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Atlantic Menhaden (*Brevoortia tyrannus*) Species Profile 38 pp

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Narragansett Bay Estuary Project

ATLANTIC MENHADEN (Brevoortia tyrannus) SPECIES PROFILE

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FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984 , and the Narragansett Bay Project (NBP) was established in 1985. Narragansett Bay was designated an "estuary of national significance" in 1988. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a program of research and planning focussed on managing Narragansett Bay and its resources for future generations.

The NBP will develop a draft Comprehensive Conservation and Management Plan (CCMP) by December, 1991, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

- management of fisheries
- nutrients and potential for eutrophication
- impacts of toxic contaminants
- health and abundance of living resources
- health risk to consumers of contaminated seafood
- land-based impacts on water quality
- recreational uses

The NBP is taking an ecosystem/watershed approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among federal, state and local agencies, as well as with academic researchers, in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. Funding was provided by the State of Rhode Island as part of Cooperative Agreement #CX812768 with the United States Environmental Protection Agency with an additional award provided by the National Marine Fisheries Service. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication as a technical report by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP. Final recommendations for management actions will be based upon the results of this and other investigations.

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EXECUTIVE SUMMARY

This Atlantic menhaden profile is the fourth document in a series intended to provide background necessary for the management of important finfish species in Rhode Island waters.

This review of the biology of Atlantic menhaden, Brevoortia tyrannus, includes nomenclature, taxonomy, stock description, range, abundance in Rhode Island waters, life history, habitat requirements, migration and movements. Also included is information on reproduction, growth and development, food and feeding, predators, competitors, disease and parasites. In addition to the commercial and recreational value of the fishery a summary of Rhode Island regulations is also included.

Atlantic menhaden were harvested by the early settlers in the 1600's for use as fertilizer and by the 1800's an industry was first developed for Atlantic menhaden to obtain oil. Ninety-six percent of the catch is sold to fertilizer, livestock, and cosmetic interests in fish meal, soluble proteins and oils, with the remainder used in pet foods and fish bait.

The 1950's marked a period with above average recruitment with the largest documented year in 1958. Atlantic menhaden stocks declined through the 1960's due to poor recruitment and truncation of the stock's age structure. Recruitment did not return to the 1950's levels until mid-to late 1970's and has shown signs of expanding again since 1980. Coastwide management plans are cooperatively formulated under the auspices of the Atlantic States Marine Fisheries Commission which is currently writing a plan for the 1990's.

The Atlantic menhaden is a schooling, plankton feeding clupeid that makes extensive seasonal migrations, moving north during spring and south during fall. Spawning of Atlantic menhaden occurs chiefly at sea, and closer to shore in the northern parts of its range. Larval Atlantic menhaden are transported by oceanic currents into estuaries where they metamorphose into juveniles. Schools of juvenile Atlantic menhaden move out of the estuary into the sea in the fall, where they will remain the rest of their lives. Schooling by size is an outstanding behavioral characteristic displayed by Atlantic menhaden that seems innate from late larval stage to old age.

Species Profile: Atlantic Menhaden
Brevoortia tyrannus

Common Name: Atlantic Menhaden
Scientific Name: *Brevoortia tyrannus*
Author: Latrobe 1802

Other Common Names: Pogy, mossbunker, fat back (Bigelow and Schroeder 1953); alose tyran (Scott and Scott 1988); bunker, shad and bugmouth (Rogers and Van Den Avyle 1983).

Classification:

Phylum:	Chordata
Subphylum:	Vertebrata
Class:	Osteichthyes
Order:	Clupeiformes
Family:	Clupeidae
Genus:	*Brevoortia*
Species:	*tyrannus*

VALUE

Commercial:

Historical accounts of the Atlantic menhaden *Brevoortia tyrannus*, fishery from its inception in the early 1800's until 1930's were given by Goode (1879), Goode and Clark (1887), Greer (1915) and Harrison (1931). Reviews of the fishery by June (1961), Henry (1965), Reintjes (1969), Nicholson (1971, 1971a), Frye (1978) and Smith et al. (1987) have described the changes that have affected the fishery in the past decades. Atlantic menhaden were harvested by the early settlers in the 1600's for use as fertilizer (Frye 1978). By the 1800's an industry was first developed for Atlantic menhaden to obtain oil (Goode 1879; Goode and Clark 1887; Frye 1978). Ninety-six percent(%) of the catch is sold to fertilizer, livestock, and cosmetic interests in fish meal, soluble proteins and oils, with the remainder used as pet food products and fish bait (Rogers and Van Den Avyle 1983).

The majority of landings are from purse seines (Figure 1). The fishery which began in the late 19th century by sailing ships, which were replaced by steam ships, which in turn were replaced with gasoline and diesel engines (Nicholson 1971b). After World War II increased demand for fish meal and oil initiated changes in the industry, by increasing the number and sizes of vessels, changed fishing methods, expanded processing facilities and increased processing efficiency.

In 1946 airplanes were introduced as a successful means of locating concentrations of fish, and remains an integral part of fishing operations (Nicholson 1971b). The first significant advance in fishing technology was the installation of fish pumps in 1946. Pumping fish directly from the purse seine to the hold replaced the time-consuming method of brailing and left more time for scouting and making additional sets (Nicholson 1971b). Plants that process Atlantic menhaden products currently operate from North Carolina to New Brunswick (Vaughan 1990).

Historically, the Atlantic menhaden fishery has generally been conducted during two seasons: a summer and fall fishery from Maine to North Carolina and an intensive fall and winter fishery off North Carolina between Cape Fear and Virginia state line (Smith et al. 1987). Currently most of the commercial catch comes from the territorial sea and estuarine waters from eastern Long Island to northern South Carolina (ASMFC 1981).

The fishery for Atlantic menhaden in the South Atlantic Bight (SAB), exploits fish of ages I-VIII, with fish of ages I-II accounting for 85% to 99% of the total catch and fish greater than age 4 being rare (June 1961; Nicholson 1975; Smith et al. 1987). In the 1970's, age composition of Atlantic menhaden in the Chesapeake Bay area shifted from age I towards a greater percentage of Age II fish (Smith et al. 1987). The purse seine fishery for Atlantic menhaden in the North Atlantic area is comprised almost exclusively of age II and older fish, with ages II and III predominating (Smith et al. 1987). The only exception is the North Carolina fall fishery, which apparently harvests a reasonably well-mixed migratory population (Ahrenholz et al. 1987).

The 1950's marked a period with above average recruitment, accentuated with large year classes in 1951, 1953, 1955 and 1956 and finally the largest documented year class of 1958 (Ahrenholz et al. 1987a). Atlantic menhaden stocks declined through the 1960's when fish became scarce in the northern half of their range due to poor recruitment and truncation of the stock's age structure (Smith et al. 1987). Recruitment did not return to the levels reached in the 1950's until the mid-to late 1970's and has shown signs of expanding again since 1980 (Ahrenholz et al. 1987a; Smith et al 1987; Vaughan and Smith 1988). To the extent that recruitment does depend on the spawning stock, this dependency has rested primarily on late age-2 spawners since the late 1960's, so large fluctuations in year-to-year availability and catches are to be expected. To increase yield and enhance the stability of the resource, it is desirable that the number of age classes contributing to the fishery be increased. It is suggested that increasing the number of older (Age-3+) spawners would aid in guarding against a possible stock collapse, brought on by heavy fishing during a period of poor recruitment (Vaughan and Smith 1988).

Coastwide management plans are cooperatively formulated under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC), but the implementation requires separate legislative or regulatory action by each member state. Individual states are not obligated to act upon cooperatively derived plans or management actions from the ASMFC (Ahrenholz et al. 1987a). ASMFC currently is rewriting a management plan for the 1990's (Sisson 1991; pers. comm.).

Catch statistics for Atlantic menhaden became confidential in Rhode Island after 1976, due to the limited number of participants in the fishery (Valliere 1991; pers. comm.). Historical catches of Atlantic menhaden in New England (Maine, New Hampshire; Massachusetts, Rhode Island and Connecticut) are combined as total numbers in Figure 2.

Recreational:

In terms of total numbers of sportfish caught in Rhode Island waters, Atlantic menhaden ranked twelfth in 1986, eleventh in 1987 and 1988 and twenty first in 1989 (Karlsson 1990). No recreational fishery is dedicated to the harvest of Atlantic menhaden (NOAA 1990). Atlantic menhaden is widely used as bait (alive/dead), either thrown back alive or dead, or given away when caught incidentally with other species (Karlsson 1990).

STOCK DESCRIPTION

Recoveries of tagged fish confirm that Atlantic menhaden compose a single stock, that intermixes during the winter in ocean waters south of Cape Hatteras, North Carolina (Nicholson 1978). Atlantic menhaden stratify along the coast by age and size during late spring and summer (Nicholson 1978) with their age and size increasing from south to north (Nicholson 1971a).

RANGE

Overall:

Atlantic menhaden occur in coastal and inland tidal waters and are distributed along the Atlantic coast of North America from the Gulf of St. Lawrence (ROM 30439) to northern Florida (Bigelow and Schroeder 1953; Reintjes 1969; Scott and Scott 1988).

Within Narragansett Bay:

Atlantic menhaden utilize Narragansett Bay and its tributaries (Lynch 1991; pers. comm.), Mt. Hope Bay and its tributaries (Marine Research Inc.(MRI) 1990). They also can also be found in Little Narragansett Bay and the Pawcatuck River (Sisson 1990), coastal ponds (Stolgitis et al. 1976; Satchwill and Sisson 1990a,1990b), and throughout the state's territorial waters; all serve as nursery areas for eggs, larvae and juvenile Atlantic menhaden. Adult menhaden also utilize these same waters as they migrate along the coast.

ABUNDANCE IN RHODE ISLAND WATERS

Herman (1963) found that Atlantic menhaden appeared to have a split spawning season in Narragansett Bay, with eggs and larvae taken May through August and again in late October, concluding that the fall spawning period was the most productive. Bourne and Govoni (1988) noted that Herman's fall catch was due to the abundant fall spawning of Atlantic menhaden that took place in 1958 but not in 1972.

Fish egg and larval populations in Mt. Hope Bay have been sampled since 1972 by Marine Research, Inc. (MRI 1991). Following 1975 when Atlantic menhaden ceased to be a dominant contributor to the Mt. Hope Bay ichthyoplankton community, bay anchovies have typically been numerically dominant among both eggs and larvae (MRI 1991). Durbin and Durbin (1988) found that from the data collected by MRI, that the most dramatic change in the larval population since 1972 has been a precipitous decline in the abundance of the Atlantic menhaden and its replacement by anchovies, predominantly the bay anchovy Anchoa mitchilli, as the dominant species in Mt. Hope Bay.

Seasonal abundance and distribution of juvenile Atlantic menhaden in Narragansett Bay, has been monitored by the R.I. Division of Fish and Wildlife annually since 1986 at 15 stations (Figure 3). They were found each year at 12 of the 15 stations (Powell 1991; pers. comm.) with the three stations excluded being 8, 9, and 12.

Atlantic menhaden are usually present in Narragansett Bay, R.I., from April to November, with peak abundance from June to mid-September (Durbin et al. 1983). The Rhode Island Coastal Fishery Resource Assessment program, has annually collected Atlantic menhaden from Narragansett Bay, Rhode Island Sound and Block Island Sound (Lynch 1991; pers. comm.).

LIFE HISTORY

The Atlantic menhaden, is a schooling, plankton-feeding clupeid (Durbin et al. 1983) that makes extensive seasonal migrations, moving north during spring and south during fall (Nicholson 1971a, 1972, 1978).

Spawning of Atlantic menhaden occurs chiefly at sea, and closer to shore in the northern part of its range (Jones et al. 1978). Atlantic menhaden spawn every month, although most spawning appears to be during the fall and winter (ASMFC 1981).

Larvae of Atlantic menhaden are transported by oceanic currents into the estuaries along the coast at an age of one to two months where they metamorphose into juveniles (Reintjes 1969; Wilkens and Lewis 1971; Kendall and Reintjes 1975; Nelson et al. 1977) and undergo extensive changes in their feeding and digestive structures (June and Carlson 1971). Larvae move toward low-salinity(1 ^{o}/oo to freshwater) areas upon entering estuaries, and prejuveniles are dependent on low-salinity marsh habitats and river shoals for nurseries (Pacheco and Grant 1965). One explanation of why low-salinity water is important to young menhaden, is that they cannot metamorphosis properly in either freshwater or high-salinity water (Wilkens and Lewis 1971). After menhaden have transformed from prejuveniles to juveniles, they appear to seek higher salinity water (Wilkens and Lewis 1971).

Schools of juvenile menhaden move out of the estuary into the sea in the fall. Schooling by size is an outstanding behavioral characteristic displayed by Atlantic menhaden that seems innate from late larval stage to old age (Reintjes 1969).

HABITAT REQUIREMENTS

Type/Substrate:

Eggs and larvae:

Atlantic menhaden spawn pelagic eggs over Continental Shelf waters and in bays and estuaries in the northern part of its range during a northward spring and southward fall-winter migration (Reintjes 1961,1969; Higham and Nicholson 1964; Kendall and Reintjes 1975).

Larval Atlantic menhaden utilize estuaries and are most abundant in surface strata (Massmann et al. 1954; June and Chamberlin 1959; Lewis and Mann 1971; Rogers et al. 1984).

Juveniles:

Juvenile menhaden utilize rich inshore coastal waters and estuaries as nursery areas for more than half of their first year before returning to the sea (Reintjes and Pacheco 1966).

Adults:

Adult menhaden occupy bays, sounds and estuaries from oceanic salinities to the upper most limits of brackish water (ASMFC 1981). According to Nicholson (1978) Atlantic menhaden range from coastal waters of northern Florida to the Gulf of Maine and occur mainly within 15 miles of the coast and in larger bays and sounds.

Temperature/Salinity:

Eggs/larvae:

Atlantic menhaden eggs were found in temperatures ranging from 10.0°C - 25°C (50°F-77°F) (Herman 1963; Walford and Wicklund 1968;Kendall and Reintjes 1975; Ferraro 1980a). Kendall and Reintjes (1975) reported Atlantic menhaden eggs in salinities of 28.0 ^{o}/oo - 32.0 ^{o}/oo. Salinity between 10-30 ^{o}/oo had no noticeable effect on embryonic development rate, while the low lethal temperature of embryos is about 7°C (44.6°F) (Ferraro 1980b).

Atlantic menhaden larvae occur over a wide range of temperature, from 0°C-25°C (32°F-77°F) (Kendall and Reintjes 1975), although most were taken in temperatures between 15°C (59°F) - 20°C (68°F). Several were taken in waters cooler than 3°C (37.4°F) a limit found to be lethal by Lewis (1966). Powell and Phonlor (1986) found in laboratory tests, that temperature was not a determinant of size at hatching, size at first feeding, and yolk volume remaining at first feeding. They did find that temperature had an effect on the rate of yolk utilization, the time between hatching and exogenous feeding and the ability of the larvae to withstand the deprivation of food.

Larval Atlantic menhaden are subjected to large variations in salinity ranging from 0 °/oo to 36 °/oo (Lewis 1966; Reintjes and Pacheco 1966; Reintjes 1969; Kendall and Reintjes 1975). Lewis (1966) reported that larval Atlantic menhaden have the best chance of survival if the temperature does not drop below 4°C (39.2°F) and salinity remains between 10-20 °/oo .

Juveniles:

Juvenile Atlantic menhaden have been reported in water temperatures from 4°C (39.2°F) - 29.8°C (85.6°F) and salinities of 4-33 °/oo (Epperly 1989;Sisson 1990;Satchwill and Sisson 1990 a,b). Juvenile Atlantic menhaden can tolerate salinities ≤1 - 36 °/oo (Reintjes 1969).

The response of juvenile Atlantic menhaden when exposed to a temperature decrease from 15°C (59°F) to 5°C (41°F), was disorientation and loss of equilibrium as the temperature approached 5°C followed by primary chill coma and death (Burton et al. 1979).

In laboratory tests of salinity tolerance, juvenile Atlantic menhaden survived transfers from high (29-30 °/oo) to low (5 °/oo) salinity and low (5 °/oo) to high salinity (26-28 °/oo) in less than 2 hours (Hettler 1976). Hettler (1976) found that when salinity decreased, respiration increased and when returned to high salinity, and the original metabolic rate, the process of adapting to changing salinities is rapid and reversible. Atlantic menhaden in the low-salinity group grew faster, and were more active than those in the high-salinity group (Hettler 1976).

A mean lethal dissolved oxygen concentration of 0.4 mg/l (milligrams/liter) was found for juvenile Atlantic menhaden that depleted their own oxygen from originally air-saturated water in sealed chambers by Thorton (1975).

Adults:

Adult Atlantic menhaden have been reported in water temperatures of 4°C - 25°C (39.2°F-77°F) Satchwill and Sisson 1990a,b). Reintjes (1969) found that adult Atlantic menhaden preferred water temperatures of 15-21°C (59°F-69.8°F). Adult Atlantic menhaden can tolerate salinities ≤1 - 36 °/oo (Reintjes 1969).

MIGRATION AND MOVEMENTS

Ocean currents carry larval menhaden to inlets and estuaries, where they move through an inlet on flood tide into the lower estuary where tidal currents sweep them back and forth in an area rich in plankton (Lewis and Mann 1971). Larval menhaden, after entry into the lower estuary, they seek to hold a favorable position until they are large enough to move upstream into lower salinities to metamorphose (Lewis and Mann 1971; Wilkens and Lewis 1971). After the menhaden have transformed from prejuveniles to juveniles, they appear to seek higher salinity water. Schools of juvenile menhaden generally move out of the estuary in the fall (Wilkens and Lewis 1971) where they move into the open sea, or into large bays where they remain the rest of their adult lives (Nicholson 1972).

From about May to October, Atlantic menhaden age-1 or older are stratified by age and size along the coast. Generally, the youngest and smallest fish are found in the more southern areas while the oldest and largest are found in the more northern areas (Figure 4) (Nicholson 1972,1978; ASMFC 1981). A north-south gradient in size and age becomes established, with the average size and age of individuals increasing with latitude (June and Reintjes 1959; McHugh et al. 1959; Nicholson 1971a,1978).

Atlantic menhaden south of Cape Lookout, N.C., generally do not continue to move northward but menhaden from Chesapeake Bay northward continue a slow northward shift throughout most of the summer. Those north of Cape Cod, Ma. begin a slow southward movement in September. By November nearly all the fish northward from Chesapeake Bay are moving southward to the offshore waters south of Cape Hatteras (Nicholson 1971a).

South of Chesapeake Bay, from about Daytona Beach, Florida to Cape Lookout, N.C. most fish are age 1 and 2 (Nicholson 1971a). Most fish landed at New Jersey plants were age 2 and 3 and fish landed at plants in New York and New England are mostly age 3 or older (Nicholson 1971a; Nicholson 1978). Fish age 4 and older accounted for 100% of the samples north of Cape Cod (Nicholson 1971a).

REPRODUCTION

Mode:

Atlantic menhaden are heterosexual and oviparous with broadcast fertilization (Jones et al. 1978).

Spawning Factors:

Spawning occurs principally at sea in shelf waters and in the larger bays and sounds from May to October in the northern part of its range and from October to April in the southern part of its range (Figure 5) (Bigelow and Schroeder 1953; Mansueti and Hardy 1967; Reintjes 1969; NMFS 1973). Spawning apparently continues in winter in the south, based on catches of eggs/larvae around Cape Lookout (Kendall and

Reintjes 1975). Atlantic menhaden spawn primarily in the evening or at night (Ferraro 1980a).

Surface temperatures in the spawning areas of Atlantic menhaden during the months of highest egg capture range between 10°C (50°F) and 20°C (68°F) (Walford and Wicklund 1968; Kendall and Reintjes 1975; Ferraro 1980a).

Reproductive Capacity:

Higham and Nicholson (1964) found that the number of ova per female increased with fish length and individual estimates ranged from 38,000 to 631,000 ova. Simultaneous maturation of two groups of ova within the ovaries suggests that an individual female may spawn more than one group of ova during a single season, however no conclusions were reached in determination of the fate of the secondary group (Higham and Nicholson 1964). June (1961) estimated fecundity at 40,000 to 700,000 ova/fish, also depending on size of the fish.

Dietrich (1979) applied a logarithmic model to describe the curvilinear relation between fecundity and length as compared to Higham and Nicholson (1964). Estimated fecundities when compared were in reasonable agreement for fish up to 275 mm (10.8 in), but diverged for large fish (Dietrich 1979). For 350 mm (13.7 in) fish the model fitted to Higham and Nicholson (1964) data predicted about 1.75 as many ova as the model fitted to Dietrich (1979).

Several aspects of Atlantic menhaden fecundity and spawning behavior were reexamined by Lewis et al. (1987) to determine if any changes had occurred and to provide a supportive base for subsequent studies on the recruitment process. These investigators made comparisons with the data collected by Higham and Nicholson (1964) and by Dietrich (1979). For valid comparisons to be made, these investigators used the same methodology employed in the earlier investigations. The investigators were unable to detect any marked changes in the reproductive biology of Atlantic menhaden. However, data from all studies were combined and equally weighted to generate a representative predictive equation for the potential number of ova spawned as a function of length:

$$E=2563e^{0.0150L}$$

Where: E=predicted number of ova L=fork length

Rhode Island Spawning Season/Location:

Atlantic menhaden appear to have a split spawning season in Narragansett Bay, with eggs present from May-August and again in late October and larvae present June-July and October-February (Herman 1963). In Mt. Hope Bay Atlantic menhaden eggs are present April-July and larvae from May-November (MRI 1990).

GROWTH AND DEVELOPMENT

Egg:

Eggs of Atlantic menhaden are spherical, with diameters ranging from 1.3-2.0 mm, they are also pelagic, highly buoyant and transparent (Bigelow and Schroeder 1953; Lippson and Moran 1974; Jones et al. 1978; Hettler 1984; Powell and Phonlor 1986). The yolk, 0.9-1.4 mm, is light yellow and faintly segmented (Reintjes 1969; Jones et al. 1978). The oil globule ranges from .11-.23 mm and has no pigment spots (Reintjes 1969; Jones et al. 1978; Hettler 1984). Perivitelline space is nearly half of the egg diameter in larger eggs (Reintjes 1969).

Embryonic Stages:

Jones et al. (1978) provided the following description of egg development (Figure 6): Embryonic axis is formed before closure of blastophore. At the 22-24 somite stage the tail is attached, with Kupffer's vesicle being distinct, blastophore closed, otoliths present and the eyes begin to form. The advanced embryo has an elongate slender dorsa-lateral chromatophores from snout to tip of tail. Just prior to hatching the anus is 9/10 the distance from head to tip of tail. Incubation time ranges between 42-74 hours at 11.5°-20°C (59-68°F) (Hettler 1976; Jones et al. 1978; Hettler 1984).

Larval Development:

Yolk sac length at hatching varies from 2.4-4.5 mm (.09-.17 in) Total Length (TL) (Figure 7) (Reintjes 1969;Jones et al. 1978; Lippson and Moran 1974). Kuntz and Radcliffe (1917) reported that newly hatched larvae appear primitive--without fins, a functional mouth or pigmentation. Yolk-sac larvae are typical of other herrings, but with a single oil globule (Lippson and Moran 1974). Yolk mass is large and ovoid with the head deflecting over and attached to the yolk (Jones et al. 1978). Newly hatched larvae have 10 protruding neuromasts along each side, forming the lateral line (Reintjes and Hettler 1967). At 2 mm (.07 in.) TL the swim- bladder-acoustico-lateralis system is fully functional (Hoss and Blaxter 1982). At 4.5 mm (.17 in) the head deflection is reduced, yolk sac is half absorbed, the anus is 1/5 TL from snout tip to tail and additional pigment on the ventral aspect of body posterior to the yolk (Jones et al. 1978).

Proportions of head and body parts of Atlantic menhaden, expressed as a percent of Standard Length (SL) are listed in Table 1. Meristics of Atlantic menhaden are compared with gulf menhaden in Table 2. Atlantic menhaden larvae 6-16 mm (.23-.74 in) SL had a mean of 47.2 myomeres, with two more predorsal myomeres and one more postanal myomere than Gulf menhaden (Hettler 1984). The gas bladder becomes evident at 11.0 mm (.43 in), conspicuously bulged in some specimens (Jones et al. 1978). Dorsal, anal, and caudal fins begin differentiating at 8.3 mm (.33 in) and at 16 mm (.63 in) the caudal fin is forked (Mansueti and Hardy 1967). Minute teeth appear on the margin of the maxillary at sizes above 20 mm (.78 in) (Jones et al. 1978).

Appearance of the scales marks the first apparent feature of metamorphosis from larval to juvenile (June and Roithmayr 1960). Given the heterogeneity in distribution of pelagic planktors and the inability of many clupeiform fishes to cope with low food concentrations, menhaden likely have a critical period of larval survival (Rogers and Van Den Avyle 1983).

Prejuvenile Development:

Prejuvenile development is considered by Lewis et al. (1972) to include Atlantic menhaden from 30-38 mm TL (1.2-1.5 in). Mansueti and Hardy (1967) considered prejuveniles to range from 23.0-35 mm TL (.91-1.4 in). In this prejuvenile stage there is a rapid increase in body depth, but little increase in length (Figure 8) (Lewis et al. 1972). Up to 35 mm (1.4 in) the ventral aspect of the chest and abdomen rounded and slightly flattened, with the greatest depth contained 13 times in TL (Mansueti and Hardy 1967). At 35 mm prejuveniles form a definite lateral band of dark pigment spots (Mansueti and Hardy 1967). At 41 mm the shoulder spot begins to form and is complete at 75 mm (Kuntz and Radcliffe 1917) and followed with additional spots by 150 mm.

Juvenile Development:

Juvenile Atlantic menhaden have been reported at sizes ranging from 25-38 mm (Mansueti and Hardy 1967; Lewis et al. 1972; Lippson and Moran 1974). There are 2-4 myomeres between the end of dorsal base and origin of anal base (Lippson and Moran 1974). Few tongue teeth (0-4) and slight tongue pigmentation are present in the 33-48 mm TL size range (Lippson and Moran 1974). The number of gill rakers increases with the growth of the fish: 40-67 at 33-48 mm TL; 60 at 60 mm; 100 at 100 mm; 135-145 at 140-170 mm SL (Jones et al. 1978).

The following descriptions are from Mansueti and Hardy (1967) with lengths given in TL. Ventral scutes are present in some 30 mm fish. Scales are present at 33 mm and scale edges are irregular at 60 mm, with blunt serrae at 100 mm. Scalation is about complete at 40-45 mm, but modified predorsal scales are not formed until around 125 mm TL and the axillary scales of the pectoral are somewhat developed at 50 mm. At 41 mm the eye is proportionally larger than in adults. Striations appear on the upper plate of the gill cover by 40-45 mm. At 33 mm the back is pigmented, a distinct dark lateral line is present and melanophores are present on the dorsal and caudal rays. At 30-35 mm a silvery lateral band is developed, then blending in with a silvery abdomen at 40-45 mm. At 41 mm a shoulder spot begins to form, with completion at 75 mm, followed by additional spots up to 150 mm.

Adult Development:

Higham and Nicholson (1964) determined that some Atlantic menhaden are sexually mature at age one, and these ranged in size from approximately 180-280 mm (18.0-28.0 cm). They also found that most females by age two (195-320 mm) and all females of age three (over 300 mm) and older were mature. According to Ahrenholz et al. (1987a) estimates of the number of fish age 2.75 and greater alive at the beginning of the fourth quarter of any given year n comprise the parental spawning stock for year class n + 1.

Bureau of Commercial Fisheries (BCF) personnel determined age of more than 116,00 Atlantic menhaden and found that 6 and 7 year old fish occurred frequently, 8, 9, and 10 year olds were uncommon and identified only one 12 year old fish (Reintjes 1969).

In adults the number of gill rakers on the lower limb of the first arch are 150-160 (Lippson and Moran 1974). Vertebrae range from 45-50 and ventral scutes range from 28-37 (Lippson and Moran 1974). The first calculations of instantaneous growth rates in fork length and wet weight, as measured from scale annuli of individual fish from Narragansett Bay during 1976 were reported by Durbin et al. (1983) as follows:

AGE	FORK LENGTH	WET WEIGHT
1	233 mm	238 grams (g)
2	233 ± 1.5 mm	241 ± 1.5 g
3	238 ± 1.4 mm	260 ± 3.6 g
4	249 ± 3.7 mm	303 ± 14.4 g
5	272 ± 10.3 mm	384 ± 39.7 g
6	274 ± 1.2 mm	407 ± 1.6 g

These investigators found that the growth rates of age 2 and age 3 Atlantic menhaden in 1976 were considerably greater than the respective average growth rates estimated for previous years, suggesting significant differences in age-specific growth rates of Atlantic menhaden in different regions and different years.

FOOD AND FEEDING

Atlantic menhaden larvae are selective carnivores and voracious feeders (June and Carlson 1971) that begin to feed on individual zooplankters (Reintjes and Pacheco 1966) four days after hatching. Prey items for larval Atlantic menhaden have been reported as copepods, copepodites with selective predation on the larger estuarine zooplankters (June and Carlson 1971; Kjelson et al. 1975).

The diet of juvenile Atlantic menhaden shifts from copepods to diatoms and flagellates (June and Carlson 1971). Diatom genera identified were, *Pleurosigma*, *Navicula*, *Nitzschia*, *Cyclotella*, *Melosira*, *Amphora*, *Gyrosigma* and *Surirella*. Flagellates in the diet included *Peridinium*, *Gymnodinium* and *Polykrikos* (June and Carlson 1971). Lewis and Peters (1984) found that the stomach contents of juvenile Atlantic menhaden consisted of vascular plant detritus(Cellulose major constituent) and aggregates of unidentified origin, bacteria, zooplankton, meiofauna and algae. Juvenile Atlantic menhaden abundance was positively correlated with abundance of microflagellates, chlorophyll a, and to a limited extent dinoflagellates and cyanobacteria which were generally greater than 3 µm in length (Friedland et al. 1989).

Adult Atlantic menhaden feed solely by filtration, with the rate of particle filtration of specific size and shape a function of the mouth area, the swimming speed of the fish, food particle concentration and the mechanical efficiency of the gill rakers (Durbin and Durbin 1975). Adult Atlantic menhaden's minimum-size threshold for filtration of particles is around 15 µm with the consequence that a substantial portion of the phytoplankton will be unavailable to them (Durbin and Durbin 1975).

PREDATORS

Predators of Atlantic menhaden eggs include chaetognaths, fish larvae, mollusks and salps (Vaughan 1977). Both yolk-sac and first feeding larva Atlantic menhaden were consumed by the copepod Anomalocera ornata (Turner et al. 1985). The copepod, Centropages typicus ingested Atlantic menhaden yolk-sac larvae, but not first feeding larvae (Turner et al. 1985).

All large carnivorous sea mammals, fishes and sea birds are potential predators of menhaden (Reintjes 1969). Goode (1879) listed the following as predators of Atlantic menhaden: whales, dolphins, porpoises, sharks, pollock (Pollacius virens), whiting (Merlucius bilinearis), striped bass (Morone saxatilis), weakfish (Cynoscion regalis), spotted sea trout (Cynoscion nebulosus), tarpon (Megalops atlanticus), swordfish (Xiphias gladius), bonito (Sarda sarda) and bluefish (Pomatomus saltatrix) which was singled out as the principal natural enemy of menhaden. Blackfin tuna (Thunnus atlanticus) (Dragovich 1969), roughtail stingray (Dasyatis centroura) (Mansueti 1960), spiny dogfish (Squalus acanthias) (Bearden 1965) and the largemouth bass (Micropterus salmoides) (Tebo and McCoy 1964).

COMPETITORS

According to Reintjes (1969) the most apparent competitors for food and space with Atlantic menhaden are the herrings, anchovies, mullets, oysters, mussels, barnacles and tube worms.

DISEASE/PARASITES

Parasites of juvenile Atlantic menhaden include trematodes, copepods, isopods (Vaughan 1977). Atlantic menhaden is host to numerous parasites, and these are summarized in Table 3. Infectious pancreatic necrosis (IPN) virus has been identified as the probable cause of "spinning disease" and associated mortalities of Atlantic menhaden (Newman 1980; Stephens et al. 1980).

Gas bubble disease was implicated as the cause of a mass mortality of Atlantic menhaden, that occurred in the discharge plume and channel area of the Boston Edison Company's Pilgrim Nuclear Power Station Unit 1 during 08 APRIL-24 APRIL 1973 (Marcello and Fairbanks 1976). Most fish kills in Rhode Island occur in schools of menhaden, which by their shear volume have the ability to carry oxygen depletion beyond the normal levels of oxygen consumption (Sisson and Satchwill 1991;pers. comm.).

Juvenile Atlantic menhaden were among fish that were killed by chlorine biocide and heated water near the effluent plume of the Canal Electric Company plant, MA. (Fairbanks et al. 1971). Wastler (1968) reported a large Atlantic menhaden kill caused by organophosphorous compound discharged by a chemical manufacturing plant in Charleston, S.C..

Cahn et al. (1973) found that Atlantic menhaden concentrate chlorinated hydrocarbons such as dieldrin, at levels of 675 parts/10^6 were found following exposure to 5-30 parts/10^9). Total mercury concentrations were determined for _Brevoortia tyrannus_, and in the plankton on which they feed as well as the water column (Cocoros et al. (1973). They found some indication that the food chain is a likely source of mercury contamination in this fish, as seen by higher levels found in the viscera compared with the rest of the fish. Also, fish mercury levels (0·3 to 0·5 part/10^6 dry weight) were about twice that for plankton (0·1-0·2 part /10^6 dry weight), with higher levels in phyto- than in zooplankton.

Warlen et al. (1977) found that the dietary source of DDT for Atlantic menhaden was via the uptake of plankton-detritus. Experimental accumulation of cesium-144 by Atlantic menhaden was principally by surface adsorption rather than by assimilation into the tissues (Hoss and Baptist 1973).

During the spring and summer of 1984, large numbers of menhaden afflicted with severe skin ulcers ('red sore' disease) were collected by the North Carolina Division of Marine Fisheries from the Pamlico River estuary N.C. (Ahrenholz et al. 1987b; Dykstra et al. 1989). Further estuarine trawl surveys conducted in the Pamlico River, N.C. revealed that ulcerative mycosis (UM) occurred sporadically between 1985 and spring 1986, but was most prevalent during May and June of 1985 and 1986 (Dykstra et al. 1989). Studies have clearly shown that UM is a widespread disease of menhaden in estuaries in Florida, North Carolina and Virginia. This newly described disease of menhaden arose in epidemic proportions throughout the mid- and south Atlantic coast in the summer of 1984. Several potentially different (and taxonomically uncertain) species of _Aphanomyces_ and _Saprolegnia_ from menhaden have been isolated. The predominant fungi isolated from all of the menhaden lesions examined belong in the genus Aphanomyces. Studies comparing the growth and sporulation capabilities of the test Aphanomyces isolate in distilled water, sporulation medium augmented with 4% saline and the three Pamlico River water samples demonstrated that the river water was the best medium for growth and sporulation. This clearly indicated that estuarine water was not inimicable to growth of this isolate and may actually be stimulatory (Dykstra et al. 1989).

ENVIRONMENTAL EFFECTS

Schools of Atlantic menhaden have measurable effects upon the estuarine waters of Narragansett Bay, R.I. by their feeding, respiration and excretion (Oviatt et al. 1972). Oviatt et al. (1972) found that the levels of chlorophyll *a* were low within the schools, indicating fish predation on phytoplankton. They also found that dissolved oxygen values tended to be lower and levels of ammonia increased within the school areas than outside the school areas.

RHODE ISLAND MINIMUM SIZE REGULATION

None.

RECREATIONAL ATLANTIC MENHADEN REGULATIONS IN RHODE ISLAND

Licenses:	Fee:
Non-Commercial	
(resident or non-resident)	None:
Bait Gill Nets Allowed	
Commercial Fishing	
Fish Traps * (must be out of water 01Jan-28,29FEB)	
License	$100.00
Plus $10.00/trap	$ 10.00
Gill Nets	$100.00
Rod and Reel includes diving	$100.00
Individual (without boat)	$100.00
Commercial Vessels (finfish only) Purse Seine Fishing	
Commercial residents vessels*	
Up to 50' LOA	$100.00
50' to 99' LOA	$125.00
over 99' LOA	$ 10.00/ft.
Multiple purpose (good for all above)	$150.00
Plus $10.00 for a gill net license	$ 10.00
Non-resident otter trawler	$ 5.00/ft.

* **RESIDENTS ONLY**

Expiration of licenses:

Commercial licenses expire annually on December 31. (Rhode Island General Law 20-2-14).

Obtaining licenses:

All marine licenses are issued by the licensing section of the Department of Environmental Management, 22 Hayes St., Providence, R.I. 02908. Tel. No. 401-277-3576.

MENHADEN REGULATIONS

Narragansett Bay in its entirety is designated a Atlantic menhaden management area. The area shall include the east and west passages of Narragansett Bay, Mt. Hope Bay and the Sakonnet River, and be bordered on the south by a line from Bonnet Point to Beavertail Point to Castle Hill Light. The southern boundary will then extend from Land's End to Sachuest Point and then to Sakonnet Light. All sections of the management area are open to Atlantic menhaden purse seining, **ONLY** during the open season as specified in part 16.02 Rhode Island General Law (RIGL). When the Rhode Island Division of Fish and Wildlife determines that the daily catch equals or exceeds 1,000,000 pounds (lbs) for any one day, the following area closures will be implemented on an emergency basis. During a closure, purse seining for Atlantic menhaden for reduction purpose (fish meal) will be prohibited in closed areas. A vessel will be considered in the reduction (fish meal) business if any portion of the vessel's catch is sold for reduction purposes. This regulation will remain in effect until modified by subsequent RIMFC action at a scheduled meeting. During any subsequent meeting, the RIMFC may determine the need and effectiveness of the regulation and initiate action to modify or temporarily suspend the area closure system.

The following areas will be closed to purse seining of Atlantic menhaden for reduction purposes when the daily catch limit exceeds 1,000,000 lbs./day:

1. Barrington/Bristol Area- north and east of a line from the abandoned lighthouse tower at Nayatt Point to the bridge at Mill Gut Cove in Bristol.

2. Bristol/Harbor- north of a line running east from Poppasquash Point to the Northwesternmost point on Hog Island, north of a line running from the northeast corner of Hog Island to the flagpole at McKee's Dock, Bristol.

3. Greenwich Bay- west of a line running northeasterly from Pojac Point to Warwick Point.

4. Wickford Area- there shall be no Atlantic menhaden seining west of (inside) the breakwater located at the harbor mouth.

5. Dutch Island- east of the northernmost end of Dutch Island to the easternmost end of the Jamestown Bridge

(Jamestown) and northeast of a line running between the flasher Fl"R"6 set at the southern tip of Dutch Island and the westernmost point of Fox Hill (Beaverhead).

6. Bonnet Shores- west of a line running southwesterly from Bonnet Point to "Watson Pier".

7. Newport Area- east of a line extending southerly from the westernmost point of the breakwater at the Naval Base to R"14" to the abandoned lighthouse at the southwest tip of Rose Island to the flasher at the northern tip of Fort Adams.

8. South Aquidneck Island- north of a line running west from Sachuest Point to the southernmost point of "Land's End".

9. Melville- south of a line running from Coggeshall Point to the northernmost point of Dyer Island and east of a line from the west shore of Dyer Island to Carr Point.

10. Mt. Hope Bay- north of a line running east/west across the Bristol narrows, Kickemuit River north of N"2".

11. Upper Sakonnet River- in the area between the Railroad bridge and the remains of Stone Bridge.

12. Middle Sakonnet River- east of a line from the western end of Sapowet Point to the westernmost end of High Hill Point, to the pipeline area on the Little Compton shore directly to the east of Black Point to Flint Point.

13. Lower Sakonnet River- west of a line running south from the eastern end of Black Point to Flint point.

Source:Rhode Island Marine Fishery Council Regulation.

Atlantic Menhaden Season--The season for taking Atlantic Menhaden from the Narragansett Bay Management Area by purse seine, for fish meal reduction shall begin annually at sunrise on 01 MAY and end at sunset on 01 October. The Narragansett Bay Atlantic menhaden Management Area will be closed for the taking of Atlantic menhaden for fish meal reduction annually from sunset 01 October to 01 MAY. This season in no way restricts the taking of Atlantic menhaden by purse seining for bait, chum or purposes other than fish meal reduction.

Source:Rhode Island Marine Fishery Council Regulation.

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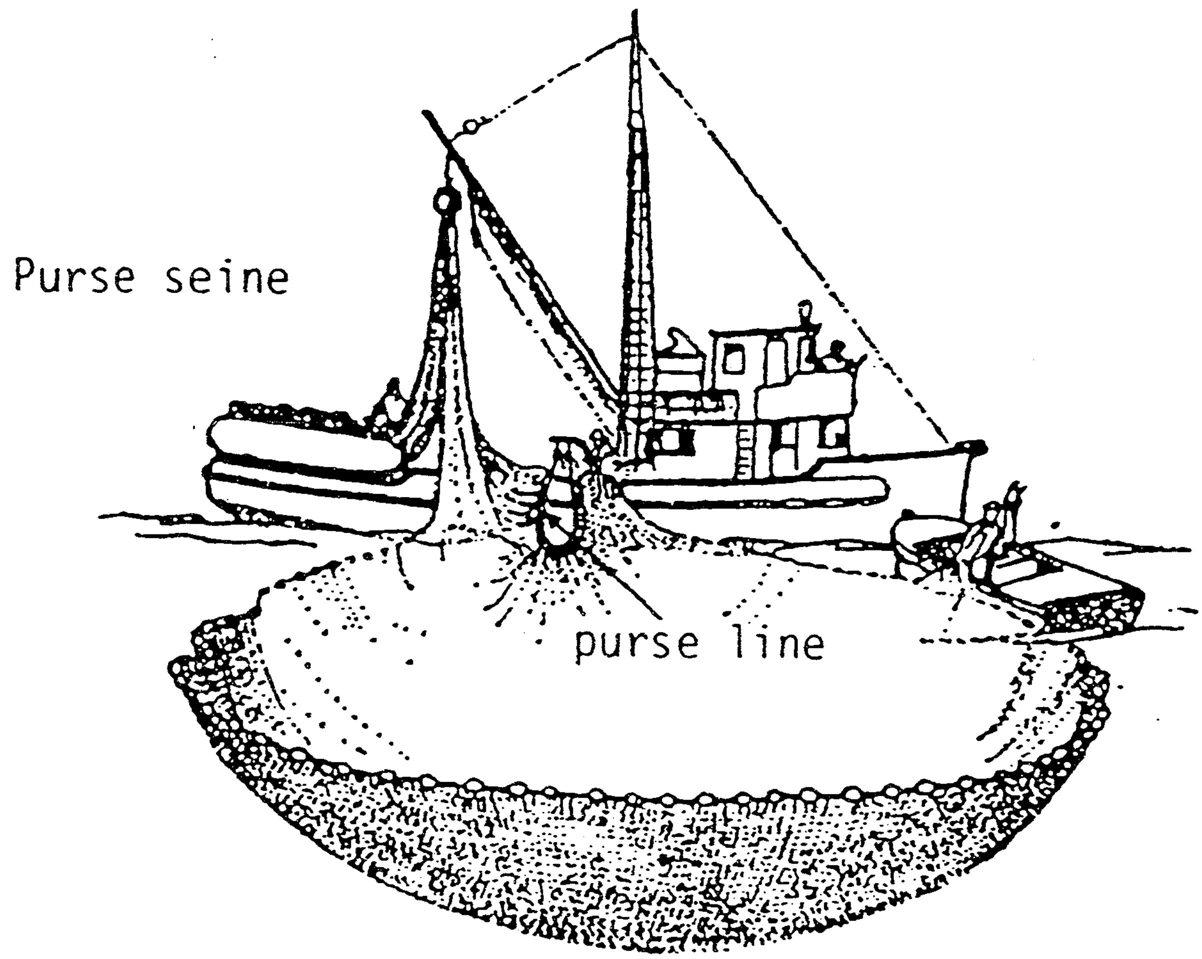
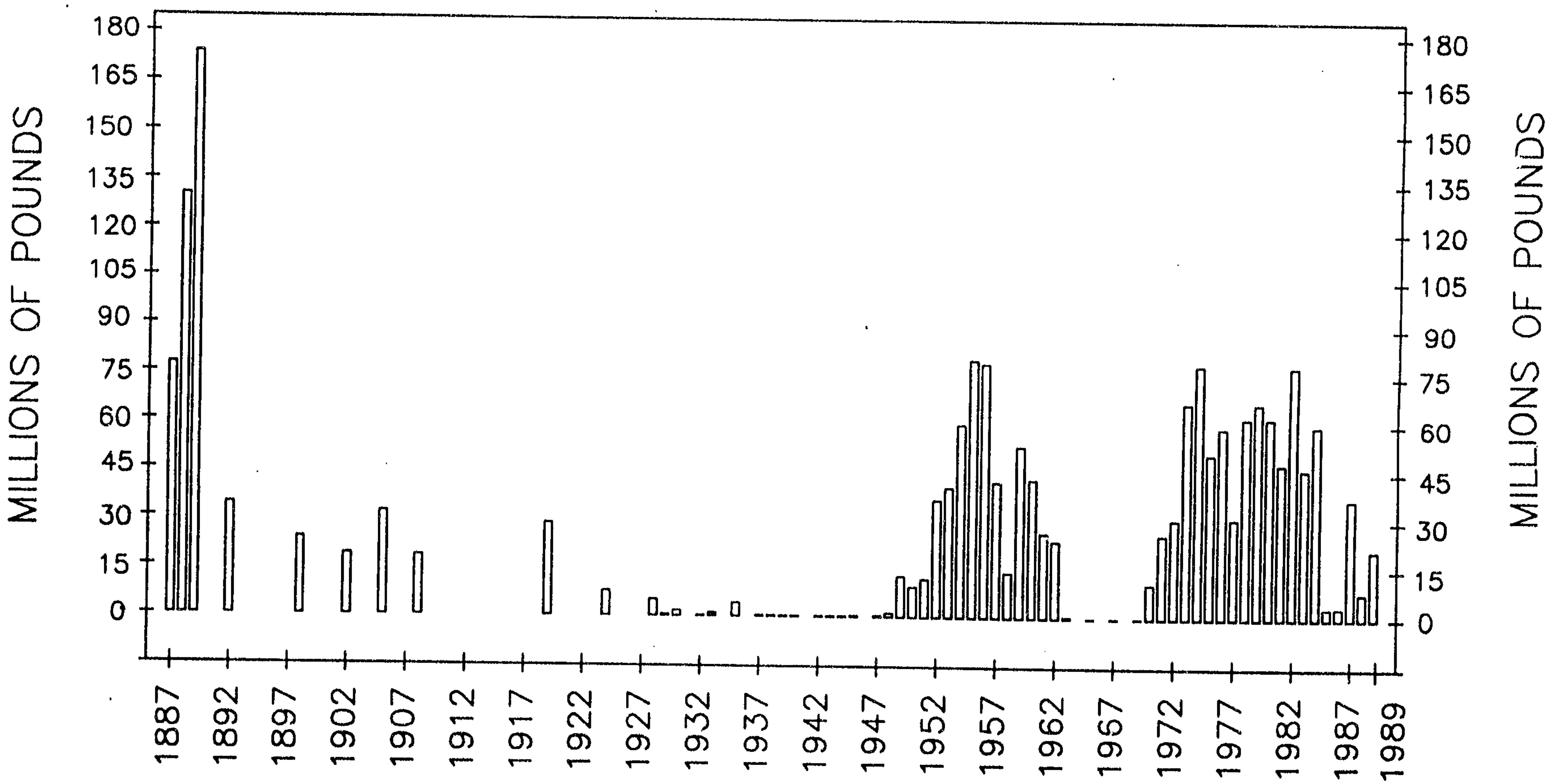
FIGURE 1



Source: Bachman and Atchison (1983)

FIGURE 2

MENHADEN HISTORICAL CATCH STATISTICS, NEW ENGLAND*



(Data Source: National Marine Fisheries Service Biostatistics Investigation, 1991)

* ME, NH, RI, CT

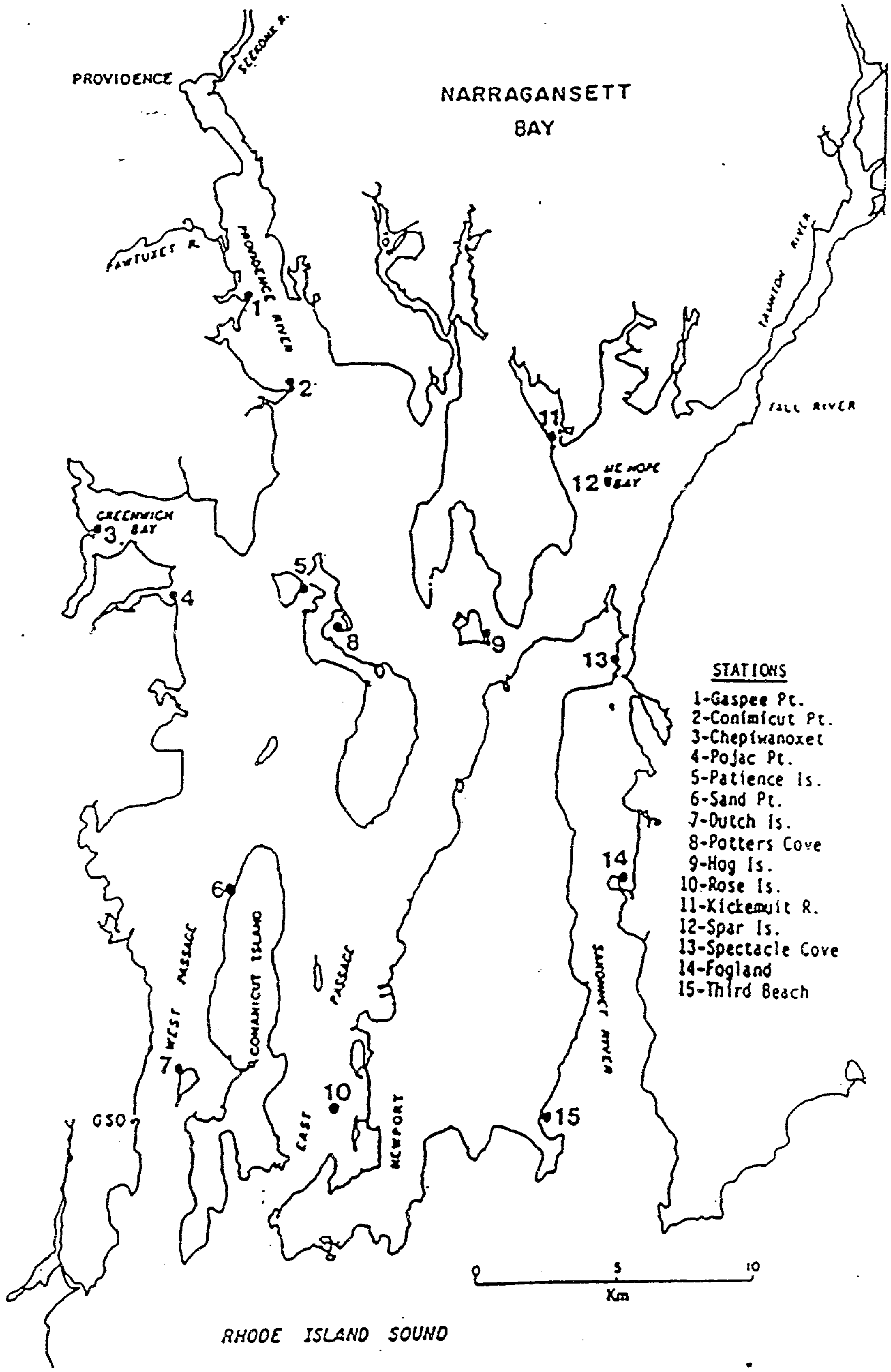
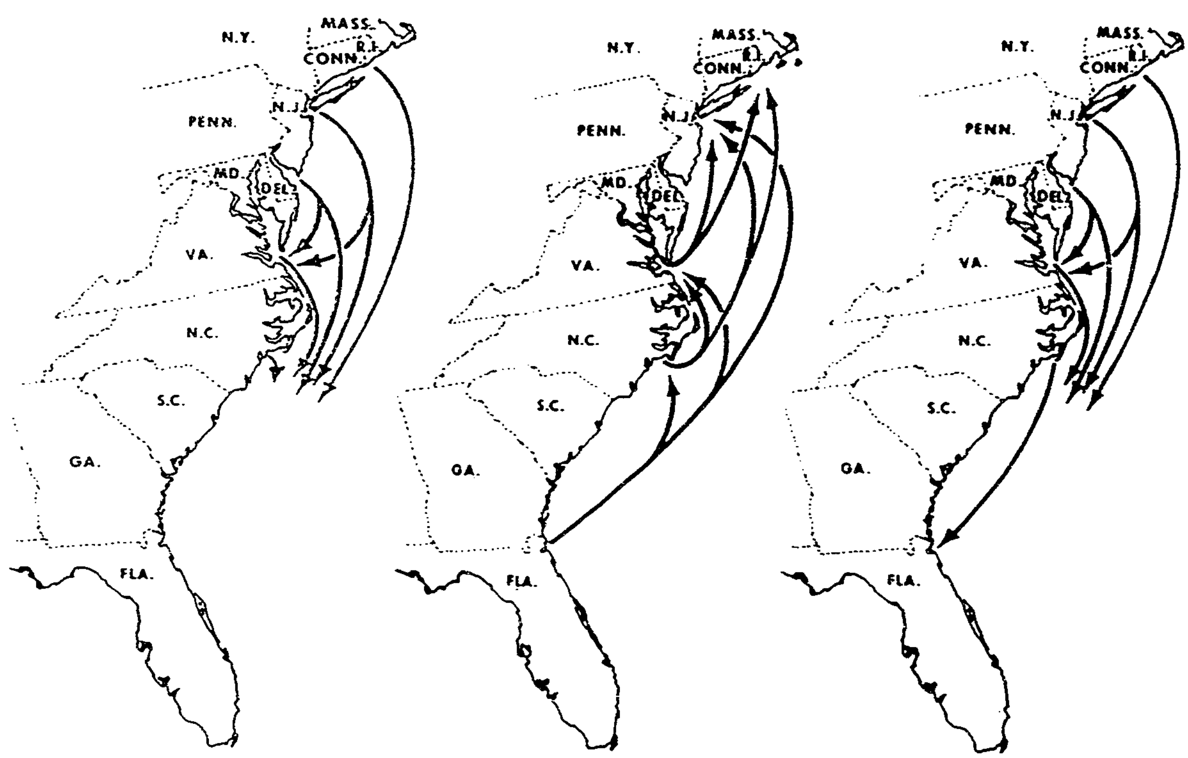


FIGURE 3

Source: Powell (1986)
Juvenile Finfish Survey Stations

FIGURE 4



FALL AND WINTER
JUVENILE

SPRING AND SUMMER
ADULT

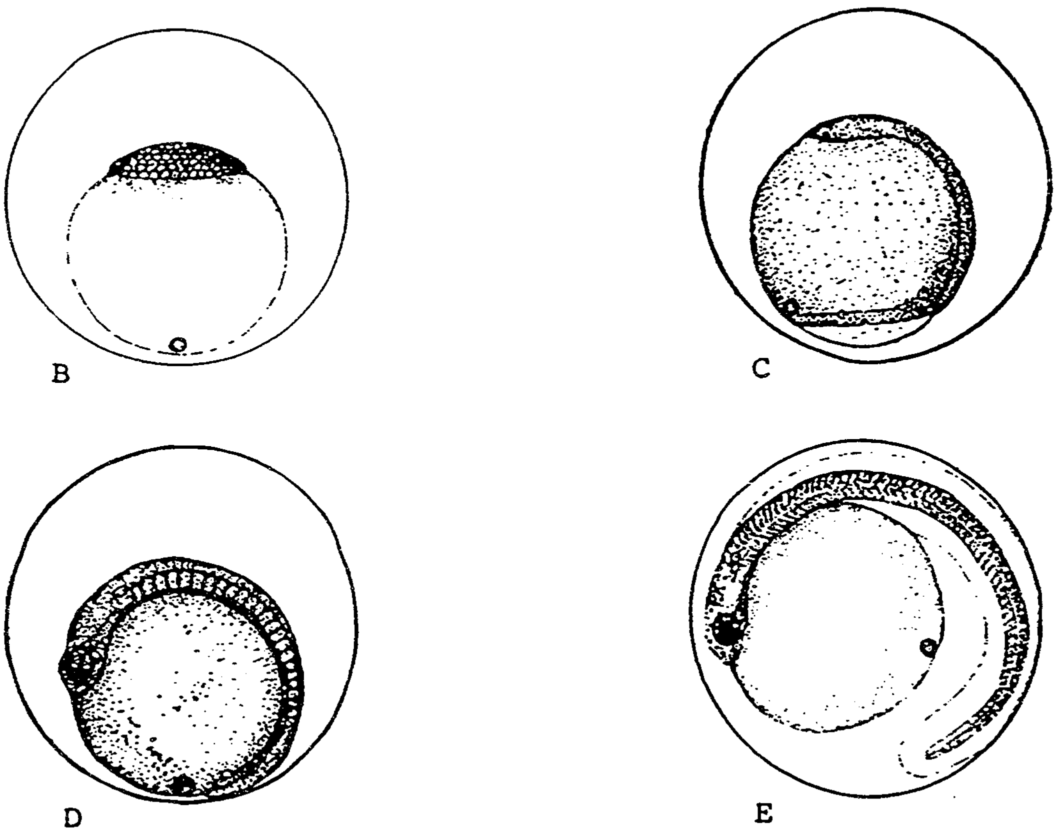
FALL AND WINTER
ADULT

Source: Atlantic States Marine Fisheries Commission (1981)

FIGURE 5

Principal spawning areas of Atlantic menhaden by months of the year. (Source NMFS 1973).

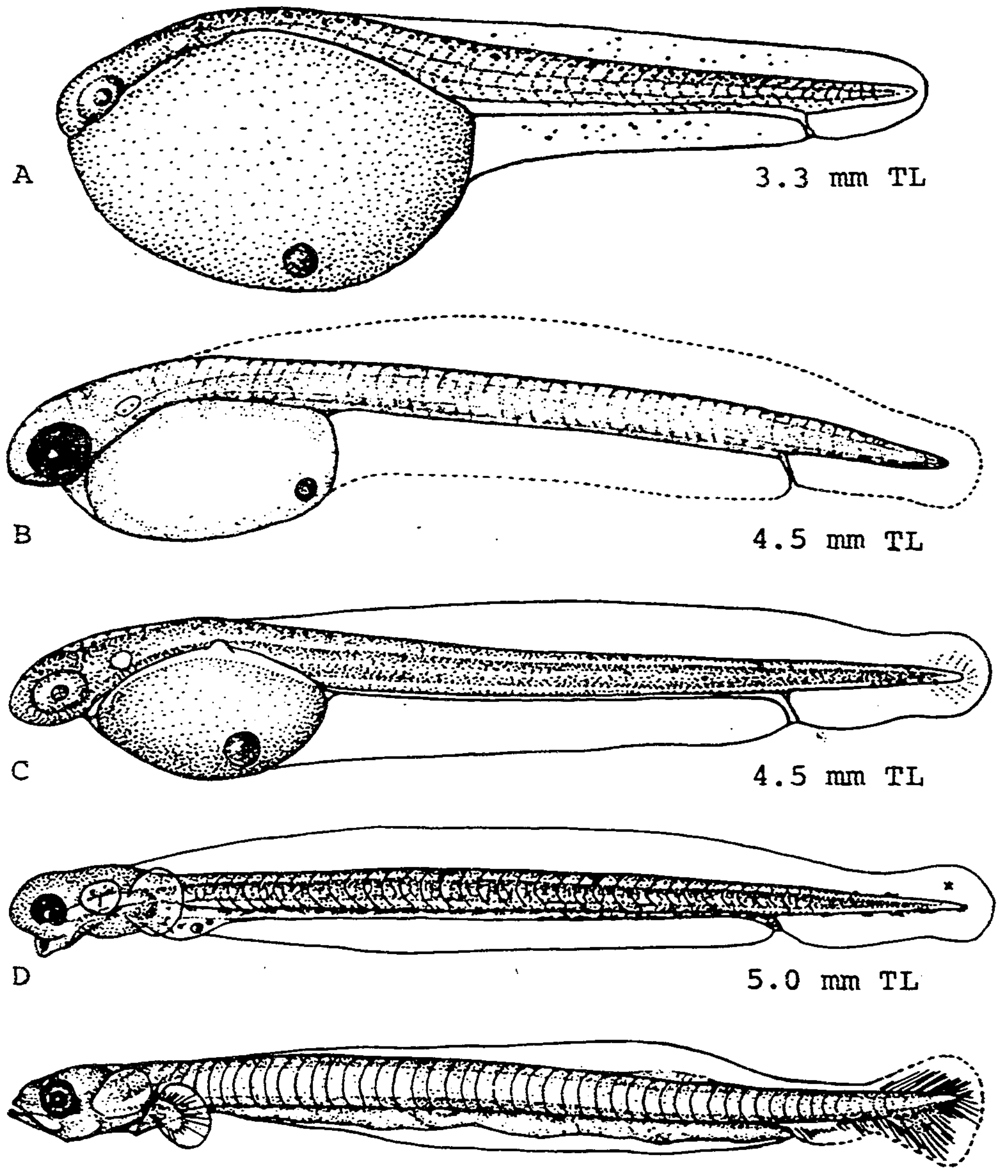
FIGURE 6



Atlantic menhaden. B. Egg, morula. C. Egg, just before closure of blastopore. D. Egg, early embryo 22–24 myomeres, blastopore closed. E. Egg, late embryo with scattered chromatophores over dorsal surface of body.

Source: Jones et al. (1978)

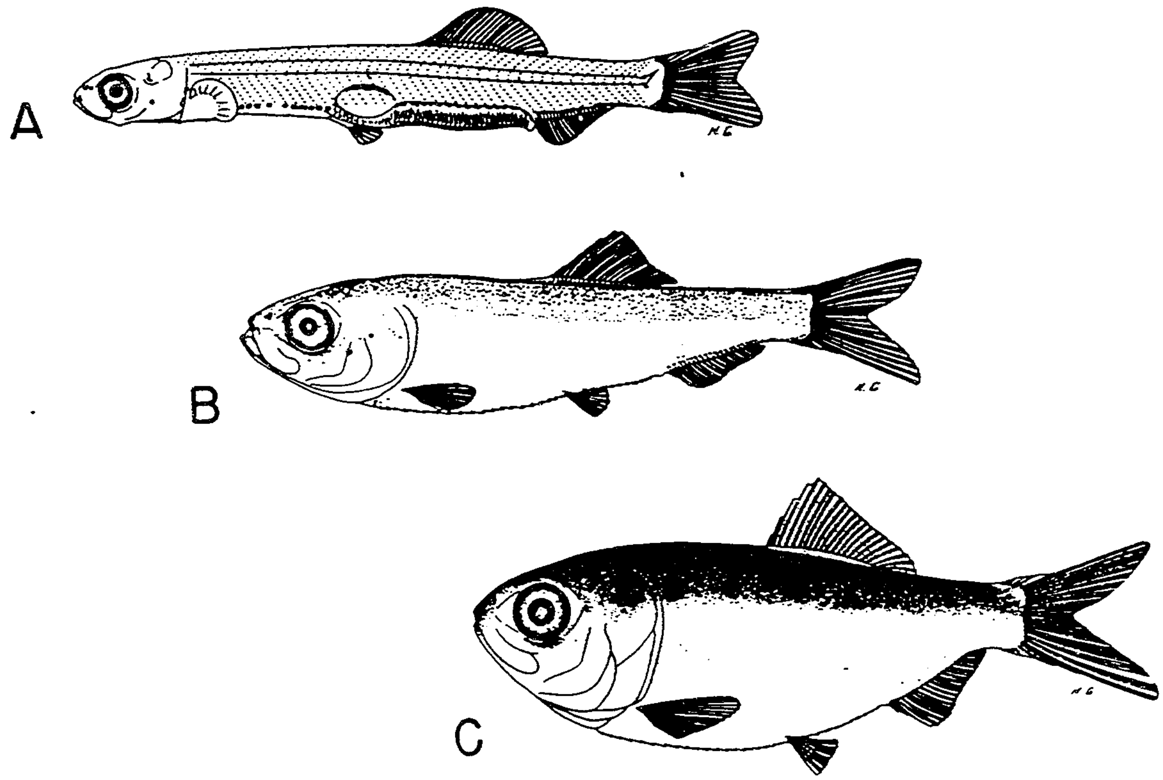
FIGURE 7



Brevoortia tyrannus, Atlantic menhaden. A. Yolk-sac larva, 3.3 mm TL, 3.2 mm SL, just hatched. B. Yolk-sac larva, 4.5 mm TL, recently hatched. C. Yolk-sac larva, 4.5 mm TL, 4.4 mm SL, recently hatched. D. Larva, 5.0 mm TL, 4.8 mm SL. E. Larva, 8.3 mm TL, 8.07 mm SL. Total myomeres 48; preanal myomeres 40.

Source: Jones et al. (1978)

FIGURE 8



—Atlantic menhaden (a) larva 27.0 mm total length (TL); (b) prejuvenile 32.0 mm TL; and (c) juvenile, 64.0 mm TL. The alimentary tracts are shown as they were visible in the preserved specimens used in drawings.

Source: Lewis et al. (1972)

TABLE 1

—Proportions of head and body parts of Atlantic menhaden, *Brevoortia tyrannus*, expressed as a percent of standard length. Characters were not developed at lengths marked with a dash.

Length class (mm. SL)	Number of specimens	Preanus length	Predorsal length	Prepelvic length	Body depth	Dorsal fin base length	Anal fin base length	Head length	Snout length	Eye diameter
3.0-3.9	4	85.4	—	—	—	—	—	14.5	1.9	6.7
4.0-4.9	10	82.8	—	—	8.3	—	—	12.0	1.9	5.4
5.0-5.9	15	81.0	—	—	8.4	—	—	12.1	2.2	5.0
6.0-6.9	7	81.4	—	—	8.4	—	—	13.3	2.5	4.8
7.0-7.9	18	82.3	71.0	—	8.0	2.6	—	13.7	2.6	4.8
8.0-8.9	12	82.7	69.6	—	7.9	4.3	—	13.9	2.6	4.8
9.0-9.9	13	82.8	67.3	—	8.3	6.5	2.4	15.0	3.0	5.2
10.0-10.9	13	85.6	66.9	—	8.6	9.5	4.2	16.4	3.4	5.3
11.0-11.9	8	85.9	66.4	—	8.7	10.1	5.0	16.6	3.5	5.4
12.0-12.9	10	84.7	64.6	—	9.1	11.5	5.5	17.6	3.7	5.6
13.0-13.9	10	83.2	63.6	—	9.4	13.0	6.7	18.2	4.0	6.0
14.0-14.9	7	82.9	62.7	45.8	9.8	13.6	7.1	18.3	4.0	6.2
15.0-15.9	7	81.7	61.9	45.3	10.0	14.0	7.8	18.3	4.0	6.2
16.0-16.9	9	80.8	62.5	45.5	11.4	14.0	8.8	20.2	4.1	6.8
17.0-17.9	8	79.9	60.2	47.6	12.8	15.2	10.0	22.9	4.5	7.3
18.0-18.9	6	77.9	58.6	47.0	14.2	15.7	10.6	23.2	4.4	7.4
19.0-19.9	9	76.9	57.3	48.0	16.1	16.0	11.8	23.8	4.6	7.8
20.0-21.9	7	74.2	53.8	48.6	19.8	17.1	14.2	27.2	4.8	8.0
22.0-23.9	3	73.4	50.4	50.9	24.7	17.7	16.1	29.8	5.5	8.0
24.0-25.9	2	72.7	51.4	51.3	25.4	17.6	15.9	31.0	5.7	7.6
26.0-27.9	3	74.7	49.6	52.8	29.1	19.6	18.0	31.1	7.0	8.3
28.0-29.9	1	72.6	48.9	51.5	29.0	17.3	16.3	31.3	6.8	7.8
30.0-34.9	4	75.4	49.6	52.4	32.6	20.0	15.6	33.0	8.2	8.8
35.0-39.9	3	76.0	49.9	53.2	36.5	20.4	16.6	33.6	7.6	7.8
40.0-49.9	4	74.9	49.6	52.2	33.5	20.5	17.1	32.2	7.6	8.3
60.0-69.9	3	74.8	48.9	52.2	33.4	19.5	16.8	32.4	7.0	5.3

Source: Hettler (1984)

TABLE 2

—Meristics in gulf menhaden, *Brevoortia patronus*, (35 specimens) and in Atlantic menhaden, *B tyrannus*, (34 specimens).

Meristic	Size (mm SL) when first stained		Size (mm SL) when all are stained		Number in full complement	
	B. patronus	*B. tyrannus*	*B. patronus*	*B. tyrannus*	*B. patronus*	*B. tyrannus*
Caudal fin rays						
Principal	8	9	9	12	10-11 (dorsal)	10 (dorsal)
	16	13	18	20	9-10 (ventral)	9 (ventral)
Procurrent					8-9 (dorsal)	7-8 (dorsal)
					7-8 (ventral)	6-7 (ventral)
Dorsal fin						
Pterygiophores	8	8	16	16	19-21	18-19
Rays	8	9	19	17	21-23	20-22
Anal fin						
Pterygiophores	9	10	16	15	17-20	17-20
Rays	10	12	17	15	18-22	19-21
Pelvin fin rays	16	15	18	18	7	7
Pectoral fin rays	18	18	21	21	13-15	15-17
Predorsal bones	19	17	21	21	9-11	10-12
Vertebrae	13	14	16	15	45-46	48-49
Ventral scutes	21	21	31	27	29-31	32-33

Source: Hettler (1984)

Table 3. Parasites of Atlantic Menhaden

Parasite	Location	Distribution	Reference
Phylum Protozoa			
Class Sporozoa			
Family Eimeriidae			
Eimeria brevoortiana	testes	Atlantic Ocean	Hardcastle (1944)
Order Myxosporida			
Chloromyxum clupeidae	flesh	Atlantic Ocean	Westman and Nigrelli(1955)
Kudoa clupeidae	body muscles	Atlantic Ocean	Kudo (1966)
Phylum Platyhelminthes			
Class Trematoda			
Cryptocotyle lingua	skin	Atlantic Ocean	Westman and Nigrelli(1955)
Hemiurus appendiculatus	stomach	Atlantic Ocean	Westman and Nigrelli(1955)
Podocotyle atomon	intestine	Atlantic Ocean	Westman and Nigrelli(1955)
Class Cestoidea			
Family Pterobothriidae			
Pterobothrium heteracanthus	skin	Atlantic Ocean	Westman and Nigrelli(1955)
Phylum Annelida			
Class Hirudinea			
Callioddella carolinensis	mouth cavity	Atlantic Ocean	Sawyer and Hammond (1973)
Phylum Arthropoda			
Subclass Copepoda			
Family Caligidae			
Caligus chelifer	body surface	Atlantic Ocean	Westman and Nigrelli(1955)
	integument	Atlantic Ocean	Kroger and Guthrie (1972)
C. schistonyx	body surface	Atlantic Ocean	Westman and Nigrelli(1955)

Table 3. Parasites of Atlantic Menhaden (pg. 2)

Parasite	Location	Distribution	Reference
Suborder Cyclopoida			
Bomolochus teres	gills	Atlantic Ocean	Westman and Nigrelli(1955)
Family Dichelesthidae			
Lernanthropus brevoortiae	gills	Atlantic Ocean	Westman and Nigrelli(1955)
Family Lernaeidae			
Lernaeenicus radiatus	body surface scales	Atlantic Ocean Atlantic Ocean	Westman and Nigrelli(1955) Dahlberg (1969)
Order Branchiura			
Argulus alosae	integument	Atlantic Ocean	Kroger and Guthrie (1972)
Subclass Malacostraca **Subdivision Peracarida** **Order Isopoda** **Family Cymothoidae**			
Olencira praegustator	buccal cavity	Atlantic Ocean	Guthrie and Kroger (1974)
Lironeca ovalis	mouth & gill region	Atlantic Ocean	Sinderman (1990)
Phylum Chordata **Subphylum Vertebrata** **Class Agnatha** **Family Petromyzonidae**			
Petromyzon marinus	body surface	Atlantic Ocean	Mansueti (1962)
Superfamily Diclidophoroidea **Family Mazocraeidae Price**			
Clupeocotyle brevoortia	Gills	Atlantic Ocean	McMahon (1963)
Mazocraeoides georgei	Gills	Atlantic Ocean	McMahon (1963)