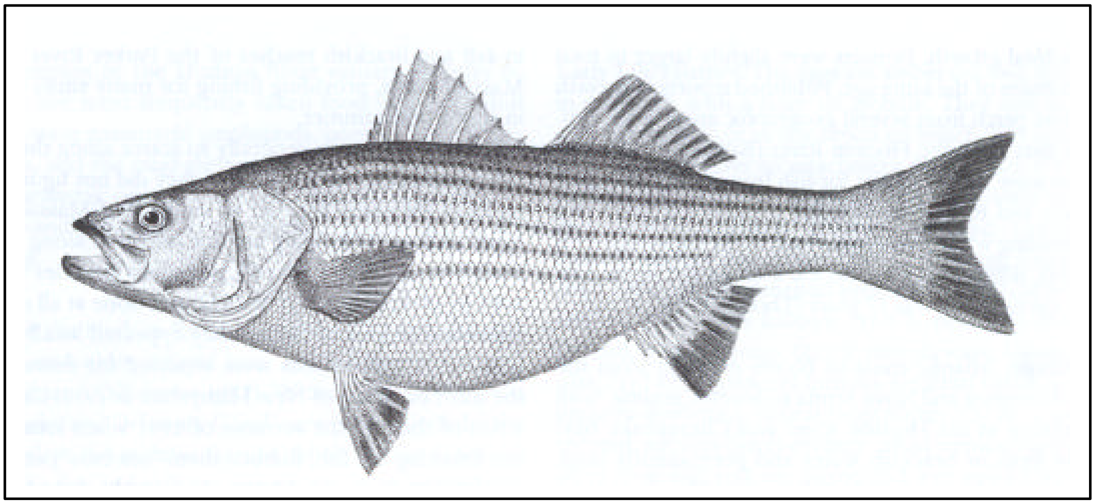
STRIPED BASS / ***Morone saxatilis*** **(Walbaum 1792) / Striper, Rockfish** /Bigelow and Schroeder 1953:389-404 (as ***Roccus saxatilis)***



Description. Body 3.25-4 times as long, to base of caudal fin, as deep, thick throughout, back slightly arched (Fig. 204). Caudal peduncle moderately stout. Head almost as long as body depth. Two spines on margin of gill cover. Mouth oblique, gaping back to eye; snout moderately pointed; lower jaw projecting. Teeth small. in bands on jaws, vomer, palatines. and in two parallel patches on tongue. Gill rakers long and slender. Young fish more slender than older fish. Two dorsal fins of about equal length; first triangular, originating over middle of pectoral fins; second regularly graduated in height from front to rear and separated from first by distinct short space. Anal about same size and form as second dorsal, originating below middle of latter. Caudal fin moderately wide, slightly forked. Pectoral and pelvic fins moderate-sized, pelvics inserting somewhat behind pectorals.

Meristics. Dorsal fin rays VIII-X, 9-14; anal III, 7-13; pectoral rays 13-19; lateral line scales 50-72; gill rakers on first arch 19-29; vertebrae 12 + 13 = 25.

Color. Dark olive green varying to bluish above, paling on the sides, and silvery on the belly; sometimes with brassy reflections. Sides barred with seven or eight narrow, sooty, longitudinal stripes, one of which always follows the lateral line. Others also may follow rows of scales and may be variously interrupted. The highest stripe is the most distinct, and all of them except the lowest are above the level of the pectoral fins. Dorsal, caudal, and anal fins are somewhat dusky.

Size. Striped bass grow to a great size, the heaviest on record being several of about 56.8 kg taken at Edenton, N.C., in April 1891. One of 50.9 kg, which must have been at least 1.8 m long, was caught at Orleans, Mass., many years ago. One of 45.7 kg is said to have been taken in Casco Bay; Maine, and fish of 22.7- 27.3 kg are not exceptional. Bass usually weigh from 1.5 to 16-18 kg. The all-tackle game fish record is a 35 .6-kg fish taken off Atlantic City; NJ., in September 1982 (IGFA 2001).

Distinctions. The rather deep and keel-less caudal peduncle, stout body; presence of two well-developed dorsal fins (spiny and soft-rayed, of about equal length), lack of dorsal or anal finlets, and a moderately forked tail distinguish striped bass from mackerels, bluefish, and jacks. The anal fin having three spines and being almost as long as the second dorsal and the maxilla not being sheathed by the preorbital bone distinguish them from croakers. The two dorsal fins are entirely separate, whereas in sea bass, cunner, and tautog, spiny and soft-rayed parts are continuous as a single fin. White perch come closest to striped bass in general appearance but the two dorsal fins of white perch have no free space between them and the fin spines are stiffer. Hybrids and backcrosses have been produced between striped bass and other closely related species. These have been stocked in reservoirs and rivers and may have interbred with wild populations of the parent stock.

Habits. Striped bass are inshore fish usually occurring no more than 6-8 km from the nearest point of land, although migrating schools doubtless pass much farther out in crossing the mouths of larger coastal indentations, such as Delaware Bay and Long Island Sound. Few fish have been caught more than 16 kIn offshore, maximum distance for strays being 97- 113 kIn (Raney 1954). Most of the total population of striped bass frequent the coastline, except at breeding season and perhaps during the winter. Among these, smaller sizes, up to 7 kg or so, are found within enclosed bays, in small marsh estuaries, in the mouths of rivers, and off the open coast. Most large bass, 14 kg or more, hold to the open coast, except at spawning time and perhaps in winter, but this is not invariable. Many run up into estuaries and into river mouths. In some rivers, good numbers (large as well as small) are caught far upstream and may remain in the rivers year-round. Striped bass off the open coast are most likely to be found along sandy beaches, in shallow bays, along rocky stretches, over and among submerged or partially submerged rocks and boulders, and at the mouths of estuaries, the precise situations that they occupy being governed by availability of food and time of day. Off outer beaches they may be anywhere right up to the breakers. When they are close in they frequent troughs that are hollowed out by the surf behind off-lying bars and gullies through which water rushes in and out across the bars as rollers break, for it is in such situations that baitfish are most easily caught and that crabs, worms, and clams are most likely to be tossed about in the wash of the breakers. When the tide is high, bass often lie on a bar or even in white water along a beach if there is a good surf running. When the tide falls they drop down into troughs or move farther out, according to the precise topography. They also lie under rafts of floating rockweed at times, probably to prey on small animals they find among the weeds. The best spots along rocky shores are in the surf generally, in the wash of breaking waves behind off-lying boulders and among them, or where a tidal current flows most swiftly past some jutting point. In mouths of estuaries they are apt to hold to the side where the current is the strongest and in breakers out along the bar on that side. In shallow bays, they often pursue small fish among the submerged sedge grass when the tide is high, dropping back into deeper channels on the ebb. They frequent mussel beds, both in enclosed waters and on shoal grounds outside, perhaps because these are likely to harbor an abundance of sea worms *(Nerds).*

Striped bass of various life-history stages can tolerate from 0.1°C to 35°C (Davies 1970). Adult bass are acrive over a temperature range of 6°-7.8° to 21°C. Present indications are that if the temperature falls lower they either withdraw to somewhat warmer water if they are off the outer coast or lie on the bottom in a more or less sluggish state if they are in some estuary. On the other hand, it is not likely that they can long survive temperatures higher than about 25°-27°C, for many were found dead in shallow estuaries in Connecticut and Massachusetts during the abnormally hot August of 1937. In general, the temperature range appears to be 13°-22°C for larvae, 5°-30°C for juveniles, and 6°-25°C for adults (Setzler et al. 1980; Coutant 1986). They are equally at home in fresh or slightly brackish water and in full oceanic salinities (35 ppt). Dissolved oxygen requirements for juveniles and adults are 3 mg.liter-l or higher at temperatures of 16°-19°C (Chittenden 1971b). Coutant (1985, 1986) hypothesized that, in certain situations, striped bass population size can be limited by an unsuitable summer habitat for adults with temperatures above 18°-25°C and dissolved oxygen concentrations below 2-3 mg.liter-l.Juveniles have a higher temperature preference of 24°-26°C, which decreases as they age and grow.

Striped bass juveniles will orient to and swim against an oncoming current, but given a choice will select the path with the least current (Bibko et al. 1974). Larger stripers 25-75 mm long are able to swim against a current velocity up to 61 cm.s-l. The maximum velocity of juveniles 8.9-11.4 cm at a temperature of 22°C is 67 cm.s-l or 5.9 body lengths (BL).S-1 (endurance to 50% exhaustion). Fish 2-14 cm can swim for 10 min at 22°C at a maximum velocity of 35-87 cm.s-l or 7.6-12.6 BL.s-1 (Kerr 1953).

Striped bass swim steadily using both symmetric and asymmetric thrusts. Thrusts are symmetric at slower velocities up to 1 BL.s-l, become slightly asymmetric up to 1.5-2 BL.s-l, and are very asymmetric above these speeds. Maximum sustainable velocities for adults are 2.9-3.3 BL.s-1 (76-86 cm.s-l) at 45 and 30 min, respectively (Freadman 1979). Bass use cyclic ventilatory movements for respiratory gas exchange at rest and at slow swimming speeds and shift to ram gill ventilation at intermediate and high velocities. The result is a substantial metabolic savings within their cruising range. Metabolic cost of active ventilation just prior to ram ventilation is estimated at 8.1% of total metabolism, so the changeover results in important hydrodynamic advantages (Freadman 1981).

During the first 2 years they live mostly in small groups. Later they are likely to congregate in larger schools; this applies especially to those up to 4.5 kg or so, which are often spoken of as school fish. Larger fish may school, but the yery biggest, 13.6-18.1 kg and upward, are more often found singly or a few together. They are most likely to be in schools while migrating, but more scattered while feeding in one generallocality. Adults often overwinter in schools in deep areas of tidal creeks and estuaries from North Carolina to the Canadian Maritimes. Small fish (2 and 3 years old), in particular, tend to school densely and they travel considerable distances without scattering, but it is not likely that a given school holds together for any long period. Fish of various sizes (i.e., ages) up to the very large ones often school together, which shows that different ages intermingle.

Food. Striped bass are voracious, feeding on whatever smaller fishes may be available and on a wide variety of invertebrates. Lists of stomach contents include sea lamprey, eel, shad, alewife, herring, menhaden, threadfin shad, anchovy; smelt, silver hake, tomcod, silverside, mosquito fish, mummichog, mullet, sculpins, white perch, yellow perch, croakers, weakfish, channel bass, flounders, northern puffer, rock gunnel *(Pholis gunnel/us),* sand lance, tautog, lobsters, crabs of various kinds, shrimps, isopods, gammarid amphipods, various worms, squid, soft clams *(Mya),* and small mussels. In the Gulf of Maine, larger bass prey chiefly on eel, herring, smelt, silver hake, sand lance, squid, large and small crabs, lobsters, and sea worms *(Nereis),* whereas small ones are said to feed to a considerable extent on gammarid amphipods and shrimps. Diets were composed primarily of fishes, the species depending on what was commonly available at the time, reflecting seasonal changes in the fish population. In Chesapeake Bay (Hollis 1952), it consisted mainly of fishes (95.5% by weight of the total diet). In summer, bay anchovy and menhaden were the principal species eaten; in winter, larval and juvenile spot and Atlantic croaker were predominant; in early spring white perch were the most important prey; and in late spring and early summer alewife and blueback herring predominated. Clupeids in general are very important food (Dovel1968).

An exception to the primarily piscivorous diet was noted in striped bass from surf waters of Long Island Sound (Schaefer 1970): 85% by volume of food of bass smaller than 399 mm FL consisted of invertebrates, primarily *Gammarus* spp., haustorid amphipods (45%), and mysid shrimp, *Neomysis americanus* (33%). Bass 40()-599mm FL ate 46% fishes (bay anchovy and Atlantic silverside) and 53% invertebrates, mostly amphipods. The largest bass, 600-940 mm FL, ate more fishes (65%), including white hake, striped mullet, tautog, and puffer but still ate large numbers (35%) of invertebrates, including amphipods, mysids, and lady crabs. Schaefer (1970) attributed the importance of invertebrates in the diet to turbidity of the surf environment, which made it more difficult for striped bass to pursue and eat fast-swimming vertebrates. Food habit studies of migrating young-of-the-year and adult striped bass in the upper Bay of Fundy (Rulifson and McKenna 1987) also showed high percentages of invertebrates. Young-of-the-year striped bass (69-94 mm FL) fed exclusively on sand shrimp *(Crangon septimspinosa),* whereas individuals 142-240 mm FL ate mainly sand shrimp and fish (hake). Larger bass (271-360 mm FL) ate mainly fishes and sand shrimp, but also polychaete worms. The largest bass (381-520 mm FL) ate mostly fishes (hake, tomcod, and silverside).

Subadult striped bass that gathered below a hydroelectric dam on the Connecticut River were found to scavenge fishes that were injured or killed while attempting to pass through or around the dam, as well as fish discarded by sports fishermen. These age-2 and age-3 striped bass contained body parts of adult American shad, blueback herring, and sea lamprey. Bass caught later in the season had fewer body parts of large fish, probably because the runs of those fish had decreased by then (Warner and Kynard 1986). Striped bass schools of different ages feed at the same time (Raney 1952). When bass are feeding on anyone particular prey, they are likely to ignore food of other sorts, and they appear to follow and feed on schools of fishes (Scofield 1928). On the whole, they seem to be more active, and to feed more actively; in the evening just after dark and just before sunrise than while the sun is high. Striped bass feed more in summer and fall and less during winter and spring (Hollis 1952). Temperature may be a determining factor. Feeding frequency declined sharply below 5°C. Adults ceased feeding below this temperature and juveniles ate smaller amounts less frequently. Feeding of subadults and adults also declines at temperatures over 26°C in seawater (Rogers and Westin 1978). Fasting occurs for a brief period during the spawning season beginning slightly before and ending slightly after spawning occurs (Trent and Hassler 1966).

Several studies have been conducted on food conversion ratios of young striped bass fed commercial fish foods (Westin and Rogers 1978; Setzler et al. 1980). Striped bass held in cages in Rhode Island coastal waters and fed a diet of ground hake had a gross feeding efficiency of 17-21% when fed 6-12% body weight per day (Rogers and Westin 1978).

Respiratory metabolism for juvenile striped bass was studied at five temperatures (8°, 12°, 16°, 20°, and 24°C) and three water velocities (0, 5, and 10 cm.s-l) (Kruger and Brocksen 1978). Differences between standard and active metabolism over a limited range of water velocities were used to calculate scope for activity. This was very similar at 8°, 12°, and 16°C, coming to 55, 44, and 45 mg O2.kg-l.h-l for an average 40-g bass. At 20° and 24°C, scope for activity increased to 99 and 143 mg O2.kg-l.h-l. The temperature optimum for juveniles appeared to be about 16°C.

Striped bass are less oxygen-efficient than white perch or spot (Neumann et al. 1981). For two sizes of bass at three different water velocities at a temperature of 15°C, oxygen consumption increased with both fish weight and water velocity. Average respiration rates for a 50-g fish at 8.6, 31.7, and 49 cm.s-l water velocity were 19, 24.3, and 33.7 mg Ozliter-l; for a 150-g fish at the same water velocities respiration rates were 31.4,41.3 and 63.7 mg O2.liter-l. Oxygen consumption rates for different sizes of striped bass at various temperatures and salinities have been summarized by Westin and Rogers (1978). Metabolic rate dependence on temperature was investigated by KIyashtorin and Yarzhombek (1975). For striped bass weighing between 1 and 3 gacclimated to 22°C, Q1O values varied from 2.1 to 1.8 between 15° and 30°C. Oxygen consumption ranged from 250 to 1,000 mg.kg-l.h-l.

Predators. Although direct information is lacking, larger bluefish and weakfish probably prey on small striped bass, but man is undoubtedly the most important predator. Cannibalism by large stripers on smaller ones has been reported during the spawning season in the Hudson River (Dew 1981). Silver hake and cod may also prey upon juvenile striped bass (Scott and Scott 1988).

Laboratory predation studies were conducted using potential fish and invertebrate predators that occur on striped bass spawning grounds in the Pamunkey River, Va. A cyclopoid copepod, *Acanthocyclops vernalis,* attacked and killed striped bass larvae. Fish species that ate striped bass larvae were juvenile and adult satinfin shiner, spottail shiner, tesselated darter, white perch, striped bass, bluegill, pumpkinseed, channel catfish, and white catfish. However, neither eggs nor larvae of striped bass were positively identified in the guts of these fishes collected in the field (McGovem and Olney 1988). A free-living copepod, *Cyclops bicuspidatus thomasi,* was found attached to a number of sniped bass yolk-sac larvae 3.2-6.4 mm TL in the Chesapeake and Delaware Canal. Damage ranged from constriction of tissue around the point of attachment to missing parts of the finfold and ruptured yolk sacs. Most of the larvae had damage severe enough to cause death (Smith and Kemehan 1981).

Parasites. Sniped bass are host to a large variety of parasites. Field studies conducted on Chesapeake Bay stripers age 0+ to 3+ (Papema and Zwemer 1976) showed the most common parasites to be protozoans *Colpanema* sp. (at age 0+); *Myxosoma morone* (age 0+); *Trichodina davisi* (all ages); *Glossatella* sp. (age 0+); Platyhelminthes, Cestoda *Scolex pleuronectes,* protocephalid larvae (type A and B); acanthocephalans *Pomphorhynchus rocci* (larvae, age 0+, and adults, ages 1-3+); Aschelminthes, Nematoda *Philometra rubra* (all ages); and crustaceans, Copepoda *Ergasilus labracis* (age 1-3+).

Although an earlier report of striped bass parasites (Merriman 1941) did not find direct evidence that pathogenicity was associated with parasitic infection, Papema and Zwemer (1976) found distinct pathological processes associated with the most common and abundant parasites. These included gill hyperplasia caused by *Ergasilis labracis;* visceral granuloma and adhesions associated with *Philometra rubra;* perforations of the gut and resulting histological changes in the gut wall by *Pomphorhynchus rocci;* extreme fibrosis of visceral organs, especially the liver and spleen, caused by proliferation by larval helminths; skin lesions from *Argulus bicolor;* and lymphocystis. These conditions probably do not cause mass mortality, but do increase susceptibility of infected fish to predation and stresses caused by water quality deterioration.

Extensive lists of parasites found on striped bass have been compiled by Setzler et al. (1980) and Westin and Rogers (1978). Bonn et al. (1976) listed parasites of cultured striped bass, which are often quite different from those found in the field.

Diseases. Cultured striped bass (Hawke 1976) and wild populations suffer from a number of diseases. Fin rot, which is be lieved to be caused by a combination of environmental stress and bacterial infection, was reported by Mahoney et al. (1973) in stripers from me New York Bight. It paralleled seasonal temperatures, wim me rate of infection being lowest in winter, increasing in spring, peaking in summer, and decreasing in fall. One of me common infectious agents in fin rot is *Vibrio.*

Pasteurellosis, an infection by the bacteria Pasteurella, was noted in Chesapeake Bay bass in 1963 (Snieszko et al. 1964). Paperna and Zwerner (1976) reported mass mortalities of age-1+ and age-2+ fish from pasteurellosis. They described the pathological conditions as appearance of necrotic foci visible as white spots in the spleen. Moribund fish showed progressive liquefaction necrosis in liver, kidney; and finally the intestine.

Columnaris disease is caused by the bacteria *Flexibacter columnaris* and manifests itself as a moldlike growth on me skin and fins. Kelley

(1969) reported that it depressed the hematocrit value of infected striped bass by 12-15%.

Lymphocystis disease has been reported in 2-year-old sttiped bass from the Chesapeake (Paperna and Zwerner 1976). This is a viral disease manifested by wartlike nodules that may reach a size of 2 mm and often cover me entire fish, but despite its alarming appearance it is rarely fatal.

Kudo cerebralis, a myxosporidian disease of connective tissue that is associated with nervous tissue, was reported by Paperna and Zwerner (1976). This disease appears as cysts embedded on me ventral and lateral surfaces of me brain and inside distal cranial nerve branches.

Epitheliocystis lesions were found on gill filaments and arches of striped bass in me York River (Paperna and Zwerner 1976). Wolke et al. (1970) found epitheliocystis disease in striped bass from Connecticut waters.

Tubercular lesions caused by an acid fast bacillus *(Mycobacterium* sp.) have been found in striped bass from four areas in California and in Coos Bay; Ore. (Sakanari et al. 1983). Prevalence of infection was 25-68% in California and 46% in Oregon. These lesions have been reported from striped bass in aquariums on the east coast (Nigrelli and Vogel 1963) and from wild populations in me Chesapeake Bay (0. E. Zwerner, VIMS, pers. comm.). Almough me fish collected did not appear to be seriously affected, this species of *Mycobacterium* is pathogenic and can cause skin lesions in humans who handle infected fish (Snieszko 1978). Caution should be used in handling any fish wimlesions.

Intestinal contents of striped bass collected in me Hudson River and Long Island Sound were examined for presence of bacterial flora mat could be opportunistic pathogens (produce disease in fish when they are stressed). Several of these bacteria were common in the gut flora: *Aeromonas, Vibrio, Pseudomonas, Enterobacter;* and *Alcaligenes.* The total number of gut bacteria was consistently higher (100-1000 times) in striped bass from me Hudson River, perhaps reflecting me higher organic content of Hudson River water, man those from Long Island Sound. The enteric bacteria were reflective of migrating fishes found in coastal waters and except for me predominance of *Aeromonas hydrophila* were similar to those of most marine fishes (MacFarlane et al. 1986).

Breeding Habits. Striped bass are very fecund, with the number of eggs produced highly correlated with age, weight, and length. Fecundity estimates range from 15,000 eggs in a 46-cm f\~\\. \M~t\~\1.~\\ ~t\d Holli~ 1963) \0 ~,(11(1,31.5 \1\ ~ ~~~ 13, 14.5-kg fish (Jackson and Tiller 1952). Westin and Rogers (1978) and Hardy (1978b) summarized fecundity data for striped bass of various ages collected in a number of areas. Fecundity per kilogram of body weight has been estimated at 173,000 eggs for Hudson River fish (Texas Instruments 1973), 176,000 for Roanoke River fish (Lewis and Bonner 1966), and 318,000 for offshore North Carolina fish (Holland and Yelverton 1973). The last authors estimated fecundity for striped bass 77-110 cm FL and 7-13 years of age and found the following linear relationships between fecundity and length, weight and age: F = 9.33 X 104FL -6.24 X 106, r = 0.85; F = 2.18 X *105W*1.17 X 104, r= 0.86; and F= 4.33 X *105A* -1.78 X 106, r= 0.66, where F=fecundity x 106, FL=fork length in cm, W = weight in kg, and *A* = age in years.

Two or three distinct sizes of oocytes occur in striped bass ovaries so either there is batch spawning or more than 1 year's oocytes are present in the ovaries (DeArmon 1948; Jackson and Tiller 1952; Zolotnitskij and Romanenko 1981). This pattern of oocyte development is group synchrony, the most common teleost pattern, where ovaries contain a heterogeneous population of smaller oocytes and a group of more synchronized developing oocytes (Specker et al. 1987).

Hermaphroditism has been noted (Schultz 1931). Westin (1978) reported a 52-cm, 16.3-kg immature hermaphrodite striper from Rhode Island. Morgan and Gerlach (1950) found that 3% of striped bass sampled in Coos River, Ore., were hermaphrodites. Moser et al. (1983) found there were increasing signs of pathology associated with egg retention on older (7-10 years) hermaphrodites.

Among Connecticut fish, Merriman (1941) found that, "approximately 25 percent of the female striped bass first spawn just as they are becoming 4 years old, that about 75 percent are mature as they reach 5 years of age, and that 95 percent have attained maturity by the time they are 6 years old:' A large percentage of the males had matured at 2 years, and probably nearly all by the time they were 3. It is probable that this applies equally to Maine bass. This remains the best information on age at maturity gathered from ocean migrating striped bass; however, its validity has been questioned. Hudson River striped bass were found to mature at 4 years of age (68%) with 28% of the males age-class 4 to 6 still immature. Females began to mature at age 4 (22%), but only 54% were mature by age 6 and 80% by age 7 (Dew 1988). Both sexes were larger when they attained maturity than fish analyzed by Merriman (1941).

Different stocks mature at different ages. Specker et al. (1987) described oocyte development in striped bass and related this to factors influencing estimates of age at maturity. They looked at migrating striped bass caught off Rhode Island and a population impounded in a saltwater cove in Massachusetts (salinity 35 ppt). Ovaries of migrating fish collected in summer had a heterogeneous group of small oocytes some of which appeared to be forming yolk vesicles. Fish collected in the fall were of two types. One had ovaries with oocytes similar to those of fish collected in summer and the other had ovaries with a batch of small heterogeneous oocytes and a batch of larger oocytes that were shown histochemically to have recruited into the gonadotropin-dependent growth phase (maturing oocytes). Striped bass from Cat Cove had oocytes that underwent the same developmental process as the migrant stock. Migrating fish collected in November with small oocytes were age-classes 3 and 4, those with small and large oocytes were from age-classes 5-7. However, it is not known if final maturation takes 1 year or more. Since Merriman (1941) established maturity from oocyte size and sampled primarily from the spring to November, when it is most difficult to judge maturity, he might have miscalculated the ages. A complete description of the stages of oocyte development in mature females throughout the year is needed so that one can assess sexual maturity of fish collected at any time of the year (Specker et al. 1987). Two studies are currendy in progress to determine age at maturity, one in Maryland on the spawning grounds and one in Rhode Island on migrating stocks.

Striped bass are assumed to return to their natal rivers to spawn, and this is supported by tagging data (Mansueti 1961b; Nichols and Miller 1967; Moore and Burton 1975). Males are the first to arrive on the spawning grounds, and females move in later. Bass spawn either in brackish water at the heads of estuaries or in freshwater rivers, not off the open coast in saltwater. Those that enter freshwater rivers may deposit their eggs only a short distance above the head of the tide, as they do in the Potomac, or they may run much farther upstream. Most spawning occurs within the first 40 km of freshwater in the river (Tresselt 1952). Within an individual river, spawning grounds may change from year to year (Parley 1966).

The major spawning area for striped bass on the east coast is now the Chesapeake Bay and its tributaries (Merriman 1941; Raney 1957; Able and Fahay 1998). Other important areas are the Hudson, Roanoke, and Delaware rivers (Richards and Deuel 1987). In the twentieth century the Delaware River ceased to produce striped bass because pollution from the Philadelphia area caused oxygen depletion, which prevented stripers from reaching their freshwater spawning areas (Chittenden 1971b). Recent improvements in water quality have resuited in increased reproduction and survival of juvenile striped bass in the Delaware River (Weisburg and Burton 1993). The Roanoke River stock appears to have a limited migratory range (Boreman and Lewis 1987). In the seventeenth and eighteenth centuries, striped bass spawned in almost every river on the coast of New England, supporting large fisheries, until these populations were extirpated (Litde 1995). Striped bass still spawn in the Saint John River, and it is probable that they also spawn in small streams tributary to Minas Basin and Cobequid Bay at the head of the Bay of Fundy; in Grand Lake at the head of the Shubenacadie River, and in the Annapolis River. Great numbers of young-of-the-year fish (4.9-7 .6 cm) were caught, for example, in winter in the 1880s in the Kennebec, where ripe fish also have been reported from the end of June into July. The only Maine or Massachusetts streams where there has been evidence of spawning bass in the past 50 years are the Mousam, Maine, where fishermen reported taking females with ripe eggs on several occasions; and the Parker, Mass., where Merriman took three young-of-the year 7.1-8.5 cm long on 4 August 1937. Davis (1966) found no evidence of spawning in Maine and no evidence of discrete populations in the estuaries he sampled: the Piscataqua, Saco, Cousins, Kennebec, Sheepscott, Penobscot, and St. Croix rivers. It is probable that spawning in Maine waters today is relatively rare.

The spawning season is from late April to early May in North Carolina, chiefly in May in the Chesapeake Bay region, and mid-May to June in the Hudson River (Raney 1952). Any bass that may spawn in the rivers of Massachusetts or Maine, or in the Bay of Fundy probably do so in June, and those of the southern shore of the Gulf of St. Lawrence and of the lower St. Lawrence River in June and July. A summary of striped bass spawning seasons was given by Hardy (1978b) and Westin and Rogers (1978).

Bass are broadcast spawners and have no special courtship sequence. During spawning a large female may be surrounded by many small males, and the latter are described as fighting fiercely with one another. The female frequently swims close to or breaks the surface of the water (Merriman 1941). Diel spawning patterns are very variable. Peaks occur most often at dawn or dusk, but spawning has been recorded at all hours during the day; as well as at night (Setzler et al. 1980).

Spawning is triggered by spring increases in temperature and varies according to the weather for that year. The number of spawning peaks also varies depending on the weather. Westin and Rogers (1978) summarized the time of spawning, temperature, and date and temperature of peak spawning for major areas from the Hudson River, N. Y., to the Savannah River, Ga., and two California rivers. In general, temperatures ranged between 10° and 26°C, with 14°-15°C usually initiating the spawning. Salinity on the spawning grounds ranged from 0 to 4 ppt (Tresselt 1952). Higher values have been recorded but it was probable that eggs drifted to those areas from farther upstream. An important requirement for successful spawning is a current turbulent enough to prevent the eggs from settling on the bottom, where they would be in danger of being silted over and smothered.

Early Life History. Eggs are spherical, nonadhesive, semibuoyant, and transparent to greenish or golden green. The eggs have a clear tough chorion, a wide perivitelline space, a single large oil globule, and a lightly granulated yolk (Raney 1952; Mansueti 1958a). Eggs average 1.25-1.80 mm in diameter when they are deposited (Pearson 1938; Raney 1952; Mansueti and Mansueti 1955). The perivitelline membrane swells during the first hours after fertilization to 1.3-4.6 mm or an average diameter of about 3.6 mm (Murawski 1969; Albrecht 1964). The yolk diameter is 0.90-1.50 (mean 1.18 mm) and accounts for 35% of the egg diameter. The oil globule diameter is 0.40-0.85 (mean 0.61), and it may fragment into several smaller ones (Mansueti 1958a). The only other pelagic eggs of that size found in estuaries in spring are those of shad and, rarely, menhaden. Shad eggs have no oil globule and menhaden have a very small one, so their eggs are easily distinguished from those of striped bass (Lippson and Moran 1974). The eggs sink in quiet water but are swept up from the bottom by the slightest disturbance, so that they tend to drift downstream with the current. Consequently, eggs that are produced far upstream may not hatch until they have reached tidewater. Egg development at 16.7°-17.2°C as described by Mansueti (1958a) is as follows: (1) Fertilization-5 min: perivitelline space begins to form; (2) 20-40 min: first cell divisions; (3) 2 h: 4- to 32-cell stage, perivitelline space fully formed; (4) 8 h: 16-cell morula stage, blastoderm appears granular; (5) 12 h: gastrulation begins, blastoderm covers half of yolk; (6) 16 h: 64 cells, gastrula, blastocoel forms, germ ring thickens; (7) 20 h: embryo developed, neural ridges and eyes visible, pigmentation present on embryo and oil globule; (8) 24 h: embryo about halfway around the yolk, pigment intensified on dorsolateral region of body and adjacent blastoderm; (9) 36 h: embryo about 1.6-2 mm long, posterior part of body free from yolk, eye well differentiated but not pigmented, embryo floats free and fully extended in egg; and (10) 48 h: hatching.

Hatching time in relation to temperature varies from 109 h at 12°C (Rogers et al. 1977) to 25 h at 26.7°C (Shannon and Smith 1967), with an average of 48 h at 17°-19°C (Westin and Rogers 1978). Optimum conditions for striped bass embryonic growth and survival have been reported as temperatures of 14°-24 °C (Albrecht 1964; Bayless 1972; Morgan and Raisin 1973) with a narrower range of 15°-18°C observed by Rogers et al. (1977). Critical oxygen levels are 3-5 mg.liter-l at 18°C (Rogers and Westin 1978; Turner and Farley 1971). Egg survival is highest at low salinities; no significant effect on survival to hatch was observed at salinities of 0-8 ppt (Morgan and Raisin 1973). Booker et al. (1969) found pH ranges from 6.6 to 9 to be satisfactory for hatching. Acidification of surface waters (low pH, high aluminum concentrations, and low water hardness) have been shown to adversely affect survival of striped bass larvae by *in situ* experiments conducted in the Nanticoke River, a tributary of Chesapeake Bay (Hall et al. 1985). Laboratory experiments confirmed that acidification levels found in the field, pH of 6.5, aluminum concentration of 0.12 mg.liter-l and water hardness of 30 mg.liter-l, were 90-99% toxic to striped bass larvae (Mehrle et al. 1984). These conditions can occur in several tributaries of Chesapeake Bay; but other tributaries have salinity and alkalinity conditions that buffer the effects of acidification (Ha1l1987).

Newly hatched larvae are 2.0-3.7 mm TL at hatch with a mean of 3.1 mm (Mansueti 1958a). They are transparent with a long slender body and a large ovoid yolk sac. The oil globule is at the anterior end of the yolk sac, which projects beyond the head or at least anterior to the eye. The mouth is unformed and the eyes unpigmented.

The rate of yolk-sac absorption is variable, ranging from 3 days at 24°C (Albrecht 1964) to 9 days at 12°C (Rogers et al. 1977). The average is about 8 days at 18°C (Rogers et al. 1977). A summary of yolk-sac absorption times at different temperatures was provided by Setzler et al. (1980). At this time the larvae are referred to as finfold stage and when fin rays form they are called postfinfold. These stages are sometimes collectively called larval stages by some authors and postlarvae by others. Duration of the larval stage varies from 23 days at 24°C to 68 days at 15°C, with an average of 33 days at 18°C (Rogers et al. 1977).

Hardy (1978b) gives a detailed description of developmental events up to the adult stage, and Westin and Rogers (1978) provide a table of important events from hatch to transformation of striped bass larvae reared in their laboratory at about 17°C. The following is a list of some important events condensed from Mansueti (1958), Hardy (1978b), and Westin and Rogers (1978): (1) Day 1: Eye pigmentation develops. (2) Day 2-5 (4.5-5.2 mm TL): Differentiation of jaws and gut begins, pectoral buds form, pelagic swimming begins, chromatophores are present and intensifying into the three areas characteristic of the species-a series of stellate chromatophores along the posterior two-thirds of the trunk and tail, concentrations along the dorsal peritoneal wall and on the dorsolateral and ventrolateral wall of the yolk and along the gut and a heavy concentration on the oil globule. (3) Day 6-8 (5.5-7.5 mm): Yolk absorption, differentiation of stomach, active pelagic swimming and feeding begins, swim bladder visible and filled in most cases; a large chromatophore present on the upper surface of swim bladder, an almost continuous line of pigment on ventral part of body from opercle to midway between anus and tip of tail. (4) Day 10-15 (10.5-12.5 mm): Teeth visible, oil globule absorbed, swim bladder filled, finfold divided into three parts. (5) Day 18-30 (12-16 mm): Differentiation of rays in caudal, anal, and dorsal fins; myotomes correlated with vertebral number, three preopercular spines present, number of teeth increases. (6) Day 30-50 (16-35 mm): Initial formation of lateral line scales, soft dorsal, anal, and caudal fins well differentiated; spinous and pelvic fins partially differentiated; body shaped like adult; pigmentation, small black dots all over body. (7) Day 50-80 (35-50 mm): Early juvenile coloration of vertical dark bars on dorsal part of body from opercle to caudal peduncle, pigmentation stronger, covered with scales, three anal spines and full complement of meristic characters. (8) Day 80-100 (50-80 mm): Development of horizontal stripes, fully developed fin rays.

Larvae are similar to white perch. Yolk-sac larvae may be distinguished by total length in relation to developmental stage, striped bass being about 1 mm longer at each stage, and the relative position of anus and gut extension beyond the yolk. In striped bass the vent is closer to the yolk with only three or four myomeres between the posterior yolk sac and the vent while in white perch there are five or six. In striped bass the gut angles directly downward to the vent whereas in white perch it extends along the tail before angling down. When the two species begin developing their fin rays (at 5- 6.5 mrn), it becomes difficult to separate them as differences are not well defined. In general, white perch have shorter, stouter bodies with a thicker caudal peduncle; preopercular spines are well defined and appear earlier than in striped bass. Between 6 and 12 mm, striped bass have teeth, whereas white perch have none (Lippson and Moran 1974). Bass also show a distinct dark pelvic spot on the liver between the pelvic fins as they develop (Drewry 1981).

More accurate identification can be obtained by clearing and staining specimens. Unique characteristics in position and shape of median ethmoid and predorsal bones, dorsal and anal pterygiophores (fin skeletal supports), vertebral column, and caudal skeleton were found in laboratory-reared striped bass and white perch (Fritzsche and Johnson 1980). Olney et al. (1983) further refined this for field-collected larvae using the same staining technique to show pterygiophore interdigitation patterns.

Behavior. Yolk-sac larvae are positively phototactic and alternate between swimming to the surface and sinking between swimming efforts (Pearson 1938; Raney 1952; Doroshev 1970). They begin to swim horizontally between 4:-5 days of age (McGill 1967). Post-yolk-sac larvae can resist water currents, and exhibit nocturnal migration patterns strongly oriented toward the bottom. This intensifies as the juvenile stage approaches. Juveniles are collected in water more than 6 m deep in the early part of the season and later migrate to shoal waters and toward the shore zone. These movements are triggered by increasing water temperatures. Falling water temperatures bring downstream movements into deeper water, so that by December juveniles leave the shore zone and migrate into deeper water or move out of estuaries entirely. Day-night beach seine comparisons show onshore movements at night, offshore movements by day; and dispersion closer to the bottom by day and throughout the water column at night. Movements are also affected by tidal stage, temperature, and salinity (Westin and Rogers 1978). Distribution of striped bass eggs, larvae, and juveniles in the Potomac estuary (Setzler-Harnilton et al. 1981) showed peak abundances of larval and juvenile bass either in areas of peak spawning or upstream in spite of the downstream river flow. Three phenomena were suggested to account for this distribution: continued upstream migration of the spawning stock, differential mortality of eggs and larvae throughout the spawning season, and the ability of older larvae and juveniles to maintain longitudinal position within the estuary. Densities of striped bass from egg to juvenile stage reported for different areas from the Hudson River to Albemarle Sound were summarized by Westin and Rogers (1978).

Because of declines in some striped bass populations, which may be linked to increasing pollution in nursery areas, numerous studies have been done on exposure of larvae and juveniles to various toxicants. A summary of the results of tests using pesticides, heavy metals, dyes, pharmaceuticals, organic substances, and fish anesthetics is given in Westin and Rogers (1978) and Bonn et al. (1976). Hall (1988) described *in situ* prolarval and yearling striped bass survival studies conducted for several years at spawning sites in the Nanticoke River, Chesapeake and Delaware Canal, and Potomac River. He described water quality conditions, test results, and procedures for relating these to young-of-the-year abundance indices. He also explained why these procedures may often give conflicting results, for example, poor prolarval survival occurred in *in situ* tests in the Potomac in 1986, but a fair juvenile index was reported. The consensus among most biologists is that overfishing was the primary cause of striped bass decline, probably exacerbated by poor spawning conditions. Other factors that have been investigated are power plant effects such as thermal pollution, impingement, and entrainment. Results of these experiments were summarized by Setzler et al. (1980).

Comparison of survivorship of laboratory-reared larvae and juvenile striped bass in various temperature-salinity combinations (Otwell and Merriner 1975) showed significant effects owing to all three factors (temperature, salinity, age). The greatest mortality rates occurred at lowest temperature and highest salinity combinations, and younger larvae had lower rates than older ones. Temperature was more limiting to growth and survival than salinity; the lowest temperature (12°C) produced 50% mortality when fish were introduced vs. 3.5% and 7.2% at 24° and 18°C, respectively. Growth experiments at three temperatures (17°,21°,28°C) of larvae from six native anadromous stocks spanning most of the geographic range of the species supported a countergradient variation in growth (Conover et al. 1997). Northern fish (New York, Maryland, and Nova Scotia) had higher growth rates than southern fish (North Carolina, South Carolina, and the Gulf of Mexico).

Experiments on digestive enzyme activities in striped bass from first feeding through larval development (Baragi and Lovell 1986) showed that larvae begin feeding 4 days post-hatch when all digestive enzymes except pepsin were present. Enzyme activities were 25-60% of those at day 32, increased until day 12, then decreased until day 16, at which point all enzyme activity increased again. The stomach is not formed until day 16 (Gabaudan 1984) when pepsin activity was detected, probably reflecting further development of gastric glands, which secrete this enzyme.

Food and feeding of larvae were studied in the laboratory as they related to mortality, point of no return, development, and energetics (Eldridge etal. 1981). Survival was direcrly related to the density of *Artemia salina* nauplii fed. The importance of the oil globule as an endogenous food source was demonstrated, as highest mortality was seen after absorption of the oil globule, which occurred much later than yolk-sac absorption. The rate of oil utilization was inversely related to food density. Starved larvae survived an average of 31 days after fertilization and did not exhibit a point of no return. Larvae starved for varying periods lost weight but recovered when provided with food, thus showing no clear point of no return (Rogers and Westin 1981).

The first food of larval striped bass is copepod and cladoceran nauplii and adults. Larval striped bass from the Potomac estuary (Beaven and Mihursky 1980) ate the largest prey items they could capture, and the food most frequently occurring in larval stomachs were adults and copepodites of *Eurytemora affinus* and cyclopoid copepod species. Other food positively selected were cladocerans *Bosmina longirostris* and *Daphnia* spp. Rotifers were selected against, probably because of size.

Some field studies (Kernehan et al. 1981; Setzler-Harnilton et al. 1981) showed circumstantial evidence that food densities influence survival of striped bass larvae. Martin et al. (1985) attempted to assess starvation in wild larval striped bass in the Potomac River estuary and to correlate this with prey densities. Nuttitional state was detern1ined by morphometrics, histology; RNA:DNA ratios, and fatty acid composition. All four techniques showed evidence of poor nutritional state early in the season but not in the latter part. Significant correlations among nutritional indices and copepod and cladoceran densities were found, indicating that the switch in predominance from copepod nauplii, copepodites, and rotifers to cladocerans (especially *Bosmina)* later in the season caused changes in the index values to a better nutritional status.

Juveniles 25-100 mm in the Potomac were nonselective feeders (Boynton et al. 1981). They ate mosdy insect larvae, polychaete worms, larval fishes, mysids, and amphipods. The diet reflected changes in the estuarine community composition associated with salinity changes; insect larvae being predominant where salinity was lest than 5 ppt. The most important food items were crustaceans *(Neomysis americanus*, *Crangon septimspinosus*, and *Palaemonetes pugio)* and fishes (naked goby, *Gobiosoma bosci*, bay anchovy, Adantic silverside, weakfish, and menhaden). Juveniles over 100 mm ate mosdy fishes (Markle and Grant 1970; Bason 1971).

Age and Growth. Striped bass are long-lived; one kept in the New York Aquarium lived to be 23 years old.

Growth of striped bass up to 70 cm length is calculated from scale annuli with the formula $1 = [(L - 1)/' / L'] + 1$, where L = TL of fish; *I'* = ratio of radius to annulus in question; L' = scale radius; and *1* = unknown TL (Scofield 1931; Merriman 1941). Annuli form on scales of bass caught in Virginia between April and June (Grant 1974) and in North Carolina from October to January (Trent and Hassler 1966). Growth from Maine to North Carolina was studied by Davis 1966 (Maine), Frisbie 1967 (Massachusetts), Westin and Rogers 1978 (Rhode Island), Merriman 1941 (Connecticut), Texas Instruments 1973 (Hudson River, N.Y.), Bason 1971 (Delaware), Jones et al. 1977 (Potomac River), Mansueti 1961b (Chesapeake Bay), Marshall 1976 (Albemarle and Pamlico sounds, N.C.), Holland and Yelverton 1973 (offshore North Carolina).

Growth rates are similar for fish from different geographical areas. Females grow larger than males; most bass of 13.5 kg and heavier are probably females. The relationship between FL in centimeters and weight in kilograms is as follows: 30-33 cm/ 0.3 kg; 45-50 cm/l.3-1.4kg; 61 cm/2.3 kg; 76-81 cm/ 4.5-6.8 kg; 83-91 cm/8.2-9 kg; 100 cm/ 13.6 kg; 109 cm/ 18 kg.

Growth of young-of-the-year striped bass in the Hudson River followed an s-shaped curve with peak growth rates (0.8-0.9 mm.day-l) occurring from mid-June to mid-August (Dey 1981). Growth was positively correlated with water temperature in the early stages of development but showed no relationship in the later juvenile stages. Neither freshwater flow nor juvenile abundance showed significant correlations with growth rate. Growth of striped bass larvae in the Hudson River was less than that reported from the Patuxent River (Mansueti 1958a) and Chesapeake Bay (Vladykov and Wallace 1952) probably because spawning occurs earlier and the growing season is longer in these more southerly locations. Jones and Brothers (1987) examined the otolith increment aging technique for larval striped bass in the laboratory under optimal and suboptimal feeding conditions. They found that daily rings were deposited and were discernible with light microscopy from day 4 posthatch (corresponding to initiation of feeding) through the first 2 months in well-fed larvae. Larvae reared under restricted feeding regimes yielded ring counts that underestimated their age by several days. Counts made using scanning electron microscopy came closer to reflecting the true age. Therefore, one cannot rely on otolith aging techniques using the light microscope in field-collected larvae without making random checks using scanning electron microscopy preparations for verification of the results.

General Range. Atlantic coast of eastern North America, from the lower St. Lawrence River and the southern side of the Gulf of St. Lawrence to northern Florida; along the northern shore of the Gulf of Mexico to Alabama and Louisiana; running up into brackish or fresh water to breed. In the last quarter of the nineteenth century they were introduced on the Pacific coast, where their range now extends from British Colombia to Ensenada, Mexico (Forrester et al. 1972). They have also been introduced into Russia, France, and Portugal. Striped bass have been stocked in many rivers and reservoirs throughout the United States. Information on transplanted stocks can be obtained from Setzler et al. (1980) and Westin and Rogers (1978).

Occurrence in the Gulf of Maine. The range includes the coastline of the Gulf from Cape Cod to western Nova Scotia. Distribution is determined by the very evident preference for surf-swept beaches and for particular stretches of rocky or bouldery shoreline, as well as for shallow bays, inlets, and estuaries. The geographic status of bass in the Gulf also depends on whether it is a good bass year or a poor one. When bass are reasonably plentiful, the outer shore of Cape Cod provides the most productive surf casting, with Monomoy Island, the general vicinity of Nauset Inlet, and the tip of the Cape northward from Highland Light being perhaps the warmest stretches. Considerable numbers, mostly smaller individuals, are caught in Pleasant Bay; within Nauset Marsh, and in Town Cove, Orleans. The most productive trolling grounds are along the eastern and southern sides of Cape Cod Bay in most summers, especially off the Eastham shore a few miles southward from Wellfleet, and off the mouth of Scorton Creek, Barnstable, and the Sandwich shore. The shores of Cape Cod and Cape Cod Bay have, in fact, been the chief centers of abundance for bass within the Gulf from as far back as the records go. Few bass are reported along the rocky stretch from the Cape Cod Canal to the entrance to Plymouth Harbor, but many are caught in Plymouth Harbor, especially off Eel Creek, and up Dux bury Bay to the salt marsh creeks that open into its head.

Surf casters account for some along Dux bury Beach on the outside and a few in the boulder-strewn area at the western end of Humarock Beach. The North and South rivers in Marshfield yield considerable numbers in good years. Anglers casting from the shore take a few on boulder-strewn stretches along the Scituate shore, and Glades Point is famous for large bass. The Cohasset shoreline yields a few yearly; occasionally a very large one. In seasons when there is a good run of the smaller sizes, considerable numbers are taken at various places within the limits of Boston Harbor; Hull Gut, Weir River in Hingham, and Wollaston Beach are well-known localities. In years in which there is a run of little fish, many are caught from the docks and bridges to the head of Boston Harbor.

The north shore of Massachusetts Bay seems not to be as attractive for bass as its succession of inlets, beaches, and rocky headlands might suggest, for catches reported are small and scattered in most summers. But the beaches and enclosed waters from a few miles north *ot* Cape Ann to the mouth of the Merrimac River are productive enough to rank second to the Cape Cod-Cape Cod Bay region. Bass are taken in the surf from Ipswich Beach, Cranes Beach, and along the entire length of Plum Island Beach. Many are caught by boat fishermen over the flats within the mouth of the Merrimac, as well as around the jetties at its entrance. Schools are often reported in Plum Island Sound, and the Parker River, emptying into it, is well known for bass.

Some are caught in Hampton Harbor, N.H. The next important bass waters (moving northward) are the lower reaches of the Piscataqua River system, marking the boundary between Maine and New Hampshire. In good years bass are to be caught in several streams that drain the southern part of the Maine coast, especially in the York, the Mousam, and the Saco, which is the most productive. Schools are sighted and a few fish are caught along intervening beaches and some in the shallows of Biddeford Pool.

In the Bay of Fundy region, striped bass are confined to large warm estuaries and neighboring fresh water, that is, to those of the Saint John, Minas Basin-Cobequid Bay; and Shubenacadie River systems and of the Annapolis. Information suggests that bass were always more plentiful in Saint John River waters than anywhere along the eastern part of the coast of Maine. Bass are well known in the Minas Basin-Cobequid region. The status of bass is especially interesting in the Shubenacadie River, for they are not only caught in freshwater there and in Shubenacadie Lake, where they are known to spawn, but some large fish remain throughout the year in the lake; that is, they behave like a landlocked population. A thousand or so are caught yearly by anglers in the lake and in the river; and it is said that fish as large as 23 kg have been taken, although most of them run small.

Bass are also to be caught in various bays and river mouths along the western shore of Nova Scotia; but there is no definite information as to how plentiful they are or how large.

Localities along the outer coast of Nova Scotia where stripers have been reported are the head of Mahone Bay, Chedabucto Bay, Mira Bay; and other harbors of Cape Breton. The shoal estuaries of the Richibucto Bay region and the estuary of the Miramichi River harbor isolated populations of bass plentiful enough to have yielded commercial catches. There is also a population (or populations) below Quebec in the lower St. Lawrence River that winters in that same general region, as proved by marking experiments carried out by Vladykov as reported by Bigelow and Schroeder. There are enough bass around Isle d'Orleans for bass fishing to be a favorite sport there, but commercial catches are so small as to suggest that the stock is not very large.

Migrations. No phase of the life history of striped bass generates as much discussion among fishermen as their migrations, and the picture remains puzzling. It seems certain that striped bass do not ordinarily travel far until they are 2 years old. Migratory patterns vary from local seasonal movements within a river system or estuary to extensive coastal migrations. In general, striped bass in Canadian waters remain within the Gulf of St. Lawrence and its river systems. Some interchange may take place among populations found in various bays and rivers around the outer coast of Nova Scotia, but it is doubtful whether these have any regular migratory association, either with Gulf of St. Lawrence fish or with those of more southern waters, except in occasional years. South of Cape Hatteras and in the Gulf of Mexico striped bass remain in the home river for their entire life cycle and migrate up and down river instead of going to sea (Raney 1957).

From Cape Hatteras north to New England some fish remain within a river system, whereas others migrate regularly along the coast following the shoreline northward and eastward as far as New England in spring, to return westward and southward in autumn. This was verified for bass 2 and 3 years old by returns from tagging experiments by Merriman (1941) at the eastern end of Long Island and in Connecticut from 1936 to 1938. Recaptures of fish that had been tagged there in May came mosdy from farther east along southern New England, one from Cape Cod Bay and another from Cohasset on the southern shore of the inner part of Massachusetts Bay. Recaptures from fish tagged in summer were mosdy from nearby (evidence of a stationary population), whereas those for autumn-tagged fish were scattered along the coast from the eastern end of Long Island to Chesapeake Bay; with one from Croatan Sound, one from Albemarle Sound, and one from Pamlico Sound in North Carolina. Chesapeake Bay harbors both migratory bass, as proved by tagging experiments and other evidence, and nonmigratory, as proved by the fact that fish of all sizes are taken there both in summer and winter, though not as many of them as in spring and fall. Similarly; some bass winter in northern waters though most of the fish appear to be migrants there, and a considerable percentage do so in the lower reaches of the Hudson River estuary.

The coastal migrating stock is predominantly female (only about 10% of the bass of northern waters are males), but males are nearly as numerous as females southward from Delaware Bay (Merriman 1941; Oviatt 1977). This is probably because larger fish migrate farther and females grow larger than males.

In the salt estuaries and open waters of the Gulf bass are taken only from late spring through the summer and until late in the fall. In years when they are plentiful enough to attract attention, they are likely to be reported about equally early in the season all along from Cape Cod to the Merrimac River. It has long been known, too, that pound nets on Long Island and along southern New England ordinarily make large catches only in spring (peak in May) and again from early October into November and that large spring catches are made progressively later in the season, proceeding from south to north, the reverse being true in autumn. Bass are generally distributed along the Massachusetts coast of the Gulf in Mayor by the first days of June. The first bass were reported in and off Hampton Harbor and in the Piscataqua River about the beginning of the second week in June (1950) and in Casco Bay about the middle of the month. They are said to appear as early as the end of May in Bangor Pool at the head of the estuary of the Penobscot in some years. In 1950 they were scattered all along Penobscot Bay before the end of June. It is probable that the seasonal schedule is about the same for the bass at the head of the Bay of Fundy; but informatio n is scant.

Once bass have appeared, they continue in evidence until well into the autumn. During this part of the year, bass off the coasts of Massachusetts and most of those in Maine are in salt and brackish waters, except for those that enter freshwater to spawn. But they are caught all summer in freshwater far above the head of the tide in the Shubenacadie and the Annapolis in Nova Scotia. Part of the stock may have a ~imilar habit in various rivers of Maine, as the Kennebec, where they ran up as far as Waterville until they were prevented from doing so by the construction of the dam at Augusta.

In rivers where bass winter, they may be taken in any month from late autumn into spring. As autumn approaches they vanish from the open coast. Most of them have disappeared along the outer coasts of Maine by mid-October or the end of that month in most years, but they may be in evidence in Maine rivers until later in autumn. Farther southward in the Gulf, they may linger equally late off open beaches. In 1950, a late season, Cape Cod Bay eastward from the Cape Cod Canal was described to Bigelow and Schroeder as "loaded" with bass until the third week in October, schools of small fish were reported on 9 November, a half a dozen were landed from the surf on 18 November, and one was caught on 3 December.

Striped bass in saltwater may be in evidence until equally late in the season in the Minas-Cobequid Bay region at the head of the Bay of Fundy, for fishermen report taking them there through October and into November. Knight (in Bigelow and Schroeder) noted that as the weather becomes colder, bass of the southern side of the Gulf of St. Lawrence penetrate into bays and arms of the sea and ascend rivers at some distance, where they spend the winter resting on the mud in a half-torpid state. According to Atkins (in Bigelow and Schroeder), bass in Maine "pass the winter in quiet bays and coves of freshwater in the rivers." It has been known for many years that some bass winter in the Parker River in northern Massachusetts. Local fishermen also say that a few bass winter in deeper parts of the North and South rivers in Marshfield, on the southern side of Massachusetts Bay, apparently in saltwater.

Capture in 1949 of a 46-cm striped bass some 97 km south of Martha's Vineyard in 128 m of water in February seems to support the view that at least some of the bass of the Cape Cod region may only move offshore to winter on bottom well out on the continental shelf in localities where otter trawlers do not ordinarily operate, as has been found to be true of summer flounder. If true, this would mean that, as Merriman suggested, some Chesapeake-hatched bass that spread northward to Massachusetts and Maine when 2 or 3 years old may never return to their home waters.

Importance. Striped bass were a familiar fish all along the coast from Cape Cod to the Bay of Fundy when New England and the Maritime Provinces were first colonized (Litde 1995). Plentiful and easy to capture because of their large size and their habit of coming into the mouths of streams and creeks, they were an important food supply for early setders. Bass were caught, dried, and eaten by New England Indians before colonists arrived (Fearing 1903). Nothing regarding bass is of greater interest to commercial fishermen and to anglers than the great fluctuations in their numbers in the Gulf within historic times. Population fluctuations from colonial times to the 1950s were summarized by Bigelow and Schroeder. Houseman and Kernehan (1976) produced an indexed bibliography of striped bass from 1670 to 1976.

Commercial Fishery. Striped bass have not been plentiful enough in the Gulf of Maine to support a commercial fishery of any great magnitude at any time during the past lOO years. It is illegal to take striped bass commercially in New Hampshire, Maine, or New Jersey as they are considered a sport fish. Commercial fishing is allowed in Massachusetts with hook and line. The gear used varies geographically, depending on local preferences and restrictions. The most frequendy used gear are gill nets, haul seines, floating traps,

pound nets, and rod and reel. Commercial landings from 1930 to 1974 by states
from Maine to North Carolina were summarized by Setzler et al. (1980). Commercial landings from 1962 to 1996 are given in Fig. 205.

Recreational Fishery. During periods of plenty, striped bass are the leading game fish in the Gulf of Maine all along the coast, from the outer shore of Cape Cod to New Hampshire waters. The number of anglers who cast for them in the surf along the beaches of Cape Cod, northward from Cape Ann to the mouth of the Merrimac, and at scattered spots elsewhere is certainly in the thousands. Many charter boats troll daily for bass in Cape Cod Bay; some also troll along the Plum Island shore and at the mouth of the Merrimac; and many fish are caught by trolling, live-line fishing, and even by still fishing in the various inlets. So far as is known, the Shubenacadie River and Lake and the Annapolis River are the only waters on the Canadian shores of the Gulf where stripers attract attention as game fish.
Striped bass are one of the most important sport fishes along the entire U.S. Adantic coast, prized by both surf fishermen and boat anglers for their large size and fighting qualities (Lyman and Woolner 1954). In the 1800s anglers established large clubs for striped bass fishermen from New Jersey to Massachusetts (Alperin 1987).
.Stripers are voracious feeders and strike almost any type of bait or lure. Baits most frequendy used are menhaden, squid, eel, crab, clams, bloodworm, plugs, spoons, flies, and casting lures. They are caught by casting, trolling, or bait fishing. Most angling occurs in inland waters but there is considerable variation in the percentages caught in the ocean and inland. In the ocean, catch by boat nearly always exceeds catch from shore. Most boat fishing is from private or rental boats rather than charters (Richards and Deuel1987). Much has been written about the techniques of surf casting, trolling, choice of lines, and baits; but it is interesting, in comparison, to read, in Wood's *New England's Prospect,* published in 1634 (p. 37), that "the way to catch them is with hook and line, the fisherman taking a great cod line to which he fasteneth a peece of lobster and threwes it into the sea. The fish biting at it, he pulls her to him and knockes her on the head with a sticke."

Culture. The desirability of striped bass for commercial and recreational purposes has led to many stocking and culture programs. Striped bass were artificially propagated in the 1800s (Worth 1882). The first transplant of striped bass stock from the Navesink River, N.J., to the west coast (lower Sacramento River) took place in 1879 (Mason 1882). When it was discovered that striped bass could complete their life cycle in freshwater (Scruggs and Fuller 1955), inland states became interested in stocking them. Striped bass culture was rapidly expanded after the development of techniques for artificial induction of ovulation by hormone injections (Stevens 1966). Today bass are produced in state and federal hatcheries for stoCking lakes, reservoirs, and impoundments for sport fishing, as well as for the control of threadfin and gizzard shad populations. Hatcheries are located in 16 different states (Westin and Rogers 1978).

Management. Striped bass management has a long history: In 1693 the General Court of Massachusetts Bay Colony ordered that they not be used for fertilizer. In 1776 New York and Massachusetts passed laws prohibiting the sale of stripers in the winter (Setzler et al. 1981). Regulations restricted netting in the Hudson River in 1892 (Richards and DeueI1987). In the 1800s there were large numbers of stripers but they nearly disappeared from New England and the Mid-Atlantic coasts by the early 1900s.
By 1938 striped bass reappeared in force, products of the huge 1934 year-class and the need was recognized for interstate cooperation for utilization of the resource. In 1942 Congress created the Atlantic States Marine Fisheries Commission (ASMFC) to develop a joint program for the promotion and protection of marine and anadromous fisheries of the Atlantic seaboard. One of their first recommendations was adoption of a 16-in. FL (40.6-cm) minimum size for striped bass (a 3-year-old fish). All the New England states, New York, New Jersey, and Pennsylvania adopted this measure, but from Delaware south the states continued to allow the taking of smaller fish. Coastwise commerdal landings fell from 6.8 million kg to 1.6 million kg by 1983 and juvenile production in Chesapeake tributaries remained poor throughout most of the 1970s and 1980s (Field 1997). The decline in the east coast striped bass stocks has been attributed to overfishing, nutrient enrichment of the habitat with the resulting temperature oxygen squeeze on subadults, deterioration of the nearshore habitat for juvenile bass from loss of submerged vegetation, decreased survival of larvae owing to environmental pollution, poor nutrition, fluctuations in the physical environment, and predation (reviewed by Setzler-Hamilton et al. 1988 for Chesapeake Bay).
In 1979 congressional action established the Emergency Striped Bass Research Study (ESBS) directing the U.S. Fish and Wildlife Service and the National Marine Fisheries Service to monitor the status of striped bass stocks and determine the causes of the decline and its economic impact (Richards and Deuel 1987). The role of the various agencies and the management perspectives were discussed in the November-December issue of *Fisheries* (Vol. 12, 1987). The ASMFC was asked to administer an inter jurisdictional management plan known as the Interstate Fisheries Management Plan (ISFMP) for striped bass of the Atlantic coast from Maine to North Carolina. This was adopted in 1981 and called for a minimum size of 14 in. TL (35.6 cm) in nursery rivers and bays and 24 in. TL (61 cm) along the coast, and banned fishing in spawning rivers during the spawning period. This plan proved inadequate and has been amended several times; by 1984 all the states within the migratory range of striped bass were ordered to adopt the new plan (Alperin 1987). In 1985 an additional amendment was adopted to protect the 1982 and subsequent year-class females until 95% have spawned at least once. This resulted in a 33-in. (83.8-cm) minimum size limit in all areas by 1987.
In 1995 spawning stock biomass in the Chesapeake Bay reached healthy levels so striped bass were formally declared to be a restored stock and commercial and recreational management restrictions were somewhat relaxed (Field 1997; Shepherd 1998a). Male spawning stocks increased from three to ten spawning age-classes between 1985 and 1995. Coastwise recreational catch climbed from an estimated 514,000 fish in 1985 to a record high of 8.5 million. The Hudson River population had not suffered the same decline in abundance as the Chesapeake stock, and the Delaware and Roanoke populations continued to produce strong year-classes. States adopted

Amendment 5 to the original management plan in 1995 to allow expanded state fisheries on the recovered populations.

Stocks. Striped bass stocks commingle along the northeastern U.S. and Canadian coasts supporting mixed-stock fisheries in which stock compositions fluctuate widely (Wirgin et al. 1997). Attempts have been made to discriminate stocks for over 50 years. The methods, results, strengths, and weaknesses of the techniques and suggestions for future research and application of these results were reviewed by Waldman et al. (1988). In general, techniques applied included those based on behavior and ecology (tagging, catch data, parasites); phenotype (meristics, morphometrics, trace element uptake, scale morphology; and isoelectric focusing of eye lens proteins); and genotype (cytogenetics, protein electrophoresis, restriction endonuclease analysis of mitochondrial DNA, and immunogenetics). Most techniques can classify stocks correctly at the 70-80% level but none is 100% accurate. All have advantages and disadvantages, and results have been further complicated by widespread stocking of nonnative stocks to supplement wild populations (e.g., stocking the Kennebec River, Maine, with Hudson River, N. Y:, striped bass). Waldman et al. (1988) recommended establishment of a library of genetic information on striped bass stoCks so that continual adjustments do not have to be made for environmental and ontogenetic changes that affect phenotypic stock discrimination, a reanalysis of the stability and usefulness of meristic characters for determining the contributions of various stocks to the coastal migrating population, and an assessment of hatchery contributions to wild populations.

Four major spawning stocks of striped bass make up the Atlantic coast migratory stock: the Roanoke stock, which spawns in the Roanoke River, N.C.; the Chesapeake stock, which spawns in Maryland and Virginia tributaries of Chesapeake Bay; the Delaware River stock; and the Hudson River stock. The Chesapeake Bay and Hudson River stocks are the most important in a mixed-stock model (Wirgin et al. 1997). Chesapeake Bay contributed the major portion of the stock (over 90%) up to 1975, as shown by discriminant analysis of five morphological characters (Berggren and Lieberman 1978). Decline in the Chesapeake stock size after the dominant 1970 year-class and the relative stability of the Hudson River stock meant that until recently the Hudson River contributed a higher percentage of the migrating stock than it did previously: The Delaware River, once an important spawning area, had low production for most of the twentieth century; but the stock has increased tremendously in recent years. Striped bass collected in Rhode Island and separated into Hudson and Chesapeake Bay stock on the basis of isoelectric focusing of eye lens proteins (Fabrizio 1987) showed that about 54% were from Chesapeake Bay and 46% from Hudson River stock.

ACKNOWLE DGME NTS .Drafts of the white perch account were reviewed by John Galbraith and John Waldman, and drafts of the striped bass account, by John Boreman, Gary Shepherd, John Waldman, and John Walter.