantities from the coastal bays during the 19th century. Ingersoll (1887) named New Jersey in his survey of states with scallop landings, but lumped figures with states to the south. The annual report of the New Jersey Bureau of Shellfisheries (1919) discussed the potential for starting a scallop fishery in the eelgrass beds along the coast, and scallops had already been purchased and planted. If successful, the test would be continued by importing more scallops as broodstock. Apparently, the experiment did not work as scallops were not mentioned in subsequent reports. No available records show bay scallop landings in southern New Jersey until 1956, when 52,300 bushels, valued at $287,000 were harvested. Good scallop setting continued for the next dozen years, with watermen who ordinarily caught quahogs and crabs participating in harvests that ranged from 700 to 63,000 bushels annually, mostly from Barnegat Bay. The total catch during this period, 317,000 bushels, was valued at just over $1,000,000. After 1967, bay scallop harvests were

[8] McCay, B., and S.R. Fegley. 1990. Results of overflight survey, Haskin Shellfish Research Laboratory, Port Norris, N.J. Personal commun.

[9] Results of unpublished 1990 survey courtesy of J. Joseph. New Jersey Bureau of Shellfisheries, Leeds Point, N.J.

[10] Kraeuter, J. 1997. Haskin Shellfish Research Laboratory, Port Norris, N.J. Personal commun.

reported in only 1973 and 1974. Only the adductor muscle of scallops, usually fried or broiled, is consumed.

Delaware Bay Oyster Fishery

Development of an Industry: Colonial Era to mid 1880's

Oysters grow in Delaware Bay from its mouth to Bombay Hook, on the western (Delaware) side of the estuary, and to just below Artificial Island on the eastern (New Jersey) side, a distance of about 80 km (50 miles) along a salinity gradient that decreases from about 30‰ to 5‰ (Fig. 1B). Oyster beds are more numerous on the New Jersey side, not only because it has greater area, but because a net inflow of water on the eastern shore, as well as prevailing westerly winds, tend to concentrate larvae on the New Jersey side. The industry on the New Jersey shore has always been much larger, producing an average of four times as many oysters and often attracting more attention, than the Delaware industry.

Thomas Campanius Holm, an early Swedish settler, wrote in 1642 that Delaware Bay oysters were "so very large that the meat alone is the size of our oysters [*Ostrea edulis*] shell and all" (Ingersoll, 1881). A chart drawn by another Swede, Peter Lindestrom, between 1654 and 1656 showed the entire Delaware shore lined with oyster beds, as well as a large bed extending west from Cape May Point in New Jersey (Miller, 1962). Oysters from the bay were an important food source for early Dutch and Swedish colonists, and the establishment of British settlements along the bayshore later in the 1600's, especially the growth of Philadelphia as the region's largest city, fostered the beginning of commercial harvests. By the 1750's, fresh oysters from Delaware Bay were being shipped to Philadelphia and New York (Smith, 1765), and pickled oysters, to the West Indies (Miller, 1962). The earliest oystermen were also farmers who probably gathered oysters from inshore areas using small boats and tongs; however, sloops and schooners capable of harvesting oysters from deep-water beds were built on the Cohansey River at Greenwich in the 1730's (Rolfs, 1971), and a 1777 map of New Jersey shows a large area of oyster beds offshore from Ben Davis Point[11].

During the late 18th century, seed oysters from Delaware Bay were being sent to Connecticut and Massachusetts for growout and subsequent marketing in New York City and Boston, respectively (Ingersoll, 1881; Kochiss, 1974). Early in the 19th century, the oyster dredge was introduced into Delaware Bay by the northerners because they wanted a more rapid and efficient way than tonging of gathering large quantities of seed (Miller, 1962).

In response to the influx of out-of-state boats, Delaware enacted "An Act for the Preservation of Oysters, Terrapins and Clams" in 1812, which restricted the taking of these species to residents of the state. There was little public support for, or enforcement of, the legislation, however, or for subsequent laws passed in the 1830's, which prevented the taking of oysters during their reproductive period, from 15 May to 15 August (Miller, 1962).

Oystering was becoming more profitable: records of a duPont household from 1828–1842 show that a bushel of oysters cost $0.50 and a quart of shucked oysters was $0.25 (Miller, 1962). Interest in the growing industry by outside investors led to the founding of the "New Jersey-Delaware Oyster Company" in 1825 (Hall, 1894). Its purpose was to improve the industry and protect the natural beds, but shareholders soon grew dissatisfied with incompetent management of the company and litigation resulted in its eventual dissolution. The existence of an important oyster fishery in the bay was acknowledged by the State of New Jersey in the "Act for the preservation of clams and oysters," passed in 1846, which specifically exempted Delaware Bay from a statewide prohibition against the use of dredges (Bacon, 1903). Although dredges were then operated entirely by hand, they had already made a major impact on natural beds, destroying their critical reef-like (i.e., vertical) nature. As described in Watson's Annals of Philadelphia written in 1843 (Ingersoll, 1881), this outcome was considered beneficial at the time:

> ". . . that our fields of oysters [i.e., Delaware Bay seed beds], notwithstanding their constant delivery, are actually on the increase, and have been augmenting in extent and quality for the last thirty and forty years. This fact . . . is said to be imputable to the great use of the dredging-machines, which, by dragging over a greater surface, clears the beds of impediments, and trails the oysters beyond their natural position, and thus increases the boundaries of the field."

The Industry Develops: 1850 to 1900

When oysters were first harvested commercially in Delaware Bay, they were transported directly to Philadelphia by the same boats that caught them, and most of the commerce was controlled by Philadelphians. After the opening of the Chesapeake and Delaware Canal in 1829, Delaware Bay oysters were shipped to Baltimore where they were shucked and canned fresh for ship-

[11]A map entitled "The Province of New Jersey, Divided into East and West, commonly called the Jerseys; from a 1769 survey." Engraved and published by Wm. Faden, Charing, 1 Dec. 1777.

ment west (Miller, 1962). Several canning houses opened in Delaware, starting around 1840; however, Philadelphia was still the major oyster marketing center in 1880, when Ingersoll (1881) estimated that 2,700,000 bushels were either consumed in the city or shipped west.

In a continuing attempt to preserve the resource, both New Jersey and Delaware passed legislation that promoted oyster planting in the Bay (reviewed by Ingersoll, 1881). In 1856, New Jersey granted the Board of Freeholders of Cumberland County, which bordered the rich oyster growing area south of Egg Island Point known as the Maurice River Cove, the right to "occupy" that section of the bay from Egg Island Point to East Point and out to the ship channel (Fig. 1B), to survey and map the area, and to lease 10-acre plots to the highest bidder for periods up to five years to "promote planting and growth of oysters." Numerous natural beds existed in the lower bay at that time and planting was forbidden on them. In addition, oyster boats were assessed a license fee, with the collections paid into an "Oyster Fund," administered by several oyster commissioners, who were expected to enforce the oyster laws and prevent theft. Neither this act, nor the earlier law of 1846, however, provided any effective means for their enforcement. The oyster industry grew rapidly after the Civil War and as pressure on the resource increased, both states were forced to remedy defects in enforcement of shellfish laws.

New Jersey enacted legislation in 1871 that created the "Maurice River Cove and Delaware Bay Oyster Association" and vested it with regulatory and law-enforcement powers. This group, made up of captains and owners of all licensed oyster boats, collected lease and boat license fees that were deposited into the "Oyster Fund" and used to hire a watch boat and crew to patrol the planting grounds. As all members of the Association had a vested interest in the oyster industry, it was expected that they would faithfully enforce laws protecting it. If the fund exceeded $2,000 at the end of the fiscal year, the surplus was to be used in support of state schools. Not surprisingly, in 1894 Hall (1894) found that no funds from this source had ever been deposited in the state treasury.

Across the bay, the State of Delaware was also trying to protect and encourage its oyster industry. In 1871, the oyster grounds were officially divided at Port Mahon (Fig. 1B) into upbay public beds and downbay planting grounds (Miller, 1962). This was followed in 1873 by an act permitting any person to lay out and stake up a 1-acre plot of bay bottom for planting (Ingersoll, 1881). It also provided for larger plots, up to 15 acres, termed "Oyster Plantations," which were leased from the state. Plantings could not, however, be made on an existing natural bed. In contrast with New Jersey, funds collected from vessel licenses and ground lease fees were paid directly to the State of Delaware, which administered and regulated the fishery.

On both sides of the bay tensions arose because of the division between privately leased grounds and natural seed beds, which remained in the public domain. During the 1880's and 1890's, perceived encroachment on the public beds by several planters who obtained riparian grants extending 0.8 km (0.5 miles) into the bay along a 10-km (6-mile) section of the New Jersey seed area just above Egg Island Point, precipitated a bloodless "oyster war" (Hall, 1894). A series of forays by oystermen on the riparian grants were designed to force a legal settlement of claims that the riparian grants infringed on the natural oyster beds. The conflict culminated in the arrest of more than 30 persons after a raid in April 1894 (McCay, In press). Subsequent court cases found that merely planting shells or oysters did not qualify as an "improvement" to the grant, which was a necessary condition for maintaining exclusive use of a riparian claim. Thus, the raiders were exonerated and any oysters on the riparian grants were considered common property. The grants themselves were eventually repurchased by the state (New Jersey Bureau of Shellfisheries, 1905a), which re-emphasized the principle that the oyster seed beds were part of the "public trust":

> "These oyster beds are the natural heritage of all the people of the State, and should be forever preserved and kept sacred to the free public use of the inhabitants of the State . . ."

The growth of the oyster industry in the Maurice River Cove and the apparent effectiveness of the 1871 legislation was described the following year by a resident of nearby Port Norris (Mints, 1964):

> "Our oyster business now seems to be in a safe and sound condition. The special officer, Mr. Gilbert Compton, with the assistance of the oystermen, has purchased a steamer, which cruises the bay and cove very greatly to the terror and annoyance of the Phila. oystermen, and. . . . we can see the boats hanging off our reach and we presume longing with wishful eye after our oysters, but the presence of the steamer in the bay bodes to them an ill omen, bearing the inscription, 'Thus Far Shalt Thou Come and No Farther.' We calculate the Philadelphians will get tired of risking their boats to the tender mercies of the New Jersey Oyster law, and will either become residents of our state, or put their boats in command of those who can employ them legitimately, for the faithful watch kept by our steamer during the season will break up a business that must prove unprofitable, and thus reassure our oystermen of permanent and sure protection. Our oystermen are engaged in planting in greater quantities than ever before but the

Figure 6
The towns of Bivalve and Maurice River, N.J., on the left and right sides, respectively, of the Maurice River in 1928. Note railroad cars adjacent to large building at center left that housed shipping companies, and sailing vessels up to six deep tied along the docks. Photograph courtesy of the Urban Archives, Temple University, Philadelphia, Pa.

great and increasing demand for cove oysters, we expect to have ready for sale all we have the capacity for producing. We anticipate the establishment of a large and profitable oyster market at our town."

This letter was written in the same year (1872) the railroad was extended to Port Norris and the neighboring port of Bivalve (then called Long Reach) on the Maurice River (Fig. 1B). After the railroad was established, the writer's forecast came true: both Bivalve and Port Norris became "boom towns." Railroad tracks, four abreast, paralleled the river at Bivalve, where the railway companies built shipping offices on the water front (Fig. 6).

A second rail line ran to the smaller port of Maurice River, directly across the river from Bivalve. Oysters could be moved easily from dockside to boxcars waiting a few meters ashore. When Ingersoll (1881) visited the area in 1879–80, the railway was still new and he estimated that of the 1,600,000 bushels sent to market from the New Jersey grounds, only 100,000 went by rail; the rest were carried by ship directly to Philadelphia, some 115 km (70 miles) up river. Soon, however, captains were attracted to the new port adjacent to their oyster beds. In 1882, Lockwood (1882) predicted that

"The whole market will soon be at Port Norris, where there are no wharfage, no commissions, and no expenses of any kind, the captain selling his own cargo. A large proportion of the boats now running to Philadelphia would not go if not owned there."

Gradually, the New Jersey industry moved from control by Philadelphians into the hands of in-state residents. By 1888, most of the harvest was shipped by rail (Nelson, 1889). Oysters harvested from Delaware waters continued to go by boat to Philadelphia or across the bay to Port Norris or Greenwich (Fig. 1B), where they were shipped by train to Philadelphia (Ingersoll, 1881; Hall, 1894). Unlike New Jersey, the coastal railroad in Delaware served primarily to transport salt hay and agricultural produce[12].

When Ingersoll (1881) visited Delaware Bay in 1879–80, there were already nearly 1,400 vessels (about 300 of them sloops and schooners greater than 5 tons) and 2,300 men employed in taking oysters from the estuary. As is the case today, the majority of these vessels were doubtless used just for gathering seed oysters in the spring, when the goal was to obtain as many oysters as possible during an 8–10 week period. Fewer boats were

[12]Tinsman, J. 1992. Delaware Division of Fish and Wildlife, Dover. Personal commun.

required to harvest oysters for market because it was done over a longer period. The sailing vessels were operated by captain-owners and crews of 5–6 men, who were paid by shares or cash wages and earned from $240 to $500 per year plus board while they were on the boats. In 1879–80, Ingersoll estimated that 1,600,000 bushels were harvested from the New Jersey side (about half of the total New Jersey harvest) and 300,000 bushels from the Delaware side.

Rarely Enough Seed For Planting

In contrast to areas around New York Harbor and New England, where oyster planting with out-of-state seed developed because natural beds were depleted, seed planted on leased grounds in Delaware Bay came from creeks and upbay beds within the bay itself. The practice of planting arose because oystermen discovered that oysters in the lower estuary grew faster and attained a better meat quality than did those taken from the upbay beds and lower salinity creeks. A natural division arose between the planting grounds and the upper bay seed beds, where low salinity protected the young oysters from major predators. Restricted seed-dredging seasons in Delaware and New Jersey legislation of 1835 and 1846, respectively, were intended to preserve the beds. The New Jersey law also contained a rough cull provision. Delaware enacted a similar measure in 1873, but it applied only to creeks and rivers.

As a matter of fact, to foster road improvement in Kent County, which borders most of Delaware's oyster grounds, it became mandatory in 1875 for oystermen to "land and deposit their oyster-shell on shore [for road repair] and [it was] unlawful to empty or throw such shells into the water...". Two years later, in 1877, the New Jersey rough cull law applying to Delaware Bay was repealed. Hall (1894) reported that, "According to the oystermen, the number of bushels of shells annually taken from the beds during the planting season considerably exceeds that of the oysters." The shells were frequently covered with spat, however, which "if they live, will in time grow to marketable size." Also, shells were valuable on the leased grounds because they stabilized otherwise soft sediments. Nevertheless, continual removal of cultch over the next quarter century surely hastened the deterioration of public beds, a condition stressed in all reports of the period.

Delaware Bay, with its expanse of seed producing and planting areas, favored the growth of sizable companies, which could afford capital investment in large dredge boats, much more so than did the Atlantic coast, where tonging was the only legal means of catching seed and where small boats could operate safely in all areas. Not all Delaware Bay oystermen owned vessels big enough to transport seed oysters in quantities needed for planting, however. To accomodate smaller oystermen who wished to continue marketing wild seed, certain areas in creeks and rivers, or at their mouths, were set aside. Dredging was prohibited, but enforcement was lax. During the 1880's conflicts between tongers and dredgers in Delaware became violent as pirate dredge boats stole oysters from both the tongers and private planters (Miller, 1962). Until MSX disease put them out of business, many small dredge boat operators and tongers sold seed oysters to the larger planters, who stationed "buy boats" in the creeks adjacent to the natural beds during the seed dredging season. Tonger's beds still exist, although in the last 35 years many have become silted over.

Although the natural beds of Delaware Bay produced large quantities of oysters during the 19th century, the demand was frequently greater than the supply, and oystermen began importing seed from the Chesapeake. From the first year of its operation in 1829, records of the Chesapeake and Delaware Canal indicate large quantities of oysters being moved in the direction of the Delaware[13]. During the 1830's, an average of 150,000 bushels per year passed through the canal. Each decade thereafter, the volume increased until during the 1880's, it averaged nearly half a million bushels a year. In fact, Ingersoll (1881) estimated that in 1879–80, the total was nearly 940,000 bushels, 700,000 of which were destined for planting in the bay and the remainder for market in or through Philadelphia. Nelson (1889) commented that although the New Jersey seed beds yielded an estimated 1,250,000 bushels in 1888, "the cry is more seed."

Over the next 70 years, imported seed continued to supplement the native supply in Delaware Bay. Originally, most came from the vast James River seed beds in Virginia or from the Maryland beds in the upper Chesapeake. Alarmed at the drain on its resource, Virginia banned the practice, and by 1900, the newly appointed Oyster Commissioners in New Jersey reported that Virginia seed was becoming scarce and expensive because Virginia was "stepping up enforcement" of the ban. Some seed was then brought from Long Island (Nelson, 1934), and in the early 1950's, hundreds of thousands of bushels were imported from the seaside bays of Virginia, especially Chincoteague Bay[14,15]. The practice ended shortly after the outbreak of MSX disease in 1957, when all imports and exports were banned.

[13]O'Connor, D. 1987. A brief overview of the history and present status of the Delaware Bay oyster fishery. Haskin Shellfish Research Laboratory, Port Norris, N.J. Unpubl. manuscr., 20 p.

[14]Bickings, H., Sr. 1989. Peterson Packing Co., Port Norris, N.J. Personal commun.

[15]Jeffries, N., Sr. 1989. McKee City, N.J. Personal commun.

The Boom Years: 1900 to 1930

For nearly 30 years beginning in 1871, the administration and policing of industry on the New Jersey side of the bay remained entirely in the hands of oystermen themselves. Hall (1894) was convinced that "the means for enforcing the law [are] so efficient, that . . . offenses are seldom committed." Nevertheless, many of the larger growers were less enchanted and petitioned the state to assume the responsibilities of the Oyster Association. Their efforts were eventually successful, and in 1899 the state took control of the industry and all of the oyster growing areas in Delaware Bay. Many of the measures enacted in previous legislation were reiterated in the act of 1899, but supervision of the industry and enforcement of the law were placed in the hands of a 3-member Oyster Commission, all of whom were industry members appointed by the Governor and who now had the full force of the State behind them. The Commission was replaced by a Board of Shellfisheries and then by Shellfish Councils, which still exist—one for the Atlantic coast and one for Delaware Bay. Its members, appointed by the governor, control ground leases and advise the Commissioner of Environmental Protection and Energy on regulatory matters.

The long-recognized division between upbay seed beds (now managed by the state) and lower bay planting grounds (now leased and patrolled by the state) was officially acknowledged in the 1899 act. By this time, natural seed beds existed only in the upper bay, and most of the lower bay was available for planting (Fig. 1B). Seed dredging was to occur between 1 April and 15 June (in 1905 this was changed to 1 May to 30 June) and became known as "Bay Season." Of major importance was reinstatement of the rough cull law, which mandated that no more than 15%, by volume, of material removed from the beds could be shell.

On the Delaware side of the bay, division between leased grounds and natural beds had occurred 30 years earlier, in 1871, but "clarifying" legislation continued, much to the confusion and dismay of the oystermen, over the next decades culminating, in 1909, in the establishment of a Shellfish Commission to foster oyster interests (Miller, 1962).

The industry prospered during the early years of this century, helped according to New Jersey officials, by the new legislation, especially the rough cull law (New Jersey State Oyster Commission, 1901; Commission for the Investigation of the Oyster Industry of New Jersey, 1902; New Jersey Bureau of Shellfisheries, 1905a, 1905b). For several years, the state bought shells and returned them to the seed beds where they caught a series of good sets and provided large quantities of native seed. The total leased acreage increased from 12,000 acres in 1900 to nearly 30,000 acres by 1914.

More and larger dredge boats were added to the fleet, which in 1929 peaked at nearly 7,700 gross tons, in New Jersey. At that time, 247 vessels larger than 5 gross tons and averaging 31 gross tons held oyster licenses in the bay. Most were between 10 and 25 m (30–80 ft) in length, and of vessels within that size range, 77 operated exclusively under sail and 177 were motorized, although the latter also carried sails (Fiedler, 1932). Power dredging had been legalized on the New Jersey leased grounds around 1905 (New Jersey Bureau of Shellfisheries, 1905a), but sail was still the only permitted method of gathering oysters on the seed beds. The number of men working on each boat varied with vessel size; however, about 2,700 men were employed on New Jersey's Delaware Bay dredge boats in 1930 (Fiedler, 1932), giving an average crew size of about 11. In Delaware, 16 vessels, averaging about 20 gross tons were licensed. Ten were sail boats and 6 operated under power. Ninety men were employed on the dredge boats, for an average crew size of just 6 (Fiedler, 1932).

Floating and Shucking—The growth of the Delaware Bay industry was built largely on marketing oysters in the shell, although the practice of shucking oysters was already well established in other areas (Ingersoll, 1881; Kochiss, 1974). A crucial marketing element involved placing oysters in floats in brackish water for one or two tides, during which time they "cleansed" themselves of mud and debris and repaired minor dredge-caused shell damage, before rail shipment (Fig. 7). They also added about 20% to their meat volume by absorption of water (Nelson, 1911). Floating made the oysters better able to survive their long rail voyages, and was widely practiced along the mid-Atlantic, including the Maurice River at Bivalve (Ingersoll, 1881; Nelson, 1911; Kochiss, 1974). By 1905, public health officials were becoming alarmed at the consequences of allowing oysters to be immersed in waters near population centers. The newly created U.S. Food and Drug Administration was also concerned that the uptake of fresh water resulted in an adulterated product. The practice was banned in 1909, but pressure from oyster interests, including those in New Jersey led by Julius Nelson (1911), resulted in an amendment that allowed floating "in waters of sufficient salinity to permit oysters to grow therein" with the proviso that they could be placed in lower salinity as long as the product was labeled "floated oysters."

At the same time, legislation was enacted to stop the pollution of water affecting oyster beds. Bivalve, with its burgeoning population and primitive sanitary facilities, was an obvious target for the new law, and members of the Oyster Association took it upon themselves to clean up the town, including diverting a drainage ditch and moving 50 families away from the wharf area (New Jersey Bureau of Shellfisheries, 1911).

Floating resumed at Bivalve, but was permanently banned in 1927 after a typhoid outbreak in 1924 was traced to New Jersey oysters (Nelson, 1929). In 1922, the first shucking house was established in Bivalve and several others quickly followed (Mints, 1976). Over the next few years, the ban on floating pushed the remainder of the industry to shucking. Ironically, the shucking process, in which meats are washed in fresh water, increases the packed volume and adds more to the value (i.e., weight) of shucked meats than it does to oysters shipped in the shell. Another benefit of this system was that shells remained near the shucking houses (Fig. 8) where they could conveniently be returned as cultch to the public beds or private grounds. After floating was abandoned, most oysters marketed from Delaware Bay were shucked, although recently the marketing of carefully culled, high value shell stock has resumed to supply restaurants on the U.S. east and west coasts.

Figure 7
Unloading eastern oysters from floats in the Maurice River at Bivalve, N.J., ca. 1905. Note woven baskets and burlap sacks. Each basket held about a half-bushel, or 100 large oysters ("primes"). The sacks, each holding 600–700 "primes," were sold to shippers for $3.50–4.00 in 1888–92. New Jersey Bureau of Shellfisheries photograph.

Figure 8
Oyster shell pile next to a shucking house on the Maurice River during the 1920's. Photograph from Rolfs, 1971.

Initial Decline: 1930 to 1957

From 1880 until 1930, Delaware Bay oyster production ranged between 1 and 2 million bushels annually (Fig. 9). On the New Jersey side, this represented 54% of the state's production in 1880 and 90% by 1930, as the once productive industry on the coast, especially Raritan Bay, fell into decline. After 1930, production remained fairly steady at about 1,000,000 bushels a year until 1957. It is not entirely clear why harvests declined around 1930. Failure to return shells to the seed beds was reducing harvests in Delaware (Miller, 1962), and drought early in the decade allowed predatory oyster drills, *Urosalpinx cinerea*, to move upbay onto the seed beds[16]. An equally important factor may have been loss of markets and frozen credit during the Depression, which made it difficult for planters to maintain their large vessels (Nelson, 1934). In fact, between 1929 and 1936,

[16]Nelson, T. C., personal commun., *in* P.S. Galtsoff (1943), Problems of the productivity of oyster bottoms of the Atlantic States. Mimeographed summary of an address at the annual meeting of the Atlantic States Marine Fisheries Commission, Philadelphia, Pa., 10 p., Haskin Shellfish Research Laboratory, Port Norris, N.J.

the number of licensed vessels fell nearly 60%, from 247 to 103. Lack of credit may also have reduced purchases of seed from other states so that planters were relying more heavily on Delaware Bay seed beds, which, despite drill predation, still produced between 800,000 and 1,000,000 bushels per year during the 1930's (Fiedler, 1931, 1932, 1934, 1936, 1938).

Another important change came to the industry during the 1930's. As roads improved, trucking began to replace rail as the preferred method for shipping oysters. By 1946, the changeover was complete and the railroad ceased transporting oysters from the Maurice River ports[17].

Despite repeated legislation to protect the resource, overharvesting of seed beds was a chronic problem in Delaware Bay. Some of the New Jersey beds nearest to the leased grounds, where both seed dredging and oyster drill predation were heaviest, had ceased production by 1900 (Commission for the Investigation of the Oyster Industry of New Jersey, 1902). The rough cull law was poorly enforced in Delaware[18] and deterioration of the seed beds was accelerated during World War II when the requirement for sail dredging was eliminated in both states. Sailing gear was removed from the sloops and schooners, and replaced by engines. Motorized boats were much more efficient at harvesting seed: they could be operated in most weather, and could dredge in smaller and shoaler areas.

By 1946, the seed beds were in such poor condition that the New Jersey oyster planters themselves co-sponsored, with the Department of Conservation, an act requiring that they return to the seed beds, at their own expense, 60% of all shells from oysters originating on the beds. During that year, they replanted nearly 500,000 bushels of shells. Subsequent legislation reduced the requirement to 40%, and in 1979, eliminated it completely, the rationale being that the natural death rate of oysters on the beds contributed far more shell than could the oystermen. Only small amounts of native shell, which the state must now purchase from shucking houses, have been planted since then.

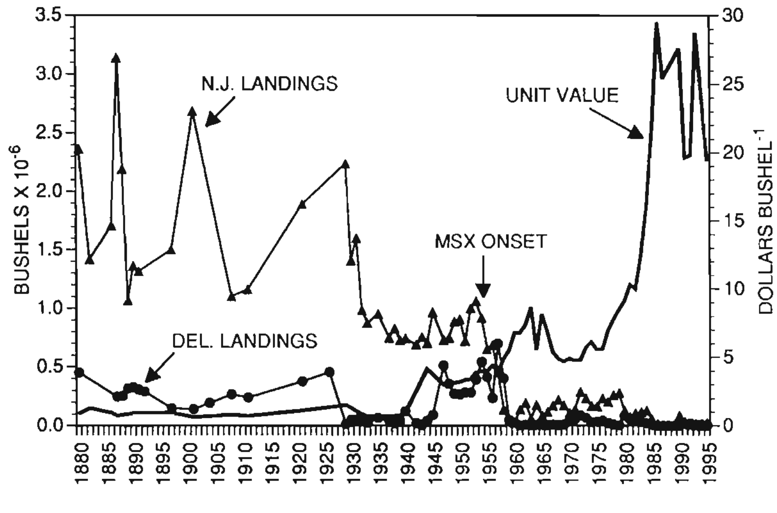

Figure 9
Reported landings of eastern oysters in New Jersey and Delaware. Most Delaware landings are from Delaware Bay. Of the New Jersey landings, about half came from Delaware Bay through 1901, but by 1930, the proportion was 90%, and it has been nearly 100% in many years since 1974.

Unexplained mortalities of seed oysters in the early 1940's[18] and again in 1950 (Miller, 1962), and a series of set failures in the late 1940's and early 1950's, left the natural beds in a condition that had never before "been so uniformly bad for so long a period as at present, and it is highly probable that the present oyster population of the Natural Beds represents an all time low[19]." Only continued importation of seed from Maryland and Virginia allowed the industry to market the average one million bushels per year that it did until 1956. In response, both the University of Delaware and Rutgers University began studies of factors influencing seedbed recruitment. Rutgers' Department of Oyster Culture, under Harold Haskin, collected data on larval abundance, setting, survival, and harvests annually between 1954 and 1991. These showed that a major influence on recruitment was the amount of fresh water entering the upper estuary[20]. During periods of low river flow, which existed from the start of the study until the late 1960's, predators, primarily the oyster drill, moved onto the lower seed beds (below Ben Davis Point) and destroyed newly set spat shortly after they

[17]Anderson, F., and H. Bickings, Sr. 1993. Port Norris, N.J. Personal commun.

[18]Galtsoff, P. S. 1943. Problems of the productivity of oyster bottoms of the Atlantic States. Mimeographed summary of an address presented at the annual meeting of the Atlantic States Marine Fisheries Commission, Philadelphia, Pa., 10 p. Haskin Shellfish Research Laboratory, Port Norris, N.J.

[19]New Jersey Oyster Research Laboratory. 1953. First annual report on the natural seed beds investigation. Haskin Shellfish Research Laboratory, Port Norris, N.J., 75 p.

[20]Haskin, H. H., and S. E. Ford. 1986. Report to the New Jersey Bureau of Shellfisheries on the Delaware Bay Oyster Project, 1984–1986. Haskin Shellfish Research Laboratory, Port Norris, N.J., 133 p.

set. Beginning in 1968 and continuing for a dozen years, however, Delaware River flows returned to, or exceeded, the average. Oyster drill numbers diminished on the lower seed beds allowing spat to survive. and those areas began a return to productivity.

In 1972, the entire Delaware Bay received a tremendous oyster set. Oysters were plentiful even on beds that had been out of production for at least 50 years, and oystermen remarked that it was the best set anyone could remember. This and subsequent good sets over the next dozen years sustained the industry from 1973 through 1985, when seed harvests from the New Jersey beds averaged 370,000 bushels per year. From 50–60 vessels, nearly all of them former schooners 12–25 m (40–80 ft) in length, averaged 400–500 bushels per day each during a 4-week season. The average vessel's catch from the Delaware seed beds was 300–600 bushels per day, totaling about 40,000 bushels annually. Daily per-vessel catches were similar to Ingersoll's (1881) estimate of about 400 bushels in 1880. Major differences, of course, were that all vessels operated under sail in 1880, the season lasted 10 weeks, 300 boats participated in the harvest, and an estimated total of about 2,500,000 bushels was caught.

MSX—Devastation and Recovery

In 1957, the oyster industry suffered its most serious blow yet. That spring, heavy mortality was discovered in oysters planted the previous year on the New Jersey leased grounds (Ford and Haskin, 1982). The cause. soon discovered to be a protozoan parasite, had never been seen before. It was initially given the acronym "MSX", standing for "multinucleated sphere unknown" and was later classified *Hasplosporidium* (formerly *Minchinia*) *nelsoni* (Haskin et al., 1966). The parasite spread rapidly over most of the bay, limited only by the fresher waters of the creeks, rivers, and upper bay (Haskin and Ford, 1982). By the end of 1959, 90–95% of the oysters on the planted grounds and about half of those on the seed beds had died. The coastal bays were also hit and the industries in New Jersey and Delaware were devastated. Their combined harvest fell from 711,000 bushels in 1956 to only 49,000 in 1960.

Gradually, the industry rebounded as the seed beds recovered in the late 1960's and early 1970's, and native oysters developed some resistance to MSX disease as a result of natural selection (Haskin and Ford, 1979). Changes in planting and harvesting practices added to the recovery. Before MSX, the seed oysters planted were very small, with as many as several thousand to the bushel. They remained on the leased grounds for 2–4 years before harvest. Predation by oyster drills was high, and the growth of surviving oysters just balanced the volume lost to predation and other causes of natural mortality so that the long-term average was one bushel of oysters marketed to one bushel of seed planted (Ingersoll, 1881)[21]. When planting resumed after the MSX epizootic, and for a dozen years thereafter, the ratio remained 1:1, even though the disease persisted on the lower bay planting grounds (Haskin and Ford, 1983). This was achieved because planters learned to avoid areas of high disease activity in the lower bay, and they sought seed oysters large enough to plant and market after only a single growing season, which minimized the time oysters were exposed to infection.

The extent of the post-MSX recovery is not reflected in the landings figures of the period, which show that, starting in 1974, less than half of the seed planted on the New Jersey grounds was brought to market. Mortality rates of planted oysters, which were being monitored by the Rutgers Laboratory, showed no evidence of an increase that could explain this change, and the ratio remained 1:1 on the Delaware side, where both seed planted and oysters marketed are closely monitored by the state shellfish agency (Haskin and Ford, 1983). Haskin and Ford (1983) hypothesized that the discrepancy, which coincided with a return to profitability of a business that had been in severe depression for 15 years, was due to substantial under-reporting of oysters marketed by New Jersey planters. In fact, the quantity of oysters marketed from the New Jersey side of Delaware Bay between 1973 and 1985 was probably close to the volume of seed planted, or from 300,000 to 450,000 bushels per year. Although that was less than half of the pre-MSX average of about 1,000,000 bushels, it was based entirely on native seed, whereas nearly half the seed planted in the 1940's and early 1950's is estimated to have been imported.

During the 1970's and early 1980's, at the peak of the post-MSX recovery, 50–100 boats with an average weight of 31–34 gross tons were licensed for seed dredging in New Jersey each year. At the same time, 6–12 boats were operating in Delaware. Most of these vessels were used solely to catch seed oysters during the short spring Bay Season. On any given day during market season, only 10–15 boats might be operating. When a planted ground was first dredged in the fall, 600–700 bushels were typically caught by the large vessels. The ground would be "worked" until the yield decreased to 50–100 bushels a day. Oysters were marketed from leased grounds from 1 September through the end of June until 1975, when year-around harvesting was legalized in New Jersey. The change permitted oystermen to harvest oysters within 2

[21]Records of oyster planters Harold Washburn and Fenton Anderson, 1937–1956. Haskin Shellfish Research Laboratory, Port Norris, N.J.

months of planting and thus to reduce exposure to potential MSX infections.

An important change to the oyster boats occurred in 1975. Two New Jersey planters, Luther Jeffries, Jr. and Robert Morgan, Jr., built an automated culling machine and within 2 years, culling machines were installed on nearly every dredge boat (Fig. 10). The machines operate by moving shells through a drum with sides of evenly spaced bars, or along a slotted conveyor belt. Shells fall through the spaces or slots and are directed overboard whereas the oysters are retained aboard. Before the advent of culling machines, crews of up to 10–14 men were required on each vessel during Bay Season to cull. Culling machines have made it possible to operate even the largest vessels with only a captain and one or two deck hands. Deck hands typically earn $100–$125 per day and captains may make as much as $300 daily.

Figure 10
Delaware Bay oyster boat with a drum-type culling machine. Oysters are dumped from dredges on each side of the vessel into hoppers that feed them into drums at the bow of the boat. The sides of the drums are steel rods, approximately 24 mm (1 inch) apart, which allow single valves to fall through and overboard. Oysters are retained in the drums, directed onto a central conveyor belt, and then moved aft to a pile in front of the pilot house. Photograph by S. E. Ford.

New Jersey vessels plant seed oysters on leased grounds of from 10 to 60 acres, generally at the rate of 1,500–2,000 bushels per acre. Because losses to MSX disease are highest downbay, only about 2,000 acres at the upbay edge of the leased area have been regularly planted for the past 30 years. In 1981 a new planting area was established adjacent to some of the lower seed beds. "Area E," as it is called, was set up to allow leasing in a section of the bay even farther removed from high MSX disease activity. Plantings in the new area were not as successful as expected, partly because the opening of Area E coincided with drought and a movement of MSX upbay, and partly because the substrate on many of the new grounds was too soft to support oysters.

Companies continue to lease grounds downbay, some of which are several hundred acres in size, as these areas occasionally receive natural sets and can be used for dredging blue crabs, *Callinectes sapidus*. Ten packing houses operated in and around Bivalve in 1977, each employing 15 to 150 people as shuckers or on dredge boats harvesting market oysters[22]. The total for all houses was about 400 employees. Some individuals worked for more than one company, however, so that the true number of persons employed was less than 400, although available records do not permit determination of exact numbers.

Although harvests did not equal those of pre-MSX years, it must be emphasized that they were based entirely on native seed. Further, it is probably unrealistic to think that annual seed harvests exceeding 1,000,000 bushels, as was reported in some years, could be sustained indefinitely. Before about 1955, each time the seed beds received a heavy set it was dredged out within 2 or 3 years during an 8–10–week season. The strategy in recent years has been to make sets last as long as possible by restricting the season to 3 or 4 weeks and by closing beds when the volume fraction of oysters on them nears 40%[23]. With this plan, the vast 1972 set, plus good sets in several succeeding years and the closing of the seed fishery to new vessels in 1980, sustained the New Jersey industry until 1985.

Weather and Parasites Cause More Problems

In 1985, after 15 years of modest prosperity, the oyster industry in Delaware Bay suffered another setback. Severe drought accompanied a resurgence of MSX disease. High mortalities affected planted and seed oysters

[22]O'Connor, D. 1977. Letter to C. Zimolzak, Cumberland Co. Planning Board. Haskin Shellfish Research Laboratory, Port Norris, N.J.

[23]Haskin, H. H. 1992. Haskin Shellfish Research Laboratory, Port Norris, N.J. Personal commun.

over the next 2 years. Recruitment to the seed fishery decreased and the low numbers of oysters on the beds caused the Shellfish Councils of both states to close them to dredging beginning in 1987. The condition of the beds improved over the next few years and when the New Jersey beds were reopened for two weeks in 1990, 160,000 bushels of seed were planted. The following year, the beds produced 290,000 bushels in three weeks, the best weekly yield in a decade.

In 1990, however, a new problem surfaced when the southern oyster parasite, *Perkinsus marinus*, cause of Dermo disease (Andrews, 1988), was found in several locations on the New Jersey side of Delaware Bay. By 1991, it had spread over much of the eastern bay, causing heavy losses of planted and seed oysters. This was not the first time that *P. marinus*, usually restricted to waters south of New Jersey, had been in the bay. During the 1950's, large numbers of oysters from the Virginia portion of Chesapeake Bay were imported (Ford, 1996). They were infected with *P. marinus*, which spread to adjacent native oysters. Despite this massive introduction of a highly contagious disease organism, no mortalities were reported and the disease effectively disappeared after imports were banned in 1959. It was concluded that temperatures in Delaware Bay were not warm enough to support the parasite without continued introductions (Ford and Haskin, 1982); however, it is likely that the parasite persisted at very low levels and proliferated beginning in 1990 during a period of record high temperatures. Interestingly, as of spring 1995, only a few cases of the disease had been detected on the Delaware side of the bay[24], although it has been found since 1991–92 in New York, Connecticut, and Massachusetts (see Ford and Tripp, 1996). The relative scarcity of oysters to serve as hosts and the more rapid flushing on the Delaware side may be responsible. Also, shucking house wastes from Chesapeake Bay and Gulf of Mexico oysters processed in Bivalve may have contributed to the New Jersey problem.

There is currently one shucking and one packing house, with combined employment of about 50, operating in Bivalve. Because of the decline in oyster production from Delaware Bay, they process mostly out-of-state oysters, especially those from Connecticut. Many oysters are packed in the shell for shipments to seafood markets and restaurants as distant as California. Oysters marketed in this way are generally served raw on the "half-shell." Shucked oysters are sold by volume (half pints to gallons) for stews, frying, or to make scalloped oysters. Shuckers are currently paid $1.00 for each pound (~1 pint) of oyster meat they shuck (Fig. 11).

Figure 11
Oyster shuckers in Bivalve, N.J., in 1993. Buckets containing oysters are brought to the shuckers by a conveyor belt from the loading dock. Shuckers grade the meats as they work, placing each shucked oyster into one of four pails: Standards (300 or more per gallon, selects (210–300 per gallon), extra selects (160–210 per gallon), and counts (160 or fewer per gallon). Shuckers produce 1–2 gallons per hour, depending on oyster size and meat quality. Photograph by S. E. Ford.

A number of smaller oyster planters have gone out of business since 1985, selling their boats to the larger remaining companies. The largest New Jersey company owns 13 vessels. Half a dozen smaller companies and individuals own 3–6 boats each. About half of the license holders own just one boat. Several large companies lease planting grounds varying from 2,500–3,500 acres, but most individuals and smaller companies each lease a few grounds totalling up to several hundred acres. The annual lease fee is $0.50 per acre in New Jersey and $0.90 in Delaware. New Jersey imposes a $0.70 tax on each bushel of oysters taken to market from leases; the figure in Delaware is $0.15.

The Future

The Delaware Bay oyster industry faces an uncertain future. The seed beds in both states have been closed for 6 of the 11 years between 1987 and 1997 because of disease-caused losses and relatively poor setting. The consequent lack of harvestable oysters has resulted in

[24]Tinsman, J. 1997. Delaware Division of Fish and Wildlife, Dover. Personal commun.

loss of skilled shuckers; a deterioration of boats, wharves, and buildings; and a diminished market for local oysters. In addition, the oysterman must contend with normal uncertainties: fluctuations in the national economy, competition for markets from other regions of the country, and variation in meat yields. One bright spot is the sharp increase in prices over the last few years (Fig. 9).

The presence of two oyster diseases makes planting of oysters in the lower bay very risky. In 1995, a new strategy was tried for the first time in New Jersey—direct marketing from the seed beds in the spring and the fall. It has been the predominant method of oystering since 1996. Each licensed vessel has received a quota of 1,000–2,000 bushels per season and harvesters are charged a $1.25 per bushel fee. From the spring of 1996 through the spring of 1997, about 88,000 bushels, worth approximately $1,800,000, were direct marketed.

Although marketing from public beds goes against the policy of encouraging private planting, it has clearly been a better utilization of the resource under the currently prevailing disease conditions. For instance, in 1991 and 1995 (the beds were closed from 1992 through 1994), 397,000 bushels were taken from the New Jersey seed beds and transplanted to the leased grounds. Because of high Dermo disease-caused mortality, only a small fraction, worth $1,189,000, was landed. Thus, for each bushel removed from the seed beds, the direct market strategy has returned nearly seven times more in dockside value compared to typical planting returns during periods of high Dermo disease.

A revision of the statutes governing the New Jersey oyster beds was initiated in early 1996 with the objective of giving industry and management more flexibility to respond to changing conditions, especially disease. Some combination of direct marketing and transplanting may result, at least as long as disease pressure so severely limits returns on planted seed.

The seed beds have returned to production twice (1970's and 1990–91) after serious depletion, and there is no reason to believe that they will not do so again. Nevertheless, their inconsistent production has led to interest in alternative sources of seed oysters. Between 1987 and 1991, the Maurice River Oyster Culture Foundation, a consortium of New Jersey planters, attempted to develop growout techniques that would make it economical to use Rutgers MSX-resistant, hatchery-reared seed in Delaware Bay. Results showed that hatchery-produced juveniles, which would take 2–3 years to reach market, cost $12–$17 per bushel to plant, whereas natural seed, most of it large enough to be marketed after one season, could be planted at a cost of only $2.50–$8 per bushel[25]. The difference in survival was not enough to compensate for the higher cost of hatchery seed. The advent of Dermo disease has placed on hold any further attempts at refining growout methods.

Although the history of the oyster fishery in Delaware Bay has been one of ups and downs since at least the 1880's, the appearance of MSX disease in the late 1950's and Dermo disease in the early 1990's placed additional burdens on an already stressed industry. Nevertheless, oysters marketed from Delaware Bay remain of very high quality. To take advantage of the bay's capacity to produce excellent oysters, the industry must be restructured to encourage new methods of culturing oysters. At present, the only cost to planters for natural seed, exclusive of vessel operating costs, is a small ($2–5 per ton in New Jersey) annual fee. Boats capable of dredging 8,000–12,000 bushels per season pay less than $350 for the license. In Delaware, a flat-fee dredge boat license costs $57.50 per year. Until the cost of natural seed comes more into line with its true value, serious private investment in alternative methods for obtaining and culturing seed will not occur.

Delaware Bay Northern Quahog Fishery

Northern quahogs are present in small numbers throughout the lower Delaware Bay, including the leased oyster grounds, where they are harvested from time to time using oyster dredges modified with extra long teeth so they can dig into the sediment. Nelson (1889) reported that most quahogs caught on the New Jersey side of the bay came from the shores of the Cape May Peninsula and were sold to hotels in Cape May. No quahogs were taken in the Maurice River Cove. It is difficult to sort out more recent landings figures in New Jersey, which are listed by county rather than by body of water. It is probable, however, that most quahogs landed in Cape May County have been taken from the Atlantic coastal bays, not from Delaware Bay. Harvests reported from Cumberland County, which could come only from Delaware Bay, are intermittent and rarely exceeded 4,000 bushels in any year. In contrast, during the 24-year period 1941–65, beginning with the legalization of power dredging and ending when surfclams captured the large-quahog market, 470,000 bushels were harvested from the Delaware side of the bay[12].

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[25]Canzonier, W. J. 1992. Maurice River Oyster Culture Foundation, Port Norris, N.J. Personal commun.

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The Molluscan Fisheries of Chesapeake Bay

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ABSTRACT

Chesapeake Bay has produced eastern oysters, *Crassostrea virginica*; softshell clams, *Mya arenaria*; northern quahogs, *Mercenaria mercenaria*; and the whelks *Busycon carica* and *Busycotypus canaliculatus.* Native Americans long used oysters as food. During most of the 1800's, many oysters from the bay were transported to northern cities and states for direct sale and planting. In the 1830's, shucking houses were constructed in Baltimore to ship oyster meats throughout the country. The city later became the center of oyster marketing, handling as much as 6 million bushels of oysters annually. By the late 1800's, the bay produced an estimated 20 million bushels of oysters. In Maryland, in the late 1800's, between 1,658 and 4,741 boats were licensed for tonging, about 719 were dredging, and between 351 and 456 buyboats transported oysters from the oyster grounds to oyster docks for sale. Following huge landings between 1870 and 1895, production fell sharply, mostly owing to a declining supply. From 1930 to 1955, production consistently ran 2.3–3.2 million bushels. Production fell briefly after 1955 but rose again when the state spread 5–6 million bushels of oyster shells/year on setting beds. In the 1980's and 1990's, MSX and Dermo diseases have reduced Maryland's harvests.

By the 1870's, Virginia oystermen were establishing a culture system that would last into the 1990's; only the volume of oysters handled changed. Planters purchased seed from tongers who had harvested them on public beds and spread them on their leases, left them for 2–3 years, harvested them, and finally hired people to shuck them. From 1930 to 1955, oyster production ranged from 2.5–3.7 million bushels/year and was the highest of any state. After 1959, the MSX disease killed many oysters and also led to a decline in oyster setting in the James River, the main seed-producing area. Dermo also contributed to the oyster mortalities. In recent years, oystering became concentrated in the James River and state harvests are small.

Softshell clams have been produced in Maryland since the hydraulic conveyor "dredge" was developed in 1951. Production peaked at 640,000 bushels in 1965, but since has fallen sharply. Northern quahogs occur in the high salinity portions of Chesapeake Bay and in Chincoteague Bay. In Chesapeake Bay, they were once harvested with shortrakes, but in this century, patent tongs are used. In Chincoteague Bay, they are also harvested by treading and with "gaff-hooks." Hatchery culture of quahogs has produced about 30 million littlenecks/year. In Virginia, most whelks are caught by dredging at night.

Introduction

Chesapeake Bay (Fig. 1) is one of the largest estuaries on the east coast of North America, and its molluscan resources are divided between Maryland in the north and Virginia in the south. In some years of the late 1880's, the bay reportedly produced nearly 20 million bushels[1] of eastern oysters, *Crassostrea virginica*, a total estimated to be nearly 60% of North America's production of this species and half of the world's oyster production (Stevenson, 1894). During that era, Maryland's oyster industry was valued at 17% of all U.S. fisheries

[1] Values for bushels used throughout this chapter are for Maryland bushels for Maryland landings and Virginia bushels for Virginia landings. The volume of a Maryland bushel is 2,800.7 cubic inches, or 1.3 times the size of a U.S. standard bushel (2,150.4 cu. inches). The volume of a Virginia bushel is 3.003.9 cubic inches, or 1.43 times the size of a U.S. standard bushel.

products and employed 20% of the people in America's fishing industry (Kennedy and Breisch, 1983). Before 1960, the James River, a Virginia tributary of the southern bay, produced the world's largest quantity of seed oysters, commonly yielding at least 2 million bushels/year. In recent years, diseases have killed most of the oysters in Chesapeake Bay.

Since the early 1950's, a Maryland fishery has produced large quantities of softshell clams, *Mya arenaria*. During the 1960's, the most productive period, Maryland's landings of softshells exceeded that of the State of Maine, formerly the largest producer of this species along the Atlantic coast of North America. The remaining fisheries are in Virginia which produces modest quantities of northern quahogs, *Mercenaria mercenaria*, and whelks, *Busycon carica* and *Busycotypus canaliculatus*.

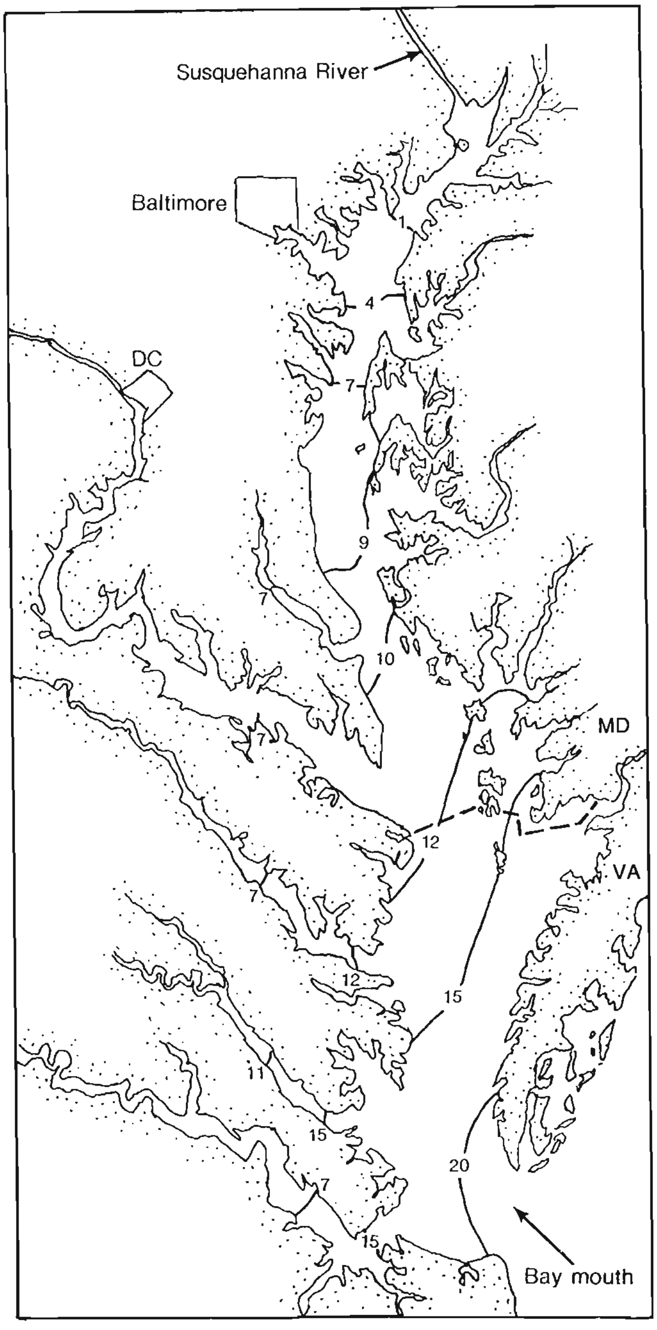

Figure 1
Chesapeake Bay and tributaries showing distribution of salinity at surface in spring (Lippson, 1973).

Habitat

Chesapeake Bay, 315 km long from the Susquehanna River to its mouth and covering 8,416 km^2 with its many tributaries, has extensive, flat, shallow (1–8 m deep) grounds with suitable salinities for growing shellfish on many thousands of acres. In Maryland, a large portion of the oyster grounds (also referred to as bars, beds, reefs, and rocks) are on the eastern shore in four large indentations—Chester River, Eastern Bay, Choptank River, and Tangier Sound. On the western shore, the Potomac and Patuxent Rivers are prominent locations. Nearly all the Maryland portion of Chesapeake Bay has salinities <15‰, and the tidal range is about 60 cm.

On Virginia's western shore, oysters have grown mostly in the Rappahannock, York, and James Rivers and in Mobjack Bay and Hampton Roads; on the Eastern Shore they have grown in Pocomoke Sound and along the east side of the Eastern Shore. In the main parts of most rivers, salinities are also <15‰, but in the lower part of the York River, Mobjack Bay, and Hampton Roads, salinities exceed 15‰. Oysters have also grown in Chincoteague Bay where the salinity is 29–35‰. The tidal range in Virginia's James River is 75–90 cm. Oysters have lived in the bay for several thousand years and now grow on solid beds of shell several meters thick in some areas.

Oysters have been a substantial component of the Chesapeake Bay ecosystem. They remove organic matter from the water, recycling it to other benthic organisms and thereby improving water quality. Rough calculations show that phytoplankton and carbon removal by the huge oyster population in 1870 was 100 times greater than in the 1980's when oyster populations were relatively small (Anonymous, 1990). During the 1800's, the oyster populations probably filtered from 50% to 80% of the water in the shallows of Chesapeake Bay during summer. The decline in oyster quantities since then may be a factor in an apparent shift in microbial food webs and resultant anoxia in deep bay waters during summers (Newell, 1988).

As oysters were harvested during 1900's, Maryland and Virginia planted shell, but the quantities were insufficient to maintain oyster stocks as high as they were in the late 1800's and early 1900's. Deforestation of the bay watersheds resulted in increased sedimentation and

Figure 2
Silt accumulation on surface of seed grounds in James River, Va., July 1971 (MacKenzie, 1983).

loss of existing cultch. In 1972, tropical storm "Agnes" washed huge quantities of silt into the bay and onto oyster grounds. Much of the shell bottom today is covered by silt (Fig. 2), and many formerly productive oyster grounds are covered by mud (Kennedy, 1989).

Predators of larvae of Chesapeake Bay oysters and probably clams are scyphozoans, ctenophores (Nelson, 1925; Purcell et al., 1991), and anemones (MacKenzie, 1977; Steinberg and Kennedy, 1979). The Atlantic oyster drill, *Urosalpinx cinerea*, and the less common thick-lip drill, *Eupleura caudata*, are the principal predators of sedentary oysters in salinities above 15‰, mostly in Virginia. Other predators are the oyster leech, *Stylochus ellipticus*; blue crab, *Callinectes sapidus*; and xanthid mud crabs (Haven et al., 1978). Softshells are preyed upon by blue crabs, while northern quahogs are preyed upon by the cow-nose ray, *Rhinoptera bonasus*; thick-lip drill, and shark eye snail, *Neverita duplicata* (Castagna and Haven, 1972).

In 1959–60, the protozoan disease, MSX, *Haplosporidium nelsoni*, entered Chesapeake Bay and thereafter has killed vast quantities of oysters where salinities were >15‰. It affected oysters much more in Virginia than in Maryland, but Maryland oysters have been affected during drought years.

The persistent presence of the fungus, called "Dermo," *Perkinsus marinus*, that becomes more intense during droughts and especially long, warm summers, kills additional oysters (Kennedy, 1989). Another disease called SSO, *Haplosporidium costale*, causes oyster mortalities in Chincoteague Bay and other seaside bays of Maryland and Virginia (Andrews et al., 1962). Diseases apparently do not cause mortalities in softshells, northern quahogs, and whelks.

Administrative Structure

The molluscan fisheries of Chesapeake Bay currently are overseen by three public administrative units: 1) The Tidewater Administration of the Maryland Department of Natural Resources (DNR), 2) the Virginia Marine Resources Commission (VMRC), and 3) the Potomac River Fisheries Commission. Earlier shellfish laws and agencies are discussed by species and state.

Maryland has kept its shellfish grounds mostly public to maximize employment; daily limits on catches in recent years have provided nearly equal earnings among fishermen. Management decisions commonly consider employment needs of fishermen, along with biological and environmental factors. Virginia has a mix of public and leased grounds, and the public grounds have provided much employment. Private companies once purchased huge quantities of oyster seed from fishermen (who harvested it from public grounds mostly in the James River), to plant on their leased grounds.

Landings figures for shellfish have been supplied to state agencies by the dealers and packers who handle the shellfish. The dealers and packers have operated on the honor system and have economic incentives to under-report the figures. Therefore, some of those reported here, especially relating to harvests of seed and market oysters, thus may be much lower, even as much as one-third, than they actually were (Morgan[2], Simns[3]).

History of the Oyster Fishery

Most activity in the Chesapeake's oyster fishery has been during the fall and winter when market oysters

[2] Morgan, C. 1994. Former owner of oyster packing firm, Weems, Va. Personal commun.

[3] Simns, L. 1994. President, Maryland Watermen's Association, Rock Hall, Md. Personal commun.

were harvested for sale. In recent years, with better refrigeration available, some oysters have been marketed in summer. In the large seed fishery in Virginia, the seed grounds were left undisturbed to collect spat and allow them to grow in summer; harvesting was from fall through spring.

Early History

Kitchen middens found along Chesapeake Bay prove that Native Americans had long used oysters for food. The largest midden covered nearly 30 acres on the shore of the Potomac River (Wennersten, 1981). Native Americans furnished early European colonists, settlers, and travelers with oysters in exchange for trinkets, tools, and other commodities (Stevenson, 1894). Later, soldiers and sailors in the Revolutionary War (1774–1776) and Civil War (1861–1865) and civilians in periods of peace left oyster shells around shores of the bay (Hargis and Haven, 1988).

In the early 1800's, a large portion of oysters harvested in Chesapeake Bay was shipped northward on schooners and sloops mainly to New York City; New Haven, Conn.; and Boston. In about 1808, vessels began transporting oysters each season to New Haven, which became the country's first oyster-packing center as those oystermen supplemented their local supply with Chesapeake Bay oysters. During 1820–25, the oyster business was much more developed in New York and New England than in Maryland. Oysters were delivered to New York City at least as early as 1816; 200 vessels transported them from Chesapeake Bay and made about 600 trips a month from September through February (Ingersoll, 1881). No wholesale markets existed along the shores of the bay for handling oysters, and local consumption probably was small (Stevenson, 1894).

In the 1830's, local opposition to the transport of unshucked oysters out of state induced some oyster marketers from Connecticut to establish shucking houses in Baltimore to prepare Chesapeake oysters for shipment throughout the country. The first shucking house began operating in 1836, and others soon followed. Oysters were shipped from Baltimore westward on the Baltimore and Ohio Railroad that began operations in 1830. Oyster packers earlier had shipped whole oysters westward to Pennsylvania, West Virginia, and the middle west on horse-drawn wagons. In 1839, about 710,000 bushels of oysters were shucked in Baltimore, and an additional large quantity was consumed along the shores. Over time, the railroad carried oysters farther, and the volume increased from 375,000 pounds to 3,200,000 pounds[4] from 1849 to 1860 (Nichol, 1937).

[4] These presumably are pounds of oyster meats rather than whole oysters.

An increased demand during 1830–64 brought an era of great expansion to the industry. The use of dredges to harvest oysters began, and the wholesale shucking trade developed (Stevenson, 1894).

As in Maryland, Virginia's portion of Chesapeake Bay (Fig. 1) had vast stretches of prolific oyster grounds in the 1800's. In areas of higher salinity, large quantities of oysters could be tonged and dredged and sold for immediate consumption. In areas of lower salinity (7–15‰), especially in the James River but also the upper reaches of the Rappahannock, Piankatank, and Great Wicomico Rivers, there were oyster grounds on which oyster larvae set regularly each year but then grew slowly and were mostly too small for consumption. In the rivers, oyster survival was good because salinity levels kept oyster drills from preying on the oysters. The best use of the small oysters was as "seed" to be planted on growing grounds in waters of higher salinity.

During most of the 1800's, oystering in Virginia involved harvesting large oysters for direct marketing and harvesting large seed for sale to northern schooners and sloops. Those vessels took the large oysters mainly to New York City and New Haven, Conn., for direct consumption. The seed was collected in the spring and taken to Delaware Bay, Raritan Bay, Long Island Sound, and Cape Cod for planting; most oysters were then harvested and marketed the subsequent fall (Ingersoll, 1881).

Oystering in Maryland

Regularity of oyster setting

Annual oyster setting on Maryland grounds has varied from light to good. From 1939 to 1993, only 9 of 55 years had counts (made in the fall on bottom shells and oysters) ranging from 100 to 300 spat/bushel. In 20 of the years, counts were from 50 to 99 spat/bushel, and in 26 of the years they were from 0 to 49 spat/bushel (Maryland DNR records). Spat densities were about five times higher on shell spread the year the spat set than on shell spread in previous years. Survival to market size usually was good and growth was rapid. After setting, oysters reach market size (7.5 cm) in 3–4 years (Kennedy, 1989).

Oyster Canning in Baltimore

The first oysters shipped from Baltimore probably were spiced or pickled meats. Around 1850, canning developed and took over as the primary oyster meat preservation method (Fig. 3). Canned oyster sales were spurred by the discovery of gold in California, because

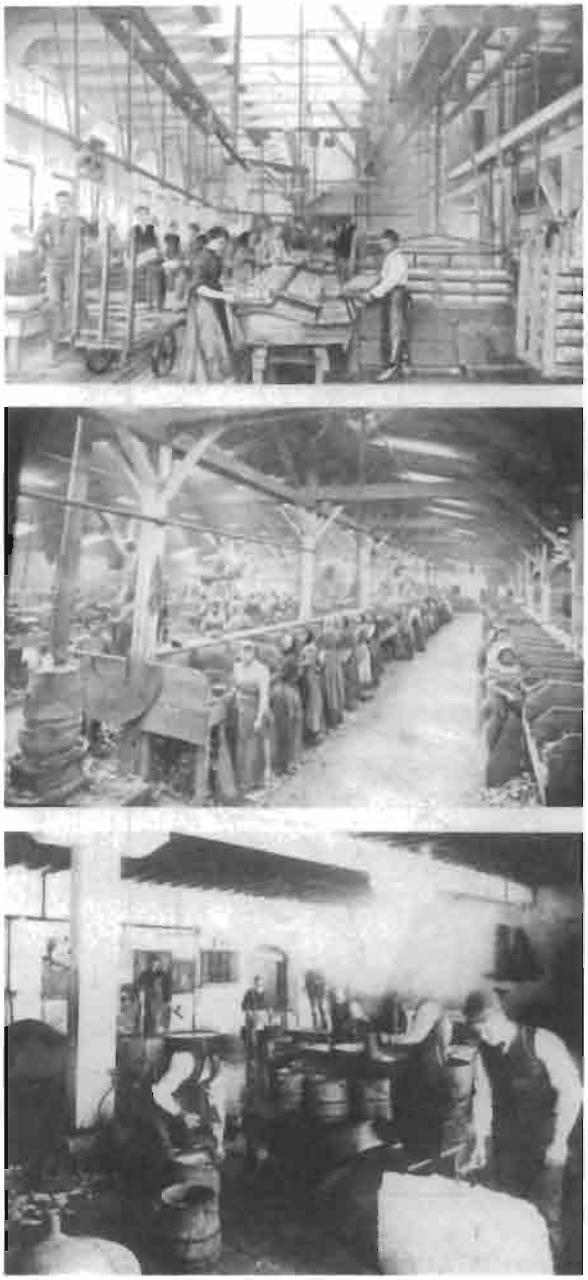

Figure 3
Upper: Processing room of an oyster canning house in Baltimore (Stevenson, 1894). Middle: Shucking room of a Baltimore marketing house in the raw oyster trade (Stevenson, 1894). Bottom: Packing oyster meats for shipment in a Baltimore marketing house, about 1900. Courtesy of the Mariners' Museum, Newport News, Va.

Baltimore's principal market for canned oysters and other foodstuffs soon became the Pacific coast. A more lasting trade in canned oysters later arose in the midwest (Table 1) (Nichol, 1937).

Table 1
Distribution of oysters received in Baltimore in the season of 1856–1857 (Nichol, 1937).

Designation	Quantity (bushels)
For local consumption	150,000
For raw shipment to	
Cincinnati and Chicago	400,000
Other cities	400,000
For canned oysters shipped to	
California	200,000
St. Louis	150,000
Other cities	310,000
Foreign ports	50,000
Totals	1,660,000

In the 1860's, Baltimore (Fig. 4) was the center of almost all Chesapeake Bay oyster trade, and it may have been the largest oyster marketing center in the world (Table 2). When more railroads were built in Maryland, some smaller ports around the bay, such as Crisfield, Cambridge, Oxford, St. Michaels, Annapolis, and many smaller places nearer the reefs also developed as market centers with shucking houses. (Market centers similarly developed in Virginia.) Large quantities of oysters were landed at other cities and towns located on the tributaries of the bay and sold to retailers and consumers without passing through the shucking houses (Stevenson, 1894).

Oyster marketing was divided into three branches: 1) the raw shucking trade, 2) the steaming trade for oyster canning, and 3) the trade in unshucked oysters. Of these, the raw shucking trade was most important. Oyster processing involved more capital than did the fishery, but only about half as many people. The marketing of unshucked oysters was comparatively small (Stevenson, 1894).

During the 1849–50 season, 1,350,000 bushels of oysters were landed at Baltimore. Landings increased to 4,765,270 and 6,090,963 bushels/season during the seasons of 1869–70 and 1892–93, respectively. Of the oysters received at Baltimore in 1890–91, about one-fifth were received from Virginia and from Virginia boats oystering in the Potomac River. Nearly all of the Potomac River was under the jurisdiction of Maryland, but Virginia oystermen had equal access to its oysters; only tonging was allowed to harvest them (Stevenson, 1894). Virginia controlled only small areas of the river.

Oyster canning boomed shortly after the Civil War ended in 1865. In the 1867–68 season, oyster production reached 9–10 million bushels, two-thirds of which were canned. But in the 1870's, the raw-oyster trade reestablished itself as the more important branch of the industry (Nichol, 1937).

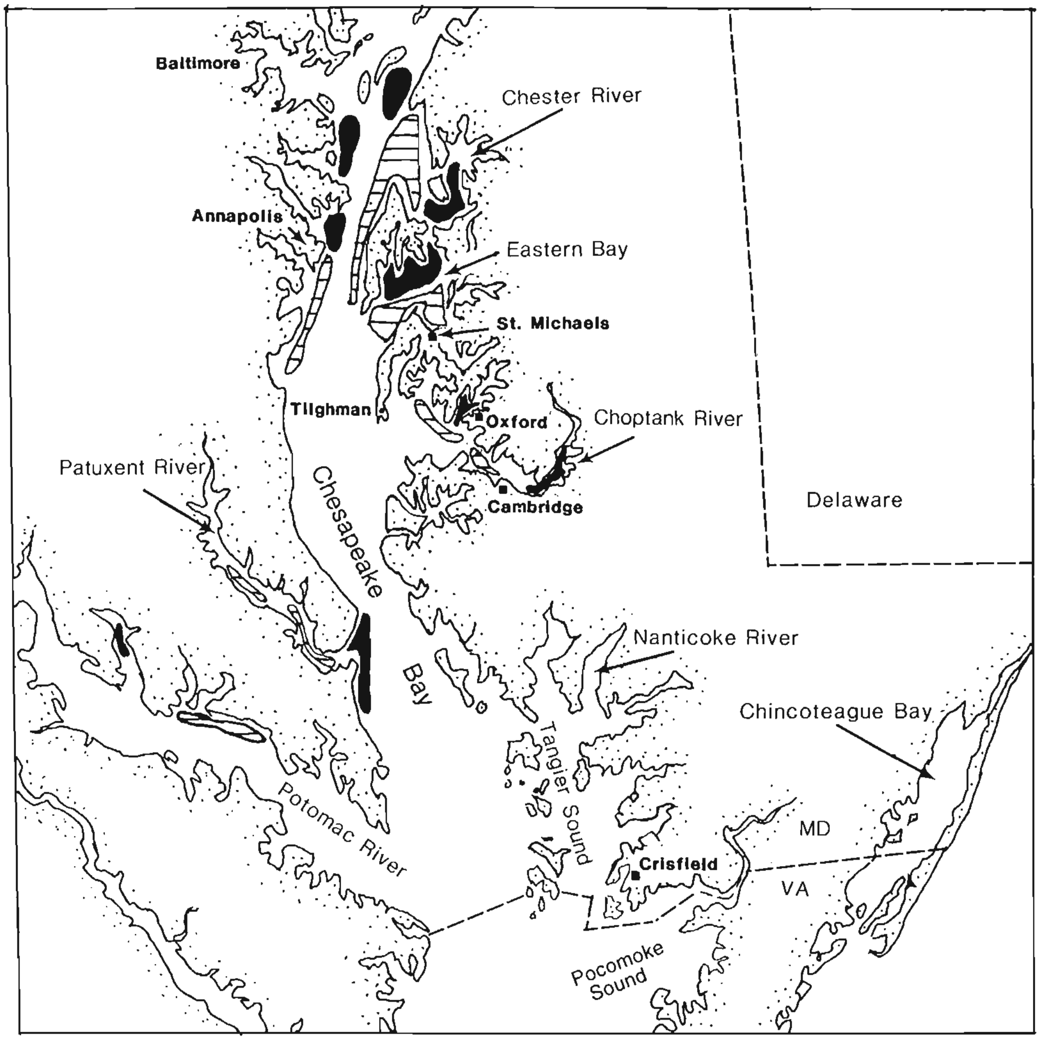

Figure 4
The Maryland portion of Chesapeake Bay showing recent oystering areas (solid areas) and softshell clamming areas (cross-hatched areas).

Table 2
Statistics of the Baltimore oyster industry before 1870 (Nichol, 1937).

Year	For local consumption (bushels)	For raw shipment (bushels)	For canning (bushels)	Total (bushels)	Establishments	Employees
1856–57	150,000	800,000	710,000	1,660,000[1]	18	1,500
1859					30	1,000–2,000
1860	200,000	2,000,000	1,000,000	3,200,000[1]	30	3,000
1862	200,000			1,700,000	33	1,700
1865	500,000	2,000,000	1,500,000	4,000,000[2]	40	3,000
1866	500,000	2,000,000	3,000,000	5,500,000[2]	>40	>4,000
1867	500,000	2,000,000	4,000,000	6,500,000	73	5,000
1868	500,000	3,000,000	6,500,000	10,000,000	80	8,000

[1] Packers paid $0.35/bushel.
[2] Packers paid $0.50/bushel.

The 1880's were regarded as the most prosperous in the history of the Maryland oyster industry with Baltimore as the main port. During that decade, Baltimore residents consumed at least 800,000 bushels of oysters/season, oyster canning factories were operating at full capacity, the city had at least 3,000 oyster shuckers and dozens of raw oyster bars, and oyster peddlers were common in its streets. In the fall season, when raw oysters were packed, oyster trains with 30–40 cars left the city for the west every day (Nichol, 1937).

Baltimore was the most northerly point of oyster canning on the Atlantic coast (Churchill, 1920). Between the 1879–80 and the 1892–93 seasons, from 1,826,428 and 3,074,770 bushels of oysters/season were steamed for canning in Baltimore's 20 canning houses. Workers carried oysters from vessels, put them in iron cars, and ran them into a steam chest for 10–15 minutes. When oysters gaped, other workers shucked them. The oysters were washed immediately in ice water, packed into cans, steamed again, and the cans were then hermetically sealed, labelled, and boxed. The entire process, from the time the oysters left the vessel until they were boxed and ready for shipment, took about an hour. Shuckers usually worked in groups of 6–8, sometimes comprising entire families of men, women, and children. They totalled about 4,000, mostly women and children, and ranged in age from 12 to 60 years. About 600 other persons were employed in the canning houses (Stevenson, 1894).

Because oyster canning and fruit canning complimented each other seasonally, they were combined by the canning industry. Packing of oysters, fruits, and vegetables grew side-by-side, and was carried on in the same plants under the same management by the same workers. For a time, oyster packing was more important, but after 1900 it was surpassed by fruit and vegetable packing as oyster canning declined (Nichol, 1937).

In the early 1890's, 58 houses in Baltimore were engaged in shucking oysters for the raw trade, ten of which further handled steamed oysters for canning. The largest one or two houses could each handle about 7,000 bushels of oysters/day. About 3,650 persons, of whom 3,200 were engaged in shucking, were employed in the raw trade. Shuckers were paid 20 cents/gallon of meats they opened (Stevenson, 1894).

Houses in smaller ports along the bay, where tonged and dredged oysters were shucked, were established after 1860; they increased sharply in number and size in the 1880's and early 1890's. The shucking trade was established in Crisfield in 1870 after a railroad line was built to the town in 1867; within 10 years, it had 28 shucking houses that employed 1,500 persons handling 700,000 bushels of oysters/year. In the late 1880's, the extent of the oyster shucking trade in Maryland was as follows: Number of people—8,523 in Baltimore, 3,585 in smaller ports; bushels of oysters shucked—2,736,342 in Baltimore, 3,362,480 in smaller ports; bushels of oysters canned—2,396,763 in Baltimore; none in smaller ports (Stevenson, 1894).

Soon after 1900, Baltimore found it increasingly difficult to meet the competition in canned oysters from other states and lost its oyster canning leadership. Besides, improved and extended service in the delivery of raw oysters had reduced the demand for canned oysters. After 1900, the city handled mostly raw oysters. In 1901–02, it handled slightly below 3 million bushels of oysters; by 1916–17, about 1 million bushels; and by the mid-1930's, between 0.5 and 0.6 million bushels. By the mid-1930's, only one oyster canning firm remained (Nichol, 1937).

First Regulations

In 1820, when its oyster production scarcely exceeded 500,000 bushels/year, Maryland issued its first oyster industry regulations. They prohibited the use of any implements other than ordinary tongs for harvesting oysters and also the transport of oysters out of state in vessels not owned wholly in the preceding 12 months by a citizen of the state, or the placement of oysters on board any such vessel to be transported. Because of the large expanse of water, however, the law did not prevent the continuation of the trade by northern vessels. From 1865 to 1895, a state licensing system was used in the oyster fishery, authorizing the use of tongs, dredges, and scrapes under certain regulations (Stevenson, 1894).

During several seasons after 1870, oyster landings ranged between 9 million and 14 million bushels/year. The largest single season harvest probably was in 1884–85 when an estimated 15 million bushels were landed; this was due to an excellent set (called a "strike" locally) on most grounds in the state (Stevenson, 1894). The harvest included seed oysters, many of which probably were discarded in shell piles. During 1873–88, the oyster industry produced an average of $5 million worth of oysters/year (Wennersten, 1981).

The distinction between "county waters" and "state waters" was important. People were not permitted to harvest oysters in the waters of any county unless they were residents of that county, while citizens of any portion of the state could harvest in all state waters. About 748 square miles (1,945 km^2) of county waters were reserved for tongers and 277 square miles (720 km^2) for tongers and scrapers; 35 of 1,334 square miles (91 of 3,468 km^2) of state waters, containing some of the best oyster grounds, were reserved for tongers, leaving the grounds in the bay including such areas as

Figure 5
Maryland oysterman on nearside of boat emptying oysters from his shaft (hand) tongs, while partner (far side) is filling his tongs. A third man, the culler, rests near cabin of boat, current. Photograph by R. J. Dodds, courtesy of the Chesapeake Bay Maritime Museum, St. Michaels, Md.

Tangier and Pokomoke Sounds for dredgers (Stevenson, 1894).

Harvest Methods

Tonging—The first records of shaft or hand tongs (Fig. 5) being used to harvest oysters date to the early 1700's (Witty and Johnson, 1988). In the early 1800's, canoes, used extensively by Indians, were almost the only type of tonging boat in use. During seasons from 1868–69 to 1891–92, between 1,907 and 5,858 boats (Table 3) were used for tonging. Most were canoes, but skiffs, bateaux, brogans (large log canoes), and sloops were also included. They ranged up to 13.7 m long, and all were under sail. Hand tongs with shafts 3.6–8.5 m long were used at depths of 3.0–6.7 m (Stevenson, 1894).

From one to three men made up the crew of each tonging boat; one crew member often was a boy whose job was to cull (i.e. separate market oysters from shells and seed that were discarded overboard) the oysters. In the 1880's, about 11,000 males, including 1,500 boys, worked in the tonging fishery. The men usually worked on shares, while the boys' wages varied from $0.50 to $1.25/day. Tongers usually worked about 125–140 days during the season; rough weather kept them ashore the rest of the time. They worked on farms and in other industries when not oystering (Stevenson, 1894). The tongers sold their oysters to local market houses or to buyboats. In the early 1890's, tongers harvested about 4.5 million bushels of oysters/season.

Table 3
Summary of various branches of the oyster industry in Maryland, in 1891–92 (Stevenson, 1894).

Item	No. of vessels	People engaged	Bushels harvested	Value of oysters ($)
Tonging	5,858	10,813	4,606,385	2,296,860
Dredging	770	5,059	3,657,965	1,740,310
Scraping	1,094	3,757	3,368,380	1,428,950
Transporting	456	1,651		
Marketing		12,108		4,650,500
Totals	8,178	33,388	11,632,730	

In 1887, patent tongs were developed to harvest oysters in waters too deep for shaft tongs. Without shafts and much larger and heavier than shaft tongs, the patent tongs were lifted with ropes and a winder attached to the vessel's mast and were opened manually when set on culling boards. They could harvest more oysters and were easier to use than shaft tongs (Stevenson, 1894; Witty and Johnson, 1988).

Dredging—Dredging began in the early 1800's. Before that, the small quantity of oysters needed to supply local markets did not warrant their use. Dredges soon were used on all Maryland grounds, except those in rivers that were reserved for tonging. Water depths over dredging reefs were mostly 4.6–9 m, but ranged up to 18 m (Stevenson, 1894).

The dredging boats ranged in size from craft barely able to carry two men with the small quantity of oysters they might harvest in one day to schooners 23 m long that carried about 3,000 bushels. In the 1892–93 season, the types and numbers of vessels engaged in dredging were schooners, pungies, and bugeyes (all two masters), 596; sloops, 32; canoes, etc., 91; for a total of 719; they were crewed by 5,600 men (Stevenson, 1894).

Pungies were first used in the oyster industry in the 1840's. They had a large keel and two raked masts. By the 1880's, bugeyes became the most important dredging vessels. Flat-bottomed schooners with cabin aft, bugeyes were cheaper to build and maintain and easier to handle than pungies (Wennersten, 1981). The average length of a vessel's life was 35 years. During summers, many vessels were used to transport farm produce and other commodities along shores of the bay (Stevenson, 1894).

Each vessel had a captain who remained aft, attending the steering and sails. The crew consisted of a mate, cook, and from two to nine hands, depending on vessel size. Most vessels carried two dredges and two "winders" or windlasses for hauling the dredges, but the smallest boats carried one dredge and one winder. The dredges weighed about 100 pounds and most were 1 m wide with 12–14 teeth. The winders were fastened to the deck of the vessel about midship, one on each side. Opposite them on the gunwales were rollers over which the dredge rope ran. Each winder was worked by two to four men at a time (Stevenson, 1894).

From 50 to 200 vessels dredged in grounds in a single locality, each harvesting 20–80 bushels of oysters/day. Most crews transported their own oysters to market, but some remained long distances from ports for months, lived temporarily on the vessels, and sold their catches to buyboats (Stevenson, 1894). The early dredging of oyster grounds may have spread and enlarged their areas (Winslow, 1881).

Scraping—The expression "scraping" is here applied to the harvesting of oysters by means of a dredge or scrape within the waters of a county. "Dredging" is applied to the form of the fishery when prosecuted in state waters. The vessels used in county waters usually were smaller than those used in state waters and consequently used lighter dredges, which were known as "scrapes." From 220 to 1,300 sailing boats, usually with four men, were licensed to use scrapes from 1869–70 to 1892–93. The boats comprised the various types used in tonging and dredging, but were mostly of medium size. In the three seasons included in 1868–71, dredge and scrape boats harvested an average of 6.73 million bushels of oysters/season (Stevenson, 1894).

Scrape-boat catches were also delivered to nearby marketing houses or sold to buyboats. Crews on the scrape boats usually returned to home ports every night (Stevenson, 1894).

The "Oyster Wars"

Relations between the oyster tongers and dredgers initially were friendly, but in the early 1870's oysters on grounds outside the rivers became scarcer, and many dredge boats, which numbered nearly 1,000, began to dredge on the tongers' grounds in the rivers. They usually did so under cover of night, to be inconspicuous. The tongers complained to state officials about the violations, but the state initially was not prepared to stop the dredgers. The tongers then attempted to stop the dredgers by shooting at them (Wennersten, 1981).

Before 1865, Maryland oyster regulations were enforced by local sheriffs and constables. In 1868, the state established an oyster police force, popularly called the "oyster navy." Its duties were to: 1) prevent dredgers and scrapers from oystering on grounds in rivers reserved for the tongers, 2) prevent dredgers from oystering on grounds used by the scrapers, 3) see that no one without a license was engaged in oystering, and 4) enforce the cull law and closed season, as well as the fish and waterfowl laws of the state (Stevenson, 1894). During the remainder of the century, the main violations were dredgers harvesting oysters on grounds reserved for the tongers. The "navy" (termed the State Fishery Force in 1872 (Plummer, 1993)) had to chase the dredgers many times, and the two groups frequently exchanged gunfire. The skirmishes were referred to as the "oyster wars" (Wennersten, 1981).

Animosity between Maryland and Virginia

Pokomoke Sound (Fig. 4) was the center of a boundary dispute between Maryland and Virginia. Boats from each state were dredging oysters in parts of the sound that the other state believed was its waters. Bad feelings between the states increased with each passing year and continued to linger even after the boundary location was finally settled. Feelings were also strained by skirmishes between Virginia dredge boats and Maryland's oyster navy on the Potomac River. Marylanders would not sell much shell to Virginia for spreading as cultch over its depleted grounds, and Virginians would not sell much James River seed to Maryland leaseholders (Wennersten, 1981). Packers in Crisfield, Md., used the shell from their shucking houses to widen the town's shoreline rather than sell it to Virginians (Sieling[5]).

Buyboats and Oyster Transportation

A large number of buyboats or "runners" carried oysters from the grounds to marketing houses, because the centers of the oyster trade, at Baltimore and other populous or railroad points, were many kilometers distant from the grounds. From 1889 to 1892, Maryland's oyster fleet included between 351 and 456 buyboats. The buyboats differed little from the dredge boats, except all were large, from 15 to 21 m long. Each laid at anchor near a fishing fleet, with a basket hoisted to its masthead signaling that oysters were being purchased (Stevenson, 1894).

Besides the buyboats in Maryland, at least 200 vessels from northern ports, with crews totalling about 1,000 men, carried oysters for 8 months of the year from Chesapeake Bay to the northern states for bedding or immediate consumption in the principal cities along the coast, especially New York City. During winter, oysters were taken for immediate consumption, whereas during spring they were bedded (Ingersoll, 1881). Each vessel carried about 2,500 bushels, and in the spring each made four to eight trips. This trade, at its height during 1840–70, purchased oysters in Maryland and Virginia (Stevenson, 1894). In the spring of 1879, 2.18 million bushels were shipped north for bedding (Ingersoll, 1881).

The planting of Chesapeake Bay oysters in the northern states later slowed considerably, owing to extensive development of private oyster grounds in the north and the consistently increasing prices of the Chesapeake oysters (Stevenson, 1894). On a small scale, bedding oysters were still carried north into the 1930's.

In the 1880's, about 33,000 people engaged in various aspects of oystering in Maryland. In addition, some other vocations were at least partly dependent upon the oyster industry. They were vessel construction, sail making, blacksmithing, house building, grocering, merchanting, medicine, and law. The oyster industry thus had enormous value to the state (Stevenson, 1894).

Buyboats continued to transport oysters within Maryland into the 1950's. The practice ended as oyster houses sent trucks to various ports to collect oysters from boats (Vojtech, 1993).

Bedding Oysters on Leases

Only a small portion of Maryland bottom was ever leased, a total of 11,000 acres in 1892 and 12,000 acres in 1952. As early as 1830, Maryland had granted 1-acre leases to citizens who wished to grow oysters. After the Civil War, the law allowed for 5-acre leases (Wennersten, 1981). In the 1880's and 1890's, production from the leases ranged from about 85,000 to 200,000 bushels a year (Stevenson, 1894). In later years, the Patuxent and Nanticoke Rivers were mostly used for bedding oysters on leases. By about the 1920's, Maryland allowed individuals to have 30-acre leases; by obtaining leases in the names of several of their family members, some individuals had rights to at least 200 acres on which to grow their oysters. Most "plants" were obtained from the James River, remained on the private leases for 1–3 years, and were dredged for market. Many were sold from 15 April to 1 September, i.e., the off-season for marketing from public grounds. From the 1920's through the 1950's, annual harvests from the leases were about 100,000 bushels (Sieling[5]).

Oyster Shucking Houses

By 1915, Maryland had about 160 houses for shucking, canning, and packing oysters. The number of oyster houses in Baltimore had declined to 28 (15 were oyster canneries), but it increased in the counties. Crisfield had by far the most with 40; Cambridge, 25; Oxford, 15; Annapolis, 13; Tilghman, 8; and St. Michaels, 6 (Churchill, 1920). Crisfield had become the most important because it was in the middle of the Chesapeake Bay coast and had a railroad terminal (Todd[6]). In the 1870's, at least 600 sailing vessels had landed oysters in Crisfield and 20 to 30 railroad cars carried oysters from its houses daily (Wennersten, 1981). The holding of harvested oysters in trays or on intertidal shores for a tide or two so they would purge mud and absorb brackish water before shucking, as was done in Delaware and Raritan Bays and farther north, was practiced on only a small scale in Maryland and Virginia (Sieling[5]).

Disposition of Oyster Shells

The fate of oyster shells has always been an important issue. Since about 400 million bushels of oysters were landed on Maryland shores from 1800 to 1890, large quantities of shells accumulated around processing houses. Shell uses were numerous (Stevenson, 1894):

[5] Sieling, F. 1994. Administrator (retired), Maryland Department of Natural Resources, Annapolis. Personal commun.

[6] Todd, C. 1994. Metomphin Bay Oyster Company, Crisfield, Md. Personal commun.

1) Road making and filling in hollows (live oysters were also harvested for this purpose (Sieling[5])),
2) Railroad bed construction,
3) Conversion into lime for making coal-gas and for farm use (small oysters were sometimes harvested with shells for lime),
4) Cultivation of oysters, some in Virginia, but also in Connecticut and elsewhere (in 1891–92 and 1892–93 about 750,000 bushels were used for this purpose each year),
5) Chicken grit, and
6) Manufacture of certain special grades of iron.

Throughout the 1900's until the 1960's, close to 1 million bushels/year of shells from shucking houses were spread on Maryland oyster grounds (Sieling[5]).

Oysters Decline

Following huge oyster landings between 1870 and 1895, production fell sharply, remaining low until the early 1930's (Fig. 6). However, some observers (Sieling[5]) believe the landings were not as large as reported and probably included seed taken to northern bays. The main cause was probably a declining supply. Harvests had been from oyster reefs that had developed over centuries. The surface shells left on them after harvesting may have become covered with silt and live organisms, especially in years of poor oyster setting. Such shells thereafter would collect far less spat than reefs covered with live oysters. Where shell beds were thin, the shells may have been dredged off leaving just the sand substrate. The planted shells helped to sustain supplies but were insufficient and the result was far smaller abundances of market oysters. The remaining

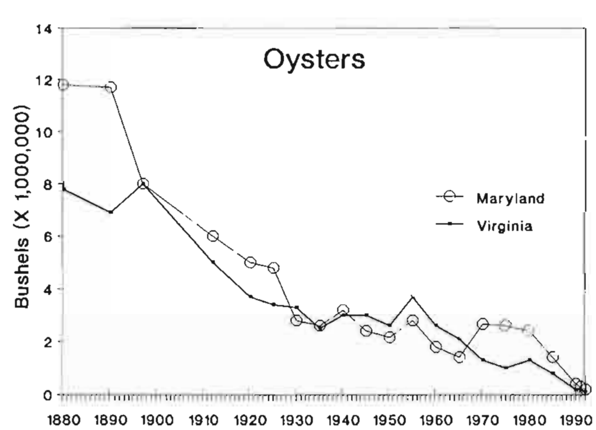

Figure 6
Historical oyster production in Maryland and Virginia.

causes seem to have been poor oyster demand and low prices.

In 1878, Francis Winslow, who was commissioned to survey the oyster grounds in Maryland, had warned that lax enforcement of the culling laws, enacted to prevent harvests of small oysters <3 inches long, and failure to plant oyster shells on the grounds would lead to a sharp decline in production. But in the 1880's, record landings were being made and too much money was being earned to think of conservation (Wennersten, 1981).

In 1893, the state passed another culling law that prohibited fishermen from taking oysters <2 $^1/_2$ inches long. The state also hired 12 inspectors to make sure the packing houses observed the new law (Wennersten, 1981).

The decline in oyster supplies intensified conflicts between the tongers and dredgers and the dredgers and police. By 1900, more packing houses were closing than were opening. In the years after 1900, the decline in the oyster industry prompted the state to prohibit powerboats from dredging oysters (Wennersten, 1981).

The drop in oyster production was sharpest in the 1920's from about 6.5 million bushels in 1920 to 3.5 million bushels in 1930. It probably was caused by a poor demand for oysters, because in the 1920's there was nationwide fear of possible illness from eating oysters harvested from polluted waters.

Around 1900, Maryland's dredging fleet consisted of nearly 1,000 skipjacks including some pungies, but by the 1930's, only about 150 skipjacks and pungies remained (Fig. 7). The skipjacks were first built for dredging oysters in the 1880's. They were one-masted boats with a V-bottom, cheap to construct, and easy to man. They soon replaced the pungies and bugeyes because they could be more economically operated and maintained. They began adding power hoists driven by gasoline engines to replace windlasses for dredges in 1906 (Vojtech, 1993). Each skipjack usually harvested 50–75 bushels of oysters/day. In the summer, they transported various types of freight, including melons and lumber, around the bay (Sieling[5]).

From 1930 to Present

Consistent Production—From 1930 to 1955, oyster production remained between 2.3 and 3.2 million bushels/year. (Virginia's production was also consistent in this period.) Production was sustained in part by Maryland's practice of regularly planting shells from shucking houses on reefs. As the years passed, however, it became more expensive to use the shucked shells for this program. After the mid-1950's, oyster production fell again, and in the early 1960's production was about 1.5 million bushels/year (Anonymous, 1990).

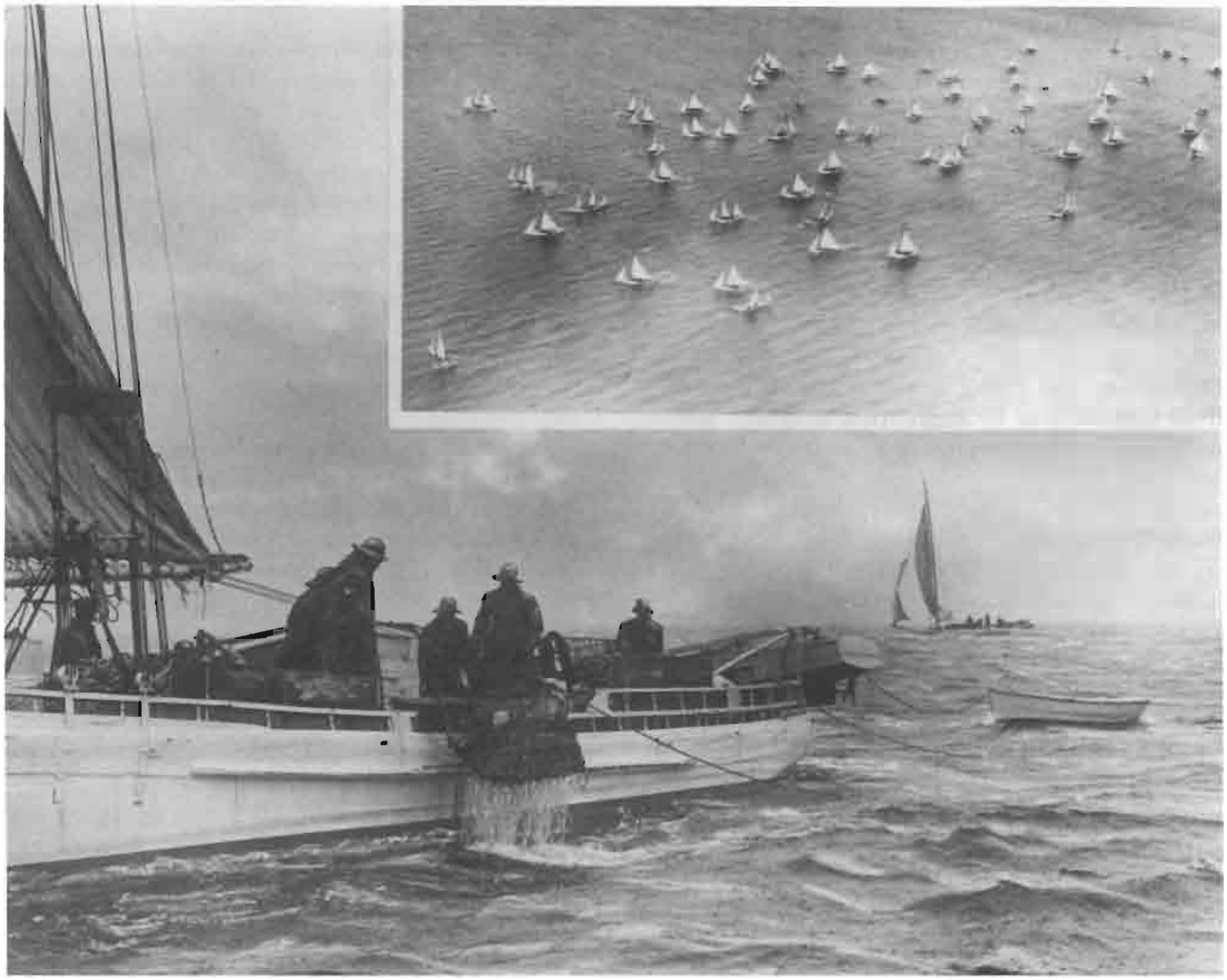

Figure 7
A skipjack dredging for oysters in Maryland, 1947. Photograph by A. A. Bodine, courtesy of The Mariners' Museum, Newport News, Va. Inset: Fleet of skipjacks (one mast) and pungies (two masts) harvesting oysters from a bed in Maryland, 1950. Photograph by H. R. Hollyday, courtesy of the Historical Society of Talbot County, Easton, Md.

Salting Oysters—A feature of the oysters harvested in northern Maryland, where salinities are low (7–10‰), is a bland flavor with a resultant weak market demand. In about the 1940's, dealers instituted a practice of transporting about 50,000 bushels of oysters/year to Chincoteague Bay where their tissues absorbed salt water and became more flavorful. Dealers held most in wooden floats (100 bushels/float), but put some on the bottom, for 3–7 days, and then sold them. They paid as little as $2.00/bushel for the oysters, $0.50 to $0.60/bushel to have them trucked to a dock on Chincoteague Bay, and they sold them for as much as $15.00/bushel for the raw-bar trade. The practice also was followed in Virginia on a smaller scale. It continued until the 1960's, when diseases began to kill many oysters (Sieling[5]).

In 1958, patent tongs with a hydraulic piston attached were developed (Fig. 8). The piston closes the tongs to gather oysters and then opens them to release the oysters over the boat's culling board. These "hydraulic patent tongs" are operated by a person using a system of levers and pedals. Because they are much easier to use, faster, and bring up twice as many oysters, they have replaced the original patent tongs.

Oyster Enhancement—In 1960, Maryland began a large program to enhance oyster abundance. Each year thereafter, the program involved dredging 5–6 million bushels of oyster shell from fossil deposits and spreading it, along with shell from shucking houses, on grounds with a good history of regular setting. From 1980 to 1989,

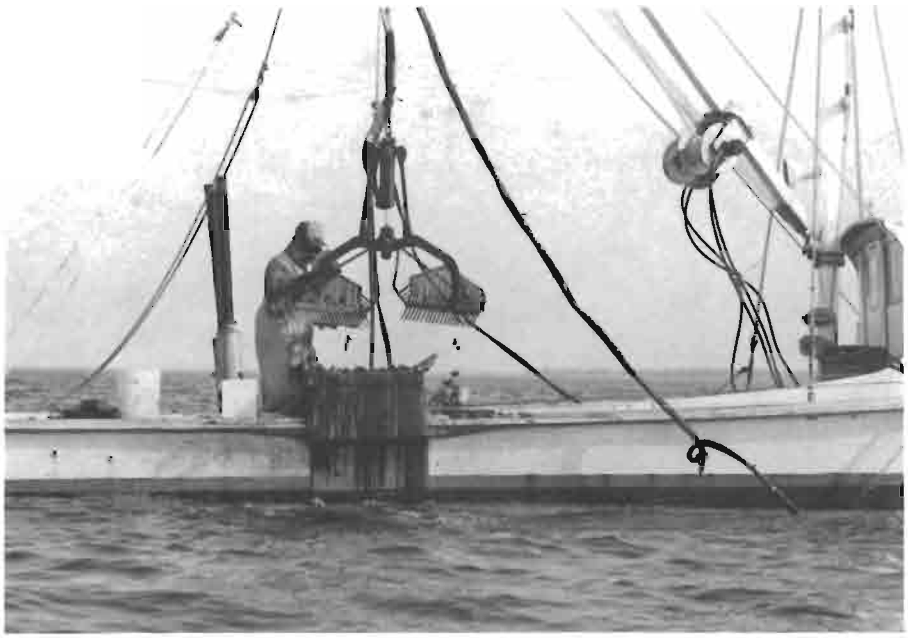

Figure 8
Hydraulic patent tongs being used to harvest oysters in Maryland, current. Photograph by F. Wells, courtesy of Chesapeake Bay Maritime Museum, St. Michaels, Md.

fossil shell represented 95% of the total. Compared with fresh shell, the dredged shell was more plentiful, less expensive ($0.36/bushel vs. $0.50/bushel), more easily obtained, and more effective in collecting oyster spat. After collecting a set, the state hired skipjacks and other private boats to transplant some seed to growing grounds, paying them $0.75/bushel to move seed 0–8 km; $0.97/bushel, 8.1–48 km; $1.08/bushel, 48.1–80 km; and $1.60/bushel to move seed more than 80 km. From 10,305 to 918,792 bushels of seed were transplanted each year between 1980 and 1990. From 1960 to the mid-1980's, the dredged shell program cost about $1 million/year, but in the late 1980's, when nearly 7 million bushels/year were spread, the cost was almost $2 million/year (Anonymous, 1990).

If the shell did not collect a set, it often collected a layer of silt and fouling organisms which kept it from collecting as many spat as did clean shell the following years. In some years, the state hired vessels to tow oyster dredges without bags over the shells to clean off the silt and turn them just before larval settlement.

The state shelling program produced a huge increase in oyster landings. Landings rose to 2–2.7 million bushels/year from the mid 1960's through the early 1980's. From the 1960's onward, the public fishery has been dependent upon this state repletion program.

In the 1960's, from 4,000 to 4,200 men crewing about 1,200 hand-tonging boats, 700 patent-tonging boats, 45 skipjacks, and other boats were harvesting oysters on good days in Maryland. Most hand-tonging boats carried two men, though one or three were also common. Men in two- and three-man crews often took turns tonging and culling. Two men commonly harvested 15–25 bushels of oysters/day (Sieling[5]).

Each skipjack was manned by a captain and six crewmen, who emptied the two dredges, culled oysters, and shovelled seed and shells overboard. While earlier crews could use only sail to power their vessels while dredging each day, a law was passed in 1966 to allow them to use a push boat for power on Mondays; a few years later, Tuesdays were also added (Vojtech, 1993). The number of skipjacks declined to about 30 in the 1970's, 25 in the 1980's, 15 in 1992–93, and 8 in 1993–94 (Sieling[5]).

In the 1960's, Crisfield had about 12 oyster houses. The smallest houses had 10 to 12 shuckers, while the largest had 50 to 75 shuckers (Todd[6]).

In 1971, the county system was abolished; afterward, oystermen could harvest oysters in all state waters without boundary restrictions (Vojtech, 1993). When oystering at some distance from home, they commonly lived on their tonging boats and skipjacks during the week (Sieling[5]).

Scuba Diving—Since the 1970's, scuba divers have harvested oysters commercially. The state restricts them to the lower parts of tributaries, while the tongers work in

Figure 9
Scuba diver about to enter water and harvest oysters in Maryland, current. Photograph by R. J. Dodds, courtesy of Chesapeake Bay Maritime Museum, St. Michaels, Md.

the upper parts. The state requires at least two to a scuba team, one diver and one tender in the boat (Fig. 9).

Oyster Diseases Depress Industry—After 1981, dominant factors in the Maryland oyster industry were the reappearance of the disease MSX and the invasion of Dermo. The grounds in Maryland's portion of Tangier Sound previously had been invaded by MSX in the late 1950's and many oysters died, but in 1981–83 many major oyster grounds were affected. There was a brief reprieve in 1984 and 1985, but this was followed by a return of MSX in previously infected areas and an expansion into more areas in 1986–88 (Anonymous, 1990).

Early in the 1980's, Maryland oyster landings fell, but less than in Virginia, Delaware, and New Jersey, because the lower salinity waters in Maryland provided some refuge for oysters from MSX and Dermo. The sporadic nature of the MSX infections made it difficult for the state to develop an effective strategy for planting shell and seed.

The heavy mortalities caused oyster production to decline from about 2.5 million bushels in the 1980–81 season to about 1 million bushels in the 1983 season. Landings increased to about 1.6 million bushels in 1984 and 1985, but fell to about 0.4 million bushels in 1987 and 1988. Each year, there were fewer oystermen. By 1989, the state had 3,196 licensed oyster harvesters, but 2,111 (66%) were part-timers who harvested less than 50 bushels of oysters each during the season. In addition, 138,700 bushels (35%) of the total annual catch of 390,676 bushels reportedly were harvested by only 139 (4.4%) of the licensed oystermen (Anonymous, 1990).

Current Oystering—The diseases MSX and Dermo have drastically reduced the supply of oysters in Maryland, and the number of boats and their daily catches have fallen (Table 4). In the early 1990's, the state spread about 1.67 million bushels of shells/year on its seed grounds (Judy[7]).

In 1994, Maryland's oyster fleet consisted of about 400 tonging boats, about 100 of which were patent tongers, 30 scuba-diving boats, and 7 skipjacks. From one to three men still crewed each tonging boat, but the skipjacks were crewed by a captain and four men in contrast with a captain and six men in an earlier period. The legal state catch limit for tong boats was 15 bushels/man/day—not to exceed 30 bushels/boat/day. The state limit for skipjacks was 150 bushels/day (Judy[7]). The oystermen pay a tax to the state of $1.00/bushel; the money is used to support management efforts (Simns[3]).

In 1992–93, oyster landings totalled 123,618 bushels with a dockside value of $2.6 million. In 1985–86, oystermen on tong boats and skipjacks had averaged

[7] Judy, C. 1994. Natural Resources Manager, Maryland Department of Natural Resources, Annapolis. Personal commun.

Table 4

Estimated numbers of molluscan boats and fishermen in Chesapeake Bay during the peak of seasons, 1993–94.

	Maryland			Virginia	
	Boats	Fishermen		Boats	Fishermen
Oystering			Oystering		
Hand tonging	300	500	Hand tonging	60[1]	90[1]
Patent tonging	100	150			
Diving	30	35	Northern quahoging		
Dredging	7	35	Patent tonging	112	125
			Treading, raking		112
Softshelling	60	75	Quahog farms		150
			Whelking	9	18
Totals	497	795		181	495

[1] About 40 boats and 60 men were in James River in May 1994.

9.8 bushels of oysters/man/day and earned $104.86/day (at an average of $10.70/bushel), whereas in 1992–93 the oystermen averaged 4.6 bushels/man/day and earned $99.80/day (average of $21.73/bushel). The tongers now average 5–6 bushels/man/day for the season, i.e., 10–15 bushels at the beginnings of seasons and 3–4 bushels at their ends. Each skipjack harvests about 30 bushels/day when using sail power, and about 40 bushels/day when using a push boat on Mondays and Tuesdays. In the early 1990's, from 30 to 40 divers were harvesting in any one day. Each team of two harvested up to 15 bushels of oysters on good days (Judy[7]).

In the 1990's, oyster harvests were consistently highest by the hand tongers, divers were second, and skipjacks third. Most oysters were shucked and sold fresh or frozen (Judy[7]). In the 1993–94 season, four shucking houses remained in Crisfield.

In 1994, Maryland had stocks of small oysters growing in a few areas, such as Tangier Sound. The oysters survived relatively well and production rose to 200,000 bushels in 1995–96 (July[7]).

Oystering in Virginia

By the 1870's, the Virginia oystermen were establishing a system of practices that would last into the 1990's without much change in equipment or methods; only the volume of oysters handled changed. Oystermen harvested seed with hand tongs from public grounds, mainly in the James River (Fig. 10). Planters then 1) purchased the seed from them, 2) spread it on their leases, 3) left it 2–3 years without further handling to grow to market size, at least 76 mm (3 inches), 4) hired tongers or used their own dredge boats to harvest the oysters, and finally 5) hired people to shuck them in their oyster houses on a piece-work basis. In addition, market oysters from public grounds were harvested and sold to shucking houses built along the shores of the Potomac, Rappahannock, York, and James Rivers and Mobjack Bay. The oysters were sold locally and in other states (Ingersoll, 1881). Two major changes in equipment used involved the conversion from sails to engines in boats and from hand windlasses to power hoists on dredge boats soon after 1900.

In 1865, dredging vessels harvested 1,083,209 bushels, and tonging crews took 981,791 bushels of market oysters from public grounds in Virginia. Ten years later, total harvests for Maryland and Virginia had doubled and presumably reached nearly 20 million bushels/year between 1875 and 1885 (Hargis and Haven, 1988).

By 1879, Virginia's oyster fleet was comprised of 4,481 canoes and skiffs manned by 8,860 tongers besides 1,317 larger sailing vessels with 5,376 men. The sailing vessels carried seed purchased from tongers to private grounds mainly in the Rappahannock and York Rivers, Mobjack Bay, and Hampton Roads, and they also dredged oysters mostly from public grounds; hand winders were used to retrieve the dredges (Ingersoll, 1881).

A prominent feature of Virginia's oyster industry since 1892 has been an Act passed by the General Assembly that year, which decreed that natural oyster grounds and the best oyster grounds of the state were not to be leased, rented, or sold, but rather held in trust for the benefit of all people of the state. The grounds, comprising 234,271 acres, have since been termed the Baylor Grounds, after J. B. Baylor who surveyed them. Virginia decreed that the grounds available for leasing were outside the Baylor Grounds. Most were between the Baylor Grounds and the shores, and most initially had

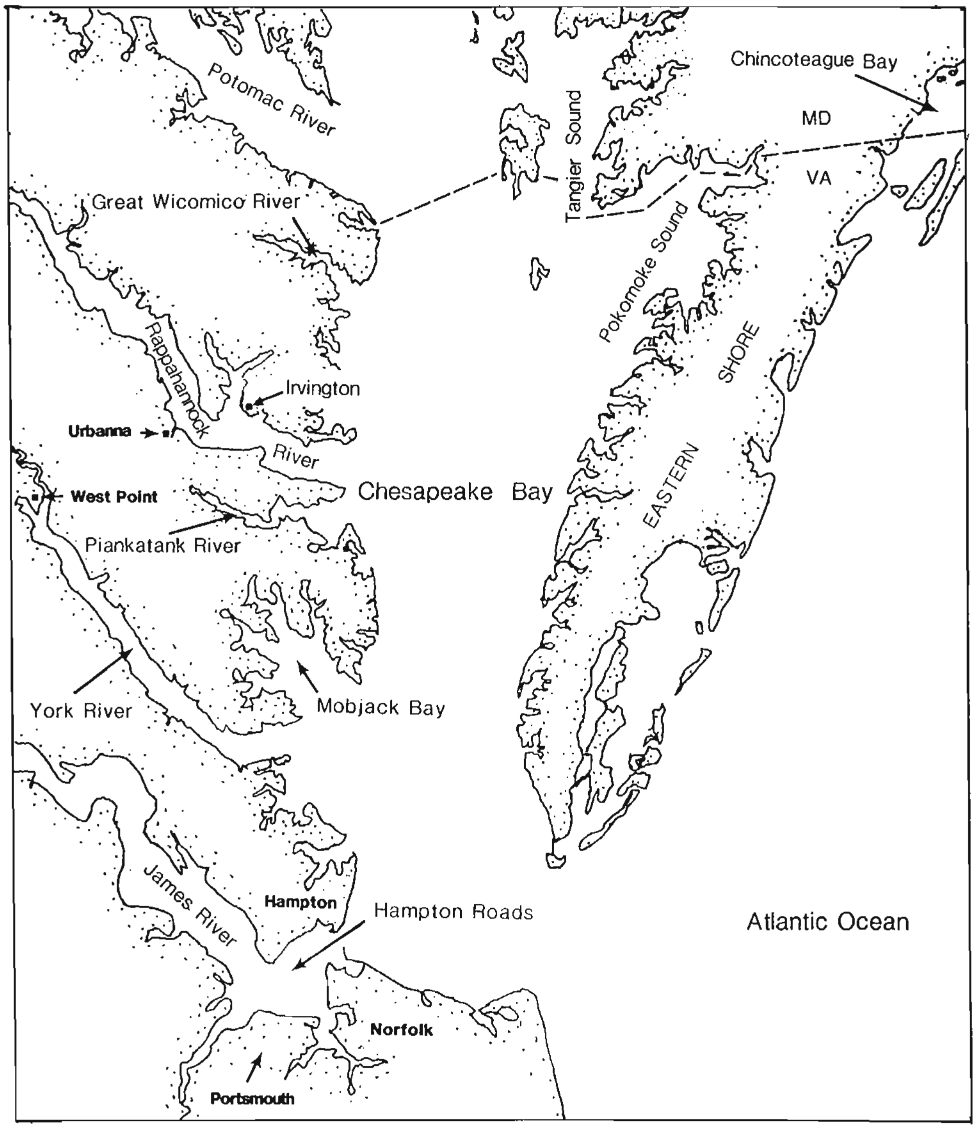

Figure 10
The Virginia portion of Chesapeake Bay showing major oystering areas.

soft, poor grounds for supporting oysters (Haven et al., 1978).

In the late 1800's, planters began formally leasing state grounds outside the Baylor Grounds to grow seed they purchased mostly from the James River. In 1926, the state began charging rent for leases, usually about $1.00/acre. New leases granted after 1960 were rented for $1.50 in rivers, $0.75 in Chesapeake Bay, and $1.50 on the Eastern Shore (Haven et al., 1978).

Over the years, planters consistently spread shell that had been shucked in their oyster houses over their leases to harden them for supporting seed. Some grounds required at least 10,000 bushels/acre (Haven et al., 1978). The shell crusts that formed over the soft grounds were generally at least 15 cm thick. By doing this, the planters eventually created thousands of acres of suitable growing grounds.

In 1900, Virginia issued 5,846 licenses to individuals for hand tonging, 246 licenses for patent tonging, and 737 licenses for dredging boats (2,500 men worked on the boats). About 3,500 people were also employed shucking and barrelling oysters (Anonymous, 1900).

Harvesting Seed

In the James River, setting densities of oyster spat were higher and more regular than in Maryland. During 1947–53 and 1958–61, average numbers of spat on bottom shells and oysters were 1,060/bushel. During one

9-year period, annual numbers of spat/clean test shell ranged from 3.8 to 21.0, 3.0 to 28.7, and 1.7 to 9.2 on three grounds (Haven et al., 1978).

Virginia established a season from 1 October to 30 May for harvesting seed and market oysters from its public grounds. From the 1920's (and probably much earlier) into the 1950's, crews on 700 to 800 boats (avg. length, 12 m) were tonging seed oysters in the James River. Each boat had a crew of 1–3, for a total of about 1,500 men. Men from distant parts of the state lived on their boats during the week and returned home on weekends. Throughout this century, some have hunted game for fresh meat during state hunting seasons when weather prevented tonging (Crockett[8], Rowe[9], Setterholm[10]).

The surfaces of James River grounds consisted of small shells on which oyster larvae set. In harvesting seed, the tongers tried to skim off the thin layer of seed and avoid digging into the shells underneath (Clark[11]). Typical daily catches of seed on good weather days were 50–75 bushels for boats with one tonger and 100–150 bushels for boats with two tongers and a culler (Crockett[8]). The tongers included small amounts of shell with the seed (Virginia allowed no more than 6 quarts of shell/bushel of seed) and, by the 1990's, had lowered the initial height (in about 1900) of some reefs by about 1.5 m (Morgan[2]). James River tonging crews sold the seed to buyboats. The largest tonging boats, holding up to 150 bushels, unloaded onto the buyboats once a day, while small tonging boats holding 40–50 bushels had to unload two-three times a day. Buyboat captains paid crews in cash after they unloaded (Burton[12]).

Annual harvests of seed oysters from the James River were commonly estimated at about 2 million bushels a year, but actual harvests may have been at least three times larger (Morgan[2]). In the 100-year period before 1959, oystermen probably harvested well over 200 million bushels of seed from the river.

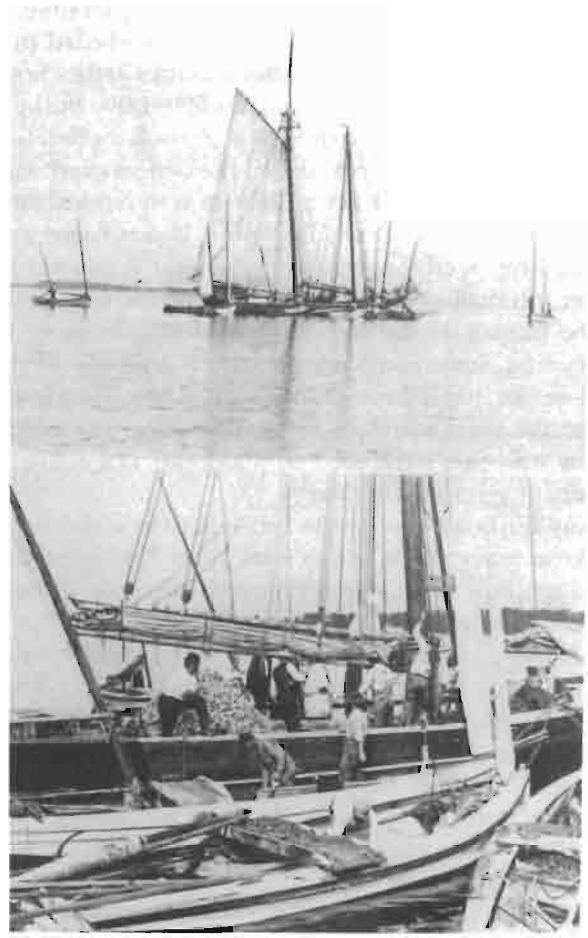

Figure 11
Upper: Schooner loading seed oysters from tonging boats in James River, Va., about 1900. Lower: Closeup of schooner loading seed oysters from tonging boats, same area and time. Note use of halyard to handle bushel bucket of oysters. Photographs courtesy of The Mariners' Museum, Newport News, Va.

Buyboats

An estimated 75–100 Chesapeake Bay buyboats (Fig. 11), about half of which were owned by the three largest oyster planters, i.e., J. H. Miles and Co., Inc., and Ballard Fish and Oyster Company, both of Norfolk, Va., and J. S. Darling Company of Hampton, Va.[13], purchased seed in the James River. Additional buyboats from northern states were present into the 1930's. Most buyboats were 15–21 m long and carried from 2,000 to 3,500 bushels of oysters. Some of the smallest ones that carried oysters to nearby areas such as Hampton Roads and the York River held 700–800 bushels. Buyboats could load on oysters from as many as eight tonging boats simultaneously, and it usually took them 1–2 days to get a full load (Burton[12]).

[8] Crockett, O. 1994. Shellfisherman, Hampton, Va. Personal commun.
[9] Rowe, J. 1994. Shellfisherman, Menchville, Va. Personal commun.
[10] Setterholm, O. 1994. Shellfisherman, Perrin, VA. Personal commun.
[11] Clark, H. 1994. Shellfisherman, Remlik, Va. Personal commun.
[12] Burton, J. 1994. Captain of oyster buyboat, Kinsale, Va. Personal commun.

[13] Mention of trade names or commercial firms does not imply endorsement by the National Marine fisheries Service, NOAA.

The large buyboats were operated by three men, the small ones by two men; all lived aboard part-time. In most years, crews shovelled the seed overboard onto leased planting grounds, but after about 1970 they hosed it overboard. The planting rate was 500–1,000 bushels/acre. When a buyboat arrived at a ground, it often took on an extra man or two to shovel the oysters overboard. In the Rappahannock River, the extras were local farmers (Dowells[14]), while in Hampton Roads some were James River seed tongers (Rowe[9]). Some leases were in water too shallow for the buyboats, and the oysters had to be put on dories and taken into shallow water for spreading. Some companies had their grounds filled in 2–3 weeks, but others planted all season (Morgan[2]). After the seed planting season ended in the spring, many buyboats were used to plant shucked shells on company grounds (Burton[12]).

Any buyboats that loaded in less than a day could make as many as five trips a week from the James River seed grounds to Hampton Roads, the shortest distance 30 km away, and the largest planting area. The run to the middle of the York river from the seed grounds took 3 hours, while the run to the Rappahannock River, 165 km away, was 9 hours (Burton[12]). About 95% of production from the York River was from James River seed (Morgan[2]).

In a season, individual buyboats often ran large quantities of seed from the James River. A typical quantity for a buyboat carrying seed to Hampton Roads was about 90,000 bushels, but a buyboat once ran 156,000 bushels of seed to Hampton Roads. A buyboat carrying seed to the Rappahannock River grounds ran about 40,000 bushels (Burton[12]).

Public Market Grounds

The public oyster grounds which Virginia maintained for its fishermen were in the Potomac, Little and Great Wicomico, Rappahannock, York and James Rivers, Mobjack Bay, and the Eastern Shore (Haven et al., 1978). The grounds were mostly 3–5 m deep. Since 1928, the state has planted some with shell and seed to help maintain oyster abundances. The quantity of shells planted/year increased from about 160,000 bushels in early years to 950,000 bushels in 1960; between 1 and 3.5 million bushels were planted in the 1960's and 1970's (Haven et al., 1978). Seed on the grounds could be sold to planters by fishermen, transplanted by the state to depleted grounds, or left in place to grow to market size for harvesting by fishermen (Wesson[15]). In recent years, the state enhancement activities were paid for by collecting a $0.50/bushel tax on each bushel of market oysters harvested, a $0.03 tax on every gallon of oysters shucked, and appropriations from the state legislature (Clark[11]).

Tonging was the only harvest method allowed on the public market grounds. Since hundreds of men worked on the grounds, their tonging kept some shell surfaces clean enough to collect sets, and those kept producing. The catch rate of market oysters was 20–25 bushels/tonger/day, or about 65 bushels/day for a boat with two tongers and one culler. The oysters were delivered to shucking or packing houses at the end of every day. Early in the season, the boats often were limited to 3 days/week because the shucking houses could not handle all the oysters that could be produced. Most men who tonged market oysters on public and leased grounds in the fall and winter worked on farms in the spring and summer (Allen[16]).

The state allowed oyster harvesting with patent tongs in certain public grounds that were too deep for hand tonging. On grounds where oysters were abundant, a man patent tonging alone could harvest about 25 bushels of market oysters/day, while two men operating two patent tongs could take about 40 bushels/day. When the catch dropped to 4–5 bushels/day, the men had to quit (Clark[11]).

Harvesting Oysters On Leases

Companies harvested oysters from their planted grounds by hiring tongers and by dredging with their own boats. The companies preferred tonging on many grounds, because dredges used improperly could break through the crust of shells they had spread to make suitable grounds for growing oysters. In the Rappahannock River, nearly all oysters were tonged; on some grounds, the remainder after tongers finished were harvested with light dredges towed by 12-m boats. In the York and lower James Rivers, Mobjack Bay, and Hampton Roads, oysters were tonged and dredged. Two tongers and one culler on a boat could harvest about 50 bushels of market oysters/day. In the 1930's, companies paid tongers about $0.25/bushel for harvesting, and by the 1950's about $1.00/bushel. Tongers transferred the oysters to company buyboats (West[17]; Setterholm[10]).

The J. H. Miles Company, Inc., which had its grounds at depths of 7.5–9 m in Mobjack Bay and Hampton

[14]Dowells, C. 1994. Former owner of oyster packing firm, Centercross, Va. Personal commun.

[15]Wesson, J. 1994. Conservation/repletion officer, Virginia Marine Resources Commission, Newport News, Va. Personal commun.

[16]Allen, S. 1994. Shellfisherman, Coles Point, Va. Personal commun.

[17]West, J. C. 1994. Shellfisherman, Gloucester, Va. Personal commun.

Roads, probably was the largest oyster company in the world earlier in this century. From 1935 to 1960, it planted from 106,000 to 1,000,000 bushels of seed/year and, from 1948 to 1957, harvested an average of 440,000 bushels of market oysters/year (Haven et al., 1978). During marketing seasons, the company produced an average of 2,000 gallons of oyster meats/day. It dredged most of its oysters with its own boats, 18–27 m long, with crews of 6–8. Two of its boats were about 30 m long; they towed four dredges, had crews of 12 men, and carried 2,800 and 3,200 bushels of oysters. They could load on those quantities in 4 hours of dredging (Snow[18]). The Ballard Fish and Oyster Company, another large firm, produced an average of 320,000 bushels/season from 1948 to 1960. In company oyster houses, shuckers often put aside any seed to be returned to the grounds for further growth (Haven et al., 1978).

Planted grounds consistently yielded about one bushel of market oysters for each bushel of seed planted. From 1947 to 1960, James River seed averaged 2,177 oysters[19]. Companies harvested from this about 300 market oysters 2–3 years later. The mortality of the original seed then was about 90% (Haven et al., 1978).

Shucking Houses

Virginia had many shucking houses near where oysters were planted, such as the south shore of the Potomac River, the Rappahannock, York, and James Rivers, Mobjack Bay, and Hampton Roads (Fig. 12). In 1915, there were 19 such houses at Norfolk and Portsmouth, 2 at Hampton, 3 at West Point, 2 at Urbanna, and many others (Churchill, 1920). About 116 were operating in 1927 (Rep. Va. Comm. Fish., 1927), 227 in the 1970's (Haven et al., 1978), 117 in 1985, and 65 in 1992 (VMRC records[20]).

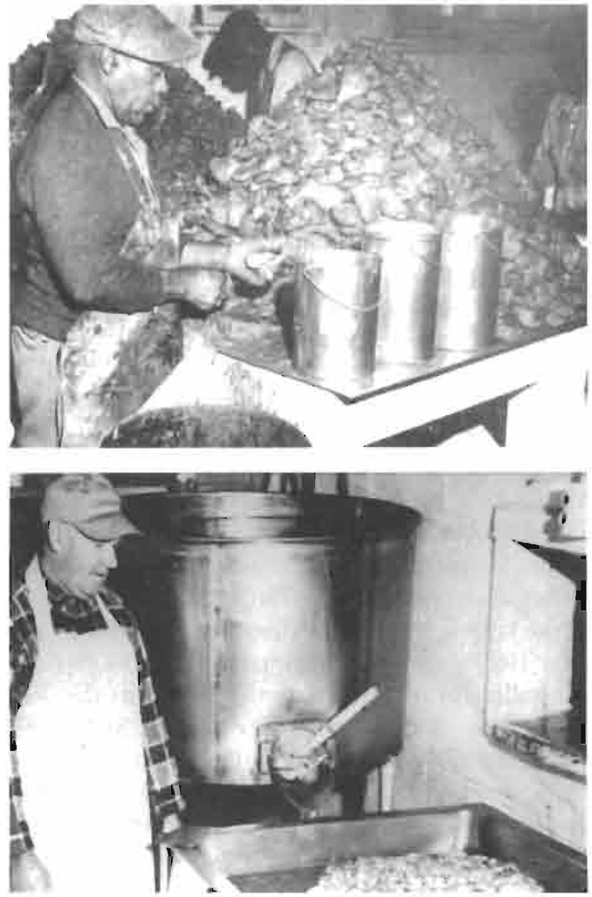

Figure 12
Processing oysters in plant, 1961. Upper: Worker is shucking oysters and placing them by size in cans. Lower: Oyster meats have been washed in blower (large tank with water) and worker will put them into cans. Photographs by R. K. Brigham, BCF.

The houses processed oysters from their own leases and those from public grounds. The people who shucked oysters in fall and winter worked nearby as farmers in spring and summer. In summer, many oyster houses switched to canning peaches, peas, and tomatoes, and most of the labor they hired for canning consisted of the wives of tongers and shuckers (Dowells[14]). Beginning about 1960, when oysters began to get scarcer, the canning companies lost some of their labor because people could not remain in the locality without the money incentive provided by the oyster work. This loss was also tied to technological developments in the menhaden, *Brevoortia tyrannus*, and alewife, *Alosa pseudoharengus*, fisheries that led to fewer jobs (Burrell[21]).

Three large companies had much larger shucking houses than the others. They were the J. H. Miles and Co., Inc., with 425 shuckers and the Ballard Fish and Oyster Company with 275 shuckers, both in Norfolk; and the J. S. Darling Company with 75 shuckers in Hampton. The Ballard Co. also had 75 shuckers in a house on the Eastern Shore (Ballard[22]). Most remain-

[18]Snow, M. 1994. Retired fisherman, P.O. Box 10230, Bavon, Va. Personal commun.

[19]This includes 1,066 oysters less than 3 inches long, 1,084 spat, and 27 market oysters.

[20]Virginia Marine Resources Commission records of license sales. On file at commission office, Newport News, Va.

[21]Burrell, V. G., Jr. 1994. South Carolina Wildlife and Marine Resources Department, Charleston, S.C. Personal commun.

[22]Ballard, C. 1994. Owner, Cherrystone Farms, Cheriton, Va. Personal commun.

ing houses had 20–50 shuckers. Most oyster shuckers were women. Some of the smaller houses had their own grounds, while others did not (Morgan[2]).

The price that houses paid for oysters was based partially on the yield of meats/bushel. The average meat yield from a Virginia bushel is 6.0–6.5 pints. In the 1930's, the houses paid leaseholders and public fishermen $0.35/bushel for good quality market oysters, and if the quality was poor and the supply abundant, the price could fall to $0.15/bushel (Morgan[2]). While most oysters were shucked, some were shipped in the shell for the raw-bar trade (Haven et al., 1978).

Shuckers usually began work at 4 a.m. and some continued into the afternoon, with breaks for breakfast and lunch. An average shucker opened 15–20 gallons/day, while an above–average shucker opened about 25 gallons/day. The oyster meats differed in size: The smallest, called standards, yielded at least 300 meats/gallon; the mediums, called selects, yielded 200–300 meats/gallon; extra selects ran 160–200 meats/gallon; and the largest, counts, had less than 160 meats/gallon. In the 1920's, shuckers were paid about $0.25 to open each gallon of meats (Johnson, 1988); in the 1930's, $0.35/gallon (Ballard[22]); in the 1950's, $1.00/gallon; and in the 1970's, $2.50/gallon (Johnson, 1988). In the 1990's, shuckers have been paid from $1.00 to $1.20/pound of meats (a gallon weighs 8 pounds) and most shuckers work about 6 hours to earn $50 to $60/day (Simns[3]).

Oystering on the Eastern Shore

On the Eastern Shore of Virginia, most leaseholders have collected their own seed. A common procedure was to spread shells in parallel rows, about 12 m long, 2 m wide, 75 cm high, and 2.7 m apart in intertidal areas. Spat commonly set in densities of 10–30/shell. They were grown in place for 1–2 years and then transplanted to subtidal growing grounds for 1–2 years of additional growth before harvesting. The heavy sets produced oysters in clumps. Peak oyster production was in 1954 when about one million bushels were landed (Haven, 1972).

Effects of Oyster Diseases

After 1959, the MSX disease began to kill most oysters larger than 50 mm in high salinity (>15‰) areas of the bay. Areas heavily affected included nearly all of Chesapeake Bay proper from the mouth of the Rappahannock River south, the lower portions of the Rappahannock, York, and James Rivers, Mobjack Bay, Hampton Roads, and the Eastern Shore. Oysters have since shown little acquired resistance, and in the 1980's annual mortalities of oysters in the high-salinity areas were 50–70% (Hargis and Haven, 1988).

Another effect of MSX has been a huge drop in setting densities of oyster spat in the James River since the early 1960's (Haven and Fritz, 1985). Most likely, a large reduction in the spawning stock, a result of high mortalities in the massive private plantings of market oysters in high-salinity downriver grounds in Hampton Roads, was responsible for the drop. Another factor may have been pollution. Chlorine and its derivatives are highly toxic to oyster larvae and occur in the river from discharges of sewage-treatment and power plants and refineries (Hargis and Haven, 1988).

With the drop in supply of seed in the James River, the Virginia Marine Resources Commission (VMRC) has developed the Great Wicomico and Piankatank Rivers as seed areas by planting several million bushels of shells in them since the early 1960's (Haven et al., 1978). From 1963 to 1970, the James River produced 74% of Virginia's oyster seed; the Great Wicomico River, 12%; the Eastern Shore, 9%; and the Piankatank River and Milford Haven area, 5% (Haven, 1972).

Another pathogen that has caused smaller oyster mortalities is Dermo. It has been in Virginia perhaps since the 1800's and earlier. Dermo is active where salinities exceed 12–15‰, and its occurrence and severity are temperature dependent. Most deaths from Dermo occur during the middle to late summer and are higher when temperatures are above normal. The death rate in 2- and 3-year-old oysters may be as high as 25% annually (Hargis and Haven, 1988). Since oysters on planted grounds began dying in large numbers, planters stopped purchasing much seed from the James River and most have left the oyster business.

Marketing Soup Oysters

In 1957, a large soup company began buying oysters, 1.5–2 inches (40–50 mm) long, from the James River as an ingredient in oyster stew. With the loss of nearly all the market for seed oysters after 1960, oyster tongers harvested the larger oysters, which became known as "soups," rather than the smaller seed. From 42 to 175 tong boats, most having two tongers and one culler, harvested them daily from the 1966–67 to the 1975–76 seasons (the number of boats declined through time) (VMRC records[20]). Each crew harvested 75–100 bushels/day during good weather (Setterholm[10]). They brought the oysters into Deep Creek, the main port for tonging boats off the James River, and put them on trucks owned by processing companies. About 3,000 bushels/day usually were landed. Buyers paid the tongers $4/bushel for them. The oysters were processed in houses in Norfolk, Urbanna, and Irvington, Va., packed in 5-gallon cans, and taken to the soup company. Most oyster buyboats by then had been scrapped or put to other uses (Perok[23]). The harvesting of soup oysters ended abruptly in 1976 when Kepone was discovered in the James River (Haven et al., 1978).

During and following the 1986–87 season, the James River seed area became the major source of 76 mm oysters in the state, producing 42.5% of the Virginia total. The total non-James River market oyster production was 539,506 bushels that season (Hargis and Haven, 1988).

Figure 13
Small oyster shucking house near Potomac River, 1994. Photograph by C. MacKenzie.

Shucking Maryland Oysters in Virginia

In the 1960's and 1970's, large quantities of Maryland oysters were shucked in Virginia oyster houses along the south shore of the Potomac River (Fig. 13) and the shores of the Rappahannock River (oyster production in Virginia had declined sharply while it increased in Maryland). From 1968 to 1975, at least 50–77% of oysters processed in Virginia were from Maryland and the Potomac River, and Virginia shucking houses processed from 50–67% of Maryland's oyster production (Haven et al., 1978). The oyster meats were packed in 15-gallon cans and brought to oyster houses along the York River and Hampton Roads, which then had few local oysters to handle, for repacking in 8-ounce and gallon cans (Burrell[21]).

In a shucking house, workers shuck oyster meats by size, measure their quantities, and then put them in blowers (tanks holding 100–200 gallons of freshwater with air blowing in their bottoms) to wash and swell the meats by 10–20% (Fig. 12). Blowers were designed to meet the requirements of the U.S. Food and Drug Administration for a hygienic product (Nichol, 1937). The meats afterward are cooled to 4.5°–7°C, packed in containers that hold from 1 pint to 5 gallons, and then placed on ice. They then are shipped to markets throughout the United States. Some oysters are also shipped in the shell for opening and processing elsewhere or for the raw-bar trade (Hargis and Haven, 1988).

The "soups" from the James River were processed differently. They were retorted, placed in a brine bath in which the meats floated, and then washed and chilled. They then were used as an ingredient in canned soups, stews, or chowders (Haven et al., 1978).

In recent years, four types of businesses have handled oysters (Hargis and Haven, 1988):

1) Shucker-packers—shippers who shuck and pack shellfish. A shucker-packer may act as a shell-stock dealer.
2) Repackers—shippers, other than the original shucker, who pack shucked shellfish into containers for delivery to the consumer. A repacker may also shuck or act as a shellstock shipper if he has the necessary facilities and permits.
3) Shellstock shippers—shippers who grow, harvest, buy, or sell shellstock. They are not authorized to shuck shellfish or repack shucked shellfish.
4) Reshipper—shippers who transship shucked stock in original containers, or shellstock from certified shellfish shippers to other dealers or to final consumers. Reshippers are not authorized to shuck or repack shellfish.

In 1985, Virginia had 53 shucker-packers, 51 repackers, 47 shellstock shippers, and 1 reshipper. Their total number had declined by 17% since 1975 (Hargis and Haven, 1978).

Historical Virginia Oyster Landings

Virginia oyster landings fell almost steadily from 7–8 million bushels/year in the 1880's to the period from

[23]Perok, S. 1994. Shellfish dealer, Menchville, Va. Personal commun.

1935 to 1955, when production ranged between 2.5–3.7 million bushels/year and usually was the highest in the United States. The main cause of the huge decline after 1880 seems to have been a great reduction in the supply of market oysters on the public Baylor Grounds. The populations of oysters apparently could not be sustained under steady harvesting with concurrent siltation and fouling of shells on the grounds and inadequate shelling. After the 1930's, most production was from leased grounds planted with seed. Since MSX invaded the Virginia oyster grounds, landings have fallen sharply and were only about 45,000 bushels in 1993 (Fig. 6).

Current Status

In the 1980's and 1990's, oystering in Virginia has been concentrated in the James River, where many oysters still occur. In the late 1980's, oysters were relatively scarce in the river, but with subsequent light sets each year, a good set in 1993, and light harvests, oysters were abundant on upriver grounds in 1994. The once-productive lower grounds have not been harvested in recent years and, without disturbance by tonging, they have accumulated a layer of silt that prevents any settlement of oyster larvae (Crockett[8], Rowe[9]). Little market exists for the James River seed. In the 1990's, the few companies remaining in business purchase only test quantities of seed to plant on their grounds each year to determine whether they will live.

In the 1993–94 oyster season, the state, acting to conserve the oyster supply, allowed oyster harvesting in the James River only until noon each day and allowed only 20,000 bushels of seed to be taken from the river. Crews in about 40 boats tonged daily. Most harvested >76 mm market oysters, getting 2–3 bushels/man/day. The harvest rate was slow because the oysters were scarce and fishermen had to pick through quantities of seed and shell to find them. The remaining boats (2 tongers and 1 culler) got 100–150 bushels of seed/day. The oysters were landed at Deep Creek and subsequently transported on trucks. The market oysters brought the fishermen $20.00/bushel and the seed, about $2.00/bushel. The remaining oystermen have since switched to crabbing or clamming or found jobs ashore (Crockett[8]).

The former production areas of the Potomac, Rappahannock, York, and lower James Rivers, Hampton Roads, Mobjack Bay, and Chincoteague Bay produce few oysters. Fishermen check the grounds for the presence of oysters every year and, in 1993–94, some oysters just under market size were present. But when the next dry cycle of rainfall occurs and salinities rise, abundances likely will fall again.

To offset the low supply of oysters, dealers imported substantial quantities of oysters from the Gulf of Mexico states, mainly Louisiana in 1994. At a cost of $12.00/bushel delivered, they were being shucked in houses along the Potomac and Rappahannock Rivers and the Eastern Shore.

Northern Quahog Fishery

The northern quahog (called "clam" locally) occurs in Chesapeake Bay proper, in the lower, high-salinity sections of tributary rivers, and in Chincoteague Bay and other bays on Virginia's Eastern Shore. Virginia's quahog fishery has been much smaller than its oyster fishery. The Eastern Shore produced about half of the quahogs in the 1930's, and two-thirds in the 1950's and 1960's (Castagna and Haven, 1972). The number of fishermen engaged recently has increased as some have switched to quahoging from oystering.

In Chesapeake Bay, quahogs were once harvested with short rakes at wading depths and with patent tongs in deeper water. Short raking was abandoned because the quahogs became too scarce in shallow areas. Patent tonging for quahogs probably began in the early 1900's. Before the mid-1920's, the tongs, 1.2 m wide, opening 1.2 m, and weighing 125 pounds, were raised with a windlass. Two men worked the rig: One man turned the windlass crank and the other handled the tongs. It took 3–5 minutes to drop and raise the tongs each time ("make a lick"). The boat drifted slowly in the current and wind, its speed being controlled with a drag anchor (Setterholm[10]).

Fishermen, using automobile parts, made the first engine-powered hoists for patent tongs in the 1920's (Setterholm[10]). As equipment improved, the tong dimensions remained the same, but the tongs grew to weigh 160–220 pounds, they could be operated by one man, and they "made licks" faster. The tongs have since been used mostly in 7.3–12 m of water, but can operate in as much as 17 m. The boats continue to drift over the grounds using a drag to control their speed. In about 9 m of water, a tonger can make about three licks/minute, but if the bottom is muddy and the clams have to be rinsed in the water, the rate may drop to two licks/minute (West[17]). In the 1990's, some boats have Loran plotters to help their captains relocate the densest concentrations of quahogs. Tongers cannot work bay waters in strong winds, and they miss many days during foul weather periods (Waymack[24]).

For the past 25 years or so, patent tongers have been harvesting quahogs in clean and polluted waters. The

[24]Waymack, B. 1994. Shellfisherman, Susan, Va. Personal commun.

quahogs are becoming scarcer in both. In summer 1994, 35–40 boats harvested in clean waters. Tonging 10–12 hours and obtaining fewer than two quahogs/lick, boats got 1,500 to 1,700 quahogs/day. The landed price/quahog was $0.12 for littlenecks, $0.07 for cherrystones, and $0.05 for chowders. The current price for littlenecks has fallen from $0.18 each a few years ago because quahog farms from Massachusetts to Florida have been glutting the market with them according to Waymack[24]. Prices for littlenecks had earlier increased sharply: In 1969 and 1970, the landed price for each littleneck was only $0.036 (Castagna and Haven, 1972).

Most of the patent tong fleet has been harvesting clams in polluted waters, in an open season from 1 May to 15 August. In the 1990's, the fleet has been concentrated in Hampton Roads, and over the past 25 years, about 75 boats have worked there daily; about 65 have had one patent tong and 10 had two. The daily catch rate has declined: In 1980, each boat harvested about 10,000 quahogs; in 1988, about 6,500; and in 1994, about 4,000, when an average of about 4 quahogs (range = 0–10) was harvested per lick. Most are littlenecks that in 1994 brought the fishermen $0.09 each; cherrystones sold for $0.04 each. Fishermen have to harvest at least 3,000 quahogs/day to make their operation profitable (West[17]).

After a day of harvesting in polluted waters, fishermen first bag the quahogs, then bring them to a state-designated landing site, and finally put them on trucks sealed by a VMRC officer. They are taken to various clean waters, placed in large trays or planted on leased grounds for at least 15 days of depuration, and then are reharvested and sold. After the season in polluted waters ends, the tongers harvest quahogs from clean areas, tong for oysters, or dredge for blue crabs in the winter (West[17]).

On the Eastern Shore, wild quahogs are harvested mostly by treading (with hands (Fig. 14) or feet) at wading depths or digging with two-tine "gaff-hooks" on bare flats at low tide. About 100–125 treaders and diggers with gaff hooks harvest quahogs year-round; each gets about 250–1,500 quahogs/day. In addition, two boats are rigged with patent tongs for harvesting quahogs in channels, 3–6 m deep (Marshall[25]).

Figure 14
Hand harvesting of northern quahogs at Chincoteague Bay, Va., 1948. Photograph by A. A. Bodine, courtesy of the Mariners' Museum, Newport News, Va.

In the past, some chowder quahogs were shucked locally. The meats were sold to make chowders and the shells were used as containers for deviled clams (Castagna and Haven, 1972).

Cultured Quahogs

A bright aspect in an otherwise depressed Virginia shellfishing scene is the recent development of quahog-rearing farms on the Eastern Shore. Quahog larvae are reared in four hatcheries. The juveniles are grown in trays filled with sand and covered with screens, and then, after growth to about 15 mm, the seed quahogs are removed and planted in sections of leased grounds covered with screens to protect them from predation by blue crabs and cownose rays. The grounds are intertidal or covered with water no more than 1 m deep at low tide, and the screens can be set in place by workers on dry flats or by wading.

In 1993, about 30 million littlenecks (about 30,000 bushels) were harvested from the seed the four hatcheries produced; the largest hatchery produced 20 million littlenecks from its seed. The hatcheries grow some seed on their leased areas, and they have cooperative agreements for growing seed with independent leaseholders. The hatcheries sell small seed to the leasehold-

[25]Marshall, D. 1994. Resource officer, Virginia Marine Resources Commission, Chincoteague, Va. Personal commun.

ers, who grow them until they attain littleneck size and are sold; the hatcheries and leaseholders share the selling price 50–50. About 150 people work in the hatcheries and on the farms. The quahog hatchery rearing and growing operations are expanding (Bois[26]).

Quahog production has varied widely since 1880. After 1965, when production was 225,000 bushels, landings fell sharply and only 65,000 bushels were taken in 1985. The total since has risen, presumably because of the Eastern Shore farming (Fig. 15).

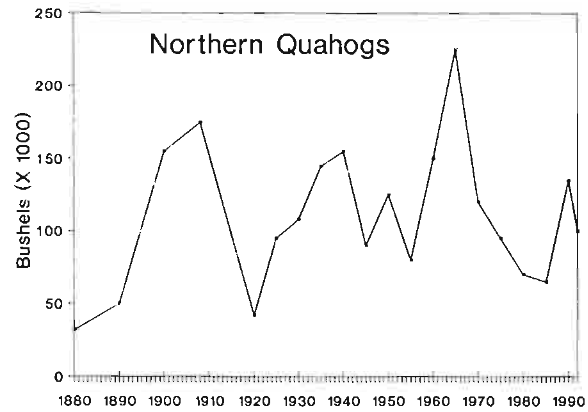

Figure 15
Historical landings of northern quahogs in Virginia.

Softshell Fishery

The softshell (called "clam" and "mannose" locally: Mannose is a Native American name for softshells) is common in subtidal grounds in Maryland and supports a substantial fishery. Juvenile softshells set in May and again in September or October (Pfitzenmeyer, 1962). Most May juveniles are eaten by blue crabs, whereas the fall juveniles have better survival. Some softshells attain the minimum legal length of 2 inches (50.8 mm) near the end of their second summer, but most reach it in their third summer. Maryland is near the southern limit of the range of the species, and in extraordinarily hot summers many softshells die, presumably from heat stress (McLaughlin[27]). Virginia has no softshell fishery.

A commercial fishery for softshells in Maryland began in 1951, when a fisherman developed a hydraulic conveyor "dredge" for harvesting them (Fig. 16). The dredge is attached to the side of a boat and consists of a head of high-pressure water jets that washes the softshells from sediments and a conveyor belt that carries them to the surface. A crew of 1–2 men picks them off by hand and puts them in baskets. Undersized softshells, shells, and stones fall off the end of the belt into the water (Hanks, 1963).

When the fishery began, fishermen used mostly crab boats, 9– 12 m long, but gradually switched to boats 12–13.7 m long and 3–4 m wide. Running the earliest dredges required three gasoline engines: One to operate the boat, one for the pump, and one for the conveyor belt. The rig then was suspended from a mast and boom rather than davits as now, and was raised and lowered using a block and tackle. The newer boats have diesel engines and use hydraulics run off the main engine to operate the conveyor belt and to raise and lower it. Their pumps generate water pressure up to 100 p.s.i., in contrast with 25–30 p.s.i produced by the earlier pumps (Pollack, 1985).

Operation of the gear initially was limited to water depths not exceeding 10 feet (2.79 m) by a legal restriction on the length of the conveyor belt (5.8 m from axle to axle) (Manning and Pfitzenmeyer, 1957). The state since has allowed longer belts, and some boats have extensions on the escalators that allow them to harvest in greater depths. The most common depths now are 4.6–6 m. The fishery is limited by state law to four counties, and the fishermen pay a $0.35/bushel state tax on softshells landed (Simns[3]).

About seven boats were harvesting softshells in 1952, the number increased to 132 in 1957, and since the early 1970's, the softshell fleet has had about 150 boats (Judy[7]). Fishermen begin work early in the morning when winds usually are light and work about 8 hours in good-weather days. They cannot work in rough weather (Sieling[5]).

In the 1960's a typical catch for a boat was about 30 bushels/day (Hanks, 1963), but the state has since imposed catch limits. The legal daily limit currently is 15 bushels/boat from 15 May to 31 October, and 8 bushels/boat from 1 November to 14 May. In the 1970's and 1980's boats commonly harvested 10–15 bushels/day at the beginning and 8–10 bushels/day at the end of the summer demand season. In April, they got 3–4 bushels/day (Judy[7]).

Until about 1980 or 1985, fishermen harvested softshells or blue crabs in summer to earn money between the oyster season. With oysters and crabs currently scarce, the boats now harvest softshells year-round. Peak harvests are from June through September, when the demand is highest (Judy[7]).

Softshell production rose quickly from 21,000 bushels with a landed value of $173,000 in 1952 to 107,000 bushels with a landed value of $431,000 in 1955. Production continued to rise and in 1969 peaked at 659,000

[26]Bois, R. 1994. Virginia Marine Resources Commission, Onley, Va. Personal commun.

[27]McLaughlin, S. 1994. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv. Oxford Lab., Oxford, Md. Personal commun.

bushels with a landed value of $2.8 million. Annual production afterward fell as virgin stocks were fished down and from 1975 to 1991 was mostly between 100,000 and 200,000 bushels, but 354,000 and 365,000 bushels were landed in 1988 and 1989, respectively. The landed value ranged from $1.2 million in 1975 to $10 million in 1989. In 1992 landings fell again to 19,361 bushels worth $1.5 million. In 1993 and 1994 production has also been low (Fig. 17); about 60 boats were fishing every day. Each landed about 5 bushels/day (Judy[7]).

Nearly all softshells have been trucked out of state to markets in New Jersey, New York, and mainly New England. In the 1990's, some were trucked to Buctouche, New Brunswick, Can., for shucking. The meats afterward were sold in New England (Simns[3]).

The landed price of the softshells has risen. In 1960, they brought fishermen about $3.15/bushel: in 1970, $4.70/bushel; in 1980, $26.55/bushel; and in 1990, $44.40/bushel (Judy[7]).

In the late 1980's New England markets began rejecting Maryland softshells because coliform counts induced by warm temperatures were too high. Health officials in New England insisted that Maryland clams had to conform to standards set by the Interstate Shellfish Sanitation Conference and their own public health departments. To meet the standards, the Maryland fishermen installed insulated or refrigerated boxes on their boats. Fishermen with insulated boxes put the softshells in the boxes and cover them with crushed ice, maintaining their temperature below 15°C on the boats (Valliant, 1990).

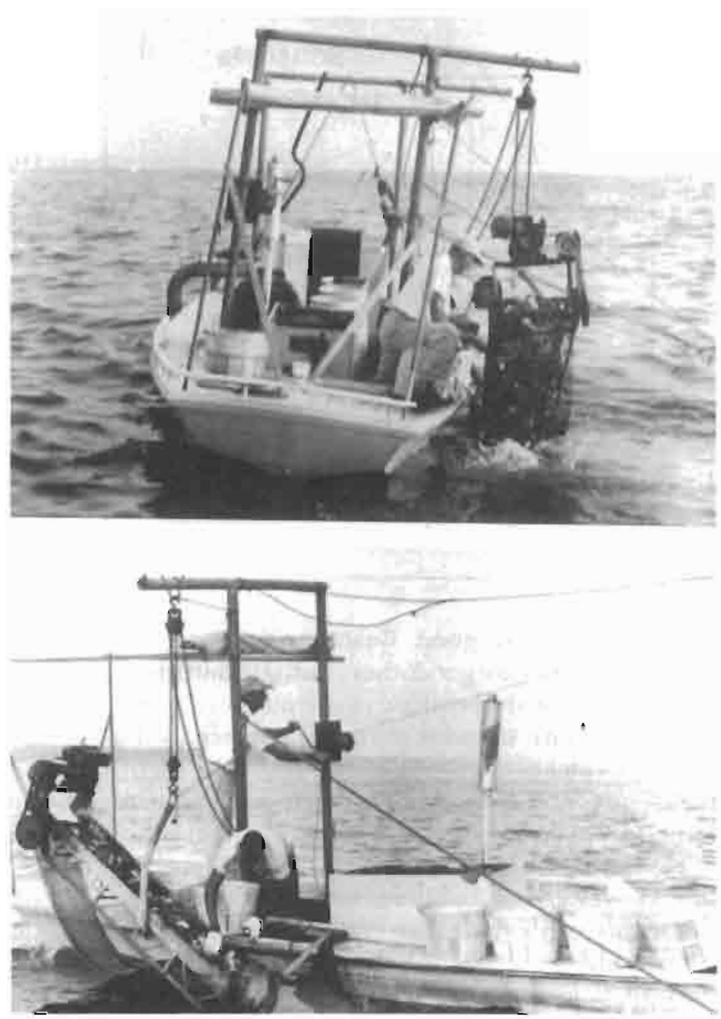

Figure 16
Harvesting softshells near Annapolis, Md., 1950's. Upper: Crewmen are picking clams from belt. Lower: Captain is adjusting height of belt while crewman picks clams off conveyor belt. Photographs by F. Wells, courtesy of Chesapeake Bay Maritime Museum, St. Michaels, Md.

Whelk Fishery

Virginia has a whelk (called "conch" locally) fishery with landing ports on the western and eastern shores of the bay. Landed are the knobbed whelk, *Busycon carica* (called "knobbie" locally), caught in the lower end of the bay; the channeled whelk, *Busycotypus canaliculatus*, caught in the lower bay and ocean; and the lightning whelk, *Busycon sinistrum*, caught in the ocean as a bycatch of the surfclam, *Spisula solidissima*, fishery. In the bay, 90–95% of the catch is the knobbed whelk, which ranges from 125 to 200 mm long (Rolley[28]).

The fishery began about 1960, when a market developed for the whelks (Snow[18]). In the bay, fishermen catch whelks with dredges in 9–14 m of water at night. The dredges, 1.5 m wide, are the same ones used for dredging blue crabs in winter. The boats initially towed two dredges, one off each side; crews took them in one at a time. Since about the mid-1970's, a different type of boat has been used; boats now are 12 to 14.6 m long and also tow two dredges but from their sterns; crews take them up together (Rolley[28]).

In the mid-1970's, Virginia approved a legal night dredging season for whelks from 1 May to 31 September (Rolley[28]). The state also limits entry into the fishery to 20 boats, but only 6–12 boats are actually dredg-

[28]Rolley, B. 1994. Shellfish dealer, Cheriton, Va. Personal commun.

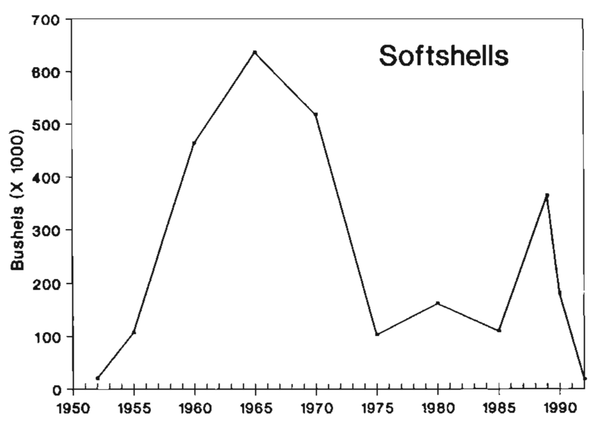

Figure 17
Historical landings of softshells in Maryland. Data courtesy of Maryland Department of Natural Resources, Annapolis.

ing when catches are good. Boats begin dredging at dusk and, if catches are good, they continue until dawn. The catch varies with the phase of the moon (if bright, catches are down), thunder storms (if one occurs during the day, catches are negligible the following night), and currents. And if an area has been dredged hard, the whelks remain buried and catches are low. A typical boat catches 30–50 bushels of whelks on good-weather nights. Harvests from mid-June through July are lower than they are earlier and later in the season, and boats miss many nights during the hottest part of the summer because of dangerous electrical storms. In winter, boats that dredge for blue crabs catch 1–2 bushels of whelks a day as a bycatch and sell them. About 50,000 bushels of whelks are landed each year (Rolley[28]).

The largest buyer, i.e., Bernies Conchs[13], located in Cheriton, Va., steams whole whelks, picks and ships the meats frozen or fresh to a canning plant in Cape May, N.J. The canned meats are distributed to outlets in the United States (Rolley[28]).

Recreational Shellfishing

Recreational shellfishing is relatively minor in the Chesapeake region. On the Eastern Shore, small numbers of local residents (but few tourists) dig northern quahogs. The Virginia recreational limit is 250 quahogs/person/day (Marshall[25]).

Seafood Promotion

Local seafoods are promoted by public agencies in each state: The Seafood Marketing Program of the Maryland Department of Agriculture and the Virginia Marine Products Board. They are funded by fishing gear licenses. Their actions consist of issuing news releases, placing recipes in state newspapers, participating in trade show exhibits in North America and Europe, exhibiting products at national restaurant shows, conducting test panels to which the press and chefs are invited, contacting exporters and importers around the world, and making personal marketing calls, besides mailing out promotional brochures.

The Future

In Maryland, resource managers and fishermen anticipate a relatively low abundance of oysters and a continued smaller oyster fishery. They are trying to devise a system to increase production by avoiding some disease losses. It will feature planting shell on grounds in high salinity waters where setting is likely to occur and then transplanting the seed to low salinity grounds where most will survive to legal market size, and also planting seed produced in hatcheries on low salinity grounds (Simns[3]).

The future of oystering in Virginia appears bleak because of the prevailing disease effects and other reasons. Management programs have been difficult to implement effectively in both Virginia and Maryland because of the weather cycle of drought and wet periods. Bands of salinity suitable for oysters move up and down rivers as the cycle changes, leaving dead oysters up-river from low salinity when a dry period shifts to a wet period and dead oysters down-river from diseases in high salinity when a wet period shifts to a dry period.

As the oyster industry has declined, fishermen and shuckers have found other employment and people have gotten used to eating fewer oysters. If oysters were to become as abundant again in the bay, the labor needed to harvest and shuck the entire supply might be hard to find, and selling it would be difficult. Considerable promotion would be required.

Nichol (1937) attributed much of the drop in oyster landings in Maryland to a decline in demand. The per-capita consumption of oysters in Baltimore in the mid-1930's was about one-twelfth as high as that in 1880. He wrote that while "decreasing supply, poor quality, faulty methods of processing and transportation, and delays in distribution" affect the demand for oysters, "to some extent, ... the shrinkage in the demand for oysters is the result of general social and economic changes. Oysters are not as fashionable as they used to be. Upon returning from the theater in days gone by, the general and accepted thing was an oyster stew served piping hot in an old-fashioned oyster parlor. An oyster supper once was an elite form of hospitality, particularly at Thanksgiving time or Christmas. So it is no longer. The art of oyster cookery is being forgotten. An increasing variety of new delicacies attract the consumer's attention. The oyster has lost its distinction."

Today, about 60 years after Nichol wrote those words, they still ring true. A factor that probably was responsible for the decline in oyster harvests was the switch in diets of people living along the Atlantic coast from oysters to beef and pork. During and following the 1880's, the railroads were largely responsible for the development of the U.S. meat industry and the abundant supply of mid-west meats to Atlantic coast population centers. As consumers began to eat more meat, shrimp, crab, and surfclams, the demand for oysters fell, as did supplies on the grounds (Haven et al., 1978). Landed prices for oysters were low. Why make extraordinary efforts to maintain supplies of a cheap product?

In the lower James River, oyster abundance could be increased by flushing silt off grounds just before oyster larvae ordinarily set. Some environmentalists might oppose doing this, fearing the silt temporarily raised might interfere with other organisms. But various storms each lift at least as much silt into the water many times a year as would one desilting. The habitat would become much improved for many species if the silted grounds could be reestablished as grounds with oysters. Such desilting and other methods to increase the quantity of clean shell on the bottom for oyster larvae would increase oyster abundance in many other grounds in the bay.

Aware of the successes in producing the introduced Pacific oyster, *C. gigas*, on the Pacific coast of North America and in Europe, especially France, some fishermen want this species introduced to Chesapeake Bay to replace the native eastern oyster in hopes it might not be as susceptible to MSX and Dermo as *C. virginica*. Two principal groups oppose this. One is the Maryland DNR which believes it might become so abundant it would crowd out the eastern oyster. If so, it might not sell as well because its flavor is different. The other group consists of biologists who believe it might not survive in the bay because its natural habitat is in cooler, higher salinity waters, but if it did they fear that this new species might adversely alter the natural environment of the bay (Sieling[29]).

The future of the fishery for wild northern quahogs appears threatened because supplies are falling steadily under heavy fishing effort. The recent large increases in the supplies of farmed littlenecks have acted to depress prices. If production of such littlenecks continues to rise, additional promotion may be needed to maintain prices and expand markets.

The future of the softshell fishery appears to be strong. Softshell stocks currently are down because of a die-off in 1991, but in the past they have come back quickly following a good set (McLaughlin[27]). The market demand is good.

Stocks of whelks appear to be holding up well. In 1993 and 1994, fishermen from Eastern Shore ports were beginning to pot channeled whelks in the ocean. From ten to twelve boats, each setting 200 to 300 pots baited with horseshoe crabs, *Limulis polyphemus*, were active in 1994 (Hudgins[30]).

[29]Sieling, B. 1994. State of Maryland, Department of Agriculture, Annapolis, Md. Personal commun.

Local Preparation of Mollusks as Food

People in the Chesapeake Bay region prepare oysters and northern quahogs several ways for the table. Oysters still are popular, though softshells are rarely eaten by the locals in Maryland and Virginia.

Oysters are eaten mostly raw on the half-shell, fried, or stewed. For frying, oysters are dipped in cracker crumbs or flour and then dropped into hot fat. An oyster (or quahog) stew consists of oysters (quahogs), milk, butter, salt, and pepper (no potatoes). Scalloped oysters are prepared by mixing whole meats with bread or cracker crumbs and milk and baking the mixture in a dish. Oysters Rockefeller is also prepared: Oysters are shucked, left in their shells, covered with spinach and cheese, and then baked.

Northern quahogs are eaten 1) raw on the half-shell (littlenecks and cherrystones), 2) as clam fritters (meats (chowders) are diced and mixed with flour, onions, a small amount of celery or celery salt, quahog liquor, and some water to make a batter and then the mixture is fried like pancakes), 3) as clam casino (cherrystones are minced and mixed with butter and crackers, topped with butter and garlic, put back in the shells, and baked), and 4) as stew (Setterholm[10]).

When softshells are eaten, they are steamed, fried in a batter, or made into soup dumplings (whole meats, onions, celery chunks or celery salt, and fried bacon with the fat drippings are mixed with enough flour to thicken and then cooked). Quahog dumplings are made the same way, but the meats are diced (Setterholm[10]).

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[30]Hudgins, G. 1994. Whelk dealer, Beaverlett, Va. Personal commun.

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Molluscan Shellfisheries of the South Atlantic Region of the United States*

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ABSTRACT

The South Atlantic region once harvested 11 species of mollusks, but the current number is seven: The eastern oyster, *Crassostrea virginica*; hard clam or northern quahog, *Mercenaria mercenaria*; calico scallop, *Argopecten gibbus*; bay scallop, *Argopecten irradians concentricus*; sea scallop, *Placopecten magellanicus*; whelk, *Busycon* spp.; and cross-barred venus, *Chione cancellata*. Native Americans, as long as 4,000 years ago, used mollusks as food, tools, and trade items. In 1880, 1,555 persons produced 290,000 bushels of oysters in the region; the oysters were gathered by hand picking. In 1902, nearly 50% of the oyster catch in North Carolina was canned, while in Georgia and South Carolina, it approached 95%. Most canneries closed during and following World War II. Today, a person can pick about 20 bushels/day, but production is at an all-time low. The hard clam has had a long history of use including as wampum by Native Americans. Hard clams have been harvested by rakes in shallow water and tongs in deeper areas. In the early 1900's, about 90% of the landings came from North Carolina, but afterward landings in South Carolina increased, and by the 1980's, Florida led in landings. The hard clam has several mariculture advantages over other species. Florida leads in the region in mariculture operations, but the largest facility is in South Carolina. A small fishery for the calico scallop began in 1959 but did not expand until mechanical shucking was developed in the mid-1960's. The scallops initially were harvested with sea scallop dredges, but recently they have been landed with modified otter trawls. The bay scallop occurs mainly in North Carolina and supports a small fishery. Landings of sea scallops dredged on offshore beds averaged 830,000 pounds of meats in the past 15 years. A whelk fishery recently was developed by shrimp fishermen during the off-season. The cross-barred venus is harvested on a small scale using hydraulic escalator clam dredges in South Carolina. At least 11,500 shellfish licenses were sold in the region in 1992.

Introduction

Eleven molluscan shellfish fisheries have been plied at one time or another in the U.S. South Atlantic region which includes the states of North Carolina, South Carolina, Georgia, and the east coast of Florida (Fig. 1). At present, seven species are still being pursued. They are the eastern oyster, *Crassostrea virginica*; hard clam, *Mercenaria mercenaria*; calico scallop, *Argopecten gibbus*; bay scallop, *Argopecten irradians concentricus*; sea scallop, *Placopecten magellanicus*; whelk, *Busycon* spp.; and cross-barred venus, *Chione cancellata*.

At one time fisheries for the following were recorded, but at the present time are no longer underway: Queen conch, *Strombus gigas*; ribbed mussel, *Geukensis demissa*; rangia clam, *Rangia cuneta*; and coquina clam, *Donax variabilis*. The fisheries are described in the following pages in depth according to their historical importance and available information.

Eastern Oyster

Habitat

The eastern oyster, *Crassostrea virginica*, grows primarily intertidally south of the Newport River, N.C. This bivalve is present in dense beds along the banks, on large flats, or on hummocks in coastal waters of the South Atlantic region in salinities ranging from around 15‰

* Contribution 318, South Carolina Marine Resources Center.

to above 30‰ (Battle, 1892; Brice, 1898; Burrell, 1986; Chestnut, 1951; Drake, 1891; Grave, 1904; Linton, 1969; Ruge, 1898) (Fig. 2). The spawning extends more or less continuously from May through October (Burrell, 1986; Chestnut, 1951; McNulty, 1953). Spat attach to other oysters throughout the spawning season resulting in dense clusters. These oysters are small, misshapen, thin-shelled, and have relatively low meat yield to shell volume. North of the Newport River, and in a few scattered locations southward, oysters grow subtidally as on the Northeast coast. Growth of southern oysters is highly variable, but may exceed 4 inches in 8 months, or it may be almost imperceptible when constrained by other oysters in a cluster (Ingle, 1950). Oysters grow throughout the year as far north as South Carolina (Burrell et. al., 1981).

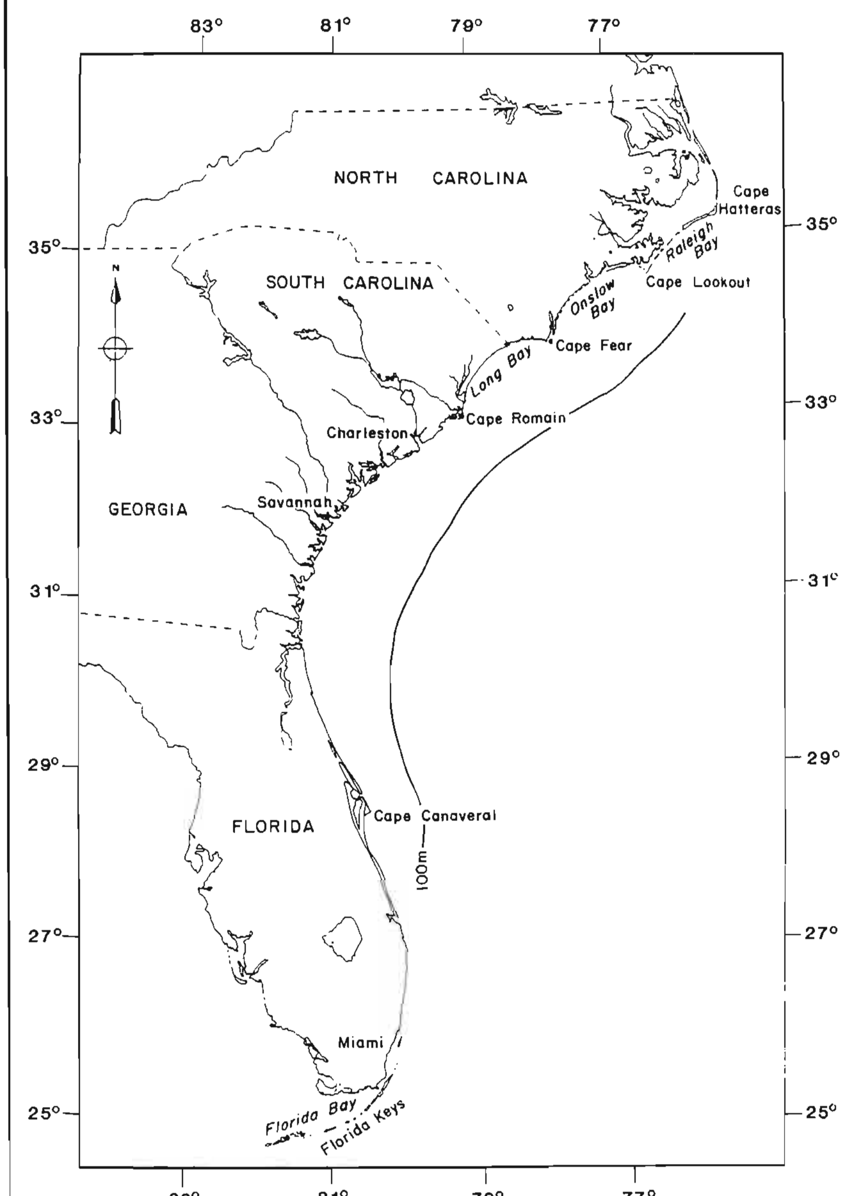

Figure 1
The U.S. south Atlantic region.

History

Native Americans used marine products certainly as long as 4,000 years ago. Evidence found in shell middens and other archeological sites indicate aboriginal use of shellfish not only as food, but as tools and trade items. So the shellfish industry dates to this time at least (Marrinan and Wing, 1980). Large circular rings of shell surrounding a central depression are found in South Carolina and Georgia. These shell rings appeared to have some ceremonial function (Keith and Gracy, 1972).

Oyster culture, to some degree, was taking place as early as 1830 in the vicinity of Charleston, S.C., and in North Carolina in 1840, but several studies indicate that the regional industry in 1880 was poorly organized and a good portion of the harvest was disposed of through bartering for other food stuffs (Colson, 1888; Ingersoll, 1881; Winslow, 1889). Dealers in North Carolina and Georgia carted shucked oysters inland by wagon for sale. Ingersoll (1881) estimated that in 1880, 1,555 persons produced 290,000 bushels of oysters valued at $115,000 in the states of North Carolina, South Carolina, and Georgia (Fig. 3). A small fishery on the east coast of Florida was reported in statistics for the entire state of Florida and therefore could not be included in the totals above. North Carolina landings from subtidal beds accounted for most of the South Atlantic harvest up until the late 1890's when steam canneries in Georgia and South Carolina utilizing intertidal oysters came into their own (Alexander, 1905; Burrell, 1982; Maggioni and Burrell, 1982; Ruge, 1898). In 1902, nearly 50% of the oyster catch was canned in North Carolina, while in Georgia and South Carolina it approached 95% (Fig 4).

Landings statistics did not differentiate between number of people employed in various fisheries in North Carolina and Florida, but in South Carolina, 2,415 and in Georgia, 1,365 persons were listed in one capacity or the other in the oyster fishery. There were 25 canneries operating in the region in 1902 (Alexander, 1905). Oyster canning reached its peak in South Carolina during the 1920's when at least 3,000 persons were employed in the fishery and 16 canneries were operating (Keith and Gracy, 1972; Maggioni and Burrell, 1982). Churchill (1920) reported 38 canneries in North Carolina, South Carolina, and Georgia plus a few at Fernandina, Fla., in 1920.

Oysters were gathered by pickers who were carried to oyster grounds by sailing vessels in early years and later by motorized vessels. In the 1920's and 1930's they remained at the oyster banks, harvesting at low tide by hand into bateaus for 4 or 5 days before returning to the canneries (Fig. 5). Each picker caught about 25 South Carolina bushels per day (one S.C. bushel = 1.8 U.S. standard bushels). The floating stock was owned by the canneries, and oyster banks were leased by them. Oysters were opened by steam at the canneries and the meats picked out by hand until 1945 when Sterling Harris of Beaufort, S.C., developed a system consisting of a slotted cylinder to shake steamed oysters into a supersaturated brine bath which floated the meat to the surface and allowed the shells to fall to the bottom (Fig 6, 7). After the meats were removed from the shell they were sealed in a tin can and heat sterilized under pressure. During and following World War II, labor shortages and unwillingness to put in the effort to gather good quality oysters caused the closing of most of the canneries (Cumbee[1], Maggioni[2]). Continued labor shortages, poor yields, and finally cheap foreign imports led to the demise of the last oyster cannery in the late 1980's (Lunz, 1950; Maggioni and Burrell, 1982; Maggioni[2]).

Figure 2
Pickers harvesting intertidal oysters using a handgrab to break the bivalves loose from the supporting shell matrix in the mid 1930's. Photo courtesy of G. J. Maggioni.

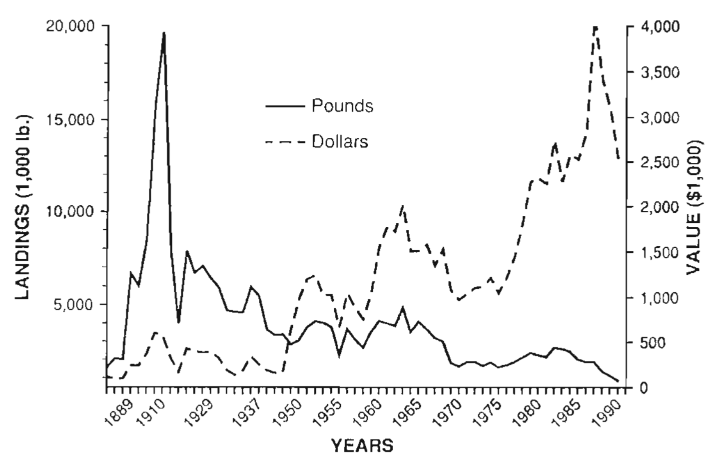

Figure 3
South Atlantic oyster landings 1880–1990 (GDNR, 1992; NCDEHNR, 1992; SCWMRD, 1992; USDOC, 1992; USDOC, 1905–40).

Raw shuck houses processed over 50% of North Carolina oysters but less than 5% of the South Carolina and Georgia oysters while the cannery was in its heyday. In the early 1960's, raw shuck houses prospered because a Chesapeake Bay oyster disease caused shortages (Maggioni and Burrell, 1982). Shucking houses pro-

[1] Cumbee, J. 1992. Retired supervisor, Shellmore Oyster Co., Awendaw, SC 29429. Personal commun.

[2] Maggioni, G. J. 1992. Retired owner, Ocean, Lake and River Fish Co., P.O. Box 629, Beaufort, SC 29902. Personal commun.

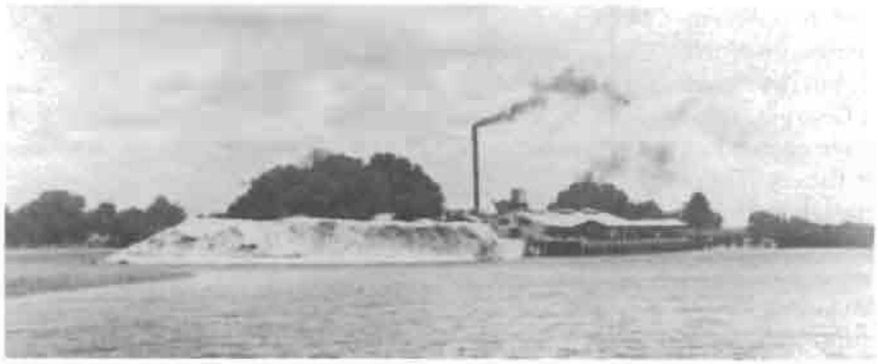

Figure 4
An oyster cannery near Beaufort, S.C., about 1935. Note the shell pile that dominates the landscape. Photo courtesy of G. J. Maggioni.

cessing intertidal oysters sometimes used a hot water dip to facilitate opening of clustered oysters (Jensen, 1965). As labor became more expensive and yield of oysters remained low, many raw shuck-house operators, beginning in the late 1960's, began importing shell stock from Maryland and the Gulf Coast (Dewitt[3], French[4]). Few shucking houses using intertidal oysters remain and most of this resource is sold as shell stock for oyster roasts (Burrell, 1986).

Today an oyster picker can gather about 20 bushels per day on an intertidal oyster bar. This varies by condition of the beds and the extent of tidal range (Dewitt[3], Reeves[5]). Shuckers can open 5 gallons of intertidal oysters per day varying by season, quality of oysters, and skill (Reeves[5]). Some shucking houses pay the picker by number of gallons his landings shuck out and the shuckers by the gallons shucked. A premium is paid after a certain goal is reached to encourage good quality by the picker and a longer work week by the shuckers (Reeves[5]).

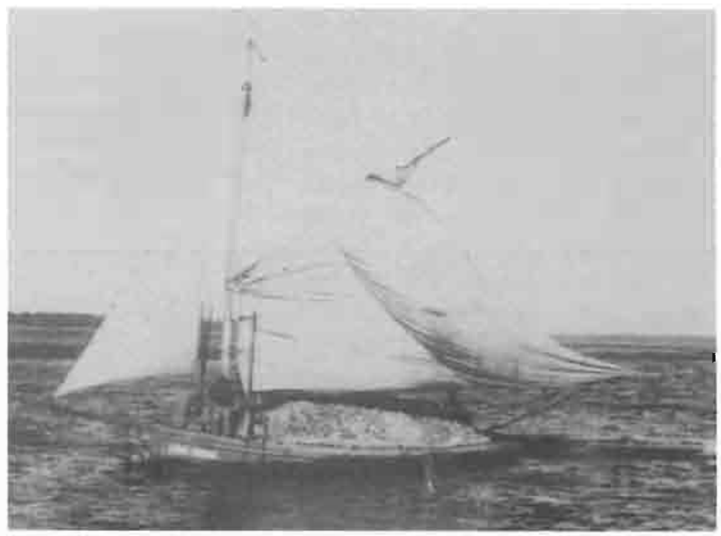

Figure 5
An oyster schooner, ca. 1935, used to transport pickers to and from oyster beds and to bring catch to canneries. Photo courtesy of G. J. Maggioni.

Disease has not been a problem for the oyster planter up until recent years when *Perkinsus marinus,* apparently in conjunction with the added stress of drought conditions, was thought to be responsible for heavy mortalities on some beds (Lewis, et al., 1992; French[4]). MSX, *Haplosporidium nelsoni,* is present, but no mass mortalities, as have occurred in the Mid Atlantic region, have been documented in the South Atlantic states (Daugherty et al., 1993; Marshall[6]). Predators such as drills, *Urosalpinx, Eupleura*; starfish, *Asterias*; whelks, *Busycon* spp.; and boring sponge, *Cliona,* though present, do not appear to make heavy inroads into inter-

[3] Dewitt, W. 1992. Dewitt Seafood, Crescent, GA 31304. Personal commun.

[4] French, J. 1992. N.C. Dep. Environ., Health Nat. Resour., Div. Mar. Fish., P.O. Box 769, Morehead City, NC 28557-0769. Personal commun.

[5] Reeves, M. 1992. Bluffton Oyster Co., Bluffton, SC 29910. Personal commun.

[6] Marshall, M. 1992. N.C. Dep. Environ., Health Nat. Resour., Div. Mar. Fish., P.O. Box 769, Morehead City, NC 28557-0769. Personal commun.

tidal oyster populations, but may be to some degree responsible for lack of subtidal oysters in the South Atlantic region (Burrell, 1986).

Management

Leasing of oyster grounds was first recorded in 1859 in North Carolina; Georgia followed in 1889, with Florida and South Carolina somewhat after that (Drake, 1891; Oemler, 1894; Ruge, 1898; SCBF, 1925; French[4]). A closed season has been adopted by all states during the warmer months except in Georgia where the Department of Natural Resources has the authority to open and close seasons throughout the year (Williams[7]). Most regulatory agencies have discretionary authority to modify closures as conditions warrant. Lease or permit holders are required to plant 125 bushels of shell or seed per acre in South Carolina, return one-third of shells harvested in Georgia, produce at least 25 bushels oysters per acre in North Carolina or do initial improvement to bottoms in Florida in order to retain leases (Marshall[6], Williams[7], Bearden[8], Berrigan[9]). Three-inch cull laws are enforced in North Carolina, Georgia, and Florida.

There were over 11,000 shellfish harvest licenses in North Carolina, 300 in South Carolina, 200 in Georgia, and a few on the east coast of Florida in 1992. These licenses are not separated by which shellfish is to be harvested and usually include harvest of more than one species (French[4], Williams[7], Joyce[10],

Figure 6
Cars containing oysters were rolled on rails into retorts where they were heated until the shells opened. The cars were rolled out of the retorts and shuckers removed the oysters from the opened shells prior to canning. Photo ca. 1930's courtesy of G. J. Maggioni.

Figure 7
A horizonal retort used prior to the middle 1940's to steam open oysters. After World War II, vertical retorts were used in conjunction with a shaker tumbler which did away with the need for shuckers as the meats could be separated from the shell in a saturated brine bath. Photo courtesy of G. J. Maggioni.

[7] Williams, B. C. 1992. Ga. Dep. Nat. Resour., One Conserv. Way, Brunswick, GA 31523-8600. Personal commun.

[8] Bearden, C. M. 1992. S.C. Wildl. Mar. Resour. Dep., Mar. Resour. Div., Box 12559, Charleston, SC 29422-2559. Personal commun.

[9] Berrigan, M. 1992. Fla. Dep. of Nat. Resour., 3900 Commonwealth Blvd., Tallahassee, FL 32399-3000. Personal commun.

[10] Joyce, E. 1992. Fla. Dep. Nat. Resour., 3900 Commonwealth Blvd., Tallahassee, FL 32399-3000. Personal commun.

Moran[11]). As of July 1992, a license or saltwater fishing stamp to harvest shellfish recreationally was required in South Carolina. At present (1992), there are 147 dealers handling shell stock, 26 shuckers and packers, one wet storage facility, four repackers, 19 reshippers and one depuration operation certified as interstate shippers of molluscan shellfish in the region (USDHS, 1992). At present, oyster production is at an all-time low because of many factors, such as the closure of productive grounds because of pollution, lack of markets for poor yielding intertidal oysters, inroads by disease in subtidal oysters, and labor shortages in both the harvesting and processing sectors (Burrell, 1982; Cowman, 1982) (Fig. 3). Recently, most states have sought to rehabilitate these resources by shell planting, relaying oysters from closed beds, seeding, and pollution abatement efforts (Anonymous, 1975; Cowman, 1982; Linton, 1969; Munden, 1982; Palmer, 1976; Reisinger, 1978; and SCWMRC, 1986). North Carolina and South Carolina have developed mechanical harvesters to relay large quantities of oysters (Burrell et al., 1991; Munden, 1982) (Fig. 8, 9).

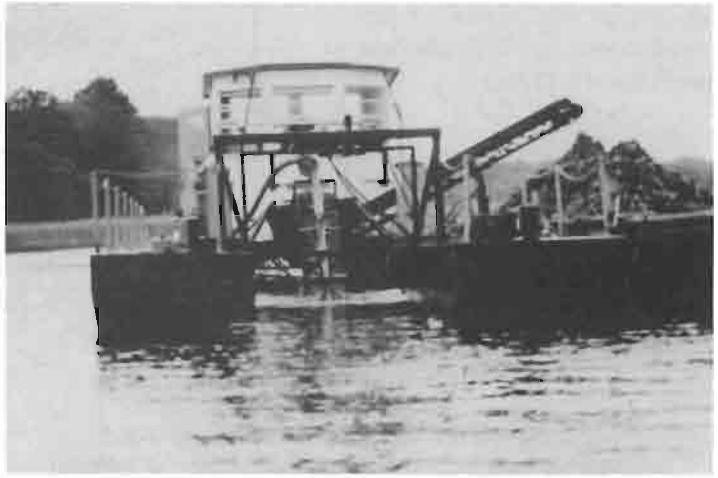

Figure 8
A mechanical oyster harvester operating at high tide on a South Carolina intertidal oyster bed. Photo by V. G. Burrell, Jr.

Shellfish grounds have been certified by various state health agencies since the mid 1920's when a typhoid epidemic in the U.S. northeast and midwest made the public aware of potential health problems associated with eating raw or partially cooked shellfish (SCFB, 1925). Currently, each state participates in the Interstate Shellfish Sanitation Conference and enforces regulations and procedures that assure harvests come from clean waters and that shellfish are processed under sanitary conditions (Shellfish Sanitation Branch, 1989). In the South Atlantic region, 2.9 million acres were classified for shellfish harvesting in 1990; 71% were approved for harvesting at anytime, 4% could be harvested at times, conditional on meeting certain criteria, 3% were restricted to harvest only if purification procedures were carried out before marketing, and 21% were closed to any type of harvesting. These percentages did not vary greatly from 1985 when 22% were classified as fully closed (Leonard et al., 1991).

[11]Moran, J. 1992. S.C. Mar. Wildl. Mar. Resour. Dep., Mar. Resour. Div., Box 12559, Charleston, SC 29422-2559. Personal commun.

Figure 9
An oyster bed harvested by a mechanical harvester. Note that the supporting shell matrix has not been disrupted. Photo by V. G. Burrell, Jr.

Mariculture

Methodology to produce hatchery seed and to produce market oysters under controlled grow-out conditions have been worked out (Burrell, 1985). However several unique problems must yet be overcome before this becomes a viable enterprise in the southeastern United States. First, a means of avoiding fouling by an over-abundant natural set must be achieved. Secondly, a long spawning season also results in poor yield for much of the year, and this must be addressed (Burrell, 1986; Heffernan and Walker, 1988). Thirdly, polyculture in ponds may lead to public health concerns which may preclude direct harvesting (Burrell et al., 1991). Some penaeid shrimp growers are also investigating using shellfish to reduce algae blooms and to improve pond effluent water quality (Hopkins[12]).

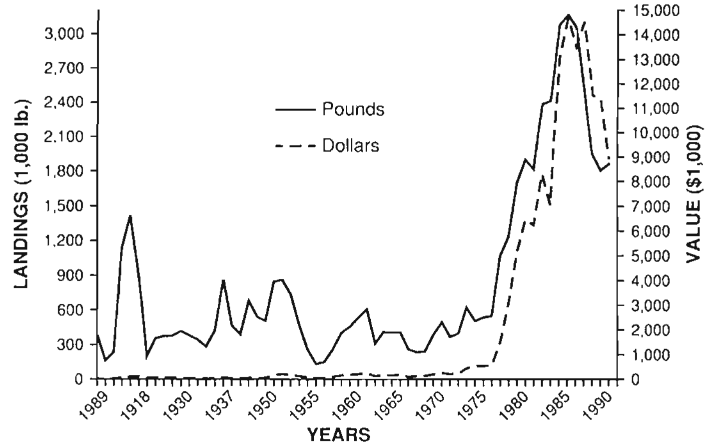

Figure 10
Hard clam landings 1880–1990, in the South Atlantic states (GDNR, 1992; NCDEHNR, 1992; SCWMRD, 1992; USDOC, 1992, 1904–40).

Outlook

Coastal development is expected to continue unabated in the near future and it is expected to impact oyster habitat not only leading to closure of growing areas because of pollution, but by changing water quality so that recruitment and growth are affected. Recreational activities such as golfing and boating will probably rival agriculture, silviculture, and other industries in their influence on shellfish growing areas. Mariculture of other species may also affect oyster culture by competing for water use and, to a degree, degradation of water quality (Burrell, 1982, 1986; Maggioni and Burrell, 1982). Most oysters in the southeast grow intertidally, and markets for this product are limited to stocks for oyster roasts and a few raw shucking operations. This oyster is best processed by heat opening and sold as a cooked product. Since the canneries have all closed, this outlet no longer exists. If a product that is appealing to the modern convenience-minded shopper can be developed using a cooked oyster this industry can once again flourish. At present, however, efforts along these lines are not progressing.

Another approach to rehabilitate the oyster industry lies in developing semi-intensive culture methods that will produce a well shaped, high-yield single oyster suitable for shucking or the half-shell trade. Use of rack and bag culture in areas of low natural spat-fall and of hatchery-produced polyploid sterile seed offer hope in this direction (Burrell, 1986; Heffernan and Walker, 1988).

Hard Clam

Habitat

The hard clam or quahog, *Mercenaria mercenaria*, is found in estuarine and nearshore coastal waters of the U.S. South Atlantic region intertidally to depths of 50 feet (16 m) (Chestnut, 1951). While they may be found in much lower salinity, they grow best above 20‰ (Castagna and Chanley, 1973; Eversole, 1987). They are found in substrates ranging from mud to sand but are most dense in sandy bottoms with shell (Anderson et al., 1978; Walker et al., 1980). Clams have the ability to withstand very low salinity for up to 3 weeks by remaining closed (Burrell, 1977). At least two spawning cycles occur in southern waters, and some clams were found to be gametogenically active all year (Eversole et al., 1980; Manzi et al., 1985; Heffernan et al., 1989; Porter, 1964). The southern quahog, *Mercenaria campechiensis*, is known to hybridize with *M. mercenaria*, but this does not occur to the extent that it would make up a significant percentage of the landings (Dalton and Menzel, 1983).

History

Early use of the colored part of the shell of hard clams as wampum by Native Americans and its presence in kitchen middens indicates that this bivalve has a long history both as food and for commerce (Keith and Gracy, 1972). An early description of the historic fishery by Ingersoll (1887) reported that south of Norfolk, Va., probably no more than 50,000 bushels per year were landed in 1880 (Fig 10). He indicated that even though this bivalve was abundant, fisherman could not be relied on to catch them on a dependable basis for market. Most of the fishery took place in North Carolina and South Carolina in 1902 as reported by

[12]Hopkins, S. 1992. S.C. Wildl. Mar. Resour. Dep., Waddell Maricult. Cent., Bluffton, SC 29910. Personal commun.

Alexander (1905). A large quantity of clams was processed as clam juice, clam chowder, and whole clams at a factory at Ocracoke, N.C., and this was responsible for high landings around the turn of the century (Chestnut, 1951). After this, and until the late 1930's, around 90% of the region's landings came from North Carolina (USDOC, 1905-1940). Thereafter, landings from South Carolina increased on a fairly regular basis and made up as much as 36% of the regional catch in some years (Lunz, 1949). In the early 1970's, a Florida fishery began to contribute significantly to the landings, and in the middle 1980's it led the southern states. This was due mostly to the discovery of a large bed of clams in the Indian River. This resource has been fished down to a large extent and now North Carolina again is responsible for more than half the regional landings (NCDEHNR, 1992; Joyce[10]).

Clams are harvested by hand using rakes in shallow waters and tongs in deeper areas. Treading, where a clammer wades in the water and feels for clams with his feet, is also done (Chestnut, 1951). With the advent of the motor boat, clams have been harvested in North Carolina by "kicking." This is accomplished by dislodging clams from the bottom by action of the propeller and catching them in a net towed behind the boat (Guthrie and Lewis, 1982). North Carolina and South Carolina also allow harvesting by hydraulic escalators, by permit, for specific areas and time of the year (NCMFC, 1991; Rhodes et al., 1977).

Individual production is difficult to estimate because of different types of gear used, harvest incidental to oyster harvest, and legal catch limits imposed (NCMFC, 1991; SCWMRD, 1991).

Small clams are subjected to predation by some fish such as cownose rays, *Rhinoptera bonasus*; drums, Scianidae; various crabs, several snails, and starfish. Adult clams are preyed on by sea gulls, which may open them by dropping them on a beach or paved roads, and by starfish, whelks, and rays (Chestnut, 1951; Eversole, 1987; Stanley, 1985). Few diseases are known to affect *Mercenaria mercenaria* in the adult stage, and no large mortalities such as have occurred in oysters have yet been recorded (Eversole, 1987; Sindermann, 1970).

Management

Leasing of clam bottoms is the same as for oysters. There is no closed season on clams in approved North Carolina or Georgia waters. A minimum size limit of 1-inch thickness exists in all states, except for aquaculture operations from which seed or juvenile clams may be sold (NCMFC, 1991; SCWMRD, 1991). Clams, by special permit, may be harvested for relaying and depuration from restricted waters (NCMFC, 1991; SCWMRD, 1991). At present, only one Florida depuration plant is certified in the region (USDHS, 1992). As mentioned, North Carolina permits mechanical harvesting by hydraulic escalators and kicking by special permit. Kicking is not allowed in other states, but South Carolina and Georgia allow other mechanical harvesting by permit only (SCWMRD, 1991; Williams[7]).

Mariculture

The hard clam has several advantages over other species as a mariculture option. It has a ready market, is most valuable as a younger animal, has few diseases, and can be cultured at high densities. Hard clams are marketed by size (littlenecks, cherrystones, and chowders). The littleneck is the most expensive, followed by the cherrystones, and lastly, the chowders. Littlenecks and cherrystones are most often eaten raw or in various baked dishes, whereas the chowders are utilized in chowders as the name implies (Chestnut, 1951; Eversole, 1987). Culture techniques have been developed to a point that it appears to be commercially viable, and investment capital is becoming available (Castagna and Kraeuter, 1981; Manzi, 1985; Manzi and Castagna, 1989) (Fig. 11, 12). Florida leads the region in number of mariculture operations, but the most extensive facility is in South Carolina. This operation is fully integrated from hatchery to marketing and has a production capacity of 140 million market size clams per year (Manzi[13]).

Outlook

Clam production will increase if mariculture operations continue to be profitable. Depuration will probably be the rule even if clams are harvested from approved waters. This could serve as a marketing tool to increase public confidence in clams as a wholesome product.

Calico Scallop

The calico scallop, *Argopecten gibbus*, occurs off U.S. South Atlantic states in beds parallel to the coast in depths of 30–300 feet (9–94 m). This small bivalve is being harvested at 40–45 mm and attains a maximum size of only 80 mm. The life span is about 18–24 months, and beds having commercially exploitable numbers oc-

[13]Manzi, J. J. 1992. Atlantic Littleneck Clam Farms, P.O. Box 12139, James Island, SC 29422. Personal commun.

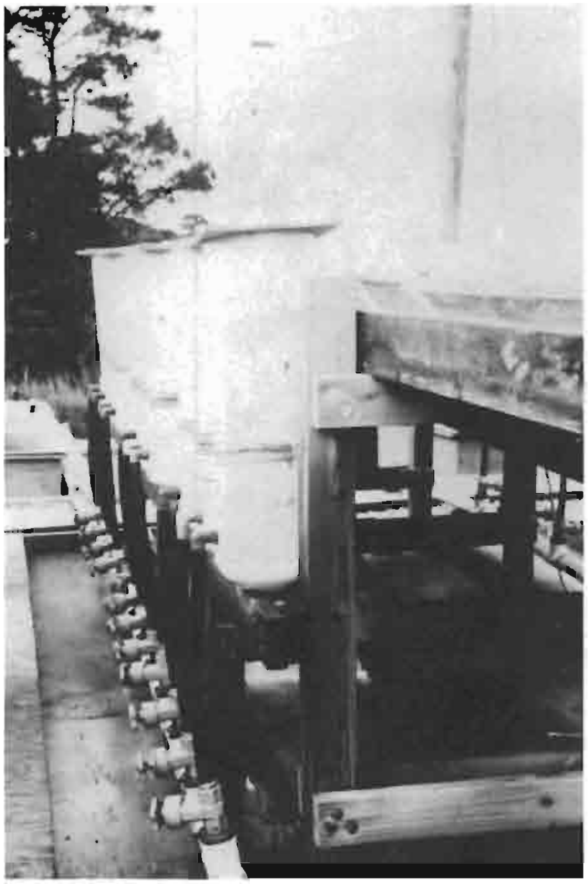

Figure 11
A clam nursery using upwellers to grow clams from 1 mm to 7–10 mm size for open-water planting. Photo by V. G. Burrell, Jr.

cur sporadically. Large fluctuations in abundance are attributed to reproductive success and mass mortalities. The causes of both are poorly understood (SA&GMFMC, 1981; Allen and Costello, 1972). Commercial quantities of this scallop were first reported off North Carolina in 1949 by the research vessel *Penny* (Chestnut, 1951).

A small fishery began in 1959 off Core Bank, N.C. The fishery did not expand greatly, however, until a mechanical shucking and eviscerating methodology was developed in the mid-1960's. Since that time, beds have been found and harvested off other South Atlantic states. The most consistent and largest landings have been in the vicinity of Cape Canaveral, Fla. (Fig. 13) (Cummins, 1971; SA&GMFMC, 1981; USDOC, 1904–1990).

In the early stages of the fishery, calico scallops were landed using sea scallop dredges, but most recently nearly all have been landed with modified otter trawls. Some Florida fishermen have experimented with tumbler dredges (SA&GMFMC, 1981; Broom, 1976; Cummins and Rivers, 1970; Cummins, 1971). Most of the Florida vessels involved in this fishery are shrimp boats that enter the fishery when a promising bed of scallops is discovered. They may go as far north as South Carolina when a bed warrants the effort. North Carolina scallops are harvested chiefly by bottom fish draggers because the beds are some distance offshore (20 miles or 30 km). In 1984, when record landings occurred off Florida, 122 boats were involved. In 1990, 31 shrimpers fished for some part of the year for Calico's in the Cape Canaveral area (Anderson[14], Marshall[7], Dennis[15]). At first scallops were shucked by hand, but by about the mid-1960's steam shucking methodology and mechanical eviscerating was developed. For a while this operation took place at sea on specially equipped vessels; however, processing has recently been carried out on shore (SA&GMFMC, 1981). Sometimes the scallops are trucked to processing plants, but if a large bed is found where shucking equipment is not nearby, often the equipment is trucked in and set up until the bed is depleted (Munden[16]).

North Carolina regulates the calico scallop harvest by allowing landings in North Carolina only during open seasons. They do not allow soaking in fresh water to swell the meats. South Carolina requires licenses on floating equipment for taking shellfish to market and requires record keeping as directed by the Marine Resources Division. The fishery is expected to continue unchanged in the next decade with periods of scarcity and plenty.

Bay Scallop

The Atlantic bay scallop, *Argopecten irradians concentricus*, is found in commercial quantities in North Carolina and in smaller amounts on the east coast of Florida. An apparent habitat need for submerged aquatic plants during early development largely precludes its occurrence in South Carolina and Georgia. It is found in high salinity (>20‰) shallow water (30 feet (10 m) or less) near the mouths of estuaries. In North Carolina, it is closely associated with eelgrass meadows, and when those die off, scallop abundance declines drastically. Predators include seabirds and starfish, but neither appears to affect abundance of the species to a great degree (Chestnut, 1951; Gutsell, 1929; Rhodes, 1991).

[14]Anderson, W. D. 1992. S.C. Wildl. Mar. Resour. Dep., Mar. Resour. Div., Box 12559, Charleston, S.C. 29422-2559. Personal commun.

[15]Dennis, C. 1992. Fishery Reporting Specialist, NMFS, P.O. Box 2025, New Smyna, FL 32170. Personal commun.

[16]Munden, F. H. 1992. N.C. Dep. Environ., Health Nat. Resour., Div. Mar. Fish., P.O. Box 769, Morehead City, NC 28557-0769. Personal commun.

Figure 12
Planting small clams in trays in the intertidal zone. Note covering nets which protect young clams from predators and also keep the clams in the trays. Photo by V. G. Burrell, Jr.

History and Present Condition of Fishery

The south Atlantic coast scallop fishery is concentrated almost entirely in Carteret County, N.C. The meat of this bivalve was first used by Native Americans for food and the shell for tools, and it is a very conspicuous component of ancient middens. An organized fishery occurred as early as the mid-1870's. Most of the scallops were shipped to New York and Boston. Because of the restricted market, prices varied considerably as did resultant harvests (Gutsell, 1929; Chestnut, 1951) (Fig. 14).

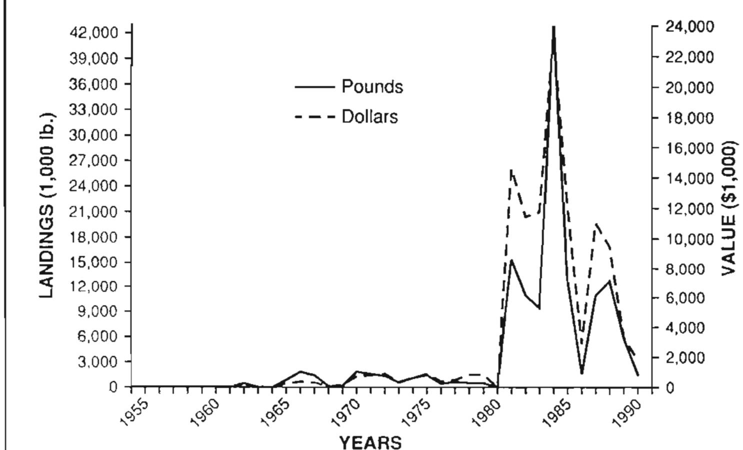

Figure 13
Calico scallop landings, 1958–90 (GDNR, 1992; NCDEHNR, 1992; SCWMRD, 1992; USDOC, 1992, 1904–40).

The fishery became better organized around 1912 or 1913 and was listed as a leading shellfishery in North Carolina. Scallop licenses averaged 707 per year during 1917–28 (Gutsell, 1929), and in 1928, North Carolina was the leading U.S. producer of bay scallop meats. Landings decreased markedly during the 1930's and 1940's coincident with the disappearance of eelgrass. In the late 1980's, North Carolina harvests again plunged. This time mortalities were associated with the occurrence of a toxic algal bloom, *Ptychodiscus brevis* (Tester et al., 1989).

In North Carolina, a license which allows harvest of oysters, clams, and scallops is required, and over 11,000 of these were sold in 1991. The harvest season is opened for 4 days prior to Christmas and then reopened the second week in January for 2 days a week until as late as early May if the abundance of scallops warrants it. Scalloping is not permitted on Saturday or Sunday or at night.

Bay scallops are harvested by dredges, and potato rakes are sometimes modified with a mesh basket to

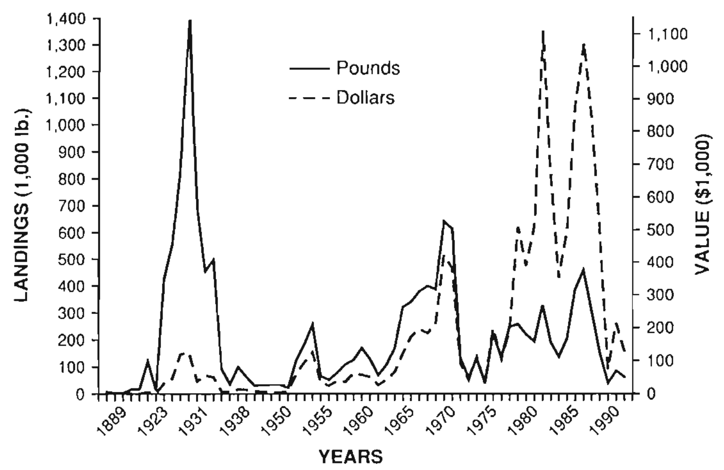

Figure 14
Bay scallop landings, 1880–90 (NCDEHNR, 1992; USDOC, 1904–40).

help retain the bivalve. Shucking is by hand, often by the catcher and family or at shucking houses. Plans are in the offing to restock the areas most severely impacted by the red tide (*P. brevis*) of 1987 (Marshall[6]).

Mariculture

Spawning and culture techniques have been developed for bay scallops (Castagna and Duggan, 1971; Castagna, 1975; Loosanoff and Davis, 1963). Grow-out in lantern nets, pearl nets, large pens, and cages have been biologically successful (Burrell and Manzi, 1987; Castagna and Duggan, 1971; Heffernan et al., 1988; Rhodes and Widman, 1980, 1984; Rhodes, 1991). However, economic feasibility has yet to be worked out for bay scallops in the United States (Rhodes, 1991).

Forecast

The wild fishery for bay scallops will probably continue in North Carolina with landings affected chiefly by environmental conditions such as health of eelgrass beds, toxic algal blooms, and degradation of habitat by coastal development. Mariculture offers potential growth of the fishery if economical growout methods can be developed.

Sea Scallops

Sea scallops, *Placopecten magellanicus*, are caught on beds north of Cape Hatteras, shucked at sea, and landed at Wanchese, N.C. This bivalve is caught using scallop dredges in deep water. Landings here have fluctuated between <1,000 pounds and over 2,000,000 pounds, averaging about 830,000 pounds in the last 15 years. Many of the scallopers have begun landing at Virginia ports because of shallow inlets in the Wanchese area (Marshall[6], Munden[16]).

Whelk

Habitat

The knobbed whelk, *Busycon carica*, and channeled whelk, *B. caniculatum*, occur from intertidal zones to depths exceeding 40 feet (13 m). The knobbed whelk is about ten times as common as the channeled whelk in catches off the South Atlantic region. These gastropods are predators of other valuable mollusks such as oysters and clams and are therefore considered a nuisance by shellfish growers. Small whelks in turn are preyed on by crabs and birds (Anderson et al., 1985; Eversole and Anderson, 1984; Magalhaes, 1948; Anderson[14]). Weinheimer (1982) reported a protracted spawning season of up to 10 months for the knobbed whelk in South Carolina. Both species are slow growing and therefore are vulnerable to overfishing (Anderson et al., 1985).

History

A fishery for whelks, principally the knobbed whelk, has recently become an off-season fishery for some shrimpers in the South Atlantic region (Anderson et al., 1985; Berrigan[9]; Munden[16]). Shrimpers seeking longer yearly use of their equipment began trawling for these gastropods between shrimp seasons in 1978. Large shrimp boats pull trawls similar to those used in the shrimp fishery, while small boats use crab scrapes. Catch/boat may exceed 100 bushels per day, but a 1992 report gave an average of 57 bushels/day in South Carolina (Eversole and Anderson, 1984; Low[17]).

Whelks are processed by partially steam cooking to loosen the meat from the shell. The soft parts are then pried from the shell and iced for shipment to markets in the U.S. northeast or frozen for Asian markets (Eversole and Anderson, 1984).

A few whelks reached the market prior to 1978 (<1,000 pounds per year). These were caught incidental to crabbing and other fisheries (Anderson[14]) (Fig 15). From a

[17]Low, R. 1992. S.C. Wildl. Mar. Resour. Dep., Mar. Res. Div., Box 12559, Charleston, SC 29422. Personal commun.

modest beginning in 1978, this fishery has increased to more than 1,000,000 pounds per year in the mid-to-late 1980's. It still ranks fourth in molluscan shellfish landings, but possible overfishing in Georgia and South Carolina led to a marked decline in 1989 and 1990 (Fig. 15).

Management

Season openings correspond to the crab trawling season in South Carolina and Georgia, beginning after the close of the white shrimp season and roughly going until the roe shrimp season begins. This is usually from January or February to mid April or early May (Keith[18]).

Outlook

The whelk fishery is at or near the point of overfishing at present and, unless more restrictive management practices are instituted, landings will continue to decline. There are no plans to augment stocks or catches by mariculture means currently (Anderson et al., 1985).

Cross-barred Venus

The cross-barred Venus or pepper clam, *Chione cancellata*, is the subject of a very small fishery in South Carolina. It is harvested by hydraulic escalator clam dredges. This clam has a very pleasant flavor and is preferred over the hard clam by some shellfish enthusiasts. It may have some potential as a mariculture species, however, no one at present is trying to culture it on a large scale (Anderson[15], Keith[18]).

[18]Keith, W. J. 1992. S.C. Wildl. Mar. Resour. Dep., Mar. Resour. Div., Box 12559, Charleston, SC 29422. Personal commun.

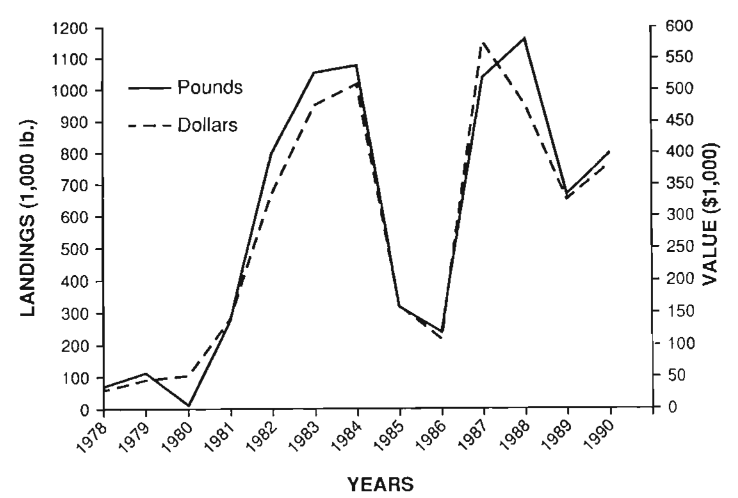

Figure 15
Whelk landings 1978–90 (GDNR, 1992; NCDEHNR, 1992; SCWMRD, 1992; USDOC, 1992, 1904–40).

Queen Conch

The queen conch, *Strombus gigas*, fishery of southern Florida was pursued until 1985. This colorful species and fishery lent its name to the equally colorful human population of the lower keys who are known as "conchs" and the area the "Conch Republic." This gastropod most often occupies shallow water grassbeds and sand flats. It is found in depths from <1 foot to 200 feet (<0.3–60 m), but is most abundant at <100 feet (<30 m). It was once captured by hooking it with a long pole (up to 30 feet long (9 m), but in recent years diving has been the most prevalent method of harvesting. The shell, up until recently, was the most desired part of the conch; however, in 1965 the Florida legislature passed a law that the meat must be used in order to legally take this animal. The next year resulted in record landings (total Florida). The catch fell after this, and in 1975 a limit of 10 conchs per person per day and 20 in possession was placed on the fishery. The fishery was closed in Florida waters in 1985 (Brownell and Stevely, 1981; Stevely and Warner, 1978; Glaser[19]).

Mariculture of *S. gigas* has been considered as a means of repletion of fished out stocks and as a means of producing juveniles for conch escargot (Berg, 1976; Berg and Glazer, 1991; Davis and Dalton, 1991). Biological techniques for culture of this species have been developed and tested; however, at present day prices and using present day methods the economic feasibility is still not proven (Berg and Glazer, 1991). The possibility of a resumption of a natural fishery on the east coast of Florida is remote because of a small population size and the unlikely event that it will be replenished.

Ribbed Mussels

The Atlantic ribbed mussel, *Geukensis demissa*, a common intertidal bivalve, has been harvested in the past and processed to provide a provitamin D which was irradiated to provide Vitamin D. This fishery was pursued prior to and during World War II in the

[19]Glazer, Robert. 1992. Fla. Dep. Nat. Resour., Div. Mar. Resour., 13365 Overseas Hwy., Marathon, FL 33050. Personal commun.

Beaufort, N.C., and Beaufort, S.C., areas. A cheaper source of Vitamin D led to the demise of this industry (Chestnut, 1951; Maggioni[2]).

Rangia

The common rangia clam, *Rangia cuneta*, was harvested in the late 1960's and early 1970's in the Beaufort, N.C., area. These were steamed, shucked, and processed with hard clam liquor as a possible substitute for hard clams. This product did not catch on and most were sold as fish bait. No landings have been reported since 1972.

Coquina Clams

The coquina clam, *Donax variabilis*, was landed in small quantities up into the 1920's in Florida. This bivalve was used to make soup and was probably the periwinkle reported by Alexander (1905), as he said they were caught in shovels fitted with wire scoops and used in "Donack" soup.

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I am very grateful to the many people who took time from their busy schedules to share their personal observations and intimate knowledge of the shellfish industry of the region. They are all listed among the personal communications. Jeffrey French was particularly helpful in providing an excellent summary of the North Carolina oyster fishery, and I thank him especially. Appreciation is due Karen Swanson for drafting the figures. George Steele reproduced the photographs loaned by G. J. Maggioni and I thank them both.

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History and Status of the Oyster, *Crassostrea virginica*, and Other Molluscan Fisheries of the U.S. Gulf of Mexico

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ABSTRACT

The eastern oyster, *Crassostrea virginica*, is by far the most important commercial mollusk landed on the U.S. Gulf coast from Florida, through Alabama, Mississippi, Louisiana, to Texas. Florida produces about 20% of the region's oysters; Alabama, 4%; Mississippi, 8%; Louisiana, 50%; and Texas, 18%. In 1986–90, combined production from the Gulf states averaged about 17.4 million pounds of meats/year. Louisiana's production of American oysters leads all states. The oyster industry has had a long history, beginning with the Native Americans. The early American colonists developed the industry during the 1800's, and it later grew into its modern form. Oyster production has tended to be highly variable largely as a result of fluctuating environmental conditions. Cultch planting has been important in maintaining productive oyster reefs. Louisiana has maintained public reefs as seed grounds and maintains seed supplies by shelling them. Oystermen have dredged seed off the public grounds and planted it on their leases for growth and marketing. In the other states, the market grounds are nearly all public. Fishermen harvest oysters in Florida and Alabama with tongs, in Mississippi with tongs and dredges, and in Louisiana and Texas with dredges. Biloxi, Mississippi, historically was the major producer of steamed (canned) oysters along the Gulf coast, handling oysters from Louisiana as well as Mississippi. The steaming ended in 1965. In the past 15 years, oysters in Florida and Louisiana have been marketed year-round instead of in the cooler months as in prior years. Other mollusks harvested for food in much smaller quantities are the sunray venus clam, *Macrocallista nimbosa*; calico scallop, *Argopecten gibbus*; bay scallop, *Argopecten irradians concentricus*; northern quahog, *Mercenaria mercenaria*; and southern quahog, *Mercenaria campechiensis*.

Introduction

The most important commercial molluscan fishery along the Gulf coasts of the states of Florida, Alabama, Mississippi, Louisiana, and Texas (Fig. 1) is, by far, that of the eastern oyster, *Crassostrea virginica*. Other molluscan shellfish harvested for food are the sunray venus clam, *Macrocallista nimbosa*; calico scallop, *Argopecten gibbus*; bay scallop, *Argopecten irradians concentricus*; northern quahog, *Mercenaria mercenaria*; and southern quahog, *Mercenaria campechiensis*. Several other mollusks are sold to the aquarium trade.

The Habitat

The U.S. Gulf coast, stretching 8,010 km (4,966 miles) from Florida Bay to the Rio Grande in Texas, encompasses 6,391,396 ha (15,781,224 acres) of estuarine areas (Table 1). The physiography and geological devel-

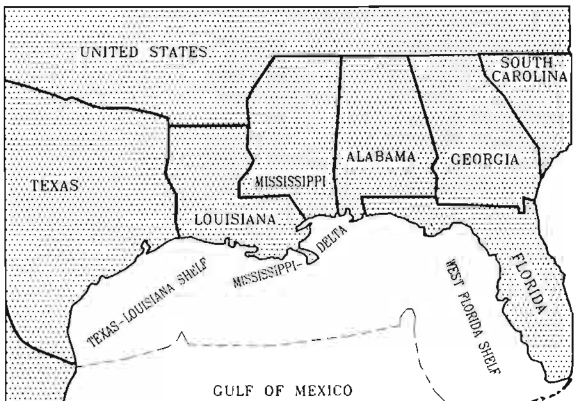

Figure 1
The Gulf coast of the United States.

opment of the Gulf of Mexico and the continental and marine geology along the Northern Gulf coast are fairly uniform (Folger, 1972). Because sediments have been deposited by rivers, estuaries average less than 2 m (6 feet) deep. The coastal zone is a low energy hydrologic regime (Grosline, 1967), and currents are usually <50 cm (20 inches)/second, except in restricted channels. Normal tidal ranges usually are <0.5m–<2 m (<1.5–<6.0 feet). Average freshwater discharge is high in the eastern Gulf, but low in the western Gulf. Salinities can range from fresh water to over 100‰. Monthly average temperatures range from 10° to 32°C (50° to 90°F). Freezing water temperatures are rare.

Oyster Resources

Most oyster reefs along the Gulf coast are covered by 0.6–3.6 m (2–12 feet) of water at low tide. The exact locations or dimensions of all oyster reefs cannot be mapped accurately, because oysters occur in almost all Gulf estuarine areas and many reefs are subtidal, making observation and mapping difficult. Due to environmental factors and oyster culture activities, the dimensions of some reefs have changed considerably over the years.

Oysters are most abundant in areas where salinities range from 10 to 30‰; in lower salinities (<15‰), the effects of diseases and predators are much lower than in higher salinities. Oysters set in good numbers every year, and their growth is rapid, attaining the legal market size of at least 3 inches (76 mm) within 2 years. Growth proceeds throughout the year in all but the coldest periods.

History and Development of the Fishery

The commercial oyster fishery in the Gulf has a long history, and nearly every aspect, including production, can be compared with a roller coaster with many "ups" and "downs" (Table 2). The fluctuations show how sensitive oysters are to environmental changes.

Commercial fishing was developed by aboriginal Native Americans who established trade for smoked oysters in many areas of North America. As the early European colonists relied on native foods and developed local economies, they expanded the industry into its modern form. Management efforts by regulatory agencies are recorded from the late 19th century, and they have been described by several authors, including Emery and Uchupi (1972). Many writers (especially Kilgen and Dugas 1989) describe how ancient oyster reefs played a substantial role in determining the developmental history of certain oyster fishing areas.

Florida Gulf Coast

The use of oysters along Florida's west coast (Fig. 2)

Table 1
Dimensions of estuarine areas of the northern Gulf of Mexico, U.S. mainland[1].

	Coastline			Estuarine area		
State	Km	Miles	%	Ha	Acres (MHW)	%
Florida	2,484	1,540	50	1,686,035	4,163,050	26
Alabama	171	106	3	321,856	794,706	5
Mississippi	226	140	5	405,308	1,000,760	6
Louisiana	903	560	18	2,736,928	6,757,848	43
Texas	1,194	740	24	1,241,268	3,064,860	19
Totals	4,978	3,086		6,391,395	15,781,224	

[1] Source: Kilgen and Dugas, 1989.

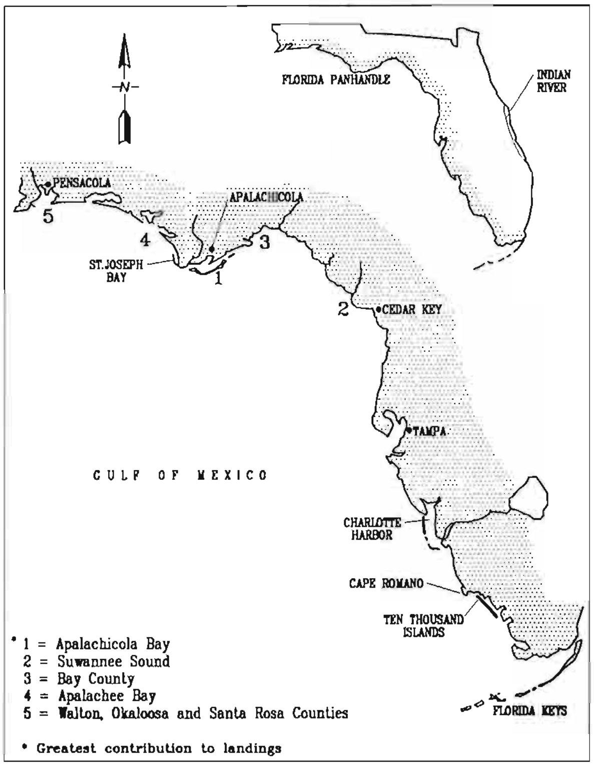

Figure 2
Florida's major west coast oyster-producing areas in order of contribution to total landings (from Berrigan et al., 1991).

predates the European colonization by thousands of years as demonstrated by numerous Native American mound and midden complexes. The first descriptions of the area's commercial oyster industry in Apalachicola Bay were by Ingersoll (1881, 1887). Since that time, surveys and research relevant to Florida's oyster resources have been somewhat continuous, beginning with Swift's surveys of 1895–98 (Swift, 1897, 1898), followed by Danglade's survey of Apalachicola Bay in 1915 (Danglade, 1917), and continuing with more recent research (Prytherch, 1933; Smith, 1937; Pearce and Wharton, 1938; Ingle and Dawson, 1953; Butler, 1954; Menzel et al., 1966; Quick and Mackin, 1971; Joyce, 1972; Berrigan, 1990; and Berrigan[1]).

By the beginning of the 20th century, researchers and fishery representatives had recognized the potential value of Florida's abundant oyster resources and identified the need for jurisdiction and control of shellfish resources (Swift, 1898; Whitfield and Beaumariage, 1977; Herbert and Associates, 1988). Previously, oysters were harvested in any manner desired without regard for resource conservation, and many reefs were reportedly damaged by indiscriminate harvesting and dredging (Swift, 1898; Whitfield and Beaumariage, 1977).

In 1913, the Florida Shellfish Commission was organized and shellfish laws were revised. Newly adopted provisions required permits for oyster dredges, the establishment of a statewide leasing program, and payment of an oyster severance tax to fund the management program (Whitfield and Beaumariage, 1977). Later revisions abolished the severance tax and prohibited the use of dredges on public reefs.

The Florida State Board of Conservation (FSBC) was created in 1933, and it assumed control of statewide shellfish management and leasing programs. In 1949, this board established the Division of Oyster Culture (DOC) to implement management practices to restore and enhance productive oyster habitat by replacing shell on public reefs. The board was reorganized in 1969, and the newly established Florida Department of Natural Resources (FDNR) assumed responsibilities for managing oyster resources. More recently, specific management responsibilities for regulating size limits, harvest seasons, bag limits, and gear have been delegated to the Florida Marine Fisheries Commission (FMFC) (Berrigan et al., 1991). In July 1993, the Florida Department of Natural Resources (FDNR) was merged with the Department of Environmental Regulation, forming the Florida Department of Environmental Protection (FDEP) which now is responsible for managing Florida's shellfish resources.

Production

Oyster production in Florida tends to be highly variable, largely as a result of fluctuating environmental conditions, but it usually ranges from 2 to 6 million pounds of meat (305,000–915,000 U.S. standard bushels of whole oysters). A Florida bushel or bag is defined as a container holding 10 gallons (volume) of culled oysters, equal to 60 pounds of shellstock (whole weight) and yielding approximately 6.56 pounds of meat. A bag contains 225–325 legal-size oysters. Reported landings averaged about 3.7 million pounds (564,000 bushels) annually during 1961–95 (Table 2), accounting for about 20% of the Gulf's production and placing Florida second to Louisiana in the Gulf's production. Florida landings generally reflect Gulf-wide trends: A gradual increase during the 1960's and 1970's, peaking at 7.2 million pounds (1,098,000 bushels) in 1981, a decline from 1985 to 1989, and relative stability during the early 1990's (Berrigan et al., 1991).

Harvests from Apalachicola Bay (Franklin County) account for about 90% of Florida's oyster landings.

[1] Berrigan, M. E. 1992. Oyster resources in Apalachicola Bay. Unpubl. manusc. on file at Fla. Dep. Environ. Prot., Tallahassee.

Table 2
Historical oyster production[1] among Gulf States, 1961–88.

	Production (1,000lb of meat weight)					
Years	Fla.	Ala.	Miss.	La.	Tex.	Total
1961–65 avg.	3,614	689	3,504	10,321	2,623	20,751
1966–70 avg.	4,508	1,072	2,356	8,689	4,004	20,629
1971–75 avg.	2,791	656	881	10.389	2,806	17,523
1976–80 avg.	5,087	812	775	9,344	2,203	18,221
1981	7,170	1,330	467	9,093	1,309	19,369
1982	4,782	1,497	2,576	12,621	3,633	25,109
1983	4,307	336	3,333	13,229	7,941	29,146
1984	6,621	477	1,378	13,952	5,168	27,596
1985	4,392	1,442	1,193	14,347	5,134	26,508
1981–85 avg.	5,454	1,016	1,789	12,648	4,637	25,544
1986	2,084	946	1,202	12,654	5,607	22,493
1987	3,518	88	132	12,027	2,897	18,662
1988	2,065	103	145	13,254	2,270	17,837
1989	1,698	5	100	11,606	2,407	15,816
1990	2,055	84	96	8,153	1,905	12,293
1986–90 avg.	2,284	245	335	11,539	3,017	17,420
1991	1,793	225	101	7,265	2,916	12,300
1992	2,499	1,202	707	9,183	2,748	16,339
1993	2,701	920	1,258	10,315	2,964	18,158
1994	2,011	712	674	11,328	4,614	19,339
1995	1,458	710	2,280	13,800	5,496	23,744
1991–95 avg.	2,092	754	1,004	10,378	5,473	19,701
1961–95 avg.	3,690	749	1,521	10,473	3,538	19,971

[1] Sources: Fisheries Statistics of the United States (var. issues) and unpubl. National Marine Fisheries Service data.

Oyster habitat occupies about 9% of Apalachicola Bay's aquatic area (45,603 ha (112,600 acres)), while commercially productive reefs cover only 2,430–3240 ha (6,000–8,000 acres). Annual production for Apalachicola Bay has been highly variable since 1980, exceeding 6.6 million pounds (1,000,000 bushels) in 1981, then declining to <0.5 million pounds (122,000 bushels) in 1986, following catastrophic losses associated with Hurricane Elena in September 1985. The downward trend in oyster production during the latter half of the decade, excluding marginal recovery in 1987, corresponded to extended periods of high salinity associated with droughts from 1986 to 1989 (Berrigan[1]). Other oystering areas, including the Suwannee Sound region, Apalachee Bay, and extensive estuarine systems in the western panhandle, are usually only marginal producers, with widely fluctuating landings and harvesting effort.

Oyster harvesting in Apalachicola Bay is highly regulated, as is the oyster industry statewide. Following Hurricane Elena in 1985, the Florida Marine Fisheries Commission implemented regulatory restrictions to foster resource recovery, including bag limits, limits on the number of harvesting days and daily hours, tolerance limits, and the implementation of a monitoring station program (Berrigan, 1988). All oysters harvested from public reefs in Apalachicola Bay were required to be passed through and tagged at monitoring stations. Inspecting and tagging harvests provided pertinent fisheries information, including landings, number of vessels engaged in harvesting, catch/vessel, and harvesting locations. Combined with extensive oyster resource assessment, this information provided oyster resource managers with a unique opportunity to monitor and provide reliable fishery forecasts. In July 1992, provisions requiring monitoring stations were revised and the practice was discontinued, largely as a result of budgetary constraints.

In Florida, the principal methods for harvesting oysters are by hand tongs and, to a lesser extent, by hand while diving or wading. Harvests are primarily from public reefs. A limited amount of dredging takes place on private leases in Apalachicola Bay.

Resource Development

As public reefs account for 90–95% of the oysters landed, Florida's resource development activities are directed toward enhancing production from these reefs. Cultch planting is important for maintaining and increasing productive oyster habitat in Florida and other Gulf states. Replanting processed or dredged shell has long been accepted as an advantageous management practice and gives resource managers the almost singular opportunity to mitigate resource losses, enhance productivity, and contribute direct economic benefit to the oyster fishery and its dependent economy. Shell planting on public reefs in Apalachicola Bay was reported as early as 1914 (Danglade, 1917), and an effective shell-planting program has been maintained since 1949 to help ensure high productivity from Florida's public reefs (Ingle and Dawson, 1953; Whitfield, 1973; Futch, 1983; Berrigan, 1990). From the inception of its predecessor agency (DOC) in 1949, the FDEP and its predecessor agencies have collected and planted at least 268,000 m^3 (7.6 million bushels) of oyster shell. Collecting and stockpiling oyster shell has benefitted from a Florida law which provides that shucked oyster shell is the property of the state. But collections of processed shell have been highly variable during recent years, resulting from decreased voluntary compliance, fluctuating landings, questions of ownership of out-of-state shell, and a shift from selling shucked meats to selling "half-shell" oysters.

When processed shell is not available, the state has turned to out-of-state sources to supply shell. From 1960 to 1992, the state purchased dredged *Rangia cuneata* clam shell and oyster shell from Louisiana to restore and construct oyster reefs. In the future, however, this source of shells may not be available, and oyster resource development in Florida and other Gulf states may be seriously threatened. Resource managers currently are investigating the use of alternative cultch materials, such as calico scallop shells and limestone aggregate.

Besides spreading shell, other methods have been implemented to enhance oyster production in historically productive areas, including relaying of oysters from restricted to approved waters, transplanting seed oysters, and the use of innovative technologies such as intensive cultivation. The use of abundant oyster stocks in waters where direct-to-market sales are currently prohibited because they are contaminated with pollutants will probably increase markedly as relaying activity expands and controlled purification techniques are demonstrated.

Cooperative management programs are conducted to transplant juvenile oysters from areas where seed stocks are abundant on intertidal reefs to subtidal areas where environmental conditions are more favorable for growth to market size and quality. Since 1982, at least 1.8 million bushels of juvenile and adult oysters have been relayed and transplanted in six coastal counties.

Florida provides good environmental conditions for shellfish culture, and some efforts are underway to develop its potential. Several multiagency and multidisciplinary projects have been established to train potential aquaculturists, primarily those involved in traditional fishery occupations who may augment their incomes while relying on their fishery skills. Six aquaculture demonstration and training programs have been implemented along Florida's Gulf coast with the support of local fishermen, communities, and government. These successful programs produce hard clams. Unfortunately, a training and demonstration program was completed in Apalachicola Bay to produced oysters, but local resistance prevented leases from being issued to project participants.

Leasing Programs

Granting sovereignty lands for oyster production has a long history in Florida. In 1881, laws were passed by the Florida Legislature that permitted individuals to obtain grants from county commissions to cultivate oysters on bottom lands where natural oyster reefs did not occur. Contractual stipulations required that the grantee cultivate his grant using shell or live oysters, and enabled the grantee to harvest exclusively and hold title to the cultivated bottoms indefinitely (Whitfield and Beaumariage, 1977). Most grants were abandoned before the laws were revised to prohibit granting of submerged lands. In 1913, a comprehensive leasing program was initiated when Chapter 370, Florida Statutes, was adopted and authority to approve shellfish leases was transferred from county commissioners to the Commissioner of Agriculture and the Florida Shellfish Commission. Since the first shellfish lease was approved on 1 May 1914, about 1,200 leases have been issued, but only about 150 remain active.

In 1933, the shellfish leasing program was transferred from the Commissioner of Agriculture to the State Board of Conservation, which was composed of the members of the Board of Trustees of the Internal Improvement Trust Fund. In 1969, the FDNR assumed the duty of authorizing shellfish leases. In 1984, the legislature provided for a new mechanism to lease submerged bottoms for aquacultural activity (Chapt. 253, Florida Statutes), and in 1989 it prohibited the issuance of additional shellfish leases under the previous law (Chapt. 370, Florida Statutes). In 1992, 150 shellfish leases (810 ha (2,000 acres)) and 25 aquaculture leases (41 ha (100 acres)) were in effect.

Leasing activity is concentrated on Florida's east coast, and only 20 shellfish leases totalling 303 ha (747 acres) are on the Gulf coast; 10 of the active Gulf coast leases (266 ha (656 acres)) are in the Apalachicola Bay system. Oyster production from leases accounts for perhaps only 5–10% of annual landings; 23 producers reported sales of 54,200 bushels of oysters in 1991.

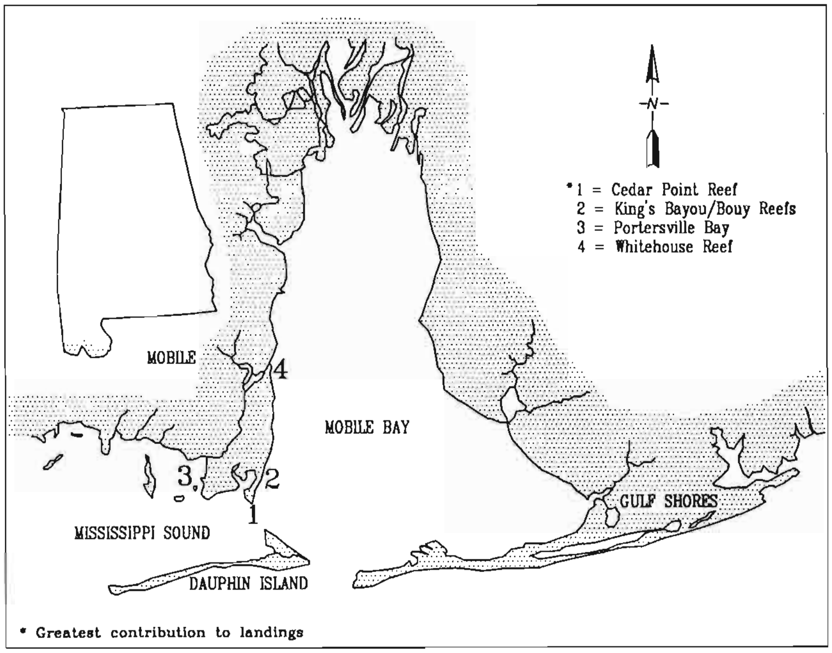

Figure 3
Alabama's major oyster-producing areas in order of contribution to total landings (from Berrigan et al., 1991).

Alabama

Alabama (Fig. 3) oyster landings averaged just under 750,000 pounds of meats (168,000 bushels of whole oysters) annually during 1961–95 and represented about 4% of the Gulf total (Table 2). Annual landings tend to fluctuate widely, but they usually range from about 400,000 to 1,500,000 pounds of meats (90,000–338,000 bushels). During 1986–90, annual landings were low, accounting for an average of 245,000 pounds of meats, while for 1991–95 the annual average landings were 754,000 pounds of meats.

Alabama currently has no oyster leases on state-regulated bottom, but there are 25 oyster leases on riparian bottoms along the northern shore of Mississippi Sound. Most were obtained recently and as yet few have produced oysters.

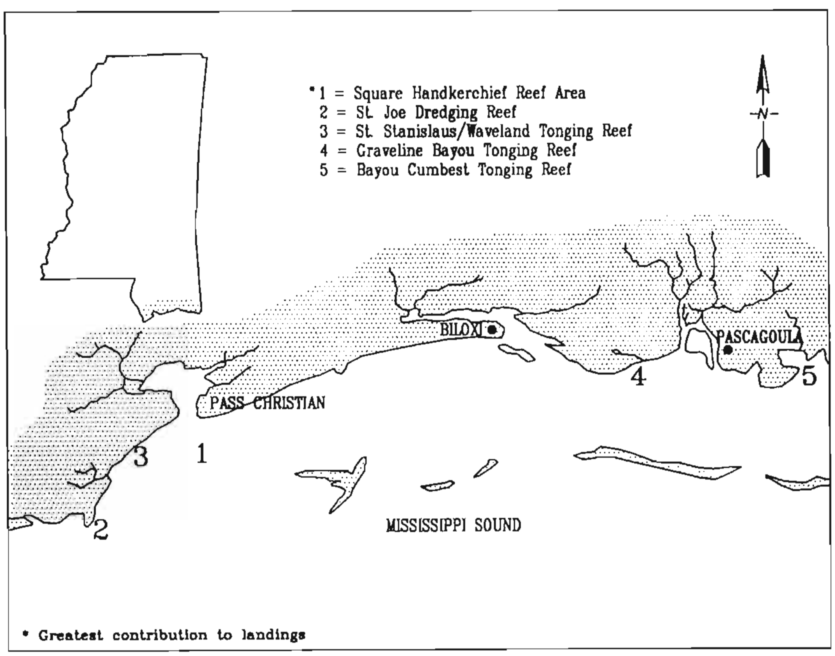

Figure 4
Mississippi's major oyster-producing areas in order of contribution to total landings (from Berrigan et al., 1991).

Mississippi

During 1961–95, oyster production in Mississippi (Table 2, Fig. 4) averaged about 1.5 million pounds of meats (337,000 bushels of whole oysters) annually, representing about 8% of the Gulf total. State oyster landings declined during 1986–90, with an average annual production of only 335,000 pounds of meats, or only about 10% of state landings in the early 1960's. However, landings have greatly increased since 1991, with 1995 production the highest in 12 years at nearly 2.3 million pounds of meats.

Oystermen had little interest in leasing grounds until 1977 when the Mississippi State Legislature enacted laws to allow lessees under bond to relay oysters from public reefs that had been permanently closed due to sewage contamination. This action sparked interest

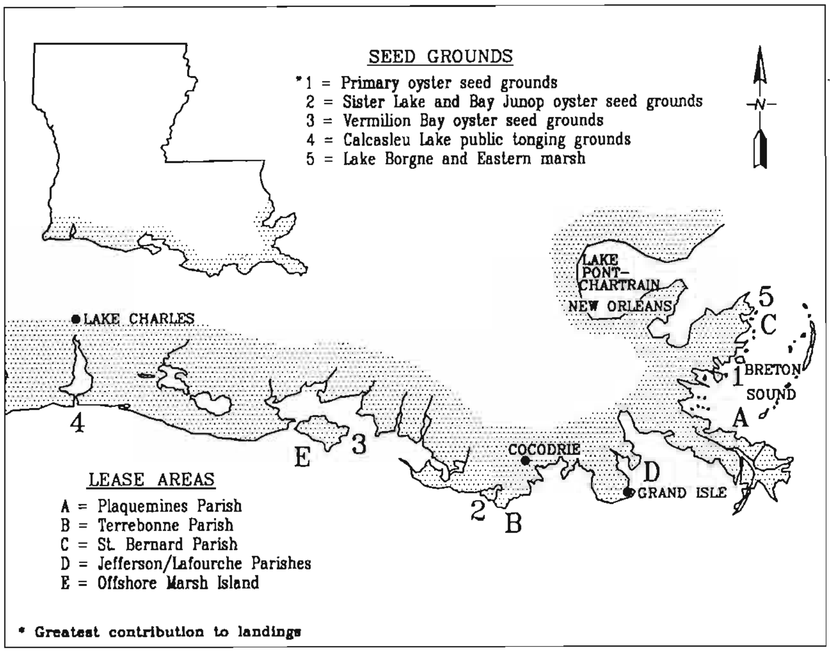

Figure 5
Lousiana's major oyster-producing areas in order of contribution to total landings (from Berrigan et al., 1991).

in leasing, and by 1979 more than 50 leases were approved.

Relaying of the contaminated oysters began in mid–1977, and by 1980 most closed areas had been nearly depleted of marketable oysters. Relaying continued to decline throughout the 1980's, and no relaying by lessees was conducted in 1989 or 1990. The number of active leases has also declined.

Louisiana

Louisiana (Fig. 5) produced about half the oysters in the Gulf of Mexico during 1961–95 (Table 2) and, in some years, has been the largest producer of eastern oysters in the nation (as it was in 1993). Its production has remained relatively constant during the past 30 years, though harvests during the 1980's were about 2 million pounds of meats above its average annual 1961–95 production of nearly 10.5 million pounds (2.3 million bushels of whole oysters).

Fishermen harvest oysters from public and private grounds. The public oyster grounds total about 324,000 ha (800,000 acres) east of the Mississippi River; however, only about half of this acreage is in production at any one time. The private grounds total about 137,700 ha (340,000 acres).

No inventory of the oyster reefs exists, nor has there been any attempt to determine the amount of productive and nonproductive reef acreage within the leased acreage. Fishermen commonly lease nonproductive areas surrounding their productive reefs to protect them from oyster poachers.

History

Prehistoric oyster use dates from at least 2,000 B.C. (Wicker, 1979). Native Americans left middens predominantly of oyster shell, showing that oysters were important in their diet. Oysters were collected by hand by wading in shallow waters (Wicker, 1979) or by crude tools devised to aid gathering. One such device consisted of rakes made of two strong poles, curved at the ends and interlaced with string vines (Dyer, 1917). Archaeologists infer that Native Americans consumed oysters smoked, dried, and raw. Oyster trading was probably not extensive due to limited transportation (Wicker, 1979).

In his Historie of Louisiane, DuPratz (1758) stated that early French settlers harvested oysters; however, they ate them only when other food supplies were scarce. By the 19th century, the market for oysters expanded, and they became popular in areas along the Gulf coast.

DuPratz (1758) also tells us of the abundance and deliciousness of the oysters in Louisiana bayous. When the Europeans arrived on the Louisiana shores, they recognized the local oyster as a "cousin" of the European flat oyster, *Ostrea edulis.* The earliest oyster consumers lived near the water and gathered oysters as they needed them for their daily consumption. As the human population increased, fishermen living near the oyster-growing areas realized the commercial potentialities of oyster and began selling them with fish.

From 1840 to 1850, many Yugoslavs arrived in Louisiana and remained in New Orleans with some relocation along the Gulf Coast (Vujnovich, 1974). Many among them had made their living as fishermen in the Adriatic Sea. Some could not find employment in New Orleans and went down the Mississippi River to fish for a living in lower river parishes (Louisiana's counterpart of counties). The rich delta country with its many bays, bayous, and inlets provided a good supply of fish, shrimp, and oysters.

As their numbers increased after the Civil War, Yugoslavs fished for oysters in other bays, lakes, and bayous of the Mississippi Delta. They set up camps, which at first were simple one-room structures built on four corner pilings. As the camps were improved, some areas later became substantial settlements, only to be destroyed by hurricanes.

The Yugoslavs remembered the successful cultivation of oysters in the old country, and decided to try to do the same with the Louisiana oysters on a somewhat larger scale but using a different method which the Louisiana Acadians later adopted. Louisiana Acadians are displaced people of French descent from Nova Scotia who settled in Louisiana's central coastal areas in the 1800's. Many became commercial fishermen.

The Yugoslavs found that the area east of the Mississippi River had an abundance of natural reefs where oysters grew and multiplied at a rapid rate. They also discovered through persistent and careful observation and experimentation that if the overcrowded, flavorless, natural-reef oysters were transferred to the west side of the Mississippi River and spread more thinly where the salinity was proper, the current steady, and the microscopic food supply plentiful, the narrow seed oysters developed a round-oval shell, matured to market size in a few months, and most important, acquired that tangy taste for which this type of oyster soon became famous.

Here, then, in the early 1800's were the beginnings of Louisiana oyster cultivation as it is practiced to the present day and the development of a dual method (use of private and public oyster grounds) of oyster fishing. The cultivated oysters soon were in great demand mainly in New Orleans and were served in all its better restaurants, oyster bars, and hotels.

At the beginning of this oyster cultivation, the method of gathering oysters was primitive. The Yugoslav oystermen picked the oysters from the water with their bare hands while wading in water, separated the market-sized oysters from clusters, dead shells, and small immature oysters, placed them in skiffs which were rowed or sailed to the favorable areas, and deposited them in the water again. In the early 1800's, they "planted" the oysters one by one, spacing them a few inches apart to give them room to grow. They enclosed the planted area with wooden boards to protect them from predators, such as drumfish, *Pogonias cromis*, and from poachers. Because this was slow, tedious, and backbreaking work, they experimented with implements to gather the oysters and bring them to the surface in larger quantities. They probably used ordinary garden rakes to scoop the oysters in small piles and later (probably during the cold winter months) crossed two of the rakes in blacksmiths' tongs fashion to harvest oysters from boats.

Tonging typically was done from wooden skiffs 4.9–6 m (6–20 feet) long; in the 1930's and 1940's, skiffs were powered by outboard motors. The skiffs have been constructed with wide beams and flat bottoms and may have a large deck and wide railing on which the oystermen stand while tonging (Fig. 6).

In 1905, a Yugoslav fisherman initiated the "new" method of fishing oysters, i.e., dredging, which is still in use, when he installed the first pair of oyster dredges on an oyster boat. The oyster dredge, a V-shaped iron frame with a ring-mesh bag about 1 m (3–4 feet) long, is towed with a chain. For many years, the dredges were hoisted aboard with manually operated winches, an improvement over tongs but still a difficult task. In 1913, oystermen developed the first power hoists for oyster dredges.

A vessel tows one or more dredges, whose sizes and weights vary among vessels, but most measure about 1 m (3 feet) wide and weigh about 120 pounds. They usually are handled from the side of the vessel slightly forward of midships, but may also be pulled from the stern.

Leasing Bottoms for Oystering

Beginning in the 1850's, the oystermen leased water bottoms from Jefferson, St. Bernard, or Plaquemines Parishes to protect their oysters and identify their location. They were charged a set fee/acre. Since 1902, however, when the Louisiana Oyster Commission (predecessor of the Louisiana Wild Life and Fisheries Commission) was established, the water bottoms have been leased from the State of Louisiana.

As of December 1991, at least 2,000 people held about 9,000 individual, active leases encompassing about 137,700 ha (340,000 acres) of Louisiana water bottoms. The leases are issued for 15-year periods and their

Figure 6
Louisiana oystermen tonging for oysters.

average size is about 14.6 ha (36 acres). Most leases are in the eastern half of the state, while others are in the central parishes of Terrebonne, Iberia, and St. Mary. No leases are located west of the Vermilion Bay complex; however, one lease is located south of Vermilion Bay, 11 km (7 miles) offshore in the Gulf of Mexico.

A 1982–85 study (Melancon, 1990) of the expenses of an oyster farmer (leaseholder) showed that the farmer harvested from 0.03 to 1.68 sacks of market oysters from each sack of seed he planted. The lower yields were attributed to vandalism and poaching. When bedding oysters from the public grounds, the vessels consumed an average of 78 gallons of diesel fuel/day, and when harvesting for market 24 gallons/day. An average of 2.1 quarts of diesel fuel was consumed/sack of oysters sold. Each year, a typical oyster farmer spent an average of 69 worker days of labor bedding seed (based on a crew of 3) and tried to take about 20 loads of 600 sacks/load from the public grounds to his leases (Fig. 7). Daily operating expenses were 18% higher while bedding than while harvesting for market sale, and a profit was made only when sufficient quantities of seed were available to bed.

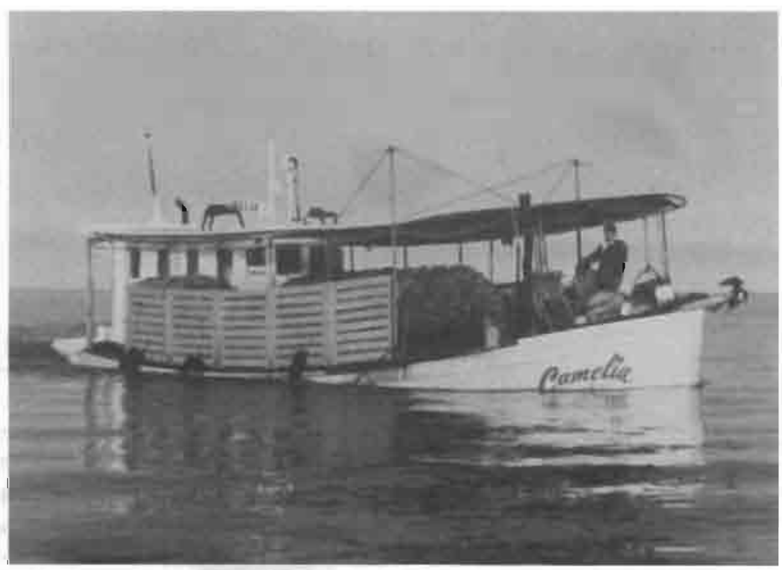

Figure 7
A Louisiana oyster lessee loading his vessel with seed oysters from a public oyster ground.

Transporting and Marketing Oysters

From the beginning of Louisiana's active oyster cultivation in the 1850's until the oyster vessels were motorized during the first decade of the 20th century, the most time-consuming activity was transportation. It robbed oystermen of precious fishing time and sapped their energy.

At first, they used regular fishing skiffs; later, they constructed low-decked, shallow-draught, one-masted, lateen-rigged sailboats 9–12 m (30–40 feet) long (Fig. 8). These oyster smacks were propelled by sails, oars, and, in shallow waters, by poles that the fishermen pushed. Since the boats did not have any equipment except basic rigging and cost only $300–$500, most oystermen could purchase their own boats. Others built two-masted schooners, which they used primarily to transport seed oysters from public reefs to their private bedding grounds and to carry the marketable oysters to New Orleans. Louisiana market ports are some distance away from the harvesting areas. A one-way trip took 1–2 days, the time governed by the winds and tides. There are currently 44 well-established docks where fishermen land oysters along the coast, with many more small docks scattered throughout the coastal area.

During the sailboat era, oystermen brought oysters to the market in New Orleans themselves or sold them to luggermen who took them to the city. Either way they were at a disadvantage. They lost almost a week's time making the round trip to sell the oysters. If, because of favorable winds, too many boats arrived at the market at the same time, they were at the mercy of the buyers who dictated the price. The oystermen had no choice but to sell at the going price for time was against them; the oysters could not keep forever.

Figure 8
A sailing vessel (smack) employed by Louisiana oyster fishermen in the early 1900's. Source: The historic New Orleans collection, Museum/Research Center, New Orleans. Acc. no. 1974.25.13.141.

The Louisiana barrel held three present-day sacks of oysters, and the market barrel held two sacks. Around 1880, the Louisiana barrel sold for $1.00 at the bedding grounds, though in New Orleans the market barrel sold for $2.00. Natural-reef uncultivated oysters were also brought to market and sold for $0.50–$0.80/barrel. The cultivated oysters were brought to the inclined landing in New Orleans at the foot of Dumaine Street in the "French Quarter" (Fig. 9) which could accommodate up to 200 boats at a time. The small boats ground their bows on the landing, the exact spot depending on the height of the river.

Before motorization of the oyster industry, when the oysters became delivered at a predictable time, the oystermen sold directly to restaurants, oyster shops, and shucking houses that sent their wagons to buy at the oyster landings.

The first oysterman in Louisiana to install a motor on his boat was a Yugoslav fishermen in 1902. Others soon followed, for although it represented a sizable investment, forcing many to borrow money or to form partnerships, they realized the enormous advantages of rapid transportation and assured timely arrival for their perishable product. The smaller fishermen kept their sailing vessels, however, and it was not until 1920 that the last of the quaint sailing smacks disappeared. The dealers, in turn, to assure delivery, started giving the oystermen orders for a definite amount of oysters on a certain day, usually on Thursday for Friday consumption.

Texas

Oysters occur in all Texas bays (Fig. 10), but their abundance varies greatly among them (Diener, 1975). Fishermen harvest oysters from public reefs that total 7,100 ha (17,532 acres) and private leases that total 954 ha (2,356 acres). About 91% of the public reef acreage is in the Galveston, Matagorda, and San Antonio Bay systems, and about 90% of the landings are from public reefs.

The remaining 10% of oyster landings are from private leases, all 43 of which are in Galveston and East Galveston Bays. Leases average about 22 ha (54 acres) each. Most oysters on them are transplants from uncertified, closed areas in public reefs (Quast et al., 1988). Leases granted in other bay systems have not been successful, and they have been returned to the state. The amount of suitable bay bottom for leases and the quantity of transplantable oysters are limited, mostly occurring in the Galveston Bay system. The other substantial concentration of oyster reefs (about 567 ha (1,400 acres)) is in Corpus Christi Bay and the adjoining Aransas-Copano Bay area.

Figure 9
French market dock in the early 1900's. Source: The historic New Orleans collection, Museum/Research Center, New Orleans. Acc. no. 1974.25.17.129.

In 1983, Texas oyster production was 7.9 million pounds of meats (1.7 million bushels) exceeding any other single-year harvest by more than 2 million pounds (430,000 bushels). By comparison, the 1976–80 average annual production of 2.2 million pounds (473,000 bushels) was less than half of the 1981–85 average annual landings (Table 2) (Quast et al., 1988).

Coastwide oyster abundance has fluctuated among years in response to changes in fishing pressure and environmental conditions (Hofstetter, 1977), but between 1956 and 1981 the overall trend in oyster abundance for the Galveston Bay system, the state's major oyster producing area, was downward at just under 1%/year. The only major exception was an extremely large population increase in 1982, but this was followed by a decrease through 1988.

From 1977 to 1986, average annual landings in Texas were 3.6 million pounds (775,000 bushels) with an average ex-vessel value of $5.5 million. The oyster industry had an average annual total economic impact through the application of a multiplier (3.12) of $17.1 million on the Texas economy during this period.

The Texas legislature historically has managed the state's oyster fishery, but limited authority has been delegated to the Texas Parks and Wildlife Department (TPWD) for adjusting the season and enforcing the laws. In 1985, the Sixty-ninth Texas Legislature finally provided the TPWD full authority to regulate the Texas oyster fishery.

Processing Gulf Oysters

In 1993 (November), About 320 dealers (shellstock shippers) were buying and selling whole shellfish, and about 140 shellfish plants were shucking and packing shellfish (shucker-packers) in the Gulf states. The dealers and plants handle mostly oysters. Most are in Florida and Louisiana (Table 3). Many of the businesses are small and their numbers vary as operators enter and leave the business frequently.

Historical Perspective

Biloxi, Miss., historically was the major producer of steamed oysters along the Gulf coast. Along with Mississippi oysters, large quantities of Louisiana oysters were processed by Biloxi factories and plants; some 90% of oysters opened in the state were brought in from Loui-

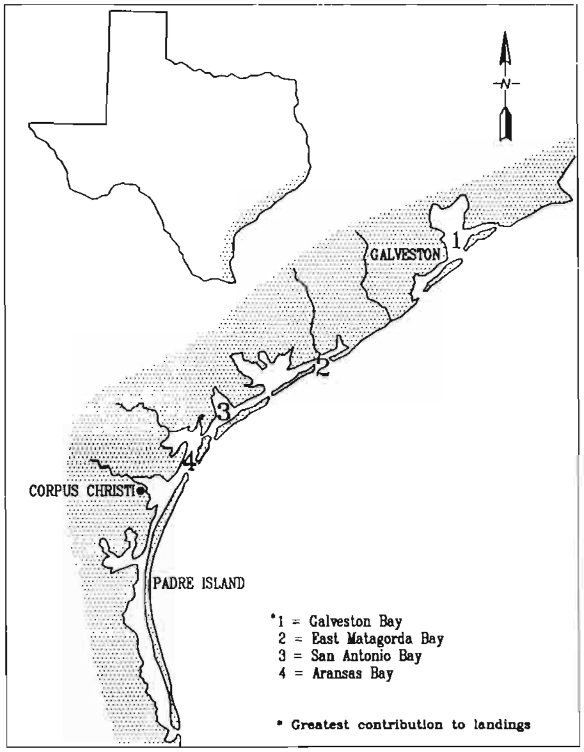

Figure 10
Texas' major oyster-producing areas in order of contribution to local landings (from Berrigan et al., 1991).

Table 3
Number of shellfish dealers and plants in the Gulf states, 1 November 1993[1].

State	Dealers (shellstock shippers)	Plants (shuckers and packers)
Florida	130	49
Alabama	29	28
Mississippi	24	12
Louisiana	122	40
Texas	16	11
Totals	321	140

[1] Source: Interstate certified shellfish shippers list, 1 November 1993. U.S. Dep. Health Human Serv., Publ. Health Serv., Food Drug Admin.

siana. Its canning operations began in the 1870's and 1880's. The first large shucking and canning factory was constructed in 1878, and by 1900, there were five or six such factories. Biloxi also had about 24 small shucking plants. In 1915, when Biloxi had 12 canneries and 6 raw houses, it was second only to Baltimore, Md., in having the most oyster canneries in the United States. Four other Mississippi cities each had 1 cannery and 1–2 raw houses. At this time, Florida had 4 oyster canneries and about 12 raw houses, Alabama had 1 oyster cannery, Louisiana had 6–7 oyster canneries, and Texas had 2–6 shucking houses in each of 9 ports, but it did not have any canneries (Churchill, 1920).

The sail-dredging schooners (Fig. 11) unloaded their oysters onto docks in front of the Mississippi factories. Workers piled the oysters into carts which measured about 2.4 m (8 feet) long and 0.6 m (2 feet) wide, and then pushed them into a steam box in the factory. When the oysters gaped, they were hand-shucked (Fig. 12) and packed into cans (Churchill, 1920). The Mississippi dredging sloops were eventually replaced by motorized vessels (Fig. 13).

In 1965, the Biloxi factories were substantially damaged by Hurricane Betsy. The Mississippi steam processors decided not to rebuild them, because competition from imports of foreign steamed oysters was increasing and consumers preferred fresh and frozen oysters. This was a wise decision at the time, because in 1978 the one remaining Louisiana steaming plant ended production for economic reasons.

Many oysters currently harvested in Louisiana year-round are taken to Biloxi by refrigerated tractor-trailer trucks to be shucked fresh along with oysters harvested from local waters. Most shuckers now are Vietnamese immigrants.

Problems of the Oyster Fisheries

Many factors, including habitat loss and pollution, contribute to oyster fishery problems along the Gulf coast. Associated issues, such as user conflicts, environmental degradation, public health, and enforcement, also consume a substantial portion of the attention of state management authorities. The combination of environmental and user-related problems has created a complicated and diverse fishery management challenge.

Habitat Losses

Loss of habitat (human-caused or natural and temporary or long-term) is perhaps the most serious and chronic problem facing the Gulf oyster industry. Oyster reefs and integral reef shell or cultch have been lost through fishing, shell removal, and dredging and filling activities. Past incidents of such destruction were most numerous in high-growth coastal areas when habitat protection laws were not in effect. In addition, oyster reefs have been scoured or buried by strong tidal surges produced by hurricanes (Berrigan, 1988), and hur-

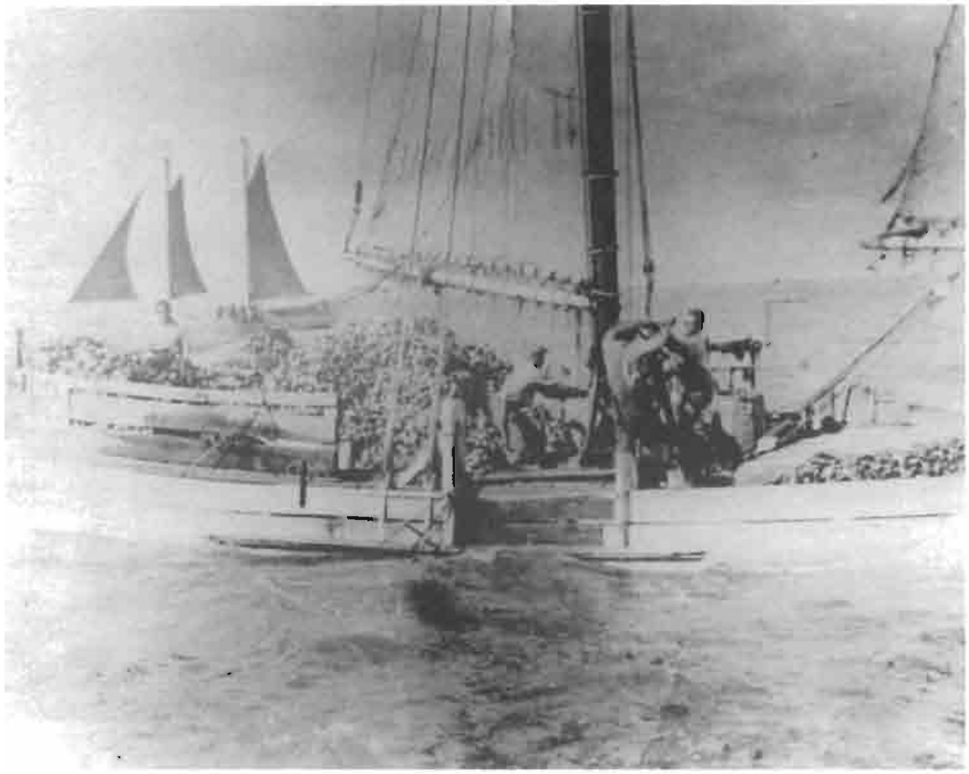

Figure 11
Crew of three men winding in a dredge on an oyster schooner in Mississippi Sound, 1930. Photograph courtesy of Maritime and Seafood Museum, Biloxi, Miss.

ricanes and storms have eliminated portions of coastal barriers and barrier islands that used to protect inshore reefs.

Restoring depleted oyster reefs or constructing new reefs with cultch has long been an accepted and successful management practice. Dredged and processed oyster shell have been widely used as cultch; however, shell availability in the future may be limited by other competing uses. The shape and noncompaction character of oyster shell make it a highly desirable material for road-bed construction, particularly in low-lying or swampy areas. An alternate cultch source for oysters would be useful, but suitable alternatives may be difficult to develop, depending on availability, cost, and effectiveness.

Changes in salinity regimes can have a profound effect on oyster populations. Total mortality of oysters and losses of reef complexes can occur as a

Figure 12
Opening oysters at a Biloxi, Mississippi, factory, 1930. Photograph courtesy of Maritime and Seafood Museum, Biloxi, Miss.

Figure 13
Oyster dredging in Mississippi Sound, 1963. Photograph courtesy of Maritime and Seafood Museum, Biloxi, Miss.

result of 1) freshwater flooding or "freshets," 2) prolonged high-salinity periods associated with droughts, and 3) freshwater diversions that lead to high salinities allowing predators to move into oyster habitats and decimate the oysters. Changes in salinity regimes may be seasonal or long term, and they may be human-induced or natural.

Many salinity changes, resulting in the greatest long-term negative impacts on oyster populations, have been associated with human actions. Channelization and other deepening projects in shallow estuaries have allowed high-salinity wedges to infiltrate reefs, and construction of levees, dams, locks, and freshwater diversion structures, as well as freshwater withdrawal from streams and shallow aquifers, have reduced the natural supplies of freshwater to reefs.

Habitat Rehabilitation

All Gulf states conduct resource development or restoration programs to mitigate habitat losses, mainly by spreading dredged or fossil oyster and clam shell as cultch. Since the early 1960's, the Gulf states have used mostly Atlantic rangia clam shells, *Rangia cuneata*, which have been relatively inexpensive and available, as a replacement shell for oyster reefs (Dugas et al., 1991). Since 1982, Louisiana has been the primary source of the dredged clam shells but future availability from this state is uncertain. The availability of processed oyster shell may also be limited since it has other uses.

The increasing need for suitable cultch combined with decreasing availability of oyster and clam shells have prompted resource managers to look for alternative cultches (Dugas et al., 1991). Substantial management problems are anticipated, if alternative cultches cannot be obtained.

Various techniques are used to establish oyster populations, ranging from building prominent structures to loosely scattering shells over existing reefs. Throughout the Gulf coast, shell is planted by washing it from the decks of barges using high pressure water streams or by dispersing it using a crane and bucket system. To make reefs as permanent as possible, shell is planted in a pattern resembling a natural reef, with thicker shell layers in the middle and thinner layers near the edges. In Florida, this practice, referred to as the "Ingle Method," has produced reefs that have remained productive for at least 40 years. Because oysters grow rapidly in Gulf waters, new reefs can produce harvestable oysters in 16–24 months (Berrigan, 1990).

Each Gulf state employs different management strategies. For example, Florida's rehabilitation efforts focus on public reefs for direct-to-market oyster harvesting, while much of Louisiana's efforts are directed toward developing oyster seed grounds where fishermen harvest and transplant the seed to their private leases. States often hire private companies to provide and disperse cultch material on designated reefs. Florida currently operates its own shell collecting and planting program, but also relies on private contractors.

Natural Mortality

Disease and environmental stress substantially limit oyster production. The incidence and severity of disease outbreaks within oyster populations may be likened to similar situations in agriculture. Once epizootics of oyster diseases are present, they may totally devastate an entire population. Resource managers have had minimal success in reducing mortality from disease.

Perkinsus marinus is the most devastating oyster pathogen, and it has caused massive mortalities. Its distribution and abundance are limited by salinity and, to a lesser degree, by temperature. Its rate of spread and development is low at salinities <14–15‰, and in wet years its incidence is much lower. The incidence and intensity of *P. marinus* may also be exacerbated by environmental stress and pollution burdens (Ray et al., 1953; Quick and Mackin, 1971; Soniat and Gauthier, 1989).

Predation represents a serious threat to oyster populations with severe consequences to commercial harvests (Berrigan et al., 1991). Numerous investigations confirm the seriousness of oyster predation by protozoans, anemones, coelenterates, helminths, mollusks, crustaceans, and finfish along the Gulf. Rocksnails (southern oyster drills), *Thais haemastoma*; stone crabs, *Menippe* spp.; and black drums, *Pogonias cromis*, have made devastating attacks upon oyster populations (Pearson, 1929; Butler, 1954; Gunter, 1955; Menzel and Hopkins, 1955; Menzel and Nichy, 1958; Menzel et al., 1966; Powell and Gunter, 1968; Hoffstetter, 1977). Low salinities act to bar rocksnails and most crabs from oyster beds reducing predation.

Pollution

Pollution is another major problem. Pollutants including bacteria, viruses, and toxic chemicals (pesticides, herbicides, petrochemicals, and heavy metals) may be accumulated by oysters to many times the concentrations in the surrounding water. Chemical pollutants and contaminants can stress and ultimately kill oysters directly or in combination with other factors, particularly diseases. Other forms of pollution may affect oyster reproduction and survival by reducing oxygen concentrations.

Pathogens from human and animal feces as well as other contaminants that reach oyster growing areas can be passed on to human consumers, causing illnesses, poisoning (PSP), or, in rare instances, death. Public health problems are aggravated when productive growing waters are located near discharges of sewage and wastes. This problem is increasingly evident in highly developed coastal areas and is exacerbated by the fact that oysters flourish in low salinity nearshore waters.

User Conflicts

Problems within the oyster fishery are also associated with leasing (privatization) and with open access (common property resources). Problems with the lease fishery primarily involve the "taking" of perceived common-property bottoms by leaseholders while excluding other resource users. Questions concerning appropriate fees, qualifying criteria, and proper marking of leases are common. Additionally, it is sometimes argued that leased areas are not sufficiently worked and could produce more oysters.

Problems with open-access fisheries occur among user groups and between users and regulators. Fishermen often squabble over preferred areas and harvest practices. An important problem with the open-access fishery centers on overfishing, whether in fact or perception. Also, conflicts occur between fishermen and dealers/processors regarding culling and adequate measures.

There is considerable conflict among oyster fishermen themselves also. Conflicts between tongers and dredgers often occur when reefs reserved for a separate gear are located near one another. Tongers perceive that dredgers work illegally on tonging reefs. Enforcement efforts to resolve conflicts are hampered by inadequate definition of the areas.

Other activities that conflict with oystering are shrimp trawling, coastal development, manufacturing, oil and gas resource development, and water use and consumption. Some user groups in coastal zones or flood plains have degraded or diverted freshwater or discharged waste water that has rendered shellfish unfit for human consumption.

Economics

The major economic problem facing the Gulf oyster industry is the highly variable supply of oysters. The broad variation and lack of predictability cause prices to fluctuate widely during and among seasons. Profits and other economic measures thus are difficult to determine. Increasing dependency is expected to be placed on private enterprise, since the private sector may be more capable of stabilizing production, ensuring a continuous availability, and guaranteeing product quality.

Recent Condition of the Oyster Fisheries

Since about the mid 1970's, harvesting and marketing oysters in Florida and Louisiana have become year-round tasks instead of occurring mainly in the cooler months. The reasons are that state regulations allow oysters to be harvested from leases in summer, and refrigeration extends shelf-life in summer. The Gulf states currently have abundant supplies of oysters, resulting from higher rainfall and improved environmental conditions during the early 1990's. But while supplies are ample in each state, landings have not increased substantially because market demand is weak. The nation's economic status and publicity linking the consumption of raw oysters (and often all oyster products) with potential public health risks have contributed to the weak demand. Publicity, accurate and inaccurate, identifying the potential risks associated with the bacterial pathogen *Vibrio vulnificus* when oysters are eaten raw, has created confusion and eroded consumer confidence.

Florida

In Apalachicola Bay, oyster abundance has fluctuated dramatically over the past decade, primarily in response to the devastating effects of Hurricane Elena in 1985 and extended drought from 1987 through 1989 (Berrigan, 1988). The hydrological impacts of Hurricane Elena damaged many of the Bay's most productive reefs, and sustained resource recovery was slowed by drought over the following years. Resource recovery was not complete until 1992, when oyster abundance reached prehurricane densities on most reefs.

Following Hurricane Elena, harvesting restrictions were imposed to foster resource recovery. Restrictions included bag limits (15 60-pound bags/day) and a reduction in the number of days/week (Monday-Thursday) and hours/day (sunup to 4:00 p.m.) when the bay was open for harvest. Daily landings averaged 7.3 bags/vessel/day from 1986 to 1991; only 4.5 bags/vessel/day were harvested in 1989. Between 1990 and 1993, landings from the bay exceeded 300,000 bags annually (>2 million pounds of meats). By 1993, harvesters were easily reaching the daily bag limits and new management policies were enacted to remove harvesting restrictions. Although oysters currently are abundant and preliminary landing statistics show that landings in 1992 and 1993 may be the highest in nearly a decade, soft market demand probably will continue to limit landings.

The size of the oyster fleet on the west coast of Florida remained fairly stable from the 1960's through the 1980's with about 500–725 boats (and vessels) and from 600 to nearly 900 fishermen (Table 4). Most oyster boats in Apalachicola Bay are 4.9–7.6 m (16–25 foot) flat bottom, shallow draft skiffs, powered by 5–250 hp outboard motors. Their gunnels have low washboards on both sides that enable the fisherman to walk and tong around the entire boat. The skiffs typically have a "dog house" to store equipment and provide the fisherman with protection from bad weather. Boats often may be used in several fisheries. For example, fishermen may harvest oysters from the same boats used to catch shrimp, *Penaeus* sp., or mullet, *Mugil cephalis*.

Most oystermen in Apalachicola Bay work only at harvesting oysters year-round. But in other parts of Florida, oystermen also fish for crabs and finfish.

Table 4
Operating units and fishermen by type of fisheries in Florida's west Gulf coast oyster industry, 1961–89[1].

	Tongs		By hand		Total	
Year	Boats and vessels	Fishermen	Boats	Fishermen	Boats	Fishermen
1961–65 avg.	594	740	33	36	627	776
1966–70 "	563	708	35	35	598	743
1971–75 "	492	593	19	19	511	612
1976–80 "	537	692	N/A[2]	N/A	537	692
1981–85 "	665	879	"	"	665	879
1986–89 "	727	799	"	"	727	799

[1] Sources: Fishery Statistics of the United States (1961–77) and unpubl. data provided by the National Marine Fisheries Service.
[2] Not available.

Table 5
Operating units and fishermen by type of fishery in the Alabama oyster industry, 1961–88[1].

Years	Dredges		Tongs		Total	
	Boats and vessels	Fishermen	Boats	Fishermen	Boats	Fishermen
1961–65 avg.	2	8	445	690	447	698
1966–70 "	3	13	398	678	401	691
1971–75 "	1	3	228	360	229	363
1976–80 "	0	0	234	376	234	376
1981–85 "	0	0	200	385	200	385
1986–88 "	0	0	143	280	143	280

[1] Sources: Fishery Statistics of the United States (1961–77) and unpubl. data provided by the National Marine Fisheries Service.

From 1989 to 1992, the Department of Natural Resources issued 712, 1,120, 905, and 872 Apalachicola Bay Oyster Harvesting Licenses, respectively. In any one day, the oyster fleet usually consists of 250–500 boats with 1–2 tongers and a culler working on each boat. Each person working on a boat must possess an oyster harvesting license. Oysters harvested from Apalachicola Bay are landed primarily in the towns of Apalachicola and East Point in Franklin County, but oysters may also be landed in towns in neighboring counties.

Alabama

In the early 1960's, Alabama had about 500 oyster boats and 700 oystermen (Table 5), but since then the numbers have declined. Alabama oystermen harvest all oysters with tongs in 4.25 m (14 foot) boats powered by outboard motors. About 150 men go oystering, but they also fish for shrimp, blue crabs, *Callinectes sapidus;* and menhaden, *Brevoortia tyrannus,* seeking whichever earns them the most money. In the 1992–93 season, in any one day, only 30–40 men were oystering.

The state limit for each boat is 12 sacks (72 pounds/sack) of oysters/day. In 1992–93, the average price fishermen received was $0.11/pound (whole oysters) or $7.90/sack. Some Alabama oystermen purchase a nonresident license to dredge or tong on Mississippi reefs.

Mississippi

The numbers of boats and fishermen have also declined in Mississippi. The fishermen harvest oysters by dredging on state-designated dredging reefs and by tonging on state-designated tonging reefs. From 1965 to 1985, the number of dredging vessels and tonging boats ranged from 663 to 811 and the number of men from 762 to 1,195 (Table 6). The dredging vessels are 11–20 m (36–65 feet) long. In the 1992–93 season, the state issued licenses for 116 resident boats and 21 nonresident boats to dredge oysters. The state limit for a dredge boat was 40 sacks of oysters/day. In any one day, 60–100 boats (and vessels) were dredging. The crews use them to dredge oysters in the fall and winter and to trawl for shrimp in the spring.

Table 6
Operating units and fishermen by type of fishery in the Mississippi oyster industry, 1961–88[1].

Years	Dredges			Tongs		Total	
	Boats	Vessels	Fishermen	Boats	Fishermen	Boats and vessels	Fishermen
1961–65 avg.	31	163	567	617	628	811	1,195
1966–70 "	21	134	465	525	531	680	996
1971–75 "	40	68	297	448	465	556	762
1976–80 "	46	38	201	364	383	448	584
1981–85 "	228	94	604	341	358	663	962
1986–88 "	101	61	347	197	197	359	544

[1] Sources: Fishery Statistics of the United States (1961–77) and unpubl. data provided by the National Marine Fisheries Service.

The tong boats are 5.5–8 m (18–26 feet) long. Usually, two men are in each boat; in some, both tong and then cull; in others, one tongs while the other culls. The state daily limit for tong boats is the same as for the dredge boats. In 1992–93, there were about 50 crews tonging per day; some crews harvested their limits in only 3 hours. The crews use the boats for oystering in the fall and winter and for blue crabbing and gill netting mullet and speckled trout, *Cynosion nebulosus*, in the spring and summer.

The state oyster season opens each year on a date in September or October, as agreed to by processors, oystermen, and the State Conservation Commission. Reef conditions play a major role in making the decision on the date. In 1993, the season opened on 11 October. The state limit for each boat initially was 40 sacks/day, but it was raised to 60 sacks/day because the oysters were abundant. The boats dredged an average of 5–6 hours a day to harvest their limits. The season closes on 30 April.

In 1992–93, the oystermen were paid $10–15/sack (a sack yields 1 gallon of meats, 8 pounds). They sold 47% of the oysters to Mississippi dealers, 15% to Alabama dealers, and took the remaining 38% home to shuck. Most oysters are shucked; dealers pack the remaining shellstock oysters in 100-count boxes and sell them to restaurants that serve them raw on the half-shell.

Louisiana

From the 1960's through the mid 1980's, about 500 oyster boats (and vessels) and 1,100 oystermen harvested oysters nearly year-round in Louisiana (Table 7). In the late 1980's, the fleet increased and, by 1992–93, during the peak of the oyster marketing season, about 600 boats were oystering on the public and private leased grounds in any one day. The dredge boats range from 7.6 to 18 m (25–60 feet) long (Fig. 14) and have from one to three men on them, depending on their size.

A typical work day for an oysterman depends on whether he is harvesting market oysters or transplanting seed. When dredging oysters for market, he leaves home about 4:00 a.m. and runs his boat to the public grounds or to his leased grounds. He has a predetermined order from a dealer for so many sacks of oysters, and in some instances the sizes of oysters as well as their saltiness is specified. The oysterman dredges until 11:00 a.m., breaks for lunch, and finishes dredging at about 2:00 p.m. He usually has harvested 75–100 sacks. He then motors back to the dock, which takes 1–3 hours, and puts the oysters on a truck to be delivered to the dealer. Sacks of oysters sold for as low as $5.00 in 1973 and as high as $28.00 in 1992; in 1993, they sold for $7.00.

The dealer trucks the oysters to local shucking houses and raw oyster bars in Louisiana or to outlets in other states for sale. New Orleans has the most raw oyster bars in the state with about 42.

When an oysterman beds seed oysters, which usually is sporadically from September through October and in February and March, his fishing excursion can last for as long as 30 days before returning home. He remains on the boat the entire time, sleeping and eating on it. Dredging usually begins early in the morning, because the oysterman is trying to put a full load of about 600 sacks aboard during the day to take to one of his leases (Fig. 7). He makes the run to a lease at night and hopefully can unload during the night and finish before morning. This allows him to return to the seed grounds that day to repeat the process. Depending on the seed supply and the quantity on his leases, an oyster farmer would prefer to make about 20 trips to the seed grounds each year.

Table 7
Operating units and fishermen by type of fishery in the Louisiana oyster industry, 1961–88[1].

	Dredges			Tongs		By hand and rake		Total	
Years	Boats	Vessels	Fishermen	Boats	Fishermen	Boats	Fishermen	Boats and vessels	Fishermen
1961–65 avg.	200	193	904	258	400	43	58	694	1,362
1966–70 "	197	228	1,004	97	138	18	20	522	1,142
1971–75 "	212	227	1,013	57	89	8	14	504	1,116
1976–80 "	210	226	1,021	79	98	1	3	515	1,119
1981–85 "	192	229	1,013	76	113	1	1	493	1,127
1986–88 "	395	239	1,292	102	169	27	35	736	1,327

[1] Sources: Fishery Statistics of the United States (1961–77) and unpubl. data provided by the National Marine Fisheries Service.
[2] Oyster tongs are limited to Calcasieu Lake/Sabine Lake, La., portions of Alabama, Mississippi, and Florida.

Texas

The numbers of oyster boats and oystermen have declined somewhat in Texas from about 250 dredging boats (and vessels) and 33 tonging boats and 600 men in the 1960's to 160 dredging boats and almost no tonging boats in the early 1980's (Table 8). The number of boats working is governed by the market demand for oysters. In 1992–93, about 65–100 boats were dredging per day, and 75% were in Galveston Bay. No one tongs oysters anymore in Texas. The dredging boats are mostly 9–12 m (30–40 feet) long, but some Louisiana-type lug boats are also used. Each has a crew of three, a man who owns the boat and steers and two hired men on wages who cull the oysters. The dredges used are 1.2 m (4 feet) wide and hold up to 6 bushels. The boats often move among Texas bays to where catches and earnings are highest.

The Texas oyster season runs from 1 November to 30 April. Oyster boats dredge from daylight to early afternoon. The state limit for each boat is 150 bushels/day, but in the 1992–93 season, the market was poor and

Figure 14
Oyster dredging vessel in Louisiana.

Table 8
Operating units and fishermen in the Texas oyster industry, 1961–1985[1].

	Dredges			Tongs		By hand[2]	
Years	Boats	Vessels	Fishermen	Boats	Fishermen	Boats	Fishermen
1961–65 avg.	135	83	537	31	33	17	17
1966–70 "	121	153	603	35	36	1	1
1971–75 "	67	162	500	13	24	0	0
1976–80 "	43	132	362	2	2	0	0
1981–85 "	54	106	349	2	3	0	0

[1] Sources: Fishery Statistics of the United States (1961–77) and unpubl. data from the National Marine Fisheries Service.
[2] Fishermen collected oysters off shallow reefs by hand during extreme low tides.

they could sell only 25–35 bushels/day. The fishermen were paid $11–14/bushel for the oysters. Nearly all the oystermen trawl for shrimp when the season is open. In the bays, the brown shrimp season runs from 15 May to 15 July, and the white shrimp season is from 15 August to 15 December.

Most Texas oysters are shucked in houses at the docks where they are unloaded. The number of shuckers in each ranges from 2–20. The remaining oysters are trucked to Louisiana and Florida for shucking.

Figure 15
Eating raw oysters in a bar in New Orleans, La., 1993.

The Future

The Gulf states will probably always have substantial commercial oyster resources. However, pollution problems and concerns associated with the consumption of raw oysters will likely dictate a different approach to oyster fishing, farming, processing, and marketing in the next 10–20 years. For many years the U.S. Food and Drug Administration, Interstate Shellfish Sanitation Conference, and state control agencies have ensured product safety by guaranteeing that shellfish harvesting areas have good water quality and are free of potential contaminants. The identification of *Vibrio vulnificus* as a causative agent in specific shellfish-borne illnesses has prompted the need for new approaches to protect public health. Public health protection must now also rely on identifying and warning all consumers of the potential risks of consuming raw shellfish. Consumer confusion about the potential for shellfish-borne illnesses has dramatically weakened consumer acceptance and sales and will remain a serious problem for the industry. Educating the consumer will be an important aspect of increasing understanding and product appeal.

Preparing Oysters for Eating

Along the Gulf Coast, people eat raw oysters in cocktails and on the half-shell (Fig. 15). Canned oysters are broiled, grilled, stewed, fried, and used in gumbo. Fried oysters are commonly placed on hero sandwiches, 6 or 12 at a time, then seasoned with ketchup or a sauce with horseradish. Although raw "half-shell" preparations are the most popular among consumers, it may become necessary to promote the numerous cooked recipes and presentations as consumers become aware of potential health risks associated with raw oysters.

Other Molluscan Resources

Florida's Sunray Venus Clam

Despite published information that commercial quantities of the sunray venus clam, *M. nimbosa*, may be present in the Florida panhandle (Akin and Humm, 1959), no major harvesting was attempted before February 1967. George M. Kirvin, of Apalachicola, Fla., had observed that when a boat became grounded on a small sand shoal near Port St. Joe, the propeller washed out many large sunray venus clams. On the basis of this observation, he applied to the FDNR for a permit to use a 68 cm (27-inch) Nantucket-type hydraulic dredge to harvest them. Since the area, called Bell's Shoal, was white sand with no silt or vegetation that could be disturbed, the permit was granted with the proviso that a FDNR biologist be present during the first few months of harvesting. The biologist's observations were published and present an excellent review of this fishery (Stokes et al., 1968). The Bell's Shoal area was relatively small and most dredging was in 5.5–7.6 m (18–25 feet) of water. Dredge tows of only 10 minutes often produced catches of at least 8 bushels of clams 127–178 mm (5–7 inches) long. Such clams were 4–5 years old.

Production was limited by mechanical problems and a lack of workers to process the clams, but the fishery gradually expanded, first through the use of a larger dredge (152 cm (60–inch) blade) and then with the addition of a second vessel. Following initial success, catches began to decline and finally ceased, prompting the FDNR to stop issuing additional permits.

While the fishery was underway, an exploratory hydraulic dredge survey along the Gulf coast by the FDNR identified some other potentially commercial quantities of sunray venus clams, but none in the concentrations first seen at Bell's Shoal. The FDNR is currently unaware of any harvests, except perhaps recreationally for the shells, meat, or both.

Calico Scallops in West Florida

The first commercial harvesting of calico scallops, *A. gibbus,* in west Florida began in 1958, though concentrations had been observed earlier. Limited markets and processing availability hampered the early efforts, but the major problem was the extreme variability in abundance of the scallops. In one year, large beds might yield as much as 20 bushels/15-minute tow, but for the next several years beds would be nonexistent. As techniques for locating scallops improved and increasing prices made the searches more profitable, stability of supply improved somewhat, but the current fishery on the east and Gulf coasts still is plagued with boom and bust cycles.

Large catches of calico scallops are shucked mechanically. When fishermen find substantial beds, their production is massive and profits are excellent. Because their equipment and facilities are costly, however, the fishermen often become bankrupt during the bust phases of the cycle. The calico scallop fishery had been concentrated south of Apalachicola and Port St. Joe, during the spring (February-May), but it ceased abruptly by June 1993.

Bay Scallops

Until the 1980's, the bay scallop, *A. irradians concentricus,* was common and often abundant in many of west Florida's nearshore coastal waters. Bay scallops are often associated with dense stands of turtle grass, *Thallasia testudinum,* and occur in shallow, high salinity estuarine systems. Populations of the bay scallop, however, experienced dramatic declines during the last two decades, and current stocks are too low to support a commercial fishery on Florida's Gulf Coast. In 1994, Florida's Marine Fisheries Commission prohibited commercial harvesting of bay scallops and restricted recreational harvesting. Landing statistics for previous commercial landings indicated a consistent trend of decreasing landings for more than 30 years. Accurate landing statistics for recreational harvests are lacking.

When stocks were sufficient to sustain commercial harvests, fishermen usually towed small, light scallop drags (dredges). The drags were pulled slowly over the grass beds, where scallops were forced out of the grass by the tynes on the leading edge of the drag into a collection bag. Bay scallops provided only an opportunistic fishery at a subsistence level. Bay scallops are taken by sport fishermen primarily by wading or snorkeling.

Because the scallop catch varies substantially, most shucking is done by hand. Annual harvests vary considerably, but are much smaller than those of the calico scallop. The largest commercial production used to be in Port St. Joe Bay (Gulf County), which has a depth of 1–2 m (4–6 feet). Commercial scallop fishing has since been banned in the bay, and for the past ten years the bay has supported a popular sports fishery. Hundreds of people using snorkels and bags now collect the scallops by hand. Florida sport harvests of scallops are larger than commercial harvests.

Oyster Drills

Some interest has been expressed in the commercial harvesting of the rock snail or oyster drill, *T. haemastoma,* as a food source in Louisiana. No major market has as yet been developed.

Quahogs

Commercial and recreational harvests of hard clams target the northern quahog, *M. mercenaria,* and the sympatric species, the southern quahog, *M. campechiensis.* Northern quahogs are most common along the Atlantic coast and rarer along the Gulf coast; southern quahogs occur southward along Florida's Atlantic coast to St. Lucie Inlet, but are more abundant along Florida's Gulf coast, except in the Keys. Various degrees of hybridization occur throughout their ranges, and may have been encouraged in Florida by the introduction of hybrid and northern quahogs during a project called Operation Baby Clam in the early 1960's. Juvenile quahogs from the U.S. Bureau of Commercial Fisheries (now NMFS) Laboratory at Milford, Conn., were distributed to six sites within Florida for growth experiments. Quahogs in southern waters reach harvest size (1 inch (25 mm) across the hinge) 15–18 months after setting.

Recorded quahog production began in Florida in 1880 and increased substantially in 1908 with the exploitation of large quahog beds in Collier and Monroe

Counties (Godcharles and Japp, 1973). For many years, the most productive and extensive quahog bed then known in the United States existed from Cape Romano southward through the Ten Thousand Islands along Florida's lower Gulf Coast (Schroeder, 1924). From 1913 to 1947, this area supported a sizeable fishery that peaked at more than 1,000,000 pounds of meats (125,000 bushels of whole quahogs) in 1932. Harvesting with mechanical conveyor-type dredges began in 1905 and continued until 1947 when production fell below the quantities necessary to operate three canning operations in Marco, Fla. (Godcharles and Japp, 1973). By 1950, landings plummeted and the resource has not recovered. The reasons for the disappearance of the quahog populations remain obscure, but coincident with the decline was a devastating outbreak of red tide (Steidinger and Joyce, 1973) and the completion of the Tamiami Trail, a major highway diverting freshwater flow in the Everglades.

Fishermen have harvested quahogs in other parts of Florida, including Tampa Bay, Charlotte Harbor, St. Joseph Bay, and the Indian River (Godcharles and Japp, 1973). Except for the Indian River during the 1980's, quahog resources have supported only short-term and intermittent fisheries. A small quahog fishery currently exists in St. Joseph Bay, where ten licensed vessels use dredges to harvest the quahogs in about 6 m (20 feet) of water.

During the 1950's and through the early 1970's, several exploratory surveys by the U.S. Fish and Wildlife Service and the FDNR failed to discover any commercial concentrations of quahogs in Florida (Godcharles and Japp, 1973). Other evidence suggests that there may yet be areas where quahogs are present but underexploited, such as the Indian River proved to be. Abundant quahogs have been observed in estuaries in Florida's panhandle (West Bay and East Bay, Bay County), but extensive resource assessment surveys have not been conducted. In the mid 1980's, a 6-month attempt to harvest quahogs commercially in Louisiana was unsuccessful because supplies were too small.

On the Gulf coast, interest in purifying quahogs from restricted waters in depuration plants has been limited. This contrasts with Florida's Atlantic coast where controlled purification has contributed substantially to quahog landings. As many as six controlled purification plants were depurating quahogs from the Indian River area during the mid 1980's.

Southern quahogs are considered less suitable for the half-shell trade than northern quahogs because they readily gape when kept in cold storage. Research is continuing to improve methods to increase their shelf life and quality.

Innovative aquaculture techniques are also being employed to increase quahog production on Florida's Gulf coast. Aquaculture training and demonstration programs in the Suwannee Sound and Charlotte Harbor regions have resulted in an emerging hard clam aquaculture industry. Currently, more than 600 ha (1,500 acres) of submerged land leases have been placed into hard clam production. This growth has been supported by the construction of more than 40 hatchery and nursery facilities using improved genetic stocks.

Table 9
Total numbers of mollusks harvested in Florida for aquarium sales, 1990–91.

Group or species	1990 (Individuals)	1991 (Individuals)
Nudibranchs	4,207	2,031
Flame scallop	43,688	30,814
White flame scallop	2,316	1,116
Chestnut turban	18,963	35,418
Other snails and cowries	72,000	41,700

Aquarium Fishery for Florida Mollusks

The fishery for aquarium sales includes nudibranchs, flame scallops, *Lima scabra*; white flame scallops, *Lima scrabra tenera*; chestnut turbans, *Turbo castanea*; other snails; and cowries, *Cypraea* sp. Nearly all nonfinfish species entering the aquarium trade are hand-collected by scuba diving and snorkeling, and great effort is expended to maintain the specimens alive and healthy. This is usually accomplished with various types of water-circulating and aerating devices on the collecting boats. Once the animals are brought back to home base, good water quality must be maintained, usually aided by extensive filtration procedures.

In 1984, Florida passed legislation requiring that anyone selling saltwater products have a license and complete a "trip ticket" for each sale to a wholesaler. Since people who gathered living marine resources for sale to the rapidly burgeoning saltwater aquarium trade also fell under this reporting requirement, FDNR began to obtain landing data on this industry for the first time. Table 9 lists the preliminary landings data (individuals taken) for 1990 and 1991 for only a few species or species groups, and should be considered incomplete. Nevertheless, they represent a substantial harvest in numbers and value that will increase over time.

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The Mangrove Oyster, *Crassostrea rhizophorae*, and Queen Conch, *Strombus gigas*, Fisheries of Cuba

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ABSTRACT

The mangrove oyster, *Crassostrea rhizophorae*, has been harvested around Cuba since pre-Columbian times. The island of Cuba and adjacent cays have numerous mangroves growing on 4,288 km of shoreline. Oysters grow on variable stretches of mangrove trees. From 1957 to 1962, about 150 boats and 450 fishermen were involved in the oyster fishery, but the number fell to 76 who were active in the mid-1970's. To harvest the oysters, fishermen cut the mangrove roots bearing oysters and loaded them into floating boxes. Between 1960 and 1977, an average of 2,288 metric tons (t) of oysters were landed/year. The oysters were sent to fish markets and sold to restaurants, hotels, and street vendors. After 1960, the fishery changed from private to government control. In the early 1980's, oyster farms were created to maintain oyster production. Between 1984 and 1989, oyster production was 1,100 t/year, about half of which came from the farms. By 1991, there were 14 farms, and new methods such as submerged raft culture and a hatchery had been introduced. The queen conch, *Strombus gigas*, the other commercially important mollusk in Cuba, also has been fished since pre-Columbian times. The Indians ate the meat and used the shells for ornaments, cutting and hammering tools, and sound-producing instruments. For many years, sponge fishermen were the only ones who harvested conchs. After the development of diving gear, the fishery expanded and 2,353 t were landed in 1977. Between 1982 and 1989, landings averaged 353 t a year.

Introduction

The mangrove oyster, *Crassostrea rhizophorae*, occurs in many sheltered areas around Cuba and its adjacent cays, more correctly considered as the Cuban archipelago (Fig. 1). Some believe this to be the sweetest tasting oyster species growing in North America and Europe. The queen conch, *Strombus gigas*, occurs on sandy bottoms around Cuba.

The Mangrove Oyster Fishery

The mangrove oyster, also known as the common oyster, commercial oyster, rock oyster, Antillean oyster, or just oyster (in Cuba "ostion"), is the climax species in the marine area of mangrove swamps, composed mostly of the red mangrove, *Rhizophora mangle*, or "mangle colorado." Cuba has mangroves growing along 4,288 km of shoreline—2,691 km along the north coast and cays, and 1,597 km along the south coast and cays. Continuous stretches of oysters, which vary in length and are more prominent in the north, are called oyster banks. They are least common around the southern cays, all farther from the main island than those in the north (Buesa, 1977c) (Table 1).

Natural History

Oysters grow on the aerial roots of the mangrove trees, in bunches containing 4–35 oysters but averaging 15. There are 6–7 oyster bunches per meter of coast, and their average biomass is 0.8 kg. The total oyster biomass in Cuba is about 2,100 metric tons (t) (Table 1). About

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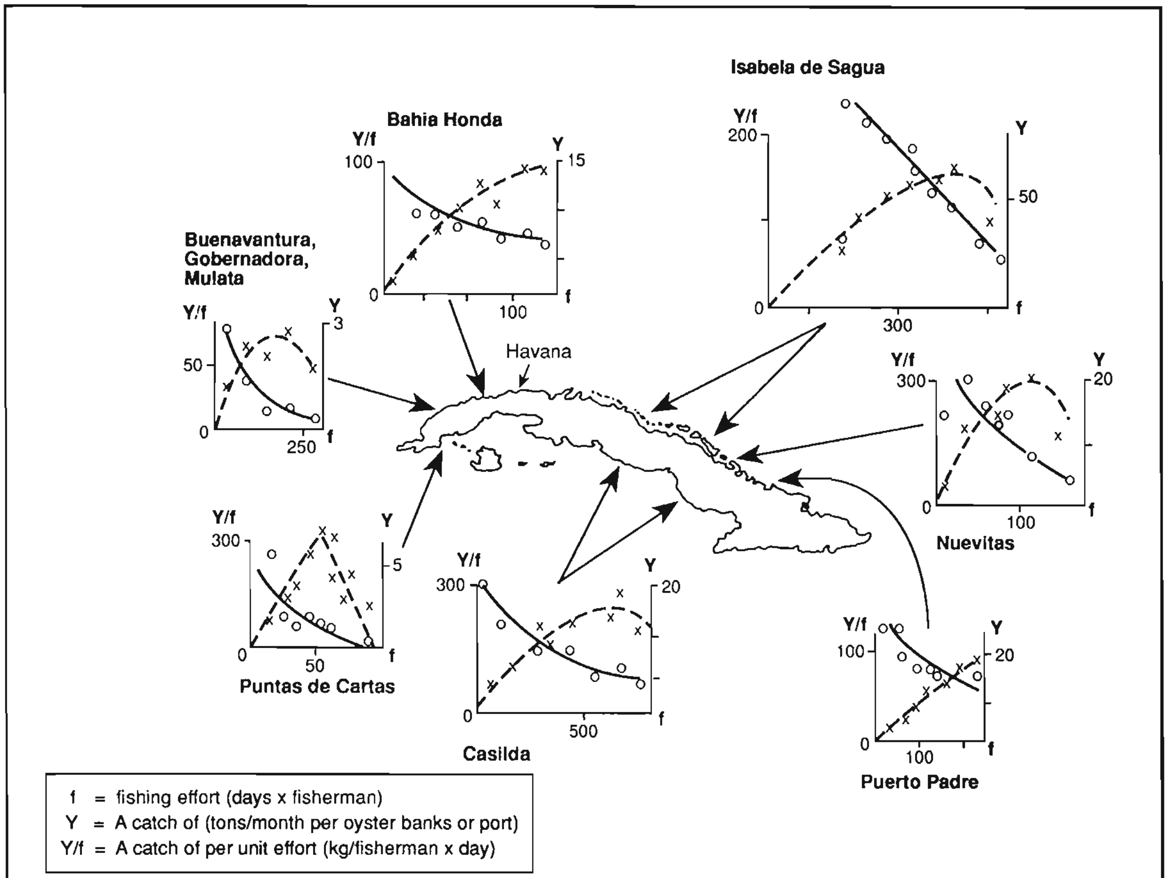

Figure 1
Cuba and its adjacent cays, and summary of oyster harvesting operations in the main oyster banks (Buesa, 1981a).

30% of oysters occur in the adjacent cays, especially on the north coast (Table 2) (Buesa, 1977g).

Oysters cannot survive great environmental variations. The best habitats have water currents of only 0.2 to 0.6 knots, yellow to brownish water 0.5 m deep or deeper, an oxygen content of 2-5 ml/L, and salinities of 26-38‰ (Fig. 2). The mangrove oyster is more marine than estuarine and is unable to survive low salinities caused by heavy rains (Buesa, 1977e). Water temperatures average about 27°C, are fairly stable, and do not adversely affect the oysters (Buesa, 1977b).

Tidal amplitudes in the Cuban archipelago range from 21 to nearly 80 cm and are larger on the north than the south coasts. The vertical amplitude of the oysters is 27–53 cm (Table 2); oysters grow best where tides range from 40 to 45 cm.

Oysters are diecious, but probably protandric hermaphrodites, with male:female ratios ranging from 1:1.3 to 1:2.9 (Table 3). The smallest identifiable male was 14 mm long, and the smallest female was 19 mm long. Spawning begins at 20-30 mm and is massive at lengths of 30-39 mm at an age of 3-4 months after spat settlement (Table 4). Fertilization is external (Soroa and Simpson, 1975a).

Spawning is continuous but there are usually peaks before and after the cold or dry season (November-December), and at the end of the rainy season (July–August). Usually, oysters >50 mm spawn first and the smaller ones follow. An average spawning accounts for 11.3–12.8 Kcal/kg of live oyster per month, and will reduce the fresh body weight by about 9%, accounting for 12–16% of the energy budget of the oyster (Buesa, 1970).

The free swimming period of oyster larvae lasts about 1 week. To ensure that sufficient larvae are present to maintain an oyster bank, a live oyster biomass of at least 1 kg/m of coastline is needed (Buesa, 1977h) (Fig. 3). Growth rate varies by area and season, but generally oysters attain the legal size of 50 mm 3–5 months after spat settlement (Table 3). Growth experiments showed that if oysters were always kept under water they would grow faster in the first 2 months, but would stop grow-

Table 1
Summary of information on natural mangrove oyster banks.

Aspect	Coastal area S.E.	S.W.	N.W.	N.E.	Total
Mangrove shoreline(km)[1]	791	806	454	2,237	4,288
Oyster bank (km)[1]	552	270	266	1,685	2,773
Oyster density in the natural banks (kg/m)					
Minimum	0.10	0.20	0.20	0.20	
Maximum	1.61	0.90	2.37	2.17	
Average	0.85	0.39	0.89	0.79	
Average size of oysters (mm)					
Minimum	24	20	24	34	
Maximum	48	41	48	51	
Average	42	40	34	45	
Population biomass (t)	471	104	236	1,330	2,141
Potential natural production (t/area/year)	3,485	447	1,015	6,814	11,761

[1] Figures include the coast of the main island and nearby cays.

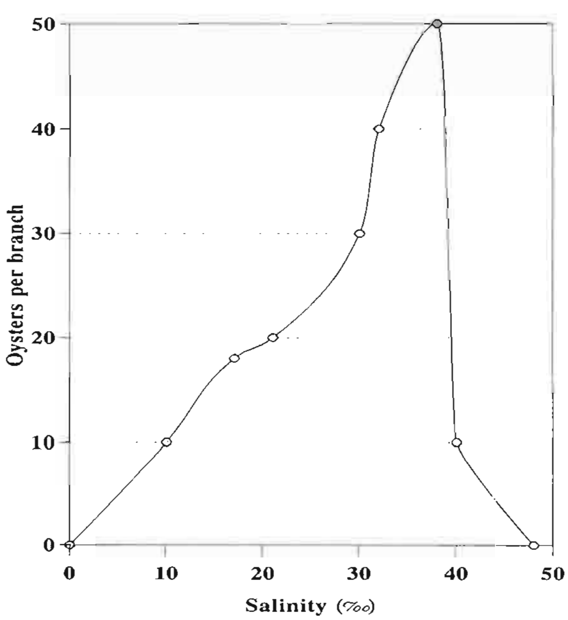

Figure 2
Density of oysters in relation to salinity in Cuba.

Table 2
Characteristics of the mangrove environment[1].

Data	North coast	South coast
Percent of shorelines with mangrove trees	84	63
Relative mangrove shoreline: main island coast/cays coasts	0.87	1.13
Tide range (cm)	37–64	21–37
Mangrove trees height (m)	3.0–4.3	2.4–2.5
Oyster vertical distribution (cm)	33–53	27–41
Bunches of oysters/m	10–12	6–17
Oysters/bunch	13–35	4–21
Oysters/m	130–420	24–357
Biomass (B) of oysters (g/m)	1.0–1.2	0.5–1.2
Individual weight (g/oyster)	2.9–7.7	3.4–20.8
Oyster total B/all other sessile filter feeders B	0.3:1–78:1	0.1:1–117:1

[1] Total biomass of filter feeder mollusks = about 2,855 t: clams = 15% (about 429 t), mussels = 10% (about 285 t), oysters = 75% (about 2,141 t).

ing at 52–54 mm when 4 months old. Oysters grew best when they were in and out of water for about equal periods and at a depth of about 45–50 mm when in water. Growth is directly related to phytoplankton abundance. In phytoplankton-rich areas as in most of the south coast, oysters attain a length of 50–80 mm within 6–8 months. In the northern areas, the length is usually 45–70 mm at the same age (Simpson et al., 1975a).

Water currents, transparency, salinity, and depths, and especially availability of food determine the wide array of sizes in the natural banks, with average sizes ranging from 24 to 51 mm (Table 1). The total wet weights for those sizes range from 6 to 9 g (an average of 7 g); they correspond to 1 g of wet meat per oyster (Castro, 1975a). Most oysters in the banks are 3–6 months old. Growth is variable, with a higher rate in the dry season (winter) than in the rainy season. The largest oyster ever found was 12 cm long (Bosch and Nikolic, 1975).

Mangrove oysters are selective filter feeders. Their stomachs have up to six times more dinoflagellates than does water near the banks (Soroa and Simpson, 1975c).

Table 3
Summary of biological information on the mangrove oyster, *Crassostrea rhizophorae.*

Aspect	Min.	Max.	Average
Male:female ratio	1:1.3	1:2.9	1:2.0
Bunches/m	6	17	12
Oysters/bunch	1	56	15
Vertical distribution (cm)	25	80	36
Shell length (mm) for ages in months			
Age 1	3	19	15
2	9	36	29
3	20	52	41
4	35	67	53
5	52	79	62
6	69	84	71
7	73	90	79
8	79	94	85
Months required to get to a shell length of			
40 mm	2.0	4.3	3.0
50 mm	2.5	6.5	4.0
Total fresh weight (g) for shell lengths of			
45.5 mm	8.16	8.21	8.19
55.5 mm	12.31	12.77	12.62
Minimum shell length (mm) at first spawning	20	32	28

Table 4A
Gonadal stages of *Crassostrea rhizophorae.*

Stage	Gonad characteristics
0	Virgin; translucid gonad, grayish-green to pale yellow.
1	Larger than Stage 0; whitish to pale ivory.
2	Covers a great deal of the other organs; ivory color; no gametes are released after pressure.
3	Covers almost totally all other organs, has an old ivory color; gonoducts are visible; gametes are released after pressure.
4	Smaller than in Stage 3; anterior portion is translucid; is a grayish spent gonad.

The chemical composition of the oyster is similar in all areas. The shell comprises 81–84% of total fresh weight, the meat 11–14%, and the remainder, 2–8%, is the intervalvar water. Proteins constitute 10–11% of the total fresh weight, carbohydrates 3–6%, fat 2–3%, ash about 3%; the bulk is water (Castro, 1975b).

Usually about 13% of all oysters in a natural bank are dead. Major causes of mortality are salinities <20‰ (caused by heavy rains) and >40‰, high turbidity, rough water, low oxygen, food scarcity, and pollutants (Bosch and Nikolic, 1975). In laboratory experiments, 80% of oysters died after 72 hours of continuous exposure to high concentrations of algae (in this case, *Nannochloris* sp. at a concentration of 8 million cells/ml). This could account for high mortalities of oysters in some eutrophicated coastal areas (Buesa, 1977h).

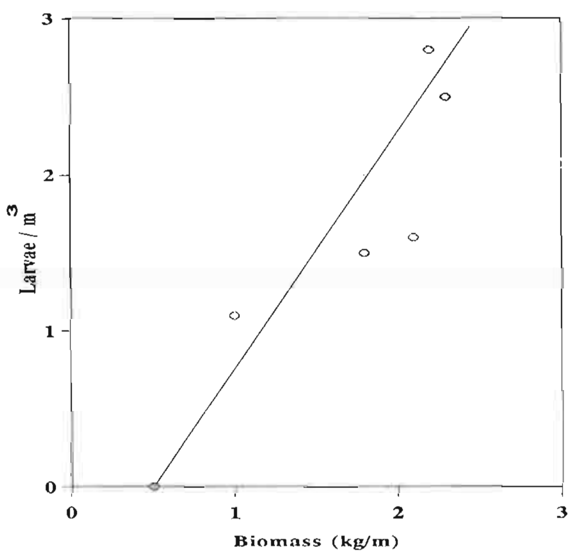

Figure 3
Density of oyster larvae in relation to density of adult oysters in Cuba.

Table 4B
Abundance of different gonadal stages in the southeast coast (Casilda area).

	Percentage of oyster in the stages			
Period	0	1 and 2	3	4
Spring	1	62	26	11
Summer (rainy season)	3	32	23	42
Autumn/winter (dry season)	17	63	17	3

About 30 species compete with or prey on the oysters. Their most important food competitor is phytophagous zooplankton, while the flat tree-oyster, *Isognomon alatus*; mussels, *Brachidontes* spp.; and barnacles, *Balanus* spp. and *Chthamalus* spp., are other important competitors for both food and space. Associated organisms also include several algae, sponges, turbelarians, other bivalves, gastropods, crustaceans, polychaetes, ophiurids, and ascidians. There are some endobiotes, such as a polyp, *Eugymnanthea crassostrea*, a sponge, *Cliona* sp., and an annelid, *Polydora hoplura*, that is able to perforate the mantle (Nikolic and Soroa, 1971; Saenz, 1978). Competition causes fewer mortalities when the oyster biomass is at least twice the combined biomass of all the other species. The most important competition is intraspecific, as the oysters compete with one another (Buesa, 1977g). Oyster predators include three gastropods (west Indian murex, *Murex brevifrons*, west Indian crown conch, *Melongena melongena*, and common crown conch, *M. corona*), two crabs (knotfinger mud crab, *Panopeus lacustris*, and Bocourt swimming crab, *Callinectes bocourti*), and one fish, the checkered puffer, *Sphaeroides testudineus* (Formoso, 1978).

History of the Fishery

Mangrove oysters have been gathered or fished in Cuba since pre-Columbian times. The Siboney Indians, who were cave dwellers and gatherers and knew no agriculture, left a midden, about 2 ha in area, in a cave east of Havana, called "El Indio." Besides oyster shells, by far the most numerous, it contains shells of clams, mussels, queen conchs, and land gastropods. The oyster shells in the entire midden represented a total live weight of about 900 t. The Siboneys were unable to survive the early European conquests.

Samples of oyster shells from the midden averaged 51.8 mm long. Oysters taken recently from the nearby Tacajo River had an average length of 51.0 mm. The difference between the two was not significantly different ($P>0.3$), and neither was the difference between the national average length of oysters, 42.8 mm, and length of shells from the midden ($P>0.5$) (Buesa, 1979a). This indicates that ecological conditions for oysters in Cuba may have remained stable for at least the last 500 years.

From 1957 to 1962 there were about 150 boats and 450 fishermen involved in the oyster fishery (Buesa, 1977f). Oyster fishermen have always used small boats, 8-10 m long (Buesa, 1964). When arriving at an oyster bank, they approached the mangroves by wading (Fig. 4) or paddling canoes, 1.5–2.5 m long, called bongos (Fig. 5). The fishermen cut the aerial mangrove roots with a machete or small ax and loaded them into floating boxes made from the petioles of the large complex leaves of the royal palm, *Roistonea regia* (Nikolic and Alfonso, 1968a).

Oyster landings from 1960 to 1964 were higher than previous years mostly because fishermen began to land oysters in 20 l cans and included pieces of roots with them. The pieces comprised up to 11% of the total weight. In addition, improved data gathering implemented in 1960 registered landings more accurately (FAO, 1983–1991; Salmon, 1963) (Table 5).

Owing to the hard work involved and the creation of other less arduous and better paying jobs, the numbers

Figure 4
Two fishermen collecting oysters from a natural bank by wading.

Figure 5
A fisherman collecting oysters at a natural bank from a "bongo." Note the small size of this auxiliary boat.

of oyster fishermen declined steadily in the 1960's and 1970's. Their numbers declined from 259 in 1963 to only 76 in the mid-1970's (Buesa, 1977h).

From 1960 to 1977, fishermen landed an average of 2,288 t of oysters per year. The maximum sustainable yield was set at about 2,500 t/year, which is an amount that 100 fishermen could land by working 20 days/month during 12 months of the year (Buesa, 1977f). The catch per unit of effort (kg/fisherman/day) was 29–138 from 1964 to 1966 and was 7–440 from 1972 to 1976 with large variations in the areas and zones sampled (90 fishing areas and 14,000 fishing trips grouped into 28 major fishing areas exploited from 10 ports) (Table 6, 7).

Landed oysters have been cleaned, sorted by size, bagged, and sent to fish markets in the main cities. They were sold to restaurants, hotels, and street vendors. The street vendors sold them at strategic street locations, usually near a popular restaurant or busy bus stop. Passers-by could purchase a "glass of oysters," the meats of 3–5 oysters, depending on their size, with lemon juice and some ketchup, for the equivalent of $1.00–$1.50, depending on the season (Salmon, 1963). The street vendors were licensed and inspected for sanitary conditions. The fisherman received as much as $1.00 per 100 oysters, while the vendor received about the same for the meat of only 3–5 oysters, but the largest profits were made by the middlemen in the port and the wholesalers.

After 1960 the fishery changed from private to government control. The fisheries department of the National Institute for Agrarian Reform (INRA) took over the entire fishery, created fishing cooperatives, and increased the pay for fishermen to about $7.00/can of 500 oysters. This was a pay increase of about 40%. All the operations (fishing, landing, cleaning, transporting, and marketing) were concentrated under the INRA. The net result was higher landings but lower quality, the depletion of some natural oyster banks, and a reduction in the number of fishermen. All those conditions forced the INRA (and later the INP or National Fisheries Institute) to approve all the research required for the establishment of a sound oyster culture policy. Implementation of the directives, however, has been extremely inconsistent.

Table 5
Mangrove oyster landings, 1960-89 in metric tons[1].

Period	Average annual landings (t) for the period	Period	Average annual landings (t) for the period
1960–64	1,993	1980–84	2,438
1965–69	2,747	1985–89	2,402
1970–74	3,038	1960–89	2,416
1975–79	1,878		

[1] Total landings in Cuba account for an average 80% of the total landings of the mangrove oyster in the Caribbean area (Cuba, Dominican Republic, Puerto Rico, Nicaragua, and Venezuela, i.e., 29,000 out of 36,275 t landed between 1978 and 1989).

Table 6
Ranges of mangrove oyster fishing activities, 1972–76[1].

Ports (areas)	Units Y (t/mo)	f (f×d/mo)	Y/f (kg/f×d)
Casilda (S.E. coast)	25–90	65–804	70–300
Punta de Cartas (S.W. coast)	2–7	13–93	30–440
Berracos, Gobernadora, Mulata (N.W. coast)	1–3	37–288	7–60
Bahia Honda (N.W. coast)	2–15	30–370	43–77
Isabela de Sagua (N.E. coast)	28–67	180–550	60–235
Nuevitas (N.E. coast)	4–21	11–166	62–305
Puerto Padre (N.E. coast)	3–18	40–235	68–128

[1] Units: Y = total landings/port = tons/month = t/mo, f = fishing effort = fishermen×day/month = f×d/mo., Y/f = catch/unit effort = kg/fishermen×day = kg/f×d.

Table 7
Summary of mangrove oyster fishing activities[1].

Area	Summary[2]
Eastern areas	2 ports in the southeast (Casilda and Santa Cruz) and 2 ports in the northeast (Nuevitas and Puerto Padre). Y : 3-90 t/mo per port f : 11-804 f×d/mo Y/f : 60-305 kg/f×d Average Y/f = 164 kg/f×d
Western areas	1 port in the southwest (Punta de Cartas) and 4 ports in the northwest (Berracos, Gobernadora, Mulata and Bahia Honda). Y : 1-5 t/mo per port f : 13-288 f×d/mo Y/f : 7-440 kg/f×d Average Y/f = 115 kg/f×d
Average Y/f :	eastern areas/western areas = 1.43

[1] Sampling: Ninety fishing areas (exploited from 10 ports) were surveyed for the period 1972–76. Total fishing trips recorded (during 712 months×areas) were 14,000.
[2] Units: Y = Total landings/port = tons/month = t/mo, f = fishing effort = fishermen×day/month = f×d/mo, Y/f = catch/unit effort = kg/fishermen×day = kg/f×d.

Among the regulations for oysters were a closed season (not really needed) and a minimum legal length of 50 mm. The legal length was never fully enforced and was unnecessary from a biological point of view, since oysters spawn at a small size and have great fertility. The manner in which oysters are gathered, on entire branches when the aerial mangrove roots are cut, made it impossible to observe a true size limit (Buesa, 1977e).

Oyster banks, especially those in the cays, are far enough from populated areas that sewage pollution has never been a problem. Thus, oysters received by the restaurants and vendors were not polluted, though it was possible for handlers to contaminate them or expose them to flying insects. Sanitary regulations were not designed especially for restaurants or street vendors, but they had to observe all sanitary regulations for any food vendor. After 1970 when oysters first appeared in some ports, such as Casilda and Isabela de Sagua, the INP "self-inspected" and was in charge of controlling sanitary conditions. Inspections were generally good in spite of the conflict of interest that self-inspection meant. There have been no official reports of food poisoning from eating oysters in Cuba.

There was once some industrial pollution of oyster banks. Wastes from paper and sugar mills, distilleries producing alcoholic beverages, and plants producing fertilizer have destroyed some banks (Milera and Arguelles, 1979).

In Cienfuegos Bay, on the western end of the southeastern insular shelf, fishermen used to gather the eastern oyster, *Crassostrea virginica*, which grew on hard bottoms. It is believed that those oysters were descendants of some seed oysters brought to Cuba by researchers from the Arnold Arboretum of Harvard University when they visited their Cuban Botanical Garden, the "Jardin de Soledad" in Cienfuegas in the 1920's. The seed oysters survived and produced a small natural population that endured at least until the 1970's (Buesa, 1977d).

Present Status

As the existing banks of mangrove oysters are located away from inhabited areas, they are not threatened with degradation. In addition, plans for industrial development in Cuba today are suspended and thus industrial contamination is not likely to be a factor in the near future. The banks that once existed near towns and cities have already disappeared.

Oysters are now a commodity for tourists who have had foreign hard currency to purchase them. Oysters are included with shrimp, lobsters, crabs, conchs, and other fancy marine products to be eaten only in hotels, restaurants, food markets, and facilities reserved solely for tourists and inaccessible to the general population, which has struggled to survive under extreme food rationing and shortages.

In the mid-1970's, government authorities considered the oyster fishery to be at a crossroads, because arduous working conditions led to a reduction in the number of oyster fishermen (Buesa, 1977f). No more than 150 people were involved in oyster gathering, and the entire fishery, including those on land, involved less than 300 people (Ubeda, 1975). Had oyster farming not been initiated, the fishery would have slowly disappeared.

Future of the Cuban Oyster Fishery

The only sure way to maintain the oyster fishery was to create oyster farms. They would provide better working conditions for the fishermen and allow planning of oyster production. All the methodology required for such farms was available in the mid-1970's from studies at a large experimental farm established in the late 1960's in Isabela de Sagua on the northeast coast (Nikolic, 1973; Nikolic and Alfonso, 1968b; Simpson et al., 1975b).

The potential for oyster farming in Cuba had been known since 1883 (Vilaro-Diaz, 1883, 1886), but not until 1951 were the first experiments with Spanish roof tiles covered with cement, similar to the method used in France, begun near Havana (Perez-Farfante, 1954). Experiments were repeated in Isabela de Sagua (Fig. 1) in 1961, and in 1964, with technical assistance from FAO, the program began earnestly (Simpson, 1975; Simpson et al., 1975b). The most important finding was that mangrove branches were the best collector for oyster spat because they were readily available and cost little (Nikolic and Alfonso, 1971) (Figs. 6, 7). Branches set in the water to collect spat each yielded 1.0–4.5 kg of oysters of several sizes after 6 months (Soroa and Simpson, 1975b).

Government technicians surveyed areas for establishing farms. The areas had to have good characteristics for oyster culture: water depth at least 0.5 m, salinity of 26–37‰, an oxygen content of 2–5 mg/l, gentle currents, and protection from large waves. Site selection was important because farm sizes would, in part, govern the oyster yield. The annual potential production of a farm can be up to 30 times the biomass of the natural population if it has a surface area of less than 100 ha, but up to 120 times if it has a surface of more than 300 ha as some lagoons have (Buesa, 1977b). A total of 198 coastal and cay areas, 103 in the north and 95 in the south, were surveyed. Of these, 14 areas in the north having a total of 55 ha and 8 areas in the south having 60 ha had good potential for culturing oysters (Soroa,

Figure 6
Oysters growing on red mangrove branches at an experimental oyster farm at Puerto Jobabo (Casilda).

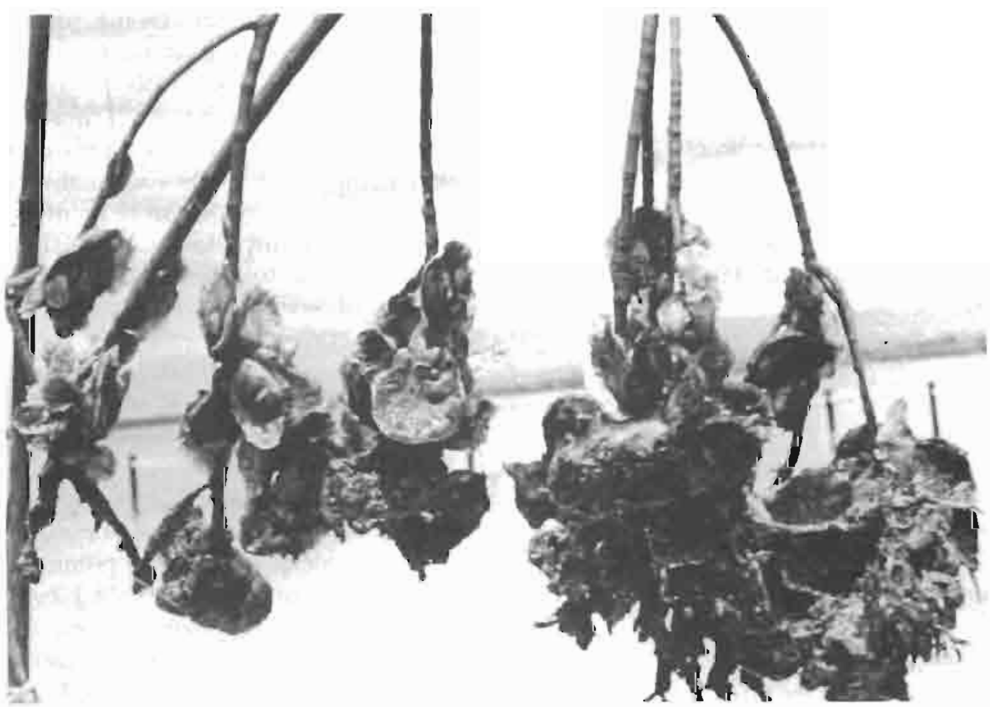

Figure 7
Four-month-old oysters growing on red mangrove branches at an experimental farm.

1975a). The overall yield of a farm was estimated to be about 7 kg/m^2 or 70 t/ha (Simpson, 1975).

In the early 1980's the Cuban government began construction of oyster farms. From 1984 to 1989 total oyster production was about 1,100 tons a year, about half of which came from the farms (Cigarra Alvarez, 1991). Currently, there are 14 such farms (Fig. 8, 9), and some new methods have been introduced, such as raft culture and a hatchery to produce spat (Baisre and Castell, 1991). The hatchery was needed to compensate for shortages of natural seed resulting from coastal pollution from sugar mills (Cigarria Alvarez, 1991). Recently, there have been unsuccessful attempts to culture C. *virginica* and the Pacific oyster, *C. gigas*; both species had high mortalities probably because temperatures were too high (Baisre and Castell, 1991).

Queen Conch Fishery

The queen conch, called "cobo" or "fotuto" in Spanish speaking countries, has also been fished since pre-Columbian times. As mentioned, its shells, whole and fragmented, are found in Indian middens. Indians ate the meat and used the shells for ornaments, for cutting and hammering tools, and to produce various sounds. From the latter use came the names "fotuto" and "botuto," Spanish words for an instrument producing a loud sound (Buesa, 1979a).

Because the conch has tough meat, it has had minimal use as a food, but has been valued mainly for the beauty of its shell. When the main use is for meat as in the Bahamas and the Turks and Caicos Islands, the shell must be broken to remove the meat, ruining the ornamental value. This means that the conch could be used for its meat or shell, but not for both.

The average population density is about 4–5 conchs/100 m (Buesa, 1979b). Less than 0.5% of all conchs are of commercial size. Conch shells grow 4–8 cm/year in length in Cuban waters (Table 8). Growth is most rapid

Figure 8
View of the Isabela de Sagua oyster farm at "Enfermeria" Cay, north of the port.

Figure 9
View of part of an oyster farm at Isabela de Sagua. Workers are attending the lines from "bongos."

in depths of 0.3–2.0 m and during May-August. The adult length is attained 2.7–4 years after metamorphosis. Food supply is important for growth and internal color of the shell; conchs that consume green algae have the brightest and reddest shells. The calcareous alga, *Amphiroa fragilissima*, several filamentous algae, and turtle grass, *Thalassia testudinum*, have been identified as conch foods (Alcolado, 1976).

The meat of the conch comprises 8–16% of its total weight. Larger conchs with more massive shells have a smaller proportion of meat than smaller ones (Alcado, 1976).

For many years, sponge fishermen were the only persons who collected conchs in Cuba, though most conchs were not then sold (Buesa, 1964). But the fishery later expanded considerably when scuba gear was developed, as it allowed fishermen to gather conchs by diving (Fig. 10); production reached 2,353 t in 1977 (Table 9) as the conchs were used as food and ornaments. Conch populations were evidently unable to cope with such an exploitation and the government closed the fishery between 1978 and 1981.

Fishing was permitted from 1982 on and, between then and 1989, annual landings averaged 353 t, which is below the calculated annual sustainable yield of 560 t (Buesa, 1979b). The recommended management for the conch is to gather them within the recommended sustainable yield limit, and to sell those with ordinary shells as food and those with beautiful shells as ornaments.

Table 8
Summary of population information on the queen conch, *Strombus gigas*.

	Segment of insular shelf			
Aspect	S.E.	S.W.	N.W.	N.E.
Shell length (cm) at each age (years)				
Age 1	11	8	10	8
2	18	13	18	15
3	23	16	23	20
Shelf area with preferential distribution of the population (km^2)	1,900	3,200	1,400	4,000
Average population density (animals/100 m^2)	3.9	4.9	3.5	4.5
Animals with commercial size in the population	0.40%	0.25%	0.49%	0.25%
Commercial density (conchs/km^2)	160	123	173	113
Commercial biomass (t)	375	486	299	558
Permissible annual catch (t)	140	130	110	180

Table 9
Queen conch landings[1] in Cuban ports.

Periods	Average landings (t)
1969–71	560
1972–74	180
1975–77	1,646
1978–80	0
1981–82	280
1984–86	444
1987–89	216

[1] Maximum landing, 1977 = 2,353 t: minimum landings, 1978, 1979, 1980, and 1981, of zero.

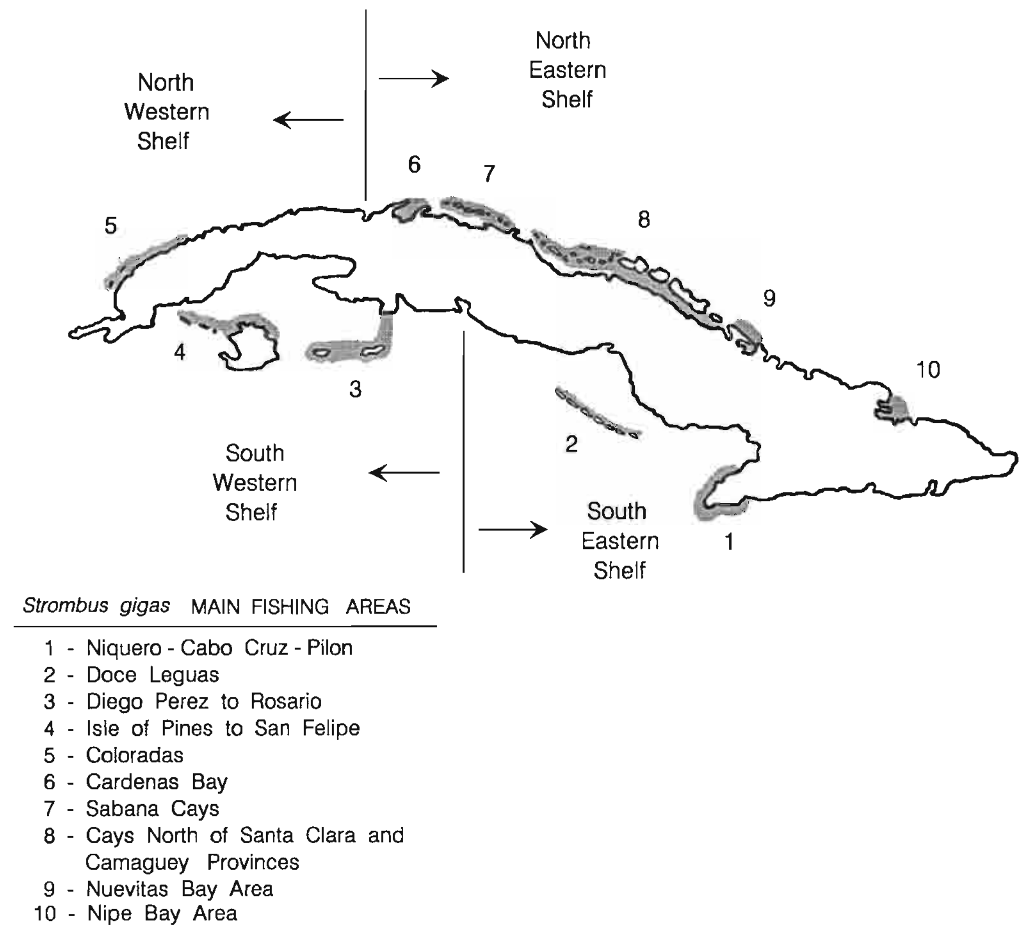

Figure 10
Cuba and its adjacent cays, and main fishing areas for the queen conch in Cuba.

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The Fisheries for the Queen Conch, *Strombus gigas*, Mangrove Oyster, *Crassostrea rhizophorae*, and Other Shelled Mollusks of Puerto Rico

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ABSTRACT

The molluscan shellfish resource of Puerto Rico is composed of a variety of gastropods and bivalves, but the two prominent species are the queen conch, *Strombus gigas*, and the mangrove oyster, *Crassostrea rhizophorae*. The fishery historically can be divided into three phases. The first occurred during the pre-Columbian period. The harvest of mollusks is one of the principal characteristics of the Taino culture, with the shells of some species also being used as tools or ornamentation. The second period covers the time from Spanish colonization through the first half of the 1900's. During this time there was little interest in molluscan fishing, although oysters were commercially harvested to some degree toward the end of the period. The most recent era is characterized by the development of large-scale fisheries for the queen conch and mangrove oyster. The former fishery peaked in 1983, yielding an estimated $930,000, but landings have since dropped by 70%. The oyster fishery, once widespread, now has been reduced to a single lagoon. The catch fluctuates and is valued at less than $100,000 per year.

Introduction

Puerto Rico (Fig. 1) is the smallest and easternmost of the Greater Antilles. It measures approximately 160 km (100 miles) long and 55 km (35 miles) wide, with 540 km (335 miles) of coastline and 5,700 km^2 (2,200 mi^2) of insular shelf. The climate, coastal geography, and oceanography of Puerto Rico with respect to its fisheries resources was presented in detail by Appeldoorn and Meyers (1993); only a brief review is given here.

Puerto Rico contains a wide variety of marine habitats, including coral and rock reefs, seagrass beds, mangrove lagoons, soft bottom areas, sand and algal plains, and sandy beaches, but these are patchily distributed. Along the northwest and north coasts the insular shelf is narrow (2–3 km) and seas are generally rough. This area is a mixture of coral and rock reefs and sand beaches. The east coast has a broad shelf that extends to the Virgin Islands, with typical depths of 18 to 30 m. The south coast is variable in width, ranging from 2 to 15 km. The shelf is widest (25 km) off the southern portion of the west coast. This area and the south coast are characterized by hard or sand-algal bottoms with emergent coral reefs, grass beds and mangroves inshore, and submerged reefs offshore and along the shelf edge.

The marine environment is tropical, with average temperatures ranging from 25° to 28.5°C; inshore maximum temperatures may reach 30°C. Coastal waters are generally clear and oligotrophic, except near river mouths and in mangrove embayments. The south and southwest coasts receive little river runoff. Pelagic primary production is low, on the order of 50 gC/m^2/yr.

However, benthic primary production from macroalgae, sea grasses, symbiotic zooxanthellae, mangroves, and benthic diatoms can be quite high. The limited production of phytoplankton places severe constraints on the abundance and distribution of commercially important, filter-feeding bivalves.

Fishing Traditions

The long tradition of molluscan shellfisheries in Puerto Rico, dating back to pre-Columbian times, is poorly documented. Early systematic works on the mollusks of Puerto Rico (Stahl, 1882; Gundlach, 1883; Dall and Simpson, 1902; McLean, 1951; Warmke and Abbott, 1961) give little or no information on commercial importance. The same is largely true for early reports on fisheries resources (Wilcox, 1900, 1904; Jarvis, 1932;

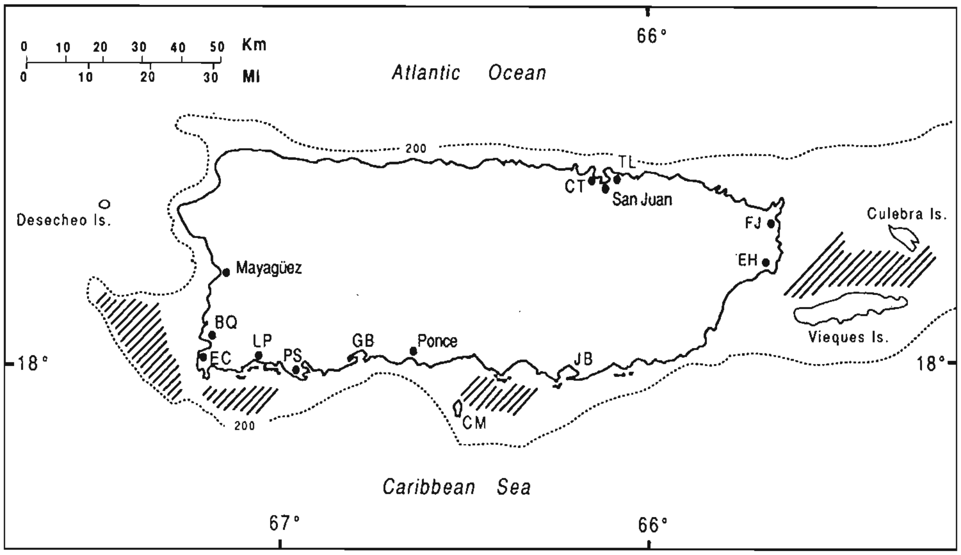

Figure 1

Puerto Rico and its insular shelf (indicated by the 200 m contour). Hatching shows the principal areas for the commercial harvest of queen conch. Other areas shown are discussed in the text: BQ = Boqueron, EC = El Combate, LP = La Parguera, PS = Playa Santa, GB = Guayanilla Bay, CM = Caja de Muertos, JB = Jobos Bay, EH = Ensenada Honda (Ceiba), FJ = Fajardo, TL = Torrecilla Lagoon, CT = Cataño.

Iñigo, 1963). The importance of these fisheries and of specific species, both culturally and economically, has varied markedly.

The first well documented culture in Puerto Rico was that of the Igneri, who came to Puerto Rico as part of the Arawak migration out of South America and the Lesser Antilles. Rainey (1940) and Rouse (1952) reported that the Igneri used a variety of coastal mollusks, but only in small amounts; the principal fishery resource was land crabs. In the area of Puerto Rico and Hispaniola the earlier Igneri culture gave rise to the Taino culture (Rouse, 1952), which persisted until the Spanish conquest of the area. In marked contrast to the Igneri, the Tainos were avid molluscan shellfishermen and left numerous large shell middens throughout Puerto Rico (Rainey, 1940; Rouse, 1952). The extent of those middens was reduced in regions well inland, although the largest reported by Rouse (1952) was 6 miles from the coast. The occurrence of middens in interior areas indicates that mollusks were transported throughout the island. The extent of middens also is lower on the Atlantic coast, where few sheltered bays exist. The Taino harvested a wide variety of coastal bivalves and gastropods; in addition to using them for food, shells were used to make a variety of tools (chisels, hoes, hand axes, plates) and ornamental objects (Rainey, 1940).

Little is known about Puerto Rican fisheries while under Spanish rule. Under Spanish rule, individuals could obtain exclusive rights to fish in the most favorable areas, and these rights were advertised and sold to the highest bidder (Wilcox, 1900). Fishing was controlled by the local port captain. Fishermen were required to obtain a license from the port captain and report catch records to him. In some areas fishermen were required to pay a tax on their catch, and all fishermen were required to enroll in the reserve force of the Spanish Navy. Unfortunately, when the United States assumed authority over Puerto Rico in 1898, the departing Spanish administration removed most records, which were subsequently lost. Furthermore, all previous fishing regulations and report requirements were eliminated.

Spanish colonizers were apparently agriculturally oriented and did not have the established tradition of fishing, as did the Tainos. Nevertheless, the consumption of seafood was relatively high. Wilcox (1900) reported the levels of imports of seafood during the last years of Spanish rule. These totalled over 34 million pounds for a population estimated to be between 800,000 and 1,000,000; yet, local fisheries at that time were considered surprisingly small and underdeveloped. Among the imports reported, shellfish constituted less than 0.05% in both weight and value; these came largely from Spain and other European countries.

The molluscan shellfish resource of Puerto Rico is comprised of a variety of bivalves and gastropods and supports both commercial and recreational fisheries.

Historically, and at present, the two most important species are the queen conch, *Strombus gigas*, and the mangrove oyster, *Crassostrea rhizophorae*. Catch statistics have been recorded only for these two species.

The Queen Conch

Habitat Description

Queen conchs are large herbivorous gastropods. They inhabit sandy bottoms in sheltered areas where bottom disturbance and turbidity are low and plant cover (macroalgae, seagrasses) is high. Historically, conch are considered to be most abundant in seagrass beds (particularly turtle grass, *Thalassia testudinum*) at shallow depths (<10 m; 30 feet). However, they can range to depths of 60 m (200 feet), although they occur infrequently at depths below 30–40 m (100–130 feet). At mid-depths they are found typically on sand and algal plains, but also occur in areas of rubble bottom or silty sand. Conch are found and fished along all coasts of Puerto Rico. However, because of its limited shelf and rougher seas, the north coast contributes little to production. Greatest production comes from the southwest corner of the island where the shelf is broad, with extensive sand-algal plains at depths of 18–24 m (60–80 feet) and inshore seagrass beds. Fishing for conch in these areas is conducted primarily from the village of El Combate, the southernmost fishing village on the west coast (Fig. 1). Favorable habitat is also found on the south coast, particularly in the vicinity of Caja de Muertos Island. Conch are also found in the deeper waters (>24 m; 80 feet) off the east coast, between the islands of Culebra and Vieques, with fishing being centered from the island of Vieques. Principal fishing areas are shown in Figure 1.

History of the Fishery

The queen conch fishery can be divided into three phases. The first is the pre-Columbian phase associated with the Taino culture. Queen conch is one of the principal species occurring in shell middens (Rainey, 1940). The meat was used for food and the shell was used to make hoes, hand axes and other tools, and ornamental objects. Harvesting was probably done by wading out onto shallow grass beds or from canoes.

The second phase began with the decline of the Taino culture and the rise of Spanish colonization and ended during the mid-1900's. During this time there appeared to be little or no conch fishing. Wilcox (1900, 1904) makes no mention of conch fishing or even of the potential of the resource, while Dall and Simpson (1902) give only a general statement about conch being an important food item within the Caribbean as a whole. The first reference specific to fishing queen conch is by Jarvis (1932), who stated that conch were harvested "by naked divers in shallow waters." At this time conch were used primarily as bait, but they were also eaten by fishermen.

The third and modern phase of the conch fishery is characterized by the development of a large-scale commercial fishery. During the 1950's and 1960's, considerable effort was spent developing local fisheries (Iñigo, 1963). While no specific reference to the conch fishery at this time was reported, in consort with the rest of the fishery it can be assumed that catch and effort increased at this time. Catch data have been collected since the late 1960's; these are given in Table 1. While the accuracy of these data is suspect, they probably represent overall trends.

In the first half of the 1970's, landings were stable, with catch rates at approximately 200,000 pounds/yr. Landings began to increase in 1975, first on the east

Table 1

Estimated landings in pounds of queen conch in Puerto Rico (by coast and total) and price per pound. Data obtained from the P.R. Fisheries Research Laboratory, Dep. Nat. Resour.

Year	Landings (pounds) North	East	South	West	Total	Price per pound
1970	465	57,611	10,058	86,164	154,298	$0.41
1971	1,250	33,750	8,750	162,500	206,250	0.41
1972	0	22,500	12,500	175,000	210,000	0.45
1973	0	13,750	8,750	162,500	185,000	0.47
1974	2,500	8,750	15,000	170,000	196,250	0.51
1975	2,500	12,500	17,500	200,000	232,500	0.63
1976	1,250	17,500	30,000	206,250	255,000	0.65
1977	3,750	35,000	83,750	191,250	313,750	0.77
1978	1,099	112,088	126,374	151,648	391,209	0.81
1979	10,299	93,913	99,219	227,881	431,312	0.91
1980	11,804	76,968	79,340	298,845	466,957	1.05
1981	11,557	46,312	48,439	220,917	327,225	1.10
1982	8,465	97,484	75,544	368,831	550,324	1.20
1983	14,459	96,923	139,603	466,123	717,108	1.30
1984	12,736	76,966	163,270	435,782	688,754	1.37
1985	18,273	208,248	61,343	293,463	581,327	1.45
1986	5,563	46,072	30,949	170,725	253,309	1.54
1987	2,150	39,166	39,600	189,895	270,811	1.63
1988	2,318	131,521	52,089	240,370	426,298	1.81
1989	1,214	97,421	41,893	146,232	286,760	1.88
1990	1,069	21,451	44,608	144,784	211,912	1.93
1991	3,945	17,220	79,219	111,690	212,074	2.02

and south coasts, then on the west coast. This increase closely follows increases in the value of conch meat (Table 1). Appeldoorn (1991), who reviewed the conch fishery, stated that the lag in production on the west coast could be explained by the generally lower price obtained for meat farther away from the metropolitan areas of the northeast. In the latter 1970's through 1983, there was a dramatic increase in production, particularly from the west coast; total landed value was estimated at $930,000. Again, this paralleled increases in the price of conch meat; suggesting that the driving force behind increased production was an increase in the value of the product.

During 1982–85, landings increased at a substantially greater rate than price (Table 1), and then began to decline. Appeldoorn (1991) attributed this increase to the occurrence of a dominant 1980 year class that temporarily increased catch per effort. Following the rapid depletion of that year class, landings dropped precipitously. That there was no large increase in price concomitant with this decline in landings probably reflects the increased importation of conch meat to supply demand. The amount of conch imported is substantial, but exact figures are not available, as conch import data are lumped with all other shellfish, including lobsters.

The increase in production during the late 1970's came from an increased number of fishermen entering the fishery, an increased use of scuba diving for harvesting, and the fishing of previously unexploited areas farther afield and in deeper waters. Interviews of fishermen in 1984, during peak production, indicated no apparent concern over decreasing conch densities, absence of large individuals, or overfishing, although some fishermen admitted they needed to range over a greater area than before. By 1986 these attitudes had changed; fishermen admitted that conch were now scarcer than before and that low densities had caused a change in fishing methods (Appeldoorn, 1991).

Characteristics of the Fishery

Commercial conch fishing in Puerto Rico has always been artisanal. The traditional fishing boat in Puerto Rico is the "yola," a small (<7 m) narrow, flat-bottomed wooden skiff (Fig. 2). During early years, these were rowed, but that gave way to the use of outboard motors (25–40 hp), primarily during the 1960's. In recent years these have been replaced by commercial fiberglass boats of similar size. A few larger boats (<10 m), some with inboard engines, have been employed in the recent conch fishery. Fishing previously done by skin diving in shallow waters is now conducted almost exclusively in deeper water with the use of scuba gear. Depths fished

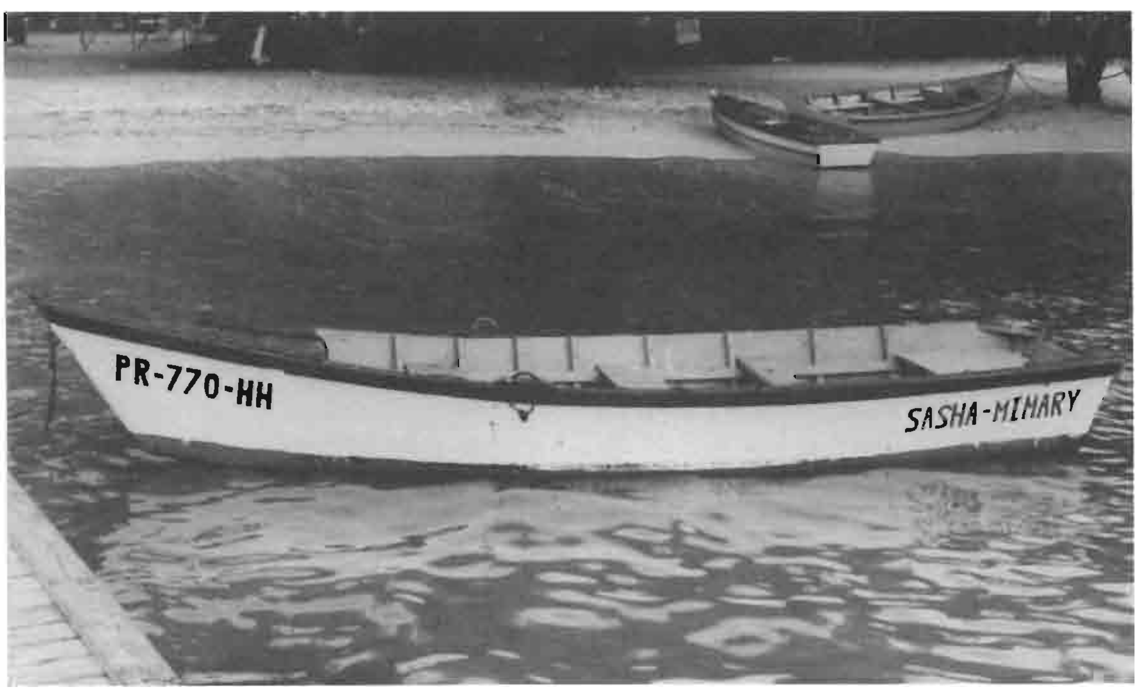

Figure 2
Typical Puerto Rican yola.

range from 7 m to >45 m. Fishermen make daily excursions and usually work in teams, with one person remaining in the boat and one or more divers in the water at any one time. On average, one or two scuba tanks per person are used per trip, although some use as many as three.

When fishing, an area is generally searched either by towing free divers or by free divers making shallow test dives to locate conch aggregations. When density is high, divers will load conchs into a basket, which is then raised to the boat, emptied, and lowered back down. Conchs are shucked by punching a hole through the shell, dorsally on the second whorl (using a hammer and chisel, rock hammer, or hatchet), and inserting a knife to cut the adductor muscle. The visceral mass is removed and, generally, the mantle is trimmed from the meat. The shucking and cleaning is done in the boat while fishing is in progress and/or while returning to port. Shells are thrown over the side while in transit. More recently, with declining densities, fishermen have started to remove the meat from the shell while on the bottom. This allows the diver to cover a greater area per dive in search of scattered individuals. When densities are high, fishermen will selectively harvest larger individuals, gradually taking smaller ones as harvesting continues; the smallest individuals taken are about 15 cm in length (Appeldoorn, 1991).

The fishery is pursued by both full-time and part-time commercial fishermen, and by recreational fishermen. In a 1992 census, there were 162 commercial fishermen who reported harvesting conch, but only about 90 regularly reported their landings. Until recently, full-time fishermen usually were specialists, fishing exclusively for conch. Recently, there has been a greater trend for fishermen to generalize by fishing lobster or spearfishing. Nevertheless, individual trips are usually dedicated to a single activity.

Traditionally, part-time fishing varied seasonally, dropping particularly during sugar cane harvesting. However, their contributions to the reported landings are slight. Monthly landings tend to show large oscillations over short and long periods, without any apparent pattern. In 1988 and 1989 the average catch per trip reported was about 90 pounds of meat (Matos Caraballo and Sadovy, 1990); however, daily catches vary greatly. The level of recreational fishing is unknown, but may be substantial in some areas. Small juvenile conch occurring in shallow grass beds are particularly vulnerable and are willfully taken.

Use of Conch

Conch are not further processed prior to sale. They are usually sold at the dock to wholesalers or directly to restaurants. Preparation for cooking involves the removal of the "skin," operculum, eyes and proboscis, and gut. The meat is softened in a variety of ways: boiling, pressure cooking, beating, or marinating. In Puerto Rico, conch is primarily served as conch salad or as conch cocktail (preparation is similar). On occasion it is stewed, often in combination with tomatoes. Conch is also a popular filling for "empanadillas," a type of turnover.

Fishermen retain the most beautiful adult shells, selling them to shell and tourist shops. There they are sold individually ($7-$10/shell) or incorporated into tourist-oriented or artisan shellcraft products.

Regulations and Mariculture

Local waters in Puerto Rico extend approximately 10 miles from shore and cover almost all of the resource. All fishermen operating in local waters are requested to report their landings. While reporting is voluntary, those complying are eligible for benefits in licensing and assistance. Federal waters are regulated by the Caribbean Fishery Management Council, composed of members from Puerto Rico and the U.S. Virgin Islands. In Federal waters, harvested conch must have a minimum total shell length of 9 in. (22.9 cm) or a shall lip thickness of 3/8 in. (9.5 mm); conch must be landed in the shell, and there is a daily catch limit of 150 conch/day for commercial fishermen. The fishery is closed from 1 July to 30 September. Regulations to extend these measures into local waters are currently under review.

Culture of conch in Puerto Rico is not currently conducted or contemplated. Research into the feasibility of conch culture was conducted during the early 1980's. This was sponsored by the U.S. National Marine Fisheries Service, the Corporation for the Development and Administration of the Marine, Lacustrine, and Fluvial Resources of Puerto Rico, the University of Puerto Rico-Mayagüez, and UPR Sea Grant, and was conducted at the UPR Department of Marine Sciences. During this time, larviculture was successfully carried out on both queen conch and the related milk conch, *Strombus costatus* (Ballantine and Appeldoorn, 1983). However, slow growth of laboratory-reared juveniles and high mortalities among field-released individuals showed that substantially more research on basic biology and ecology was needed before mariculture would be practical (Appeldoorn and Ballantine, 1983).

Prognosis for the Future

The queen conch is considered to be overfished (Appeldoorn, 1992). The fishery is currently conducted in deeper offshore waters, and fishermen are pressing the limits of diving safety in pursuit of conch. Most Puerto Rican diving accidents can be attributed to this fishery. The deepwater conch represent the oldest individuals, and the fishery in the past has survived on the harvest of this surplus biomass, as opposed to surplus production. The fishery on the west coast developed earlier, and old conch have since disappeared. They can still be found in the deeper waters around Vieques off the east coast. Deepwater areas were considered to serve as a refuge for mature conch, but as these become increasingly depleted, the potential for sustained recruitment failure will increase.

Management is needed to curtail fishing mortality to improve yield per recruit and prevent recruitment overfishing. The large size of conch, coupled with their slow mobility and aggregative behavior, make them quite susceptible to fishing. However, management of fishing effort will probably not restore conch harvest to previous levels. Inshore areas, particularly shallow, sandy seagrass beds, are thought to have been important as settling and nursery grounds, as well as for supporting mature conch. The abundance of conch in pre-Columbian shell middens attests to the past availability of the resource in shallow areas. For reasons unknown, these areas do not seem to be productive anymore. The most likely explanation is that nearshore habitat has been modified or destroyed.

Inshore habitats have been substantially affected by human activities. Siltation has increased as a result of coastal development and poor land-use practices. Power boats contribute substantially to sediment resuspension in shallow areas. Beaches associated with nearby grass beds may constitute a primary settlement area for queen conch (Stoner et al., 1994); almost all such beaches in Puerto Rico receive heavy recreational use. Given the lack of planned management and the potential for loss of inshore habitat, a continued decline in the fishery is expected.

The Mangrove Oyster

Habitat Description

Mangrove oysters primarily are found in the intertidal and shallow subtidal zones attached to the roots of the red mangrove, *Rhizophora mangle.* Highest concentrations are found in inlet lagoons, where waters are calm, with little exchange with the sea outside but where they are subject to wind-driven circulation (Mattox, 1949). Historically, the largest and most abundant populations are found on the Caribbean side of the island (Mattox, 1949). The most important area for oysters is Rincon Lagoon in Boqueron on the west coast (Fig. 1, 3), which is 2.4 km long and 0.8 km wide in its greatest dimensions. Oysters are more abundant along its northwest side.

Other principal areas where oysters grow include the mangrove lagoons off of Guayanilla, La Parguera, Salinas, and Jobos Bay on the south coast; Fajardo and Ceiba (Ensenada Honda) on the east coast; and Puerto Real on the west coast (Fig. 1) (Wilcox, 1900, 1904; Mattox, 1949). Oysters are concentrated in a narrow band, as the tidal range along the south coast is small (<10 cm) (Kjerfve, 1981). Temperature range is 25°–30°C, and best growth is achieved at 28°C and a salinity of 38‰ (Mattox, 1949). Mangrove oysters can spawn year-round, and spawning appears to be triggered by sudden decreases in salinity that occur after heavy rains (Watters and Acosta Martínez, 1976).

History of the Fishery

Mangrove oysters were one of the principal mollusk species harvested by the pre-Columbian Tainos. Shell middens near mangrove lagoons (Fig. 3) are composed almost entirely of mangrove oysters (Fig. 4). As with queen conch, the importance of local oyster populations was slight among early European colonizers. At the beginning of this century, Wilcox (1900) reported oysters among the shellfish imported. Some fishing was done in a few areas, but not all (Wilcox, 1904). Oysters from Guayanilla were occasionally harvested, placed in old kerosene tins, and sold in Ponce for $0.20 per tin. Oysters were harvested, in equally low numbers, elsewhere, such as Fajardo, and sold for prices ranging from $0.01 to $0.10 per dozen.

Mattox (1949) reported on the oyster fishery during the 1940's, when the principal area was in Boqueron Bay. The Boqueron oyster harvest was then estimated at 4,000 oysters per week or, at roughly 10 per pound, 25,000 pounds/yr. At $0.20/pound, the year's catch was worth about $5,000, and it was sold in San Juan, Mayagüez, and Ponce. Minimum size was 45 mm shell length, and the average size was 57 mm. Mattox considered the fishery to be stable.

By the early 1970's, only the Boqueron population was still supporting fishing, and Puerto Rico was importing over 90% of its oysters (Watters and Acosta Martínez, 1976). Other once productive areas had declined for a variety of reasons: sewage, extensive cutting of mangrove roots for oyster harvest (e.g., Jobos Bay), and development (e.g., marinas in Fajardo, Roosevelt Roads Naval base in Ensenada Honda, an oil tanker port in Guayanilla). By 1970, between one-fourth and one-third of Puerto Rico's mangroves had been destroyed, with the vast majority of this destruction occurring during the 5-year period of 1965–70 (Heatwole, 1985).

Landings data specific for mangrove oysters have been reported since 1972 (Table 2). Estimated catches

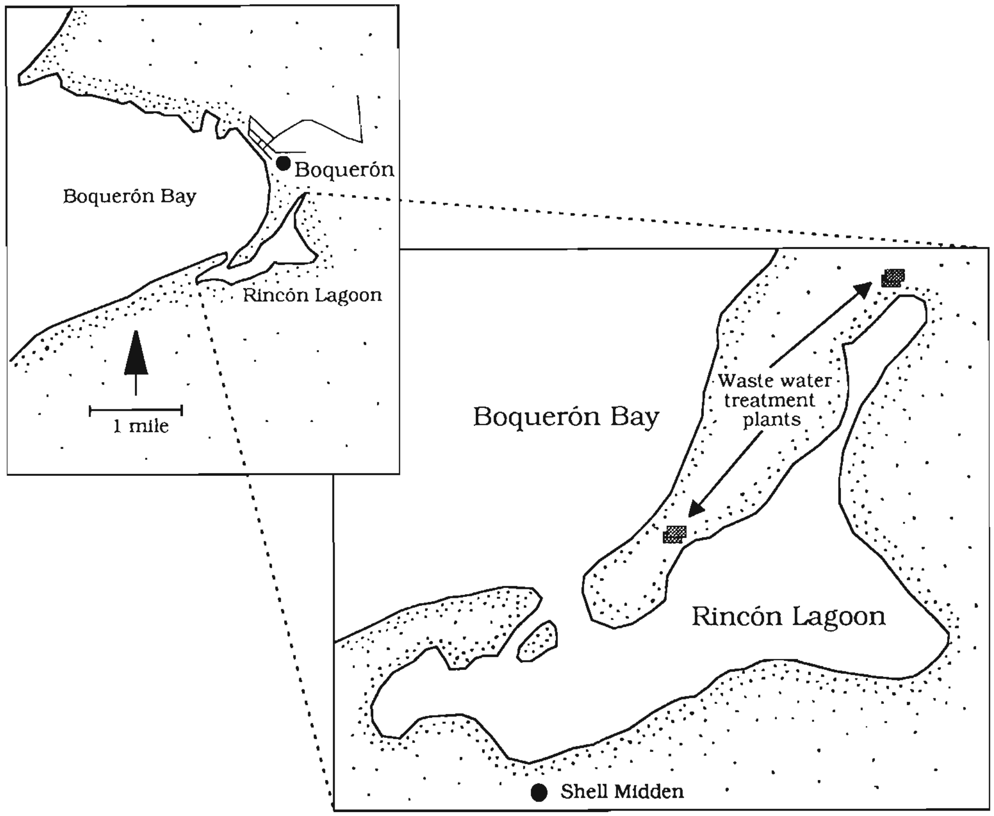

Figure 3
Rincon Lagoon off Boqueron Bay.

of 40,000 to 60,000 pounds of whole oysters in the early 1970's agree well with independent estimates reported by Watters and Prinslow (1975). Prices at that time were $1.00/pound. Reported landings have since varied considerably, but generally have been higher than in the early 1970's, at around 70,000 pounds/yr. Recent landings data are not reliable because most oyster fishermen have refused to cooperate with the data collection program in protest over the closure of areas in the lagoon near sewage outfalls (Fig. 3). The two sewer outfalls come from small primary treatment plants serving about 100 small vacation cabins operated by the Puerto Rico Department of Natural Resources as part of the adjacent Boqueron Beach Recreational Center.

Price per pound began rising during the early 1980's (Table 2), and over the past four years has fluctuated between roughly $1.50 and $2.00/pound. The catch of oysters is valued at less than $100,000/year.

Oysters in Boqueron are harvested by fishermen from small, outboard-powered boats. They are primarily sold to restaurants or from small kiosks for the tourist trade in coastal towns, particularly in Boqueron, where they are sold directly by the fishermen (Fig. 5). Prices at the kiosks run from $1.50 to $2.00/dozen. In an average weekend a fisherman may sell 30–40 dozen, which are eaten raw. Only about 8–10 fishermen currently harvest oysters in Boqueron.

Regulations and Mariculture

It is unknown if the Tainos practiced any form of husbandry. The West Indian murex, *Murex brevifrons*, a predator of mangrove oysters, is common in oyster-dominated middens, but they may have been harvested directly for food. Wilcox (1904) reported that no oyster cultivation or husbandry was practiced at the turn of the century. The only husbandry mentioned by Mattox (1949) was the removal of murex when encountered by fishermen. Mattox made specific recommendations to improve oyster harvests. These included the enhancement of settling substrate by planting stakes of mangrove branches into shallow, open areas, banning the cutting of mangrove roots for the harvest of oysters,

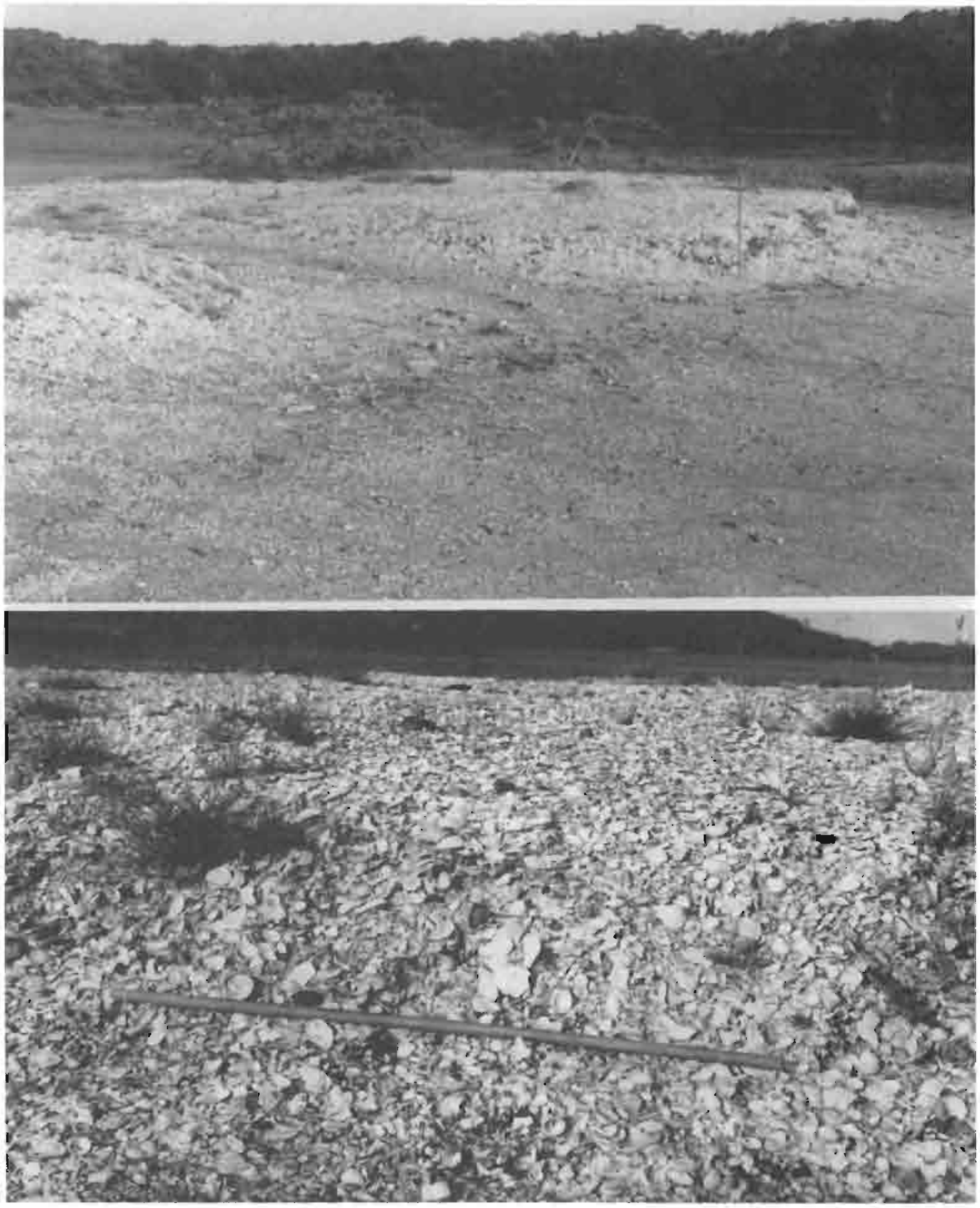

Figure 4
Taino shell-midden located on the south side of Boqueron Bay. Left: Entire midden; vertical rod is 3 feet long. Right: closeup view of the midden; horizontal rod is 3 feet long.

and regulating the diversion of fresh water away from lagoonal areas. This last situation was particularly worrisome in Boqueron where freshwater was being diverted for agriculture. Occasionally salinities reached a peak of 40‰; furthermore, reproduction could have been affected by attenuating an important spawning cue.

In the early 1970's, Watters and Prinslow (1975) and Watters and Acosta Martínez (1976) made specific studies into the mariculture of mangrove oysters, using natural sets. Their principal method was to enhance settling substrate with plaster-covered boards suspended from rafts. Despite complete biological and economic studies using cheap and locally available materials which showed the feasibility of such culture, none of their techniques were adopted.

The Puerto Rico Environmental Quality Board establishes standards for water quality. A year-long study conducted in 1983[1] found no enteroviruses in oysters

Table 2
Estimated landings in pounds of mangrove oysters (by coast and total) for Puerto Rico and price per pound. Data from the Fisheries Research Laboratory, Dept. Nat. Resour.

	Landings (pounds)					Price per
Year	West	South	North	East	Total	pound
1972	62,500	0	0	0	62,500	0.92
1973	37,500	0	0	0	37,500	1.00
1974	51,250	2,500	0	0	53.750	1.00
1975	40,000	0	0	0	40.000	1.00
1976	95,000	0	0	0	95,000	1.00
1977	73,750	0	0	0	75,000	1.00
1978	69,231	4,396	1,099	0	74,726	1.00
1979					66,000	
1980					68,000	
1981					48,000	
1982					68,000	
1983	87,811	0	0	339	88.150	1.27
1984	82,368	13	170	34	82,585	1.38
1985	51,184	0	1,241	0	52.425	1.23

from Boqueron, although coliform bacteria were found in oysters near the two outfalls; water near the outfalls always exceeded maximum contamination level for shellfish growing waters, while areas away from the outfalls exceeded this level only on occasion. The study also reported several undocumented cases of hepatitis resulting from the consumption of raw oysters. The areas near sewage outfalls are now closed to shellfishing.

In an effort to preserve mangroves, as opposed to enhancing oyster production, the cutting of mangroves has been banned, and this is enforced by the Puerto Rico Department of Natural and Environmental Resources (DNER). Recently, efforts have been made to return a freshwater flow into Rincon Lagoon in Boqueron. This effort has been led by the U.S. Fish and Wildlife Service and the DNER. Again, this was not done with oysters in mind, but to preserve wildlife, principally birds, in the areas of Cartagena Lagoon (source of the fresh water flowing toward Boqueron) and the Boqueron Bird Sanctuary, adjacent to Rincon Lagoon. The latter area had originally been diked off from the lagoon by DNER to create an open, freshwater habitat for birds, but it is now periodically opened to allow exchange of fresh and salt water. At present there are no specific management measures regulating the level of harvest.

[1] Hazen T. C., and E. W. Billmire. 1985. Assessment and control of enteric virus contamination of shellfish in tropical waters. Univ. Puerto Rico, Sea Grant Prog. Final Rep. EN/P-45, 31 p.

Prognosis for the Future

The current fishery in Boqueron appears stable. Principal threats to its continued productivity are coastal development, which could degrade water quality in the lagoon and adjacent Boqueron Bay, and overfishing. Based on reported catch levels, the lagoon is highly productive and can withstand heavy fishing. Nevertheless, the chronically high levels of unemployment in Puerto Rico could drive others into the fishery, resulting in overfishing.

Over the past 10 years the mangrove areas in Puerto Rico have stabilized and in some areas have increased. Areas near La Parguera and Playa Santa are now state forests, and the outer portion of Jobos Bay is now managed under the U.S. National Estuarine Sanctuary Program. Thus, there is potential to enhance production by rehabilitating such once-productive areas. At present, Puerto Rico has no policy on the use of public water for commercial mariculture, so it is unlikely mariculture will soon be forthcoming.

Other Species

Several other mollusks are harvested commercially and recreationally in Puerto Rico, but for most, there is little or no historical or current information. The fisheries for a few of the more important species are briefly reviewed.

Thick Lucine, *Lucina pectinatus*

The thick lucine, sometimes called mud clam, is a common deposit-feeding bivalve that reaches a maximum length of 4–5 cm (Warmke and Abbott, 1961). It is found in intertidal and shallow subtidal areas, buried deep in the firm mud of lagoonal channels, particularly in mangrove habitats. Sanders Mair (1976), working off La Parguera on the southwest coast, reported densities up to $8/m^2$. Water temperatures varied from 24 to 35°C, and salinities varied from 32 to 39‰, with greatest changes occurring after heavy rains.

This species is common in Taino shell middens located near appropriate habitats (Fig. 3). Jarvis (1932) reported that clams were occasionally harvested with the aid of a pointed stick in Boca Congrejos (near San Juan) and other lagoons. He did not mention which species, but the most likely possibilities were *Lucina* or *Mercenaria.* In southwest Puerto Rico, the thick lucine is currently harvested in the area of La Parguera (Fig. 1) and sold raw to tourists at the same kiosks selling mangrove oysters (Fig. 5). Since this species shares its habitat with that of the mangrove oyster, its history of habitat loss and future potential are similar.

Figure 5
Top: closeup of kiosk showing piles of mangrove oysters (left) and mud clams (right). Bottom: typical kiosks in Boqueron selling raw shellfish.

Hard Clam, *Mercenaria* spp.

Three taxa of hard clam, all exotic, occur in Puerto Rico: *Mercenaria mercenaria, M. mercenaria notata,* and *M. campechiensis.* The distribution and commercial importance of hard clams was reviewed by Juste and Cortés (1990). Hard clams occur only in specific areas; the mechanisms for their introduction are unknown, but they must have occurred during the period of Spanish colonization. The areas of occurrence are Cataño Lagoon and Torrecilla Lagoon on the north coast, Fajardo and Ceiba on the east coast, and Playa Santa on the south coast (Fig. 1). In Cataño Lagoon, maximum temperatures reach 38°C and salinity varies between 15 and 34‰; clams were found only in the sandy sediments occurring near shore.

In Torrecilla Lagoon, commercial harvesting of clams is thought to have existed for over 100 years, but it ceased in 1986–87. Several toxic acid spills occurred at that time which may have been responsible for killing large numbers of clams. In Fajardo, hard clams are commercially harvested from Isleta Marina, a small island just offshore, and sold by fishermen to retailers. They were also fished off Playa Santa, at the small island of El Obispo, but overfishing has reportedly reduced the population to near extinction.

West Indian Top Shell, *Cittarium pica*

The top shell is common among the coral reef habitats of Puerto Rico and reaches a maximum dimension of about 10 cm (Warmke and Abbott, 1961). Although no records are available, this species is quite popular and is fished by commercial (mostly part-time) and recreational fishermen. They are collected by hand by wading along the top of reefs, or by skin and scuba diving. Jarvis (1932) reported that various gastropods were collected, and the top shell must have been one of these.

West Indian Fighting Conch, *Strombus pugilis*

The fighting conch reaches a maximum shell length of 10 cm. It occurs primarily in soft, silty-sand bottoms in sheltered areas, but may occur offshore in clean sand areas. It is very common in Puerto Rico (Warmke and Abbott, 1961).

The fishery for fighting conch has only recently developed. It is fished primarily for its shell, which is sold in large numbers to tourists, either directly or via artisanal shellcraft. The extracted meat is not wasted, but is used as a substitute for queen conch as a filling for "empanadillas." No records are kept on the levels of harvest, but Reed (1992) documented that fishermen harvested one entire population, estimated at 10,000 individuals, in less than a week.

Milk Conch, *Strombus costatus*

This species is smaller than the queen conch (<17 cm shell length) and has a thicker shell. It is fairly common and found in roughly the same habitats as queen conch, but prefers slightly softer sediments.

The milk conch is occasionally fished by recreational and part-time commercial fishermen. Despite its abundance, its smaller size and thicker shell make it less attractive to full-time conch fishermen.

Caribbean Donax, *Donax denticulatus*

The *donax* species is common along the sandy beaches of Puerto Rico and reaches 2.5 cm in length (Warmke and Abbott, 1961). It has been found in pre-Columbian shell middens dating back to the Igneri culture (Rainey, 1940). While Warmke and Abbott (1961) make no mention of its fishery importance, they stated that it is good in chowder or served over rice.

Donax has the local distinction of having an annual festival celebrated in its honor. This is held in the town of Añasco, just north of Mayagüez on the west coast. The clams are served as a filling in "pastelles."

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