A Decline in Starfish, *Asterias forbesi*, Abundance and a Concurrent Increase in Northern Quahog, *Mercenaria mercenaria*, Abundance and Landings in the Northeastern United States

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Introduction

The common starfish, *Asterias forbesi,* is distributed throughout the coastal waters (salinities >16‰ to 18‰) of the northeastern United States (Loosanoff, 1945; Galtsoff, 1964). Its populations fluctuate widely, with years of great abundance followed by years of scarcity (Galtsoff, 1964). Starfish feed on a variety of barnacles and mollusks (Mead, 1901; Galtsoff and Loosanoff, 1939; MacKenzie, 1981), including the northern quahog, *Mercenaria mercenaria* (Galtsoff and Loosanoff, 1939; Burnett, 1960; Doering, 1981, 1982a, b; MacKenzie, 1981), but they are best known for their destruction of oysters in Long Island Sound (Galtsoff and Loosanoff, 1939; Galtsoff, 1964; MacKenzie, 1970a, b, c, 1981). The larger the quahog the less vulnerable it is to starfish predation, but at shell lengths ≥5 cm a quahog can be killed by an aggregate attack of multiple starfish (Doering, 1981).

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ABSTRACT—The abundance of the common starfish, Asterias forbesi*, fluctuates widely over time. The starfish is a predator of pre-recruit northern quahogs,* Mercenaria mercenaria*. During the 1990's, starfish became scarce in Raritan Bay and Long Island Sound. Quahog populations concurrently erupted in abundance and quahog landings have risen sharply in both locations. The extensive scale of this observation would seem to imply a cause and effect; at the least, both populations may be responding differently to a large scale exogenous factor.*

The northern quahog ranges from the Gulf of St. Lawrence to Florida (Abbott, 1974). With rakes, dredges, and by treading, fishermen harvest the quahog over most of its range (Burrell, 1997; Ford, 1997; Jenkins et al., 1997; MacKenzie, 1997a, b; Wallace, 1997; MacKenzie et al., In Press). In Raritan Bay (New Jersey), fishermen harvest quahogs only with a modern design of the bull rake, which they often call a bubble rake, while in Long Island Sound (Connecticut), fishermen harvest quahogs with hydraulic dredges. The commercial industry grades the quahogs into four broad size categories: littlenecks, the smallest (6.2 cm; typical length) and youngest (usually about age 4 in Raritan Bay and ages 4–5 in Long Island Sound); topnecks (7.4 cm); cherrystones (8.2 cm); and chowders (9.0 cm), the largest and oldest. A bushel contains about 550 littlenecks, 265 topnecks, 200 cherrystones, or 135 chowders. The smaller the quahog the higher the market price per bushel. Northern quahogs can live at least 46 years (Jones et al., 1989) but lose value as they age. This is due to the unusual circumstance that smaller quahogs are worth more than larger quahogs per animal.

In this paper we describe observations of a sharp decrease in the abundance of starfish coincident with a large increase in abundance and landings of northern quahogs in Raritan Bay (New

Starfish on a mussel bed in Raritan Bay.

Jersey) and Long Island Sound (Connecticut) in the northeastern United States.

Methods

We determined the distribution and abundance of starfish in Raritan Bay from data collected by the staff of the James J. Howard Marine Sciences Laboratory which conducted resource assessment cruises in the bay throughout the year from 1992 through 1997. The study utilized a stratified random sampling design. This design insures a statistically valid sample and facilitates a comprehensive coverage of all the ecological zones within a study area (Wilk et al.[1]). Fish and megainvertebrates were collected by otter trawl fished from the 19.8 m NOAA R/V *Gloria Michelle*. The trawl, with an 8.5 m headrope and a 10.4 m footrope, was towed for 10 min at 3.7 km/h at each sampling location. Animals were identified and weighed by species and number of individuals counted. The method was a reliable sampler for starfish, often capturing hundreds of individuals in a tow.

In Raritan Bay, the distribution of quahogs was determined by direct observations of sites being harvested and from fisherman interviews. Landings records of quahogs in Raritan Bay were obtained from the New Jersey Department of Environmental Protection and from the James T. White Depuration Plant[2] in Highlands, N.J.

In Connecticut, the abundances of starfish and quahogs and quahog landings were determined from the Connecticut Department of Agriculture's Division of Aquaculture in Milford, and interviews of commercial shellfishermen.

Results

In Raritan Bay, starfish abundance fell sharply after 1992; its abundance before that is unknown. About 36 per tow were caught in 1992, when they were distributed over the central, southeastern, and northeastern parts of the bay (Fig. 1, 2). About 10.5 per tow were caught in 1993, and only 2–4 per tow were taken during 1994 through 1997; by 1997, starfish were present in only the northeastern part of the bay (Fig. 3). In Raritan Bay, 10–15 years ago, harvestable beds of quahogs were confined to three tiny areas (Fig. 2). The quahogs now are widely distributed (Fig. 3). To handle the increased quantities available to be harvested in the beds, a depuration plant with a daily capacity of 240 bushels was opened in Highlands, N.J., in 1995 (Fig. 4). A smaller plant with a daily capacity of 120 bushels of quahogs had opened 5 km away in Sea Bright, N.J., in 1992.

[1] Wilk, S. J., E. M. MacHaffie, D. G. McMillan, A. L. Pacheco, R. A. Pikanowski, and L. L. Stehlik. 1996. Fish, megainvertebrates, and associated hydrographic observations collected in the Hudson-Raritan estuary, January 1992–December 1993. U.S. Dep. Commer., NOAA, NMFS, Northeast Fisheries Science Center, Lab. Ref. Doc. 96-14.

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

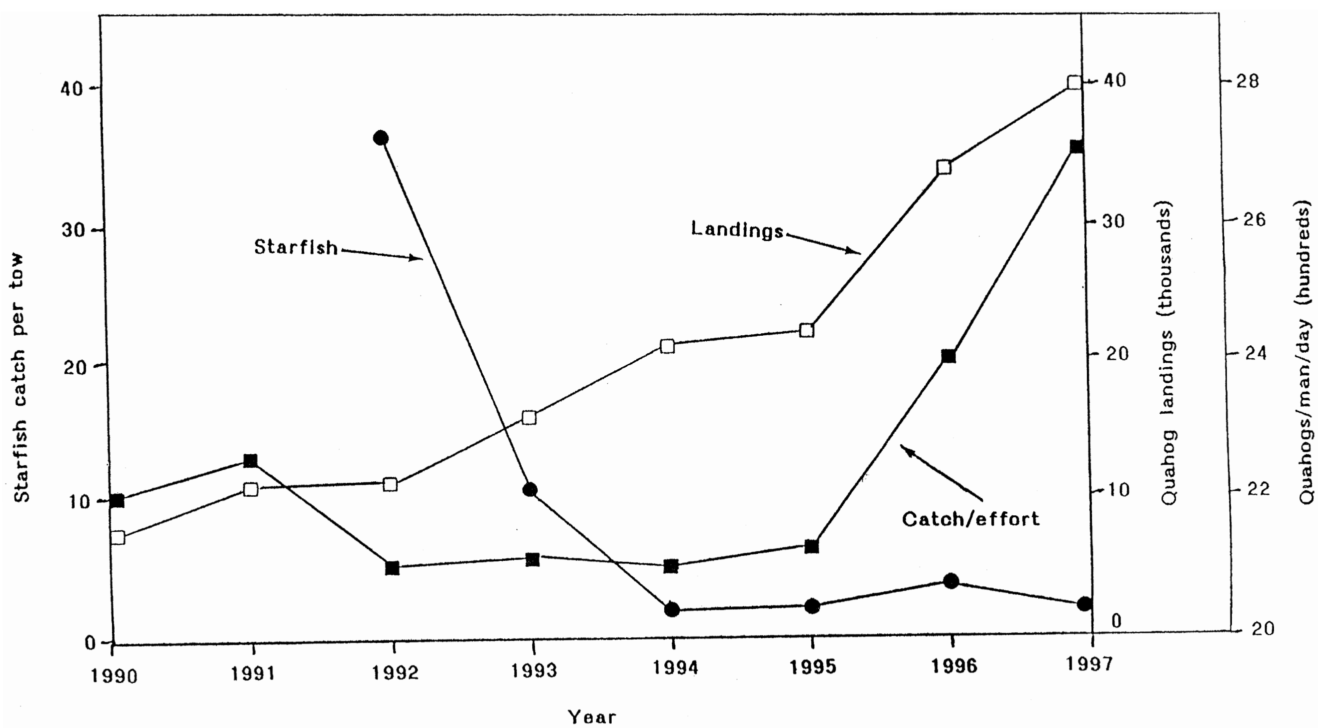

Figure 1.—Relative abundance of the common starfish in Raritan Bay 1990–97 survey trawls, and commercial landings and catch/unit of effort of quahogs in Raritan Bay, 1990–97.

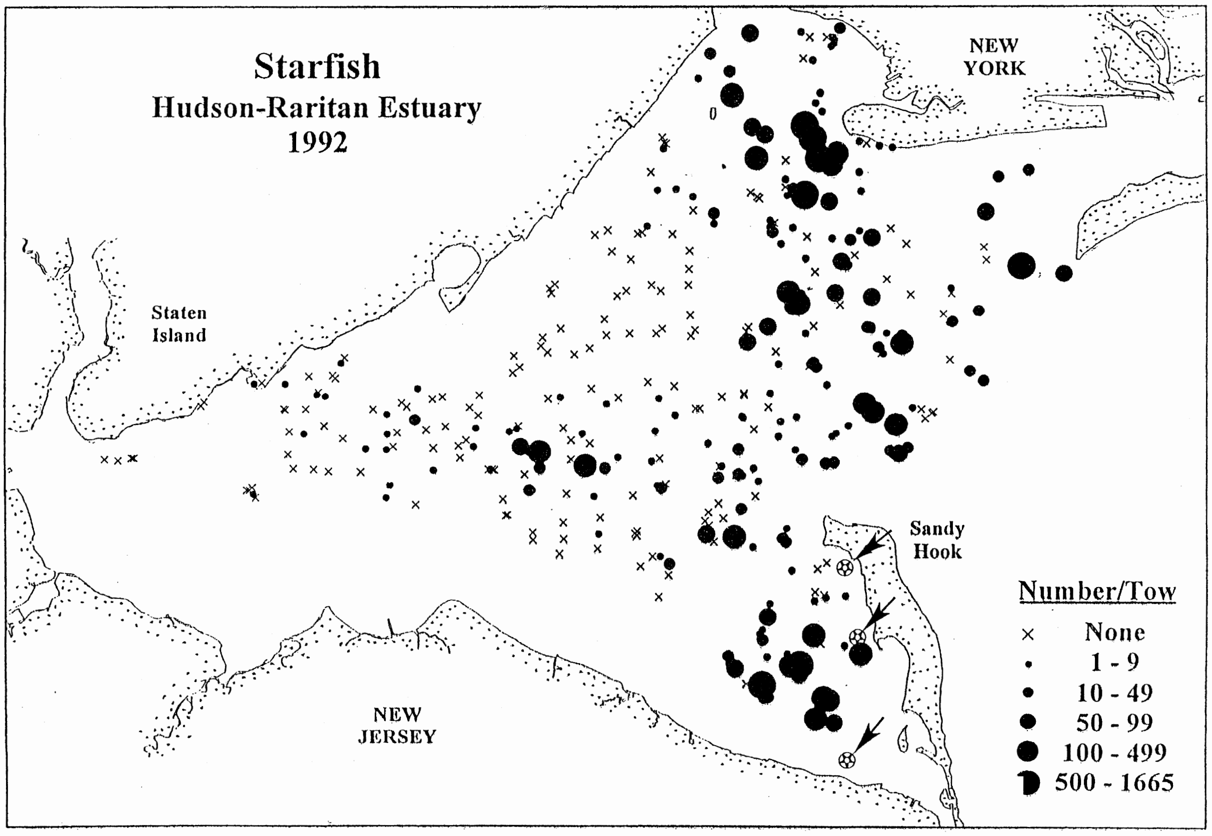

Figure 2.—Distribution and abundance of the common starfish in Raritan Bay in 1992. The "X's" show station locations where no starfish were collected. The arrows point to the only three tiny commercial quahog beds present in New Jersey in the late 1980's–early 1990's.

Quahog landings were nearly consistent each year from 1990 through 1992 at about 10 million individual quahogs/year. But landings rose steadily after that, reaching 40 million in 1997 (Fig. 1). The reason for the rise in numbers of quahogs landed is that a larger proportion of the catch consisted of littlenecks. In 1994–95, the average number of quahogs/bushel that the Highlands plant handled was 465, whereas in 1997 it was 575, an increase of about 24%. During the summer of 1996, the plant took in about 74,000 littlenecks/day, whereas during the summer of 1997, it took in about 113,000 littlenecks/day, or a 53% increase over 1996. The number of quahogs landed per digger per day was consistent each year from 1990 through 1995 at about 2,000 to 2,200 quahogs. The daily catch/digger afterward increased to 2,400 in 1996 and to 3,500 in 1997 (Fig. 5). The increase was due to the larger portion of littlenecks in the catch.

In Connecticut, starfish have shown a long-term decline in abundance since the 1970's. In the late 1950's, 1960's, and 1970's, the industry had to take aggressive measures to remove the starfish from beds to protect their oysters (MacKenzie, 1981). Starfish have been a negligible problem for oyster growers since the mid 1980's and have nearly disappeared from the Connecticut oyster beds (Volk[3], Hopp[4]). Concurrent with the starfish disappearance, fishermen found quahogs to be abundant in areas where they had never found them before, so much so that it became worthwhile for them to lease hundreds of acres of public bottoms from the state in the region from Greenwich to Branford for harvesting the quahogs (Fig. 6). Commercial harvesting from Connecticut's public bottoms is illegal. The quahogs were distributed from just offshore to as far as 4 km from the coast where depths are as much as 15 m, on bottoms that held no harvestable quantities of quahogs 10 years before (Hopp[4], Williams,[5] Bloom[6], White[7], Blogoslawski[8]).

[3] Volk, John. Connecticut Department of Agriculture, Division of Aquaculture, Rogers Avenue, Milford, Conn.

[4] Hopp, David. Tallmadge Brothers, Inc. Bridgeport, Conn.

[5] Williams, Larry. Shellfish leaseholder, Milford, Conn.

[6] Bloom, Hillard. Tallmadge Brothers, Inc., Norwalk, Conn.

[7] White, George. Tallmadge Brothers, Inc., Bridgeport, Conn.

[8] Blogoslawski, Walter. Milford Laboratory, NMFS Northeast Fisheries Science Center, Milford, Conn.

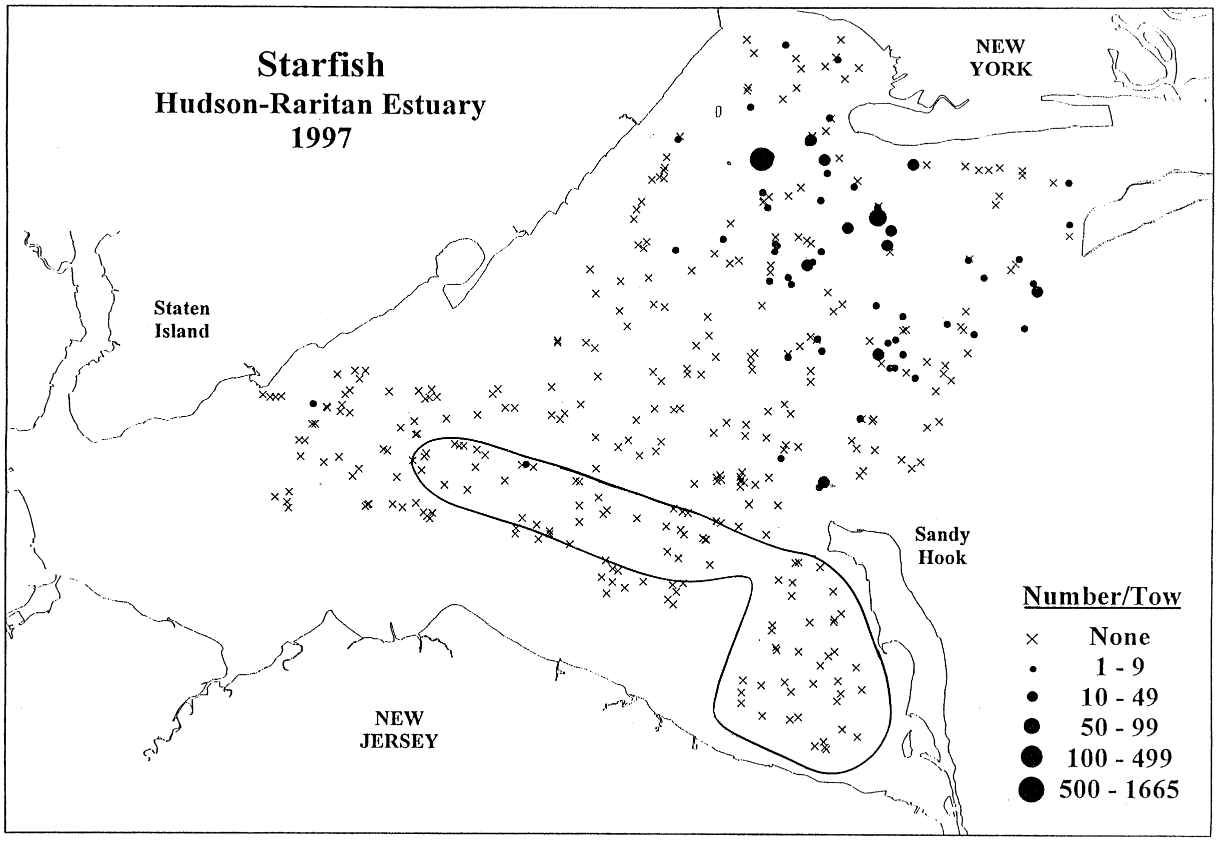

Figure 3.—This figure is similar to Figure 2, except that the northern quahog distribution had substantially expanded as shown by the outlined area in 1997. The bottom sediments in the outlined area consist entirely of mud.

The years of largest harvests in Connecticut were from 1986 to 1996. Connecticut quahog production was relatively low from 1940 through 1970, usually running about 10,000 bushels/ year. In 1985, production rose sharply to 70,000 bushels, by 1992 to 135, 000 bushels, and by 1996 to 200,000 bushels (Fig. 7). Production fell in 1997 and 1998, and is further lower in 1999 as stocks in the inshore beds have been depleted. The current stock of quahogs in the offshore beds consists mostly of littlenecks (Hopp[4], White[7]).

Figure 4.—Quahog depuration plant in Highlands, New Jersey, 1999.

Discussion

We suggest that the dramatic increase in abundance and landings of northern quahogs in Raritan Bay and Long Island Sound may be the result, at least in part, of the concurrent sharp decline in the abundance of starfish. If so, this is the first observed example of a resource species becoming more abundant following a natural downswing in starfish abundance. Although it cannot be directly shown that reduced starfish predation is a major factor in the increase in quahog landings, reduced predation must logically always lead to increased abundance of prey if other factors remain unchanged. We have no explanation for the abundance decline of the starfish. It will be difficult to prove experimentally that starfish predation limits recruitment of northern quahogs in Raritan Bay and Long Island Sound, because one cannot easily replicate the treatment (abundance of starfish) randomly amongst experimental units (quahog beds).

Figure 5.—Raker bringing his quahogs ashore at Sea Bright, N.J., following harvest in Raritan Bay, 1997.

If starfish once preyed extensively on quahogs in Raritan Bay and Long Island Sound, they likely consumed mostly small juveniles rather than sizes from littlenecks to chowders, just as starfish prey mostly on small oysters, usually spat and 1-year-olds, in Connecticut (Galtsoff and Loosanoff, 1939; MacKenzie, 1981). Starfish can prey on small clams, as shown by MacKenzie (1981), who observed that starfish ingested whole dwarf surfclams, *Mulinia lateralis*, that were 2–4 mm long, and Mead (1901) who observed single starfish devouring more than 50 dwarf surfclams in 6 days; dwarf surfclams grow to 8–13 mm long (Abbott, 1974).

An alternate cause of the increased abundances of northern quahogs may be increased setting of quahogs in Raritan Bay and Long Island Sound. If so, perhaps the same ecological factors that favored quahog abundance also inhibited starfish abundance.

Despite the uncertainty of a correlation between starfish and quahog abun-

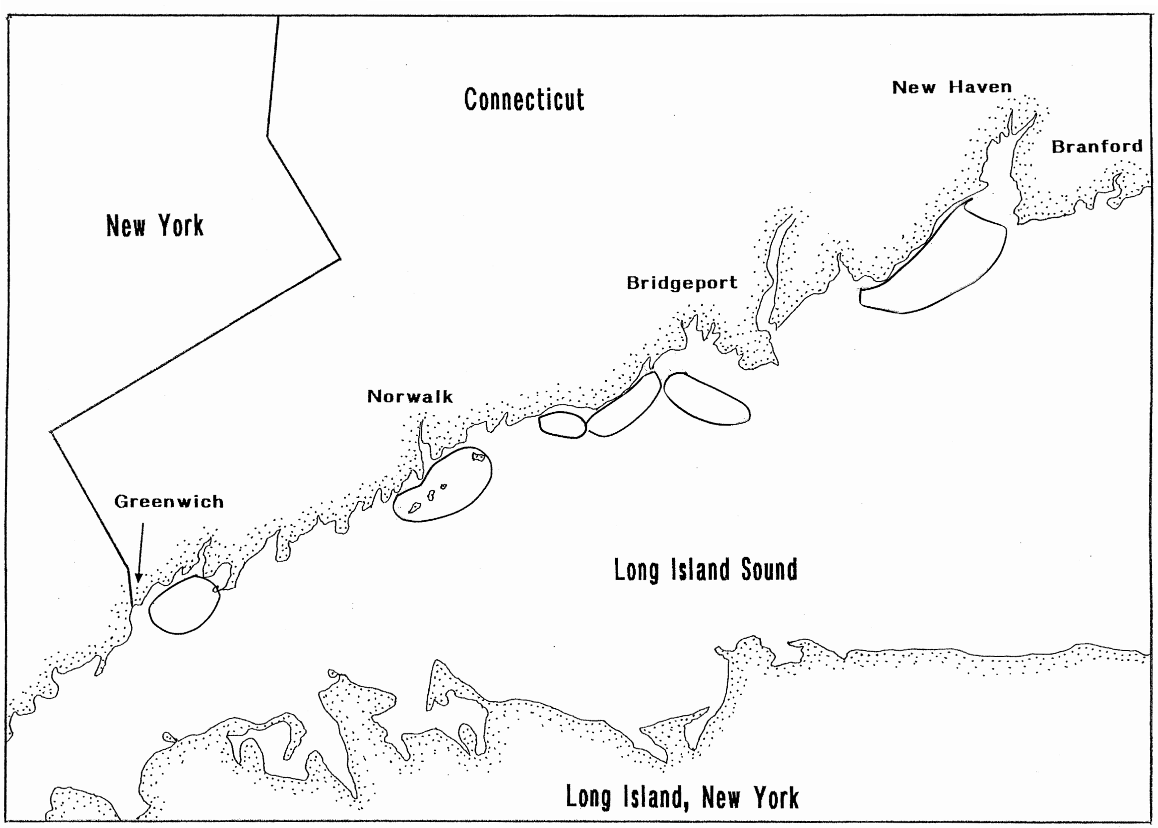

Figure 6.—The outlined areas show the distribution of quahogs in Connecticut in the mid 1990's.

Figure 7.—Landing quahogs in Milford, Conn., following harvest from beds off the Connecticut shore, 1998.

dances, it may be worth trying to sustain the present high abundances of the quahogs by controlling starfish, should that population begin to grow in the future. Starfish have been controlled in Connecticut and in bays on Long Island, N.Y., by dragging mops over starfish-infested bottoms, a method first tried in the 1800's (Ingersoll, 1881; MacKenzie, 1996). The mops consist of a metal bar, about 3.7 m wide, trailing large cotton bundles which entangle the starfish. The starfish would be destroyed after being captured. Other methods can be used when starfish are overabundant.

Literature Cited

Abbott, R. T. 1974. American seashells, 2nd edition. Van Nostrand Reinhold Co., N.Y., 663 p.

Burnett, A. L. 1960. The mechanism employed by the starfish, *Asterias forbesi*, to gain access to the interior of the bivalve, *Venus mercenaria*. Ecology 41:583–584.

Burrell, V. G., Jr. 1997. Molluscan shellfisheries of the South Atlantic region of the United States. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Volume 1, Atlantic and Gulf coasts, p. 171–185. U.S. Dep. Commer., NOAA Tech. Rep. 127.

Doering, P. H. 1981. Observations on the behavior of *Asterias forbesi* feeding on *Mercenaria mercenaria*. Ophelia 20:169–177.

________ . 1982a. Reduction of attractiveness to the sea star *Asterias forbesi* (Desor) by the clam *Mercenaria mercenaria* (Linneaus). J. Exper. Mar. Biol. Ecol. 60:47–61.

________ . 1982b. Reduction of sea star predation by the burrowing response of the hard clam *Mercenaria mercenaria* (Mollusca:Bivalvia). Estuaries 5:310–315.

Ford, S. E. 1997. History and present status of molluscan shellfisheries from Barnegat Bay to Delaware Bay. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Volume 1, Atlantic and Gulf Coasts, p. 119–140. U. S. Dep. Commer., NOAA Tech. Rep. 127.

Galtsoff, P. S. 1964. The American oyster *Crassostrea virginica* Gmelin. U. S. Dep. Inter., Fish Wildl. Serv., Fish. Bull., 480 p.

________ and V. L. Loosanoff. 1939. Natural history and method of controlling the starfish (*Asterias forbesi*, Desor). Bull. U.S. Bur. Fish. 31:75–132.

Ingersoll, E. 1881. The oyster industry. *In* G. Brown Goode (Editor), The history and present condition of the fishery industries. U.S. Gov. Print. Off., Wash., D.C., 251 p.

Jenkins, J. B., A. Morrison, and C. L. MacKenzie, Jr. 1997. The molluscan fisheries of the Canadian Maritimes. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Volume 1, Atlantic and Gulf coasts, p. 15–44. U.S. Dep. Commer., NOAA Tech. Rep. 127.

Jones, D. S., M. A. Arthur, and D. J. Allard. 1989. Sclerochronological records of temperature and growth from shells of *Mercenaria mercenaria* from Narragansett Bay, Rhode Island. Mar. Biol. 102:225–234.

Loosanoff, V. L. 1945. Effects of sea water of reduced salinities upon starfish, *A. forbesi*, of Long Island Sound. Trans. Conn. Acad. Arts Sci. 36:813–835.

MacKenzie, C. L., Jr. 1970a. Feeding rates of starfish, *Asterias forbesi* (Desor), at controlled water temperatures and during different seasons of the year. U.S. Dep. Inter., Fish Wildl. Serv. Fish Bull. 68:67–72.

________ . 1970b. Oyster culture in Long Island Sound 1966–69. Commer. Fish. Rev. 32(1):27–40.

________ . 1970c. Causes of oyster spat mortality, conditions of oyster setting beds, and recommendations for oyster bed management. Proc. Natl. Shellfish. Assoc. 60:59– 67.

________ . 1981. Biotic potential and environmental resistance in the American oyster (*Crassostrea virginica*) in Long Island Sound. Aquaculture 22:229–268.

________ . 1996. History of oystering in the United States and Canada, featuring the eight greatest oyster estuaries. Mar. Fish. Rev. 58(4):1–78.

________ . 1997a. The U.S. molluscan fisheries from Massachusetts Bay through Raritan Bay, N.Y. and N.J. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Volume 1, Atlantic and Gulf coasts, p. 87–118. U.S. Dep. Commer. NOAA Tech. Rep. 127.

________ . 1997b. The molluscan fisheries of Chesapeake Bay. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Volume 1, Atlantic and Gulf coasts, p. 141–169. U.S. Dep. Commer. NOAA Tech. Rep. 127.

________ , A. Morrison, D. L. Taylor, V. G. Burrell, Jr., W. S. Arnold, and A. T. Wakida-Kusunoki. In press. A history of quahoging in the eastern North America: Canada, the United States, and Mexico. Mar. Fish. Rev.

Mead, A. D. 1901. The natural history of the starfish. Bull. U.S. Fish Comm. 1899 (1901):203–224.

Wallace, D. E. 1997. The molluscan fisheries of Maine. *In* C. L. MacKenzie, Jr., V. G. Burrell, Jr., A. Rosenfield, and W. L. Hobart (Editors), The history, present condition, and future of the molluscan fisheries of North and Central America and Europe. Vol. 1., Atlantic and Gulf coasts, p. 63–86. U.S. Dep. Commer., NOAA Tech. Rep. 127.