NOAA Technical Memorandum NMFS-NE-148

Essential Fish Habitat Source Document:

Ocean Quahog, *Arctica islandica*, Life History and Habitat Characteristics

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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Essential Fish Habitat Source Document:

Ocean Quahog, *Arctica islandica*, Life History and Habitat Characteristics

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Editorial Notes on Issues 122-152 in the *NOAA Technical Memorandum NMFS-NE* Series

Editorial Production

For Issues 122-152, staff of the Northeast Fisheries Science Center's (NEFSC's) Ecosystems Processes Division have largely assumed the role of staff of the NEFSC's Editorial Office for technical and copy editing, type composition, and page layout. Other than the four covers (inside and outside, front and back) and first two preliminary pages, all preprinting editorial production has been performed by, and all credit for such production rightfully belongs to, the authors and acknowledgees of each issue, as well as those noted below in "Special Acknowledgments."

Special Acknowledgments

David B. Packer, Sara J. Griesbach, and Luca M. Cargnelli coordinated virtually all aspects of the preprinting editorial production, as well as performed virtually all technical and copy editing, type composition, and page layout, of Issues 122-152. Rande R. Cross, Claire L. Steimle, and Judy D. Berrien conducted the literature searching, citation checking, and bibliographic styling for Issues 122-152. Joseph J. Vitaliano produced all of the food habits figures in Issues 122-152.

Internet Availability

Issues 122-152 are being copublished, *i.e.*, both as paper copies and as web postings. All web postings are, or will soon be, available at: *www.nefsc.nmfs.gov/nefsc/habitat/efh*. Also, all web postings will be in "PDF" format.

Information Updating

By federal regulation, all information specific to Issues 122-152 must be updated at least every five years. All official updates will appear in the web postings. Paper copies will be reissued only when and if new information associated with Issues 122-152 is significant enough to warrant a reprinting of a given issue. All updated and/or reprinted issues will retain the original issue number, but bear a "Revised (Month Year)" label.

Species Names

The NMFS Northeast Region's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991[a]), mollusks (*i.e.*, Turgeon *et al.* 1998[b]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[c]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[d]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998[e]).

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[a]Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

[b]Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[c]Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

[d]Rice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

[e]Cooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (U.S.)* 96:686-726.

FOREWORD

One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats.

Magnuson-Stevens Fishery Conservation and Management Act (October 11, 1996)

The long-term viability of living marine resources depends on protection of their habitat.

NMFS Strategic Plan for Fisheries Research (February 1998)

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), which was reauthorized and amended by the Sustainable Fisheries Act (1996), requires the eight regional fishery management councils to describe and identify essential fish habitat (EFH) in their respective regions, to specify actions to conserve and enhance that EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." The MSFCMA requires NMFS to assist the regional fishery management councils in the implementation of EFH in their respective fishery management plans.

NMFS has taken a broad view of habitat as the area used by fish throughout their life cycle. Fish use habitat for spawning, feeding, nursery, migration, and shelter, but most habitats provide only a subset of these functions. Fish may change habitats with changes in life history stage, seasonal and geographic distributions, abundance, and interactions with other species. The type of habitat, as well as its attributes and functions, are important for sustaining the production of managed species.

The Northeast Fisheries Science Center compiled the available information on the distribution, abundance, and habitat requirements for each of the species managed by the New England and Mid-Atlantic Fishery Management Councils. That information is presented in this series of 30 EFH species reports (plus one consolidated methods report). The EFH species reports comprise a survey of the important literature as well as original analyses of fishery-independent data sets from NMFS and several coastal states. The species reports are also the source for the current EFH designations by the New England and Mid-Atlantic Fishery Management Councils, and have understandably begun to be referred to as the "EFH source documents."

NMFS provided guidance to the regional fishery management councils for identifying and describing EFH of their managed species. Consistent with this guidance, the species reports present information on current and historic stock sizes, geographic range, and the period and location of major life history stages. The habitats of managed species are described by the physical, chemical, and biological components of the ecosystem where the species occur. Information on the habitat requirements is provided for each life history stage, and it includes, where available, habitat and environmental variables that control or limit distribution, abundance, growth, reproduction, mortality, and productivity.

Identifying and describing EFH are the first steps in the process of protecting, conserving, and enhancing essential habitats of the managed species. Ultimately, NMFS, the regional fishery management councils, fishing participants, Federal and state agencies, and other organizations will have to cooperate to achieve the habitat goals established by the MSFCMA.

A historical note: the EFH species reports effectively recommence a series of reports published by the NMFS Sandy Hook (New Jersey) Laboratory (now formally known as the James J. Howard Marine Sciences Laboratory) from 1977 to 1982. These reports, which were formally labeled as *Sandy Hook Laboratory Technical Series Reports,* but informally known as "Sandy Hook Bluebooks," summarized biological and fisheries data for 18 economically important species. The fact that the bluebooks continue to be used two decades after their publication persuaded us to make their successors – the 30 EFH source documents – available to the public through publication in the *NOAA Technical Memorandum NMFS-NE* series.

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SEPTEMBER 1999

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INTRODUCTION

The ocean quahog, *Arctica islandica*, is a bivalve mollusk (Figure 1) found in temperate and boreal waters on both sides of the North Atlantic (Weinberg 1995). In U.S. waters, quahogs are managed under the Mid-Atlantic Fishery Management Council's Atlantic Surfclam and Ocean Quahog Fishery Management Plan (MAFMC 1997). This Essential Fish Habitat Source Document provides information on the life history and habitat requirements of ocean quahogs in U.S. waters.

LIFE HISTORY

A brief synopsis of the life history characteristics of ocean quahogs is provided in Amendment #10 of the Atlantic Surfclam and Ocean Quahog Fishery Management Plan (MAFMC 1997). More detailed information is provided here and in Ropes (1978).

EGGS AND LARVAE

The eggs and larvae of ocean quahogs are planktonic, drifting with currents until the larvae metamorphose into juveniles and settle to the bottom (MAFMC 1997). Eggs range in size from 80-95 µm in diameter (Loosanoff 1953). Larvae go through three stages of development, with the duration of each stage being temperature dependent. Fertilized eggs hatch into planktonic trochophore larvae, which develop into veliger larvae, the first larval stage to possess a bivalved shell. Veligers in turn develop into pediveligers, a transitional "swimming-crawling" larval stage with development of a foot for burrowing.

The minimum larval development period of ocean quahogs is 55 days at 8.5-10^{o}C (Lutz *et al.* 1981, 1982), 60 days at 10-12^{o}C, (Landers 1972, 1976), and 32 days at 13^{o}C (Lutz *et al.* 1981, 1982). There is some variation in reported lengths at which metamorphosis occurs, from 175-200 µm (Landers 1972, 1976) to 240 µm (Lutz *et al.* 1981, 1982).

Mann and Wolf (1983) studied larval behavior in the laboratory. Trochophores were negatively geotactic (i.e., tend to move up in the water column), showed no phototaxis (i.e., did not orient themselves toward light), and showed no change in swimming behavior when water pressure was changed from 1-3 bar. Veligers also showed no phototaxis, but veligers 160-190 µm long moved upward with an increase in pressure and downward with a decrease in pressure. However, larger veligers showed no response to pressure change.

JUVENILES

Growth of ocean quahogs is relatively fast during the juvenile stage. In a 3-year laboratory study, Lutz *et al.* (1982) found that quahog length ranged from 1.0 to 3.9 mm 7.5 months after metamorphosis. Kraus *et al.* (1989, 1992) reported a laboratory growth rate of 18.5 mm/year for the first two years of life, and 7.3 mm/year for the third year. In a one-year field caging study, Kennish *et al.* (1994) found that quahogs 9.2-19.9 mm shell length grew an average of 10-22 mm/year.

Recruitment of juveniles into the population is relatively low. The protracted spawning period suggests that recruitment may occur at low levels over several months, rather than in a single strong pulse. Kennish and Lutz (1995) attribute low recruitment to adverse environmental factors (poor substrate, high temperatures) and predation on recently settled individuals.

ADULTS

The ocean quahog is among the longest-lived and slowest growing of marine bivalves and may reach a maximum age of 225 years (Ropes and Murawski 1983; MAFMC 1997). They grow very slowly or not at all and individuals of similar size may vary greatly in age. Quahogs off Long Island grew 0.56 mm/year in 1970 and 1.17 mm/year in 1980, while those off New Jersey grew an average of 1 mm in 1.6 years. In Whitsand Bay, UK, quahogs grew 0-1.5 mm/year (Kennish *et al.* 1994; Kennish and Lutz 1995). Ocean quahogs from Georges Bank appear to be the youngest (Ropes and Pyoas 1982), suggesting that conditions there are favorable for quahog growth.

Growth rates may be reduced at high density. Beal and Kraus (1989) noted that growth was reduced by a factor of 1.2 when density was increased from 323-645 clams/m^2. Growth is also dependent upon temperature. Stable isotopes show a consistent growth shutdown temperature of about 6^{o}C for a clam from Nantucket Shoals, implying a May-December growing period (Weidman and Jones 1993).

REPRODUCTION

Ocean quahogs mature very slowly. Rowell *et al.* (1990) report the mean age of sexual maturity for Nova Scotian quahogs to be 13.1 years for males and 12.5 years for females. The earliest age of maturity was 7 years for both sexes, and maturity occurred at about 49 mm shell length. Ropes *et al.* (1984b) found that immature clams off Long Island were 2-8 years old, and 19 to 46 mm long. Thompson *et al.* (1980b) reported the average age of maturity for Middle Atlantic Bight quahogs was 9.38 years, but this was extremely variable.

Ocean quahog spawning is protracted, lasting from spring to fall. Multiple annual spawnings may occur at the individual and population levels (Mann 1982). Off Rhode Island, Loosanoff (1953) reports ocean quahog spawning from late June to late October. Mann (1982, 1985) reported a more protracted spawning period for the same region from May to November, with the most intense spawning occurring from August to November. Off New Jersey, spawning occurred from September to November, and sometimes persisted into January (Jones 1981). Fritz (1991) noted higher visceral weight in ocean quahogs off Cape May in spring and summer than in fall and winter, suggesting late summer spawning. Off Nova Scotia, spawning occurred from July to September; in some years, all individuals showed evidence of partial spawning from February to May (Rowell *et al.* 1990).

FOOD HABITS

Larvae are planktotrophic, and have been reared on unicellular algae in the lab (Landers 1976; Lutz *et al.* 1981, 1982). Mann (1985) reports the range of algal concentrations (5.4×10^2 to 6.77×10^4 cells/ml) at a New England site to be sufficient for larval growth. In laboratory experiments with Baltic Sea animals, Witbaard *et al.* (1997) showed that cell densities ranging between 5 and 7×10^3 cells/ml were adequate to keep juveniles alive at 9°C.

Ocean quahogs are suspension feeders on phytoplankton, using their relatively short siphons which are extended above the surface of the substrate to pump in water. Extremely high algal concentrations may interfere with feeding (Winter 1970). In the laboratory, Winter (1969) showed that the maximum rate of algal filtration by adult quahogs occurred at 20°C and 50×10^6 cells/l, but such high algal concentrations are unlikely to occur in the field. In a 24 hour period, two feeding periods alternate with two digestion periods (Winter 1970).

PREDATION

Many animals prey on ocean quahogs. Invertebrate predators include rock crabs (Stehlik 1993), sea stars (Kennish *et al.* 1994), and other crustaceans (Kraus *et al.* 1991). Teleost predators of ocean quahogs include longhorn sculpin, *Myoxocephalus octodecemspinosus*, ocean pout, *Macrozoarces americanus* (Packer and Langton, in prep.), haddock (Clarke 1954), and cod (Clarke 1954; Brey *et al.* 1990). Medcof and Caddy (1971) noted many predators feeding on quahogs damaged by a dredge. These included cod, winter flounder, sculpin, skates, moon snails, and hermit crabs. Other potential predators seen in the dredge tracks but not observed feeding included eelpout, sea stars, and whelks.

HABITAT CHARACTERISTICS

Information on the habitat requirements and preferences of ocean quahogs are presented here and are summarized in Table 1. This review and synthesis concentrates primarily on U.S. stocks; most information from north of the Gulf of Maine was not considered.

EGGS AND LARVAE

Although larvae in laboratory studies can survive temperatures as high as 20°C, they tend to grow optimally between 13 and 15°C (Mann and Wolff 1983). In field studies southwest of Cuttyhunk, Massachusetts, Mann (1985) showed that the highest concentrations of larvae occurred between 14 and 18°C from August to September. They were found at depths of 1-30 m in May and from 20-40 m from late July to November. Larvae were collected at an average salinity of 32.4 ppt.

JUVENILES

Juvenile ocean quahogs are found offshore in sandy substrates (Kraus *et al.* 1989, 1992) but may survive in muddy intertidal environments if protected from predators (Kraus *et al.* 1991). Witbaard *et al.* (1997) showed that laboratory-reared juvenile quahogs were able to grow at temperatures as low as 1°C. Shell growth increased tenfold between 1 and 12°C, however the greatest change in growth rate occurred in the lower temperature range of 1-6°C. Small changes in spring bottom water temperatures may have a large impact on the resulting shell growth (Witbaard *et al*. 1997). Juveniles have been shown to survive temperatures as high as 20°C (Kraus *et al.* 1989, 1992). In the Middle Atlantic Bight, juvenile ocean quahogs are typically found at depths of 45-75 m and at salinities of 32-34 ppt.

ADULTS

Adult ocean quahogs are usually found in dense beds over level bottoms, just below the surface of the sediment which ranges from medium to fine grain sand (Medcof and Caddy 1971; Beal and Kraus 1989; Brey *et al.* 1990; Fogarty 1981; MAFMC 1997). Based on field distributions on both sides of the Atlantic, Golikov and Scarlato (1973) estimated the optimal temperature for ocean quahogs to be 6-16°C. Mann (1989) reported the inshore limit of quahog distribution as the 16°C bottom isotherm in summer months. Merrill *et al.* (1969) reported a lethal temperature of 13-16°C; quahogs held at 21°C died in a few days. Although the species has been found at depths of 14-82 m, most are found at depths of 25 to 61 m (Merrill and Ropes 1969; Serchuk *et al.* 1982) and some have been found as deep as 256 m (Ropes 1978). Ocean quahogs are found at oceanic salinities, but Oeschger and Storey (1993) successfully kept them at 22 ppt in the lab for several weeks.

Ocean quahogs are capable of surviving low dissolved oxygen levels. In both the laboratory and field, quahogs can burrow in the sand and respire anaerobically for up to seven days (Taylor 1976). Declining O_2 tension results in an increased rate of ventilation, reduced O_2 utilization, and heart rate changes (Brand and Taylor 1974; Taylor and Brand 1975). Under anoxic conditions, enzymes are modified to reduce metabolism and energy release (Oeschger 1990; Oeschger and Storey 1993). Quahogs may also undergo self-induced anaerobiosis (Oeschger 1990). Even with the ability to survive hypoxic conditions, ocean quahogs may still experience negative effects of low oxygen levels. During a hypoxic event off New Jersey in 1976, up to 13.3% of ocean quahogs died in the shoreward part of the population. However, quahogs in deeper water were not subjected to hypoxia (Ropes *et al.* 1979).

The environmental stimuli for spawning are unclear. Jones (1981) notes that the initiation of spawning may be coincident with the highest bottom temperature. Mann (1982) suggests that temperature is probably a spawning stimulus, but only in conjunction with other stimuli, such as increases in pH, food availability, and increases in dissolved oxygen. In the laboratory, rapid temperature changes, salinity changes, or sperm suspensions did not induce spawning in ripe individuals (Landers 1976).

GEOGRAPHICAL DISTRIBUTION

The ocean quahog is distributed on the continental shelf from Newfoundland to Cape Hatteras (Weinberg 1995). Greatest concentrations are in offshore waters south of Nantucket to the Delmarva Peninsula (Serchuk *et al.* 1982). The inshore limit of their distribution appears to be defined by the 16°C bottom isotherm in the summer months (Mann 1989). They are found in relatively shallow water in eastern Maine (but never intertidally) and in deeper, more offshore waters south of Cape Cod (MAFMC 1997).

The terms pre-recruit and recruit are used here in describing the distributions of juveniles and adults. These terms refer to the exploited and unexploited portions of the stock. Ocean quahogs are exploited at a minimum shell height of 8 cm; thus, pre-recruits are ≤ 7 cm, and recruits are ≥ 8 cm.

EGGS AND LARVAE

Little is known about the distribution or abundance of ocean quahog eggs and larvae in the field. Mann (1985) noted quahog larvae in southern New England waters in May (1-30 m depth) and from July to November (20-40 m depth). The highest larval concentration was 512 larvae/m^3 in September at a 30 m depth. High larval concentrations were associated with temperatures of 14-18^{o}C. The presence of larvae in May suggests that larvae may survive over the winter. Larval settlement is believed to occur throughout the adult distribution range (Mann 1989).

Eggs and larvae are not enumerated by the Northeast Fisheries Science Center (NEFSC) Marine Resources Monitoring, Assessment and Prediction (MARMAP) program.

JUVENILES AND ADULTS

NEFSC summer ocean quahog surveys [see Reid *et al*. (1999) for details] collected ocean quahogs from Georges Bank to Cape Henry, Virginia (Figure 2). The greatest number of catches was made from Long Island to the Delmarva Peninsula. They occur further offshore south of the Hudson Canyon. The distribution of pre-recruits and recruits appears to be the same. However, pre-recruits are not sampled well by the survey gear. Thus, Figure 2 may not accurately reflect the actual distribution of pre-recruits. The Gulf of Maine was not surveyed; however, quahogs tend to be found in fishable concentrations in relatively nearshore waters of the Gulf (Weinberg 1998).

STATUS OF THE STOCKS

Total commercial ocean quahog landings increased dramatically between 1976 and 1979, from 2,500 metric tons (mt) to 15,800 mt, and rose to more than 20,000 mt by 1985 (Weinberg 1995). Landings have remained high ever since (Figure 3; Weinberg 1995, 1998). Landings in 1996 were 21,600 mt, a 3% decrease from 1995. There was a significant downward trend in catch per unit effort (CPUE) from 1986 to 1994, decreasing from 146 bushels per hour (bph) to 75 bph; CPUE has since increased to 100 bph in 1996 (Figure 3).

The September 1997 report to Congress, ‘Status of Fisheries of the United States’ (National Marine Fisheries Service 1997) states that the ocean quahog is not overfished at the present time, nor is it approaching an overfished condition. However, other reports have stated that the ocean quahog resource is fully exploited in some areas (Weinberg 1995).

RESEARCH NEEDS

- Obtain more accurate estimates of population sizes. Because ocean quahogs may remain deeply burrowed for long periods of time, dredges may miss many clams in assessment studies. Consequently, the true population size is unknown. Consideration should be given to different gear efficiencies in different sediment types, and studies should be extended into deeper water in all regions. Sampling techniques other than hydraulic dredges should be used on an experimental basis.

- Investigate recruitment of individuals to the population (patterns of settlement, early growth, and survival). Field data on the early life history phases of ocean quahogs are lacking. Incorporation of settlement and recruitment rates into population models would yield a more accurate picture of population dynamics.
- Study the effects of total closure (e.g., the ban due to PSP in quahogs from Georges Bank) or reduced fishing disturbance on settlement and recruitment, using regional or within-region differences in fishing intensity.
- More life history (growth, spawning cues) information is needed from the southern part of the range (south of New Jersey) and from deeper waters. Samples from the commercial catch can be used to obtain better estimates of size-specific meat weights and spawning times in different regions. These data can be correlated with real-time environmental data available from satellites, sub-surface observing systems on the continental shelf, and sensors placed on board commercial vessels.
- Determine the genetic structure of the ocean quahog resource over its entire range. Present models and management plans assume that the larval stage is long enough such that all populations are linked, but the marked life history differences in the inshore Maine population suggest that this is not likely over all spatial scales. If spawning times vary on a regional basis, and spawning is spread over a considerable part of the year in some populations, certain populations may act as larval sources at one time of the year and not at others, depending on seasonal changes in hydrographic regimes. Molecular techniques would be extremely useful in determining genetic structure.

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Table 1. Summary of life history and habitat parameters for ocean quahog, *Arctica islandica*.

Life Stage	Size and Growth	Habitat	Substrate	Temperature	Salinity
Larvae [1]	Larval period (hatching to settlement) is 32 days long at 13°C and 55 days at 8.5-10°C. Size at metamorphosis ranges from 175-240 µm.	Larval settlement believed to occur throughout adult distribution range. Larvae present in New England waters in May and July to November.		Larvae abundant at temperatures of 14-18°C.	Found at oceanic salinities.
Juveniles [2]	Metamorphosis occurs at 175-240 µm. Growth is relatively fast during juvenile period: in the field, individuals 9-20 mm long grew 9.5 mm/year; in the lab, individuals 2-5 years old grew 18 mm/year.		Medium to fine grain sand, sandy mud, silty sand.	Capable of surviving laboratory experiments at temperatures of 1-20°C.	Found at oceanic salinities.
Adults [3]	One of the longest-lived bivalves. Maximum age of 225 years. When > 50 mm, growth very slow (< 1 mm/year), or not at all. Growth is negatively correlated with density.	Although capable of surviving in shallower sites, most commercial concentrations found at 25-61 m depth. Occur shallower in Gulf of Maine, and deeper south of Cape Cod.	Medium to fine grain sand, sandy mud, silty sand.	Restricted to cooler waters where temperatures rarely exceed 20°C. Optimal temperature range: 6-16°C. Inshore limit appears to be the 16°C bottom isotherm in summer.	Found at oceanic salinities, but kept successfully in the lab at salinities as low as 22 ppt.
Spawning Adults [4]	Earliest age of maturity is 7 years, but mean is 13.1 years and 49.9 mm for males, and 12.5 years and 49.2 mm for females.		Medium to fine grain sand, sandy mud, silty sand	Spawning may occur when a critical temperature is reached (13.5°C), but other stimuli (DO, pH, food availability) may also be important. Lab studies have shown no effect of temperature on spawning.	Role of salinity as a stimulus for spawning unclear. Changes in salinity did not induce spawning in the lab.

[1] Landers (1972, 1976), Lutz *et al.* (1981, 1982), Mann and Wolf (1983), Mann (1985, 1989)
[2] Murawski *et al.* (1980, 1982), Fogarty (1981), Lutz *et al.* (1982, 1989), Ropes *et al.* (1984a, b), Kraus *et al.* (1989, 1991, 1992), Kennish *et al.* (1994), Witbaard *et al.* (1997)
[3] Merrill and Ropes (1969), Merrill *et al.* (1969), Medcof and Caddy (1971), Golikov and Scarlato (1973), Ropes (1978), Jones (1980), Murawski *et al.* (1980, 1982), Thompson *et al.* (1980a), Fogarty (1981), Ropes and Pyoas (1982), Serchuk *et al.* (1982), Turekian *et al.* (1982), Ropes and Murawski (1983), Ropes *et al.* (1984a, b), Beal and Kraus (1989), Fritz (1989, 1991), Weidman and Jones (1993), Kennish *et al.* (1994), Kennish and Lutz (1995)
[4] Loosanoff (1953), Medcof and Caddy (1971), Landers (1976), Fogarty (1981), Jones (1981), Mann (1982), Beal and Kraus (1989), Rowell *et al.* (1990)

Table 1. cont'd.

Life Stage	Currents	Prey	Predators	Notes
Larvae [1]	Eggs and larvae are planktonic, drifting with currents until larvae metamorphose and settle to bottom.	Phytoplankton		Three larval stages: trochophore, veliger and pediveliger.
Juveniles [2]		Phytoplankton	Predators include rock crabs, sea stars, boring snails and teleost fish (cod, haddock, sculpin, and ocean pout).	Age at first maturity varies from 6 to > 14 years, and may depend on growth rate and locality.
Adults [3]		Suspension feeders on phytoplankton. Pump water using their siphons.	Predators include rock crabs, sea stars, boring snails and teleost fish (cod and haddock).	Occur in dense beds over level bottoms. Capable of surviving low oxygen levels; can burrow into the substrate and respire anaerobically for up to a week. Critical O_2 tension 5-7 kPa.
Spawning Adults [4]				Extended spawning period, from May through December, with several peaks during this time. Multiple spawnings likely.

[1] Mann (1985)
[2] Clarke (1954), Thompson *et al.* (1980b), Lutz *et al*. (1982), Kraus *et al*. (1989, 1991, 1992), Rowell *et al*. (1990), Kennish *et al*. (1994), Witbaard (1997)
[3] Clarke (1954), Winter (1969, 1970), Medcof and Caddy (1971), Ropes *et al.* (1979), Stehlik (1993)
[4] Loosanoff (1953), Landers (1976), Jones (1981), Mann (1982, 1985), Rowell *et al.* (1990), Fritz (1991)

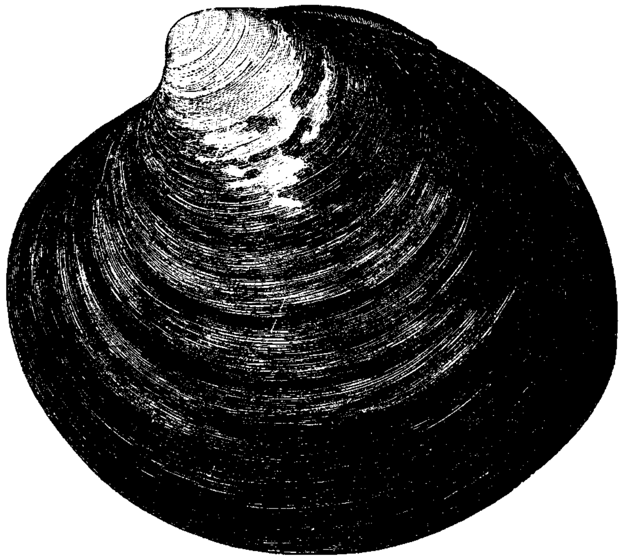

Figure 1. The ocean quahog, *Arctica islandica* (from Goode 1884).

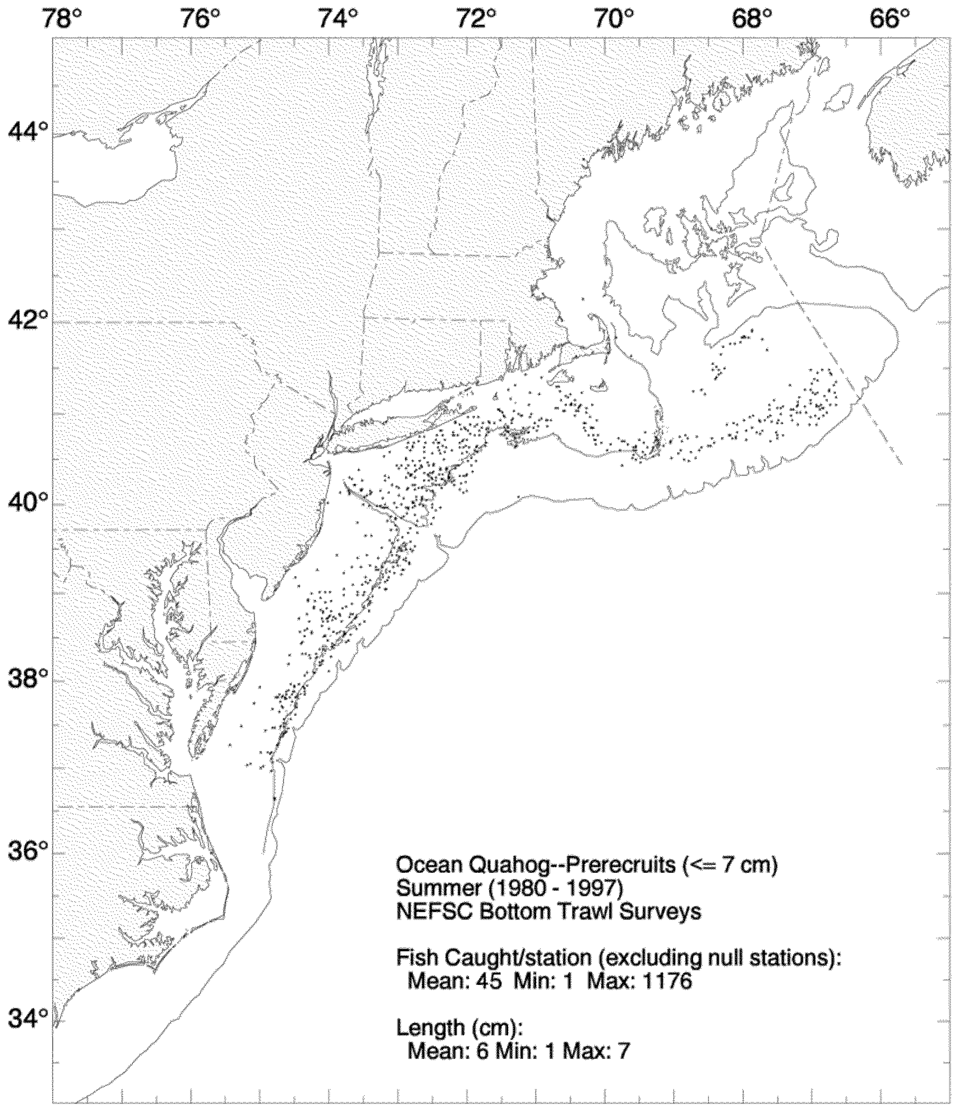

Figure 2. Distribution of ocean quahog pre-recruits (≤ 7 cm) and recruits (≥ 8 cm) collected during NEFSC summer ocean quahog surveys [see Reid *et al.* (1999) for details]. Black dots represent stations where ocean quahogs were taken. The Gulf of Maine was not surveyed.

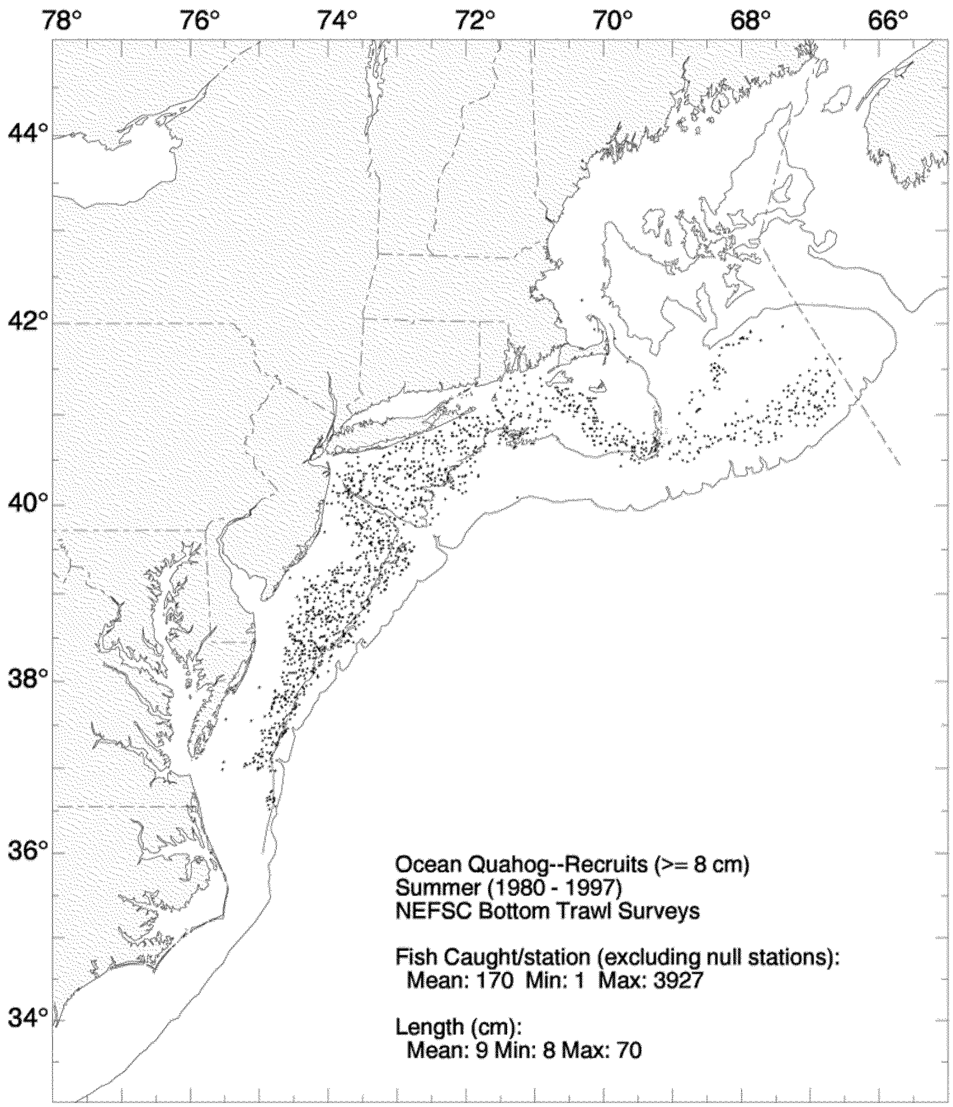

Figure 2. cont'd.

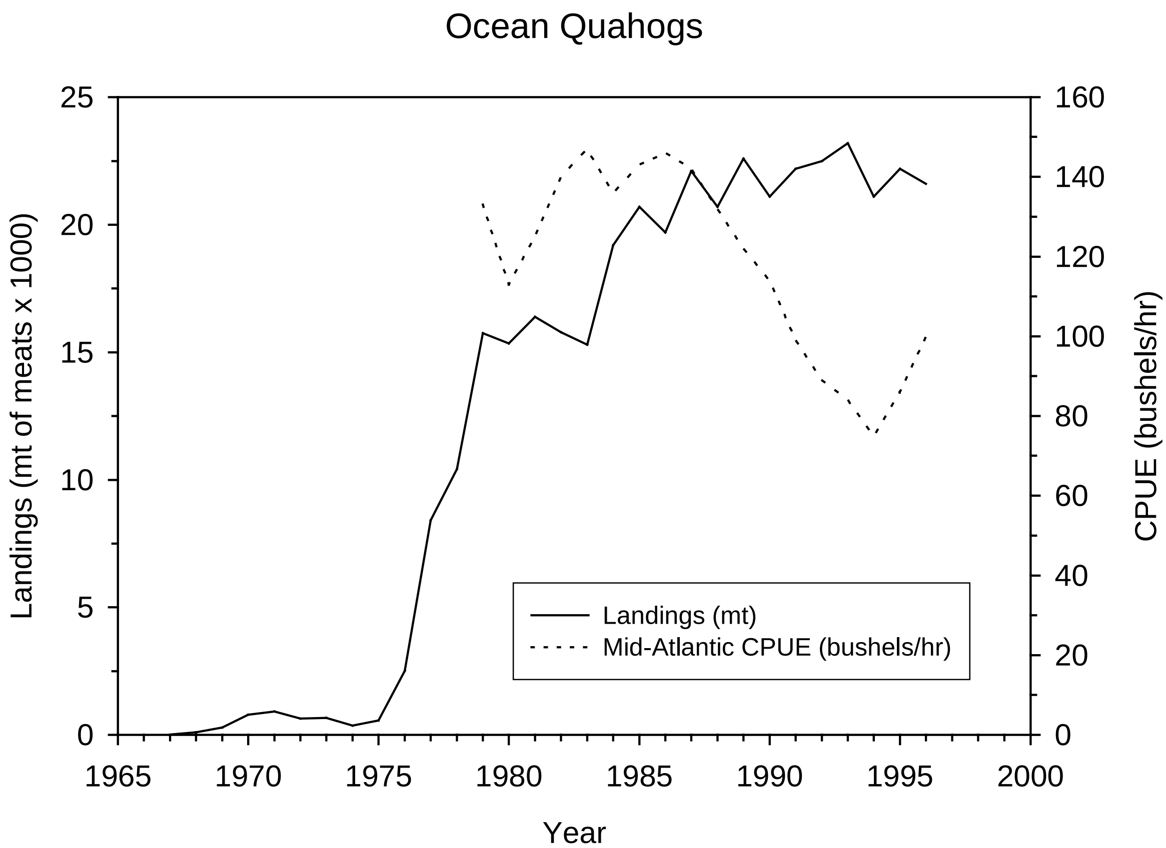

Figure 3. Commercial landings and survey indices for ocean quahog in the Mid-Atlantic region.

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