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 $3^1/_2$-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-

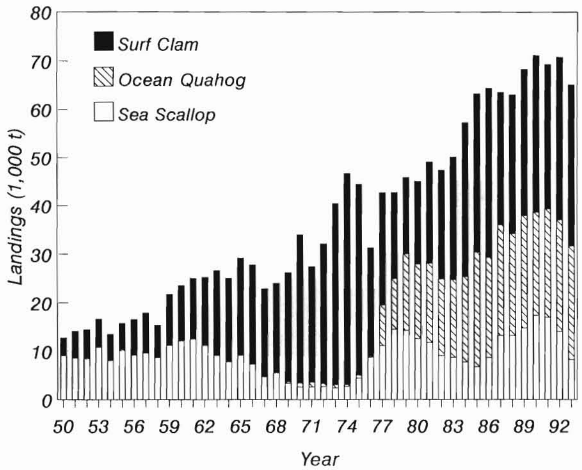

Figure 1
U.S. landings (thousands of metric tons, meat weight) of sea scallop, ocean quahog, and surfclam, 1950–93. Data are for all regions fished by U.S. vessels.

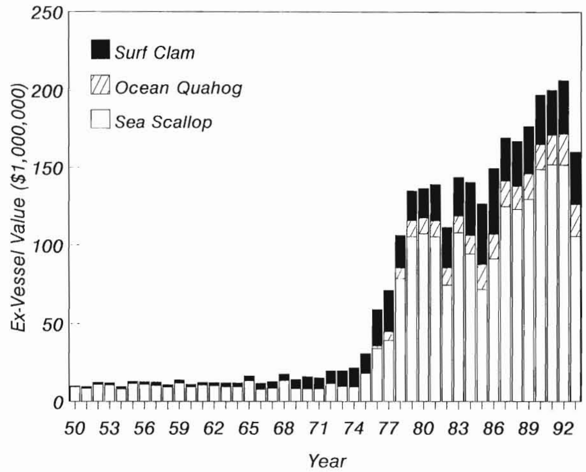

Figure 2
Ex-vessel value (millions of U.S. dollars) of sea scallop, ocean quahog, and surfclam landings, 1950–93. Data are not deflated (i.e. current values).

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.

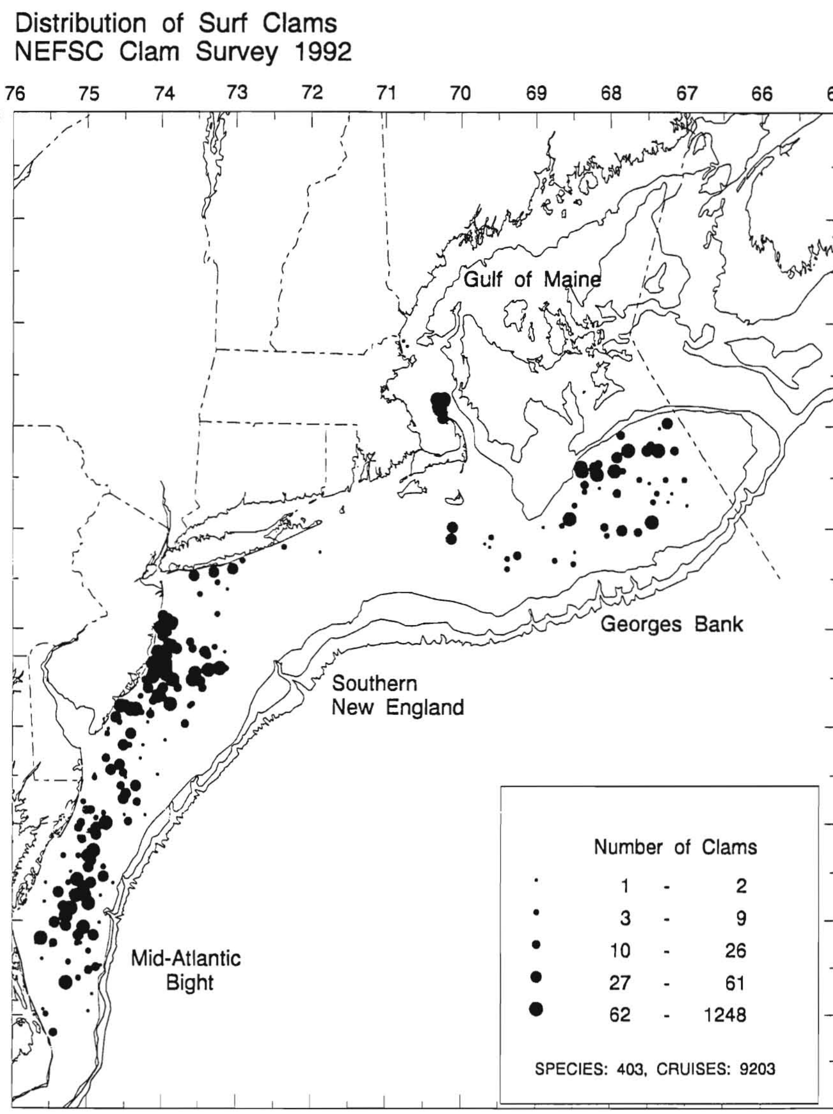

Figure 3
Geographic distribution of surfclam populations sampled in hydraulic dredging surveys off the northeast U.S. during summer, 1992. Data are numbers of clams caught in each 5-minute tow with a hydraulic clam dredge. Survey stations are primarily located in the Mid-Atlantic, southern New England, 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

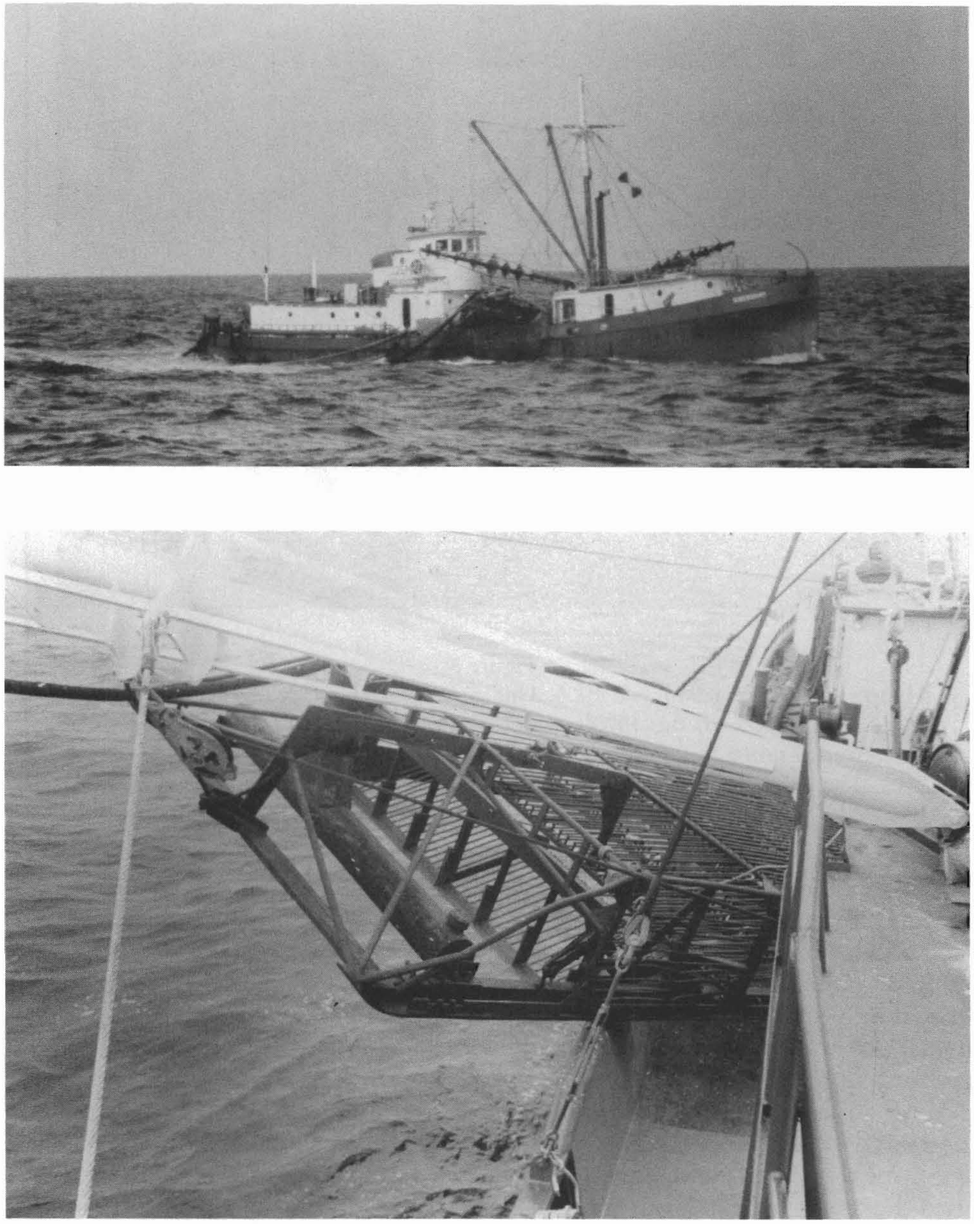

Figure 6
A surfclam-ocean quahog dredge vessel (above), and hydraulic clam dredge (below). Typically, these vessels will tow two dredges, one off each side of the vessel. Dredges are up to 20 ft wide and use high pressure water jets to slurry the substrata and clams before the dredge knife lifts the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

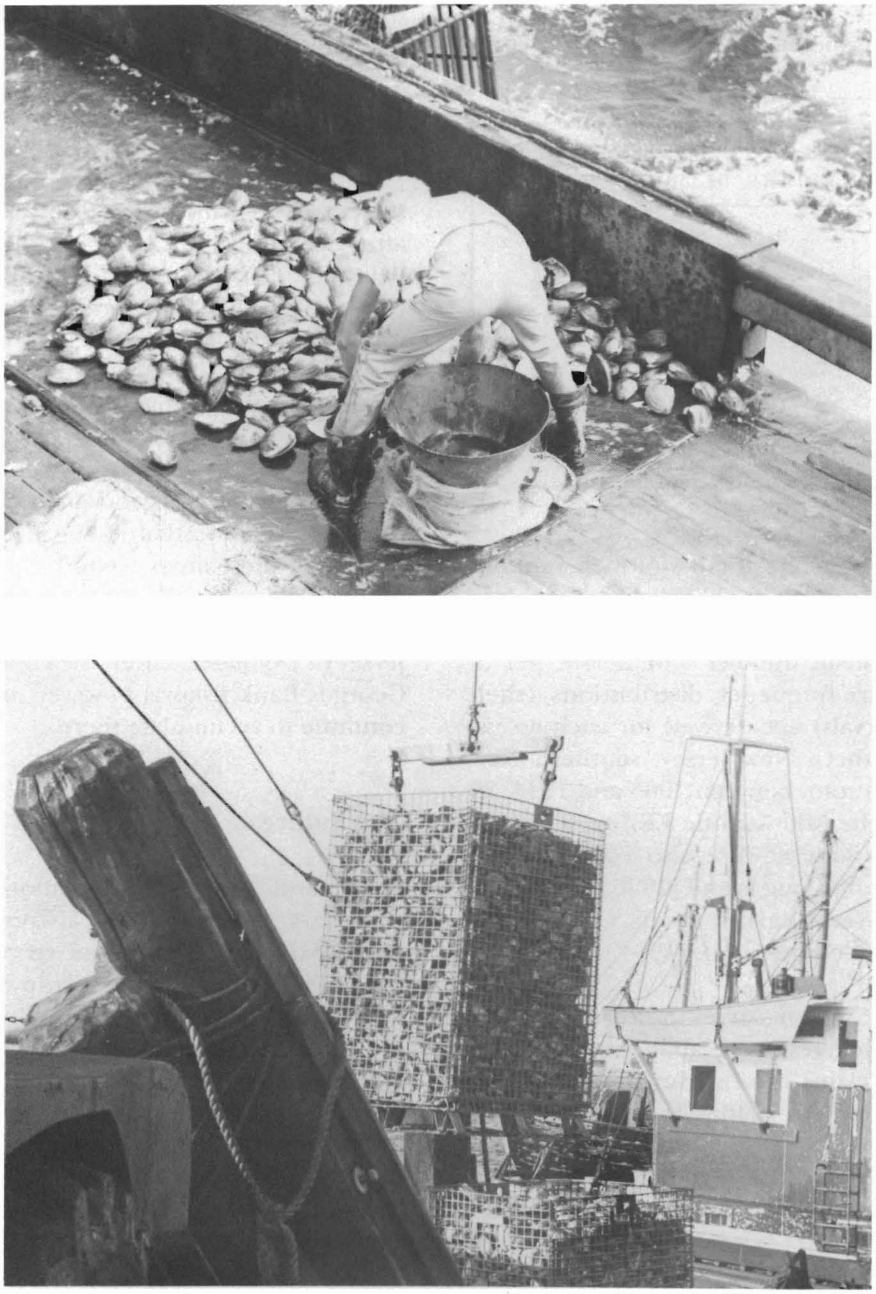

Figure 7
Two methods for handling clams onboard the fishing vessel. In the upper picture, a crewman loads bags by hand. This method was used until the early 1970's, when the 32-bushel cage was introduced (lower photograph). The cages are loaded onboard by hand or conveyors. They are off-loaded by crane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

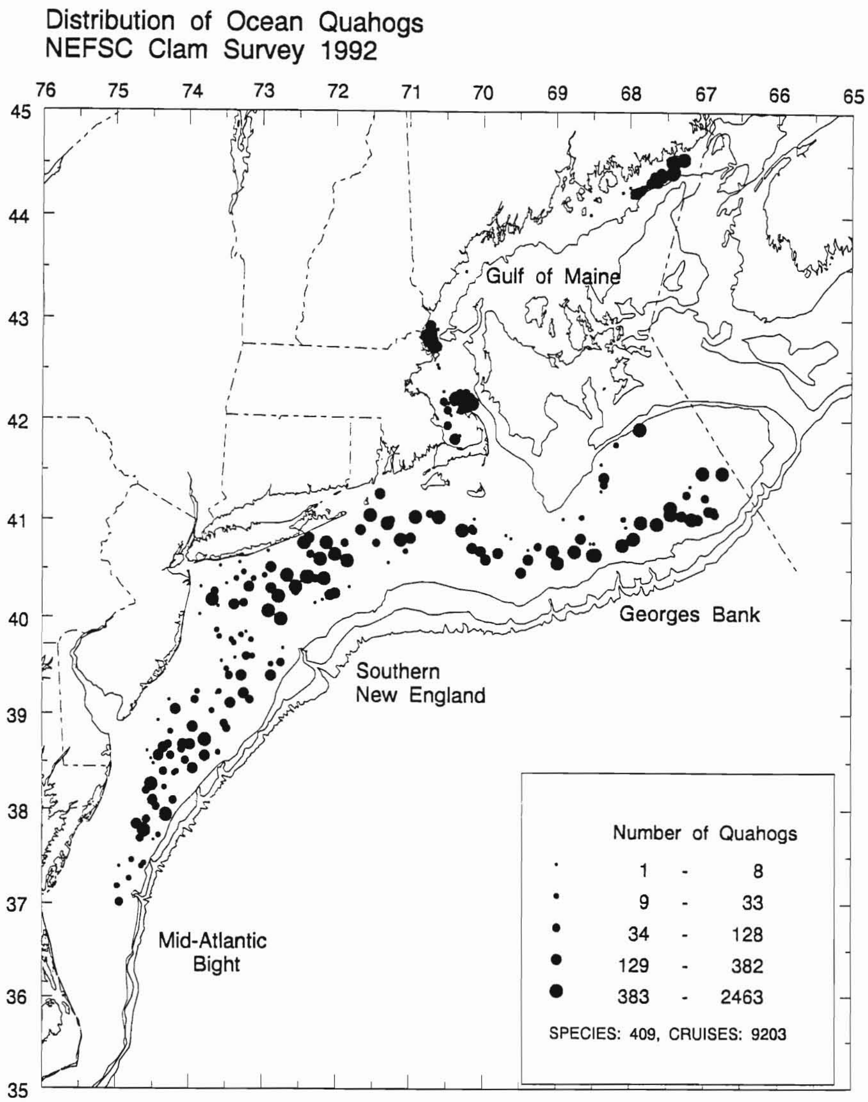

Figure 8

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).

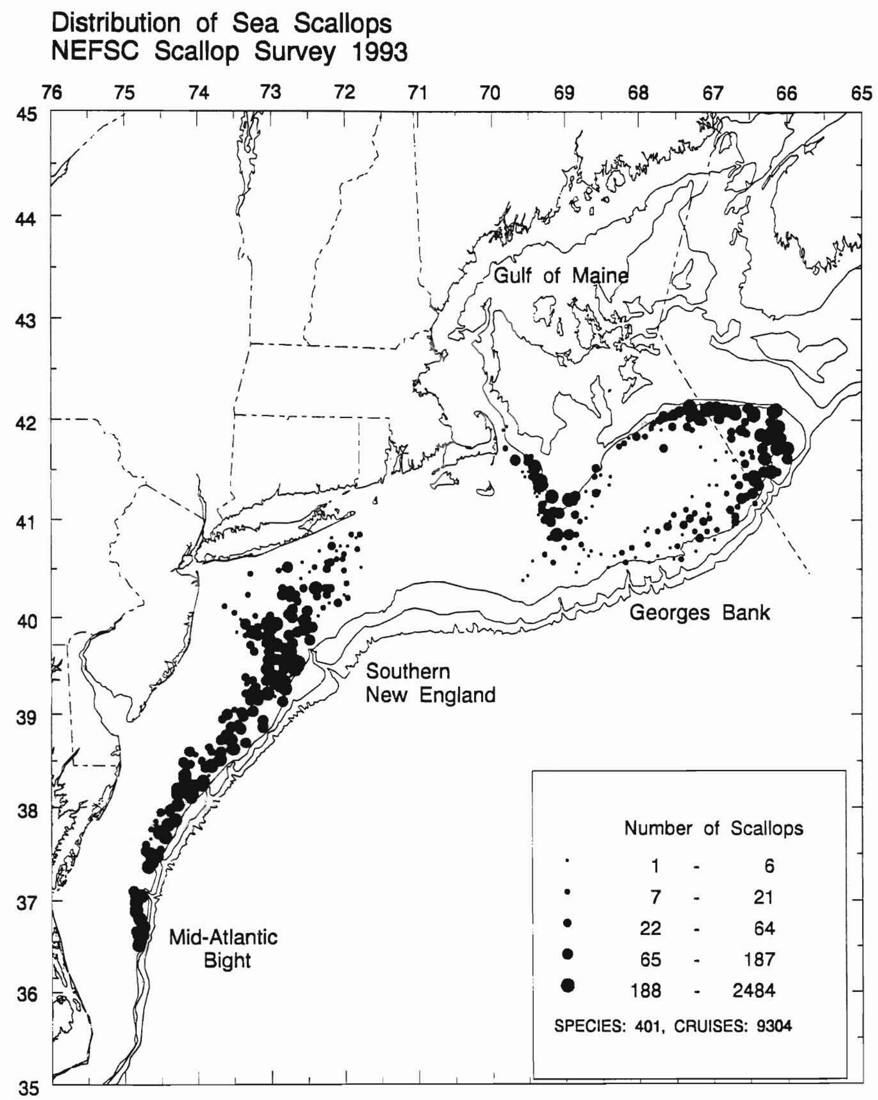

Figure 9
Geographic distribution of sea scallop populations sampled in dredging surveys off the northeast U.S. during summer, 1993. Data are numbers of scallops caught in each 15-minute tow with a scallop dredge. No stations are sampled off Southern New England, owing to the historic dearth of scallops 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.

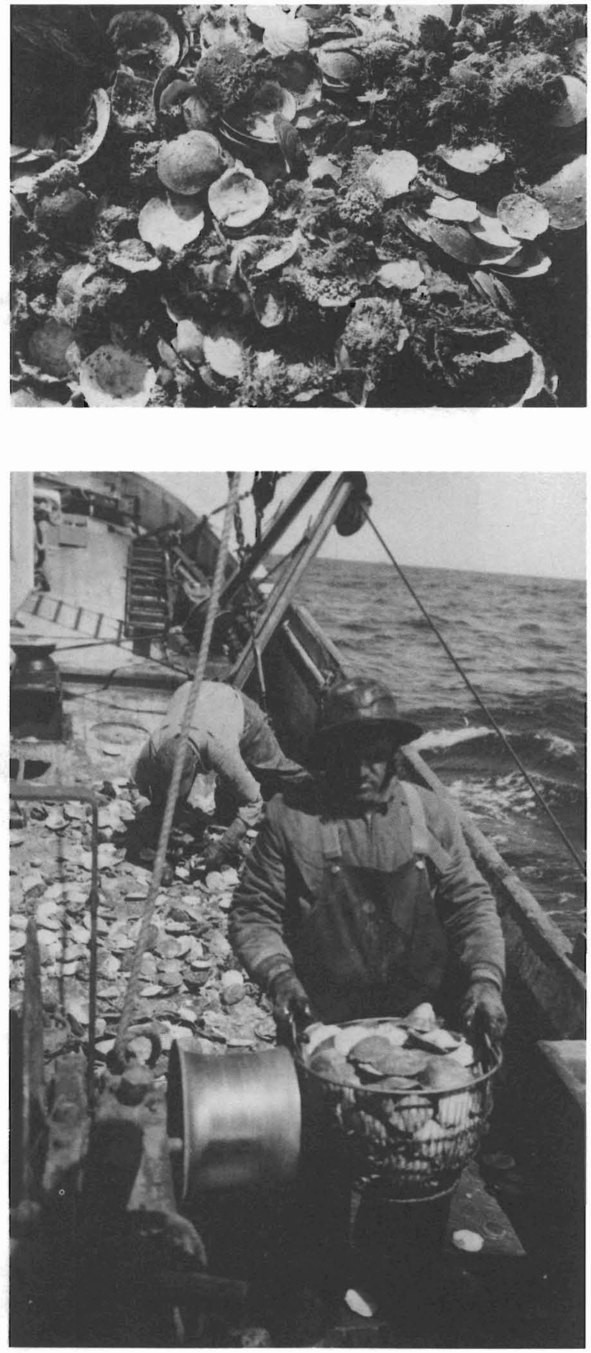

Figure 10
Unsorted catch of sea scallops and other benthic invertebrates and debris (above). Catches are still sorted by hand as they were in the early days of the fishery. Scallops are generally opened by hand (below) at sea, but in some cases they are landed live in the shell and shucked ashore.

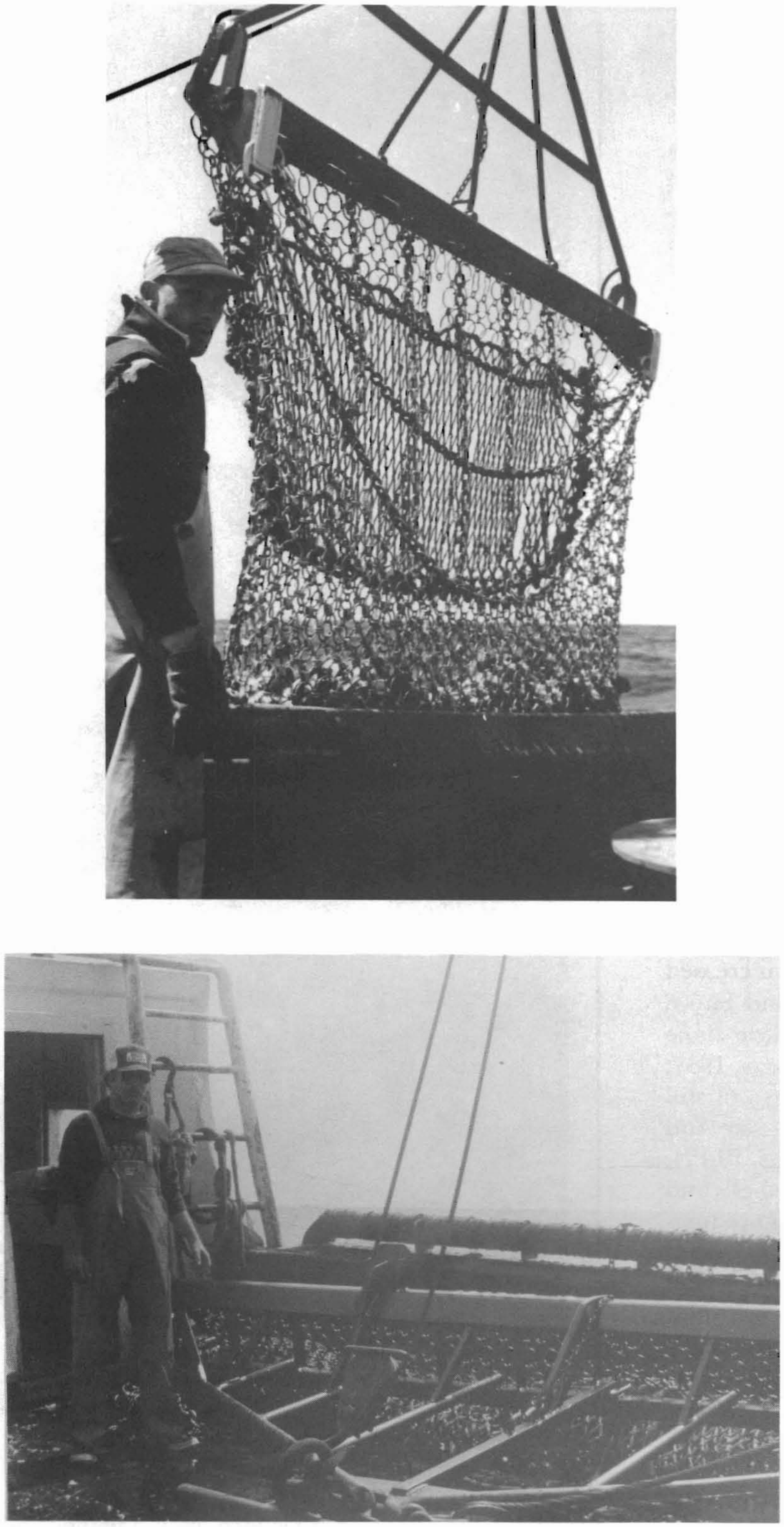

Figure 11
Sea scallop dredges used in the fishery in the early 1960's (above) and the early 1990's (below). Although the design of the dredges has remained similar, the most notable development is that dredges used now are much larger.

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.

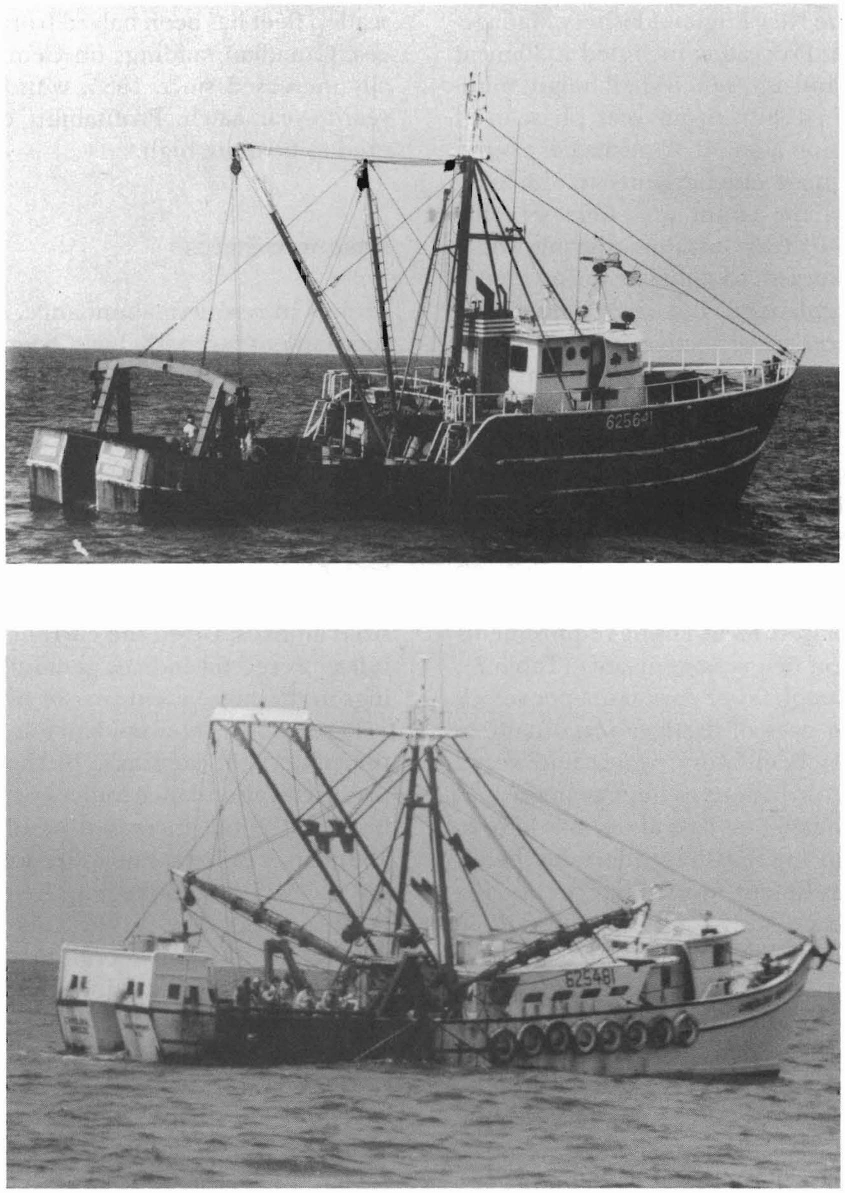

Figure 12
Two typical sea scallop fishing vessels used off the northeast U.S. coast during the 1990's. The vessel above is typical of those hailing from northern ports, such as New Bedford, Massachusetts, whereas the vessel below is typical of southern vessels from North Carolina and Virginia. Note on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

Characteristic	Vessel size class: 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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