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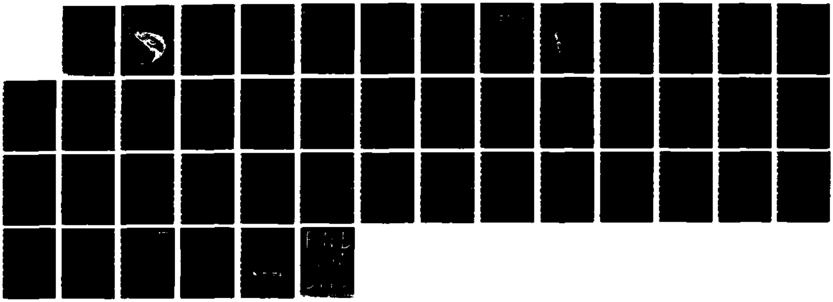

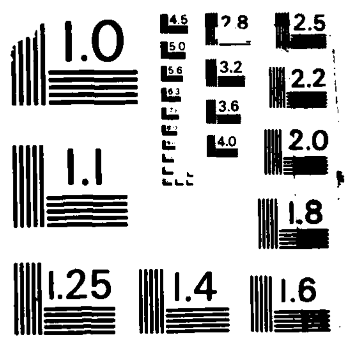

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October 1983

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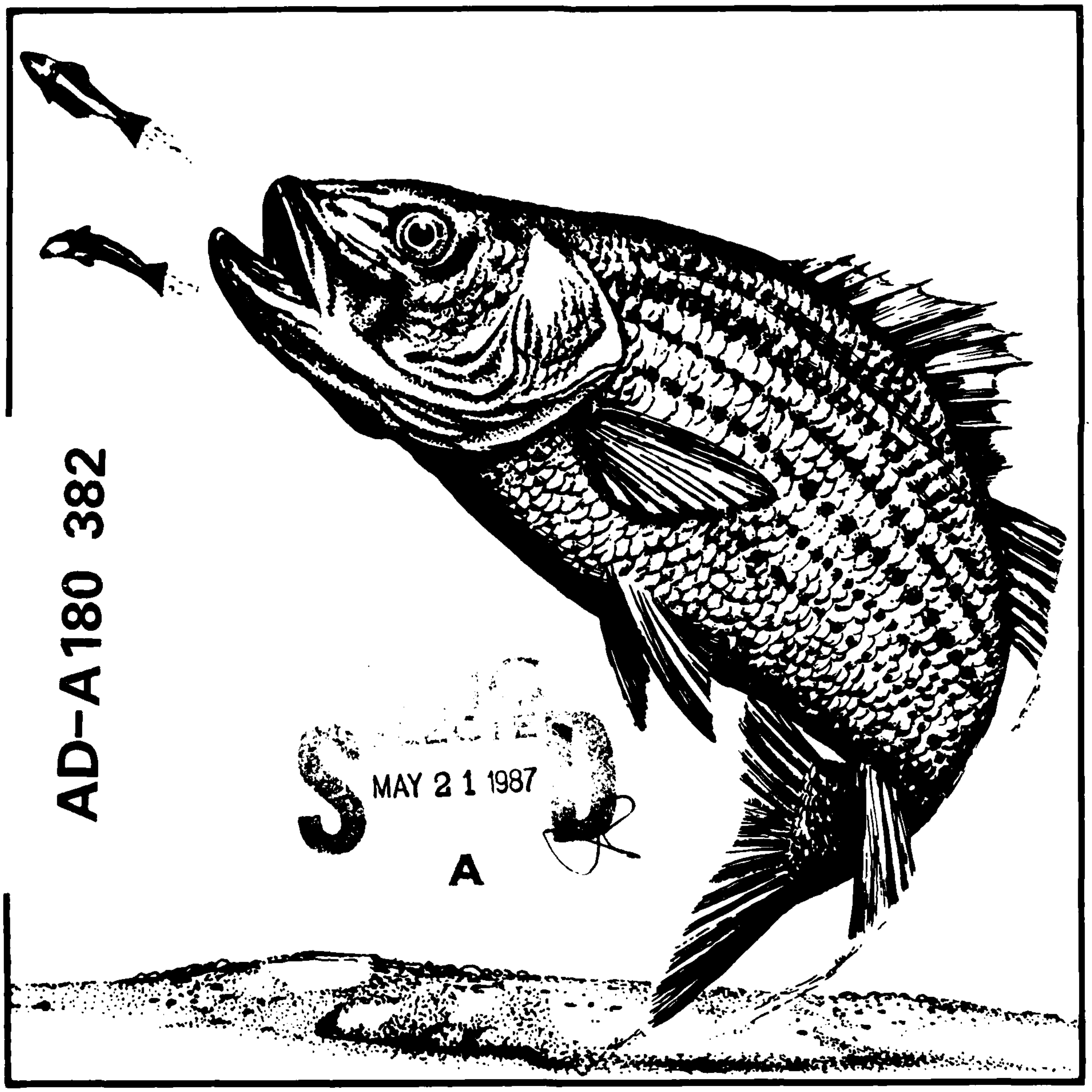
Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

STRIPED BASS



Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

FWS/OBS-82/11.8
TR EL-82-4
October 1983

Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic)

STRIPED BASS

by

Clemon W. Fay, Richard J. Neves, and Garland B. Pardue
Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

Project Manager
Larry Shanks
Project Officer
Norman Benson
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

This study was conducted
in cooperation with
Coastal Ecology Group
U.S. Army Corps of Engineers
Waterways Experiment Station

Performed for
National Coastal Ecosystems Team
Division of Biological Services
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

CONVERSION FACTORS

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (gm)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (mt)	2205.0	pounds
metric tons (mt)	1.102	short tons
kilocalories (kcal)	3.968	BTU
Celsius degrees	1.8(C°) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
BTU	0.2520	kilocalories
Fahrenheit degrees	0.5556(F° - 32)	Celsius degrees

CONTENTS

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

A Habitat Suitability Index (HSI) model has been completed by the U.S. Fish and Wildlife Service for the striped bass. HSI models are designed to provide a numerical index of the relative value of a given site as fish or wildlife habitat.

Suggestions or questions regarding this report should be directed to:

Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Boulevard
Slidell, LA 70458

or

U.S. Army Engineer Waterways Experiment Station
Attention: WESER
Post Office Box 631
Vicksburg, MS 39180

This series should be referenced as follows:

U.S. Fish and Wildlife Service. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11. U.S. Army Corps of Engineers, TR EL-82-4.

This profile should be cited as follows:

Fay, C.W., R.J. Neves, and G.B. Pardue. 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) -- striped bass. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.8. U.S. Army Corps of Engineers, TR EL-82-4. 36 pp.

ACKNOWLEDGMENTS

We are grateful for reviews by David Whitehurst, Virginia Commission of Game and Inland Fisheries, Roanoke, and Mark Bain, Department of Fisheries, University of Massachusetts, Amherst.

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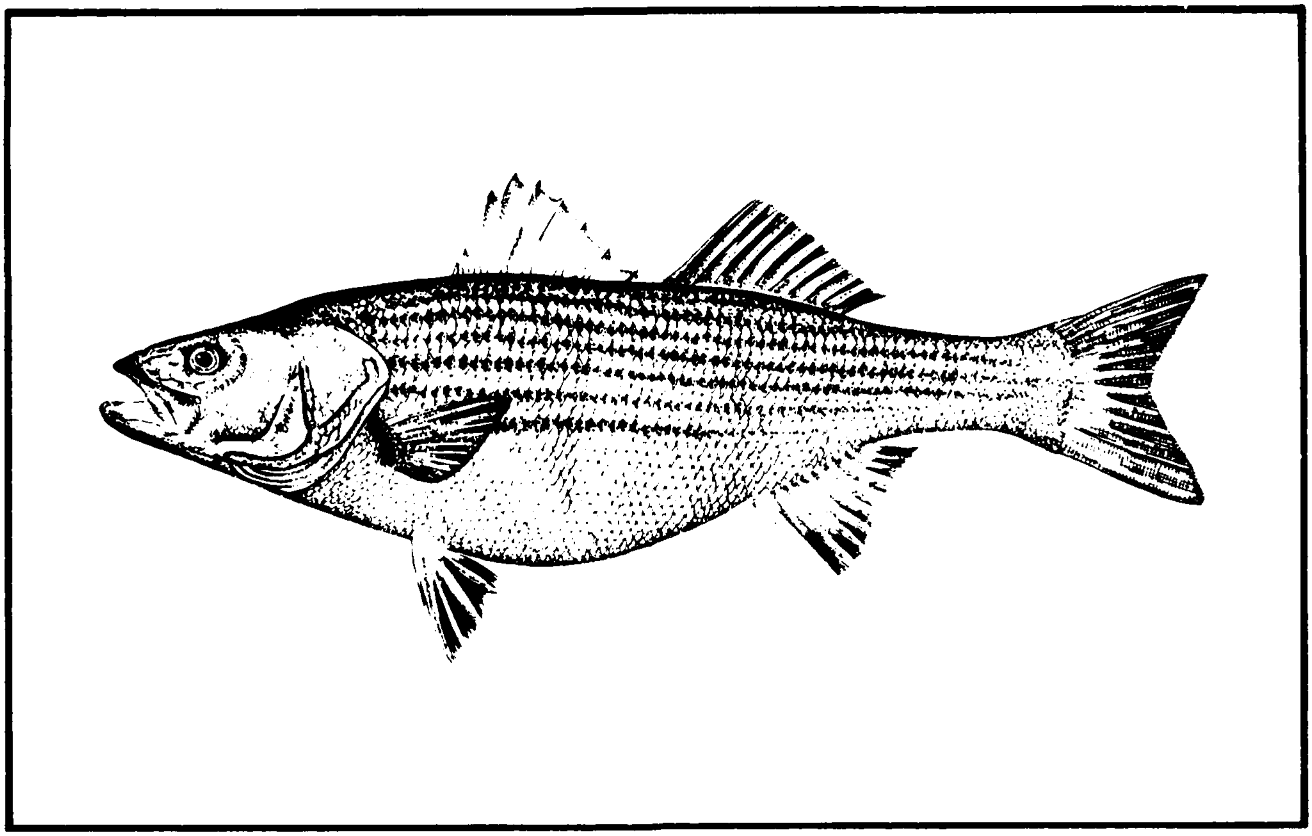


Figure 1. Striped bass.

STRIPED BASS

NOMENCLATURE/TAXONOMY/RANGE

Scientific name........ Morone saxatilis
Preferred common name .. Striped bass (Figure 1)
Other common names ... Striper, rock, rockfish, greenhead, squid-hound, linesider, roller (Westin and Rogers 1978)
Class.................... Osteichthyes
Order..................... Perciformes
Family................. Percichthyidae

Geographic range: Atlantic coast from the St. Lawrence River, Canada (Magnin and Beaulieu 1967), west to Montreal (Vladykov and McAllister 1961), and south to the St. Johns River, Florida (McLane 1955). Gulf of Mexico from west Florida coast to Louisiana (McIlwain 1968). Introduced to North American Pacific coast in 1879, now extending from British Columbia south to Ensenada, Mexico (Forrester et al. 1972). Introduced into waters of the Soviet Union (Doroshev 1970), France and Portugal (Setzler et al. 1980). Landlocked form has been introduced successfully into many freshwater impoundments in North America (see Figure 2 for map of mid-Atlantic distribution of striped bass).

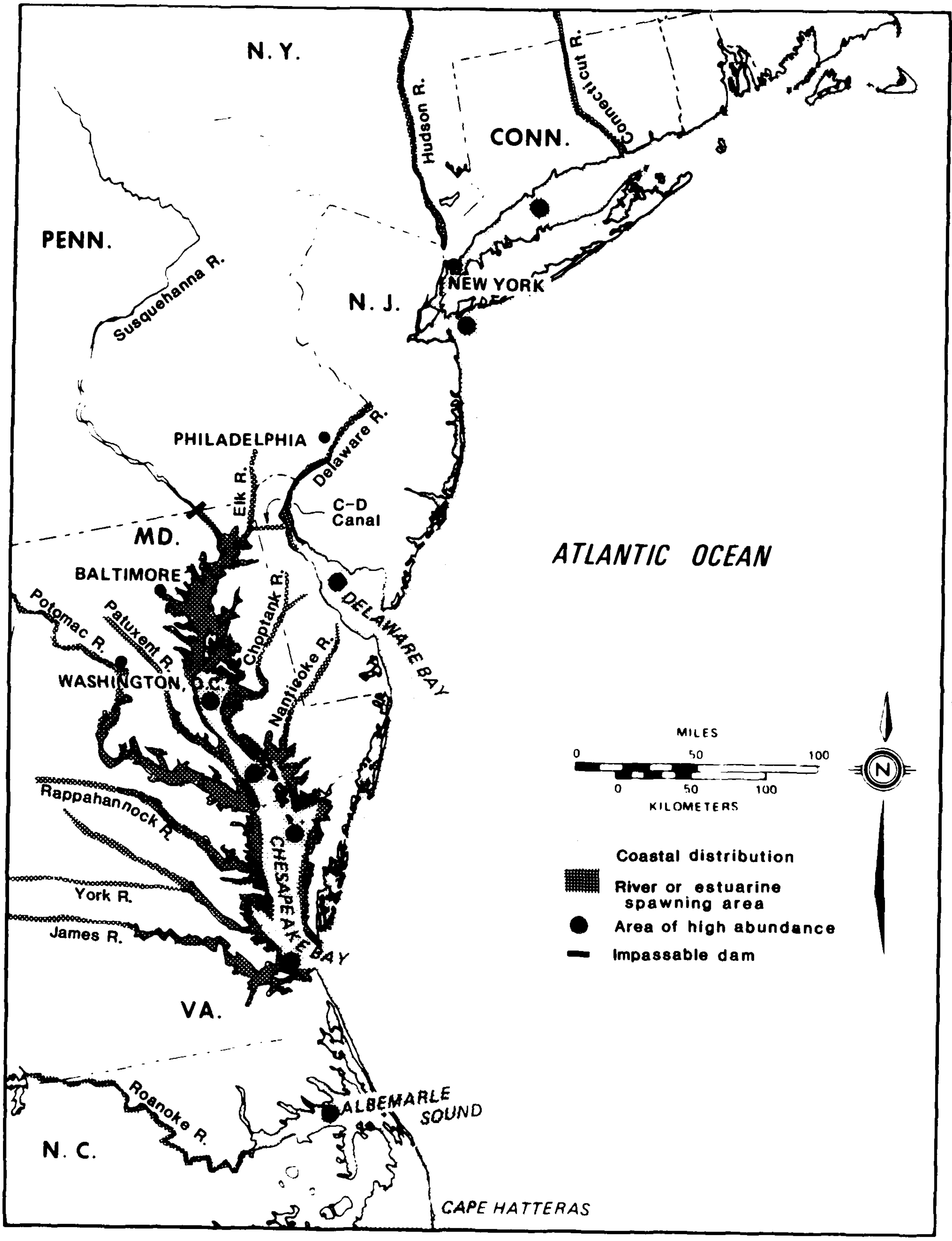


Figure 2. Mid-Atlantic distribution of striped bass.

MORPHOLOGY/IDENTIFICATION AIDS

The majority of this information is taken from Hardy (1978), as summarized in Setzler et al. (1980). For further information, the reader is referred to summaries by Westin and Rogers (1978) and Smith and Wells (1977).

Body elongate, moderately compressed. Color: dorsally, light green to olive, steel blue, brown to almost black; laterally, silver with 7-8 dark, longitudinal, continuous stripes, one of which always follows the lateral line, and three of which are below the lateral line; ventrally, white to silver with brassy iridescence. Two dorsal fins present, one spiny and one soft, separated at the base and approximately equal in length. Two spines present on posterior edge of operculum. Teeth at base of tongue in two distinct parallel patches. Maxillary extending nearly to middle of orbit, lower jaw projecting.

Meristic characters: First dorsal fin spines 8-10, usually 9; second dorsal fin rays 9-14 (10-14 in Chesapeake Bay), usually 12; anal fin rays 7-13 (9-12 in Chesapeake Bay), usually 11; anal spines 3, increasing stepwise in length. Scales ctenoid, 50-72 along lateral line (53-65 in Chesapeake Bay). Vertebrae 24-25, usually 25. Gillrakers on first arch 19-29 (21-27 in Chesapeake Bay).

Proportions as times in standard length; greatest depth, 3.45-4.20; average depth at caudal peduncle, 9.6; head length, 2.9-3.25. Proportions as times in head length; eye, 3.0-4.9; longest dorsal spine, 2.3; second anal spine, 5.0-6.0; maxillary, 2.5 (Hardy 1978).

REASON FOR INCLUSION IN SERIES

The striped bass is a major fishery resource of both recreational and commercial importance. It has a wide natural range and thrives in many freshwater, estuarine, and marine habitats. The striped bass can be considered a "generalist" in many respects and tolerant of a variety of environmental conditions. However, certain critical life stages and physiological activities of the striped bass are strongly influenced by environmental factors, which act to limit survival and abundance of the species (Bain and Bain 1982a).

The mid-Atlantic coast is particularly important for striped bass, because most of the major Atlantic coast spawning grounds and an extensive recreational fishery occur within the region.

LIFE HISTORY

Reproductive Physiology/Strategy

Striped bass are heterosexual, though hermaphroditism has been reported (Schultz 1931; Morgan and Gerlach 1950; Westin 1978). Females grow larger than males, and most striped bass over 13.6 kg (30.0 lb) are females (Bigelow and Schroeder 1953).

Most male bass mature during their second year, and all are mature by age three. Most females mature during their fourth (Delaware and Potomac Rivers, Upper Chesapeake Bay) or fifth (Connecticut and Hudson Rivers) year, and all are mature by their sixth year (Pearson 1938; Bason 1971; Texas Instruments, Inc. 1975a; Wilson et al. 1976).

Striped bass are polygamous and egg fertilization is external (Setzler et al. 1980). Fecundity of striped bass is highly correlated with weight, length, and age (Westin and Rogers 1978). Documented total fecundity estimates range from 15,000 eggs in a 46-cm (18.1-inch) fish (Mansueti and Hollis 1963) to 40,507,500 in a 13-year-old, 14.5-kg (32.0-lb) fish (Jackson and Tiller 1952). Mean fecundity estimates (or ranges) for representative ages of striped bass from several mid-Atlantic areas are given in Table 1. Not all ova present in a female will mature in 1 year. Generally, 10% to 30% of the ova of a female striped bass mature in a season, particularly in larger, older bass (Jackson and Tiller 1952; Lewis and Bonner 1963).

Table 1. Mean fecundities (or range if mean unavailable) of striped bass of representative spawning ages, lengths, and weights, from various mid-Atlantic areas.

Location	Age (yrs)	Thousands of mature ova	Weight (kg)	Length (cmFL)[a]	Source
Hudson River	6	451	-	55.1	Texas Instruments, Inc. (1973)
Hudson River	8	1,548	-	80.9	Texas Instruments, Inc. (1973)
Hudson River	10	1,841	-	88.9	Texas Instruments, Inc. (1973)
Chesapeake Bay	4	68	2.0	51.2	Jackson and Tiller (1952)
Chesapeake Bay	6	856	5.9	71.3	Jackson and Tiller (1952)
Chesapeake Bay	8	1,682	7.2	83.0	Jackson and Tiller (1952)
Chesapeake Bay	10	2,510	9.7	92.1	Jackson and Tiller (1952)
Potomac River	12-14	3,257-4,864	20.1-25.6	108.7-115.6	Hollis (1967)
Roanoke River	4	320	1.8-2.2	50.8-53.1	Lewis and Bonner (1966)
Roanoke River	6	454	2.7-3.1	55.9-58.2	Lewis and Bonner (1966)
Roanoke River	10	1,090	6.4-6.8	71.1-73.4	Lewis and Bonner (1966)
Offshore, N. Carolina	8	1,073	7.3-8.8	80-84	Holland and Yelverton (1973)
Offshore, N. Carolina	9	2,100	7.7-13.6	82-98	Holland and Yelverton (1973)
Offshore, N. Carolina	10	2,922	9.0-19.0	89.2-109.0	Holland and Yelverton (1973)
Offshore, N. Carolina	11	2,928	12.2-12.7	95.0-98.7	Holland and Yelverton (1973)

[a]FL = fork length.

Linear relationships are available for the Roanoke River, North Carolina (Lewis and Bonner 1966), and Hudson River, New York (Texas Instruments, Inc. 1973), that predict the number of mature ova in a striped bass from its weight. Similar relationships are available for fecundity based on body weight, length, and age of striped bass off the North Carolina coast (Holland and Yelverton 1973).

Spawning

Striped bass are anadromous, spawning once a year in fresh or nearly fresh water. Along the Atlantic coast, the spawning period ranges from mid-February in Florida to June and July in the Gulf of St. Lawrence (Bigelow and Schroeder 1953; Barkuloo 1970). Table 2 gives spawning seasons and peaks for some of the major striped bass spawning areas of the mid-Atlantic region. The months of April, May, and June span the time of nearly all spawning activities in the mid-Atlantic region.

The principal spawning areas for striped bass along the Atlantic coast are found in Chesapeake Bay and its tributaries (Merriman 1941; Raney 1957; Kernehan et al. 1981). Spawning locations for selected areas of the mid-Atlantic region are given in Table 3. Kernehan et al. (1981) suggested that previous, inadequate sampling had underestimated the importance of the Upper Chesapeake Bay as striped bass spawning grounds. Other researchers stated that the Chesapeake-Delaware Canal (C-D Canal) is the most important mid-Atlantic region spawning area (Hollis 1967; Dovel 1971; Dovel and Edmunds 1971; Warsh 1977). Based on total eggs spawned in an area, data from Kernehan et al. (1981) showed that, for the years 1973-1977, Upper Chesapeake Bay from Turkey Point southeast to Worton Point is far more important than the relatively small C-D Canal.

Males arrive first on the spawning grounds in the spring, while most females remain offshore until shortly before spawning (Vladykov and Wallace 1952; Trent and Hassler 1968; Holland and Yelverton 1973). After arrival of the females on the spawning grounds, characteristic mating behavior consists of a single female surrounded by up to 50 males, at or near the surface (Setzler et al. 1980). Eggs are broadcast loosely in the water, and normal spawning duration for a single female is less than 4 hr (Lewis and Bonner 1966).

Spawning peaks are apparently triggered by a noticeable increase in water temperature, generally beginning at temperatures of at least 14° C (57 °F), though spawning at lower temperatures has been observed (Johnson and Koo 1975; Mihursky et al. 1976; Westin and Rogers 1978).

Eggs

Live striped bass eggs are characteristically transparent, green to golden green, spherical, nonadhesive, and semibuoyant, with a single large oil globule and a wide perivitelline space (Raney 1952; Mansueti and Mansueti 1955; Westin and Rogers 1978). Fully water-hardened eggs (1-2 hr after fertilization) range from 1.3 mm (Murawski 1969) to 4.6 mm[1] (Albrecht 1964) in diameter. Mean diameter in the C-D Canal was reported at 3.4 mm (Johnson and Koo 1975). Striped bass eggs average 280 mg total wet weight (Eldridge et al. 1977), and 0.3 mg dry weight (Westin and Rogers 1978).

Striped bass eggs hatch from 29 to 80 hr after fertilization, depending on water temperature (Setzler et al. 1980). Two equations have been reported for calculating hatching time of striped bass eggs (Polgar et al. 1976; Rogers et al. 1977). The equation from Polgar et al. (1976) is:

[1] 25.4 mm = 1 inch.

Table 2. Spawning seasons and peaks (where available) for striped bass from major spawning areas along the mid-Atlantic region.

Location	Season	Peak	Source(s)
North Carolina	Late April, May	-	Chapoton and Sykes (1961)
Chesapeake Bay	April, May, early June	-	Chapoton and Sykes (1961); Dovel (1971)
Ches.-Del. Canal	Mid-April to mid-June	April 20 to May 10	Kernehan et al. (1981)
Potomac River	Mid-April to mid-June	April 23 to May 8	Setzler-Hamilton et al. (1981)
Delaware River	Late May to mid-July	June	Raney (1952)
Hudson River	Mid-May to mid June	Last 2 wks. of May	Raney (1952); Rathjen and Miller (1957)

Table 3. Spawning grounds and peak locations (where available) for major mid-Atlantic striped bass populations.

Location	Distance upstream from mouth (km)	Peak location distance (km)	Source(s)
Roanoke River	161.2-253.9	200-241	Fish and McCoy (1959); Dovel and Edmunds (1971)
York River	64.9-111.2	74.1	Rinaldo (1971)
Potomac River	94.5-157.5	97.5-139[a]	Boynton et al. (1977)
Potomac River	80-156	107-139[a]	Setzler-Hamilton et al. (1981)
Ches.-Del. Canal	Throughout Canal	-	Kernehan et al. (1981)
Upper Chesapeake Bay	Turkey Pt. to Worton Pt.	-	Kernehan et al. (1981)
Delaware River	107.5-231.6	-	Murawski (1969)
Hudson River	First 46 km of freshwater	-	Rathjen and Miller (1957)

[a] Specific peak locations: 1974, Douglas Point (km 116); 1975, between Maryland Point (km 107) and Indian Head (km 139); 1976, Possum Point (km 128); 1977, Maryland Point (km 107) and Douglas Point (km 116) (Seltzer-Hamilton et al. 1981).

$$I = -4.6\,T + 131.6$$

where I is incubation time in hours and T is incubation temperature in degrees C.

Larvae

Survival of the striped bass larval stage is considered to be most crucial for future population abundance of mid-Atlantic striped bass stocks. In combination with environmental conditions during early life stages, survival rate of larvae probably determines the occurrence of occasional dominant year classes, so evident in striped bass populations (Bain and Bain 1982a).

At hatching, striped bass larvae range in length from 2.0 to 3.7 mm, with a mean of 3.1 mm. Yolk sac absorption time varies from 3 to 9 days, depending upon water temperature (Albrecht 1964; Eldridge et al. 1977; Rogers et al. 1977). Yolk sac larvae attempt to remain near the surface, but sink between swimming efforts. They require enough turbulence to keep them from settling to the bottom where they are often smothered (Pearson 1938; Raney 1952; Mansueti 1958a; Barkuloo 1970). In laboratory aquaria, yolk sac larvae were able to swim horizontally and exhibited positive phototaxis at 4-5 days (McGill 1967).

Figure 3 illustrates the morphology of 6.2-mm finfold larvae (Hardy 1978), 12.0-mm postfinfold larvae, and 29.0-mm juvenile striped bass (Mansueti 1958a). More detailed descriptions and drawings of early developmental stages of striped bass are given in Pearson (1938), Bigelow and Schroeder (1953), Mansueti (1958a), Doroshev (1970), Hardy (1978) and Westin and Rogers (1978).

The finfold stage lasts an average of 11 days (Polgar et al. 1975), and the postfinfold stage 11-65 days, depending upon water temperature and nutritional state of the larvae (Rogers et al. 1977). Rogers et al. (1977) found the following durations for the larval stage (finfold and postfinfold stages combined) at different temperatures: at 15°C (59°F) - 68 days, at 18°C (64°F) - 33 days, at 21°C (70°F) - 24 days, and at 24°C (75°F) - 23 days.

Setzler-Hamilton et al. (1981) and Kernehan et al. (1981) provided extensive information concerning the horizontal and vertical distribution of striped bass eggs, yolk sac larvae, finfold larvae, and postfinfold larvae, in the Potomac River Estuary and the C-D Canal, respectively. Generally, larval stages remained in or near the area spawned, and apparent change in location was upstream in the Potomac Estuary, despite a net downstream flow of water (Setzler-Hamilton et al. 1981). Two mechanisms were proposed to explain this observation (originally proposed in Polgar et al. 1976):

1) Active spawning stock continually migrates upstream over time; therefore samples indicate an "upstream movement" of larvae.

2) Differential (higher) mortality of early-spawned versus late-spawned larvae.

Additionally, post yolk-sac stages tended to be midchannel-oriented and in highest concentrations near the river or estuary bottom (Kernehan et al. 1981).

Juveniles

The duration of the juvenile phase (from metamorphosis to sexual maturity) varies with sex. In the mid-Atlantic region, male bass from 25 mm (1 inch) to approximately 300 mm (12 inches) and female bass from 25

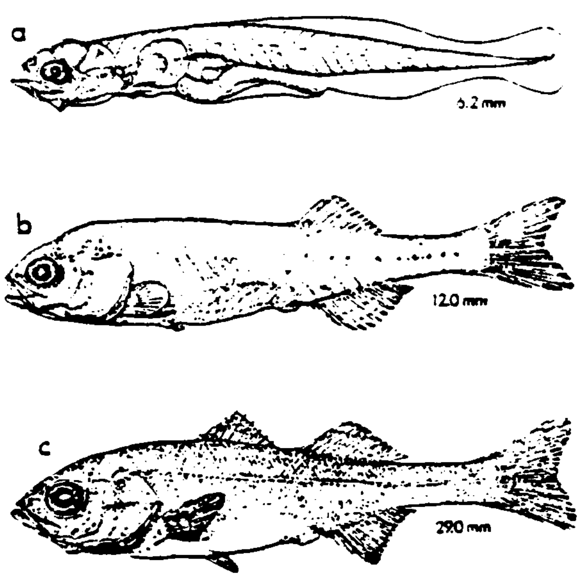


Figure 3. Morphology of striped bass postlarvae and juveniles; a. finfold larva (Hardy 1978); b. postfinfold larva (Mansueti 1958a); c. juvenile (Mansueti 1958a).

mm (1 inch) to approximately 500 mm (20 inches) are generally considered juveniles. The upper length limits correspond to ages 2 or 3 for males and 4 or 5 for females (Westin and Rogers 1978).

The initiation and extent of juvenile striped bass migrations vary with location (Westin and Rogers 1978), and most juveniles remain in the river and estuarine areas where they were spawned. Little evidence exists for coastal migrations of bass less than 2 years old (Vladykov and Wallace 1938; Merriman 1941; Mansueti 1961; Massmann and Pacheco 1961). During the first summer, young-of-the-year striped bass generally move downstream (Markle and Grant 1970; Mihursky et al. 1976) and shoreward (Raney 1952; Carlson and McCann 1969; Texas Instruments, Inc. 1974; Kernehan et al. 1981). Ritchie and Koo (1968) observed that tagged young-of-the-year remained stationary or moved upstream from release points in the Patuxent River, Maryland, subsequently moving downstream to Chesapeake Bay proper during their second year. Setzler-Hamilton et al. (1981) also found some upstream movement of 1976 juvenile striped bass during their first summer in the Potomac Estuary. During winter months, juveniles may move toward deeper water and downstream (Westin and Rogers 1978).

Schooling behavior has been observed for juvenile striped bass, and generally they are found in groups of a few fish to thousands in riverine and estuarine areas (Westin and Rogers 1978).

Adults

Numerous tagging studies have determined migratory and distributional patterns of adult striped bass. Westin and Rogers (1978) provided an extensive review of tagging studies and migratory patterns of striped bass. Generally, striped bass in the Gulf of Mexico, from Florida to southern North Carolina, and in the St. Lawrence River, show little coastal migration (Raney 1957). Most populations from those areas are riverine (Vladykov 1947; Scruggs and Fuller 1955; Scruggs 1957; Murawski 1958; Barkuloo 1970; Dudley et al. 1977). From Cape Hatteras, North Carolina, to New England, substantial numbers of striped bass leave the bays and estuaries at age 2 or 3 and join coastal migrations, moving north in summer and south in fall and winter (Vladykov and Wallace 1938, 1952; Merriman 1941; Chapoton and Sykes 1961; Clark 1968). The longest migrations are those of large, female bass. Bigelow and Schroeder (1953) found that 90% of all striped bass caught in northern waters were females. Similarly, striped bass catches from the Rhode Island (Oviatt 1977) and North Carolina (Holland and Yelverton 1973) coasts, and Long

Island's south shore (Schaefer 1968b), consisted of 90%, 90%, and 85.7% females, respectively.

Since more than 50% of the Atlantic coast striped bass catch originates from spawning grounds in Chesapeake Bay (Setzler et al. 1980), spawning success and young-of-the-year survival in the Chesapeake Bay area may largely determine subsequent striped bass catches and stock sizes from Long Island to Maine (Tiller 1950; Raney 1952; Mansueti 1961). Koo (1970) concluded that Chesapeake Bay striped bass between ages 2 and 3 contributed significantly to the entire Atlantic coast fishery. Kohlenstein (1981) showed that approximately 50% of the 3-year-old female striped bass in Chesapeake Bay, and a smaller percentage of 2- and 4-year-old females, moved to the coast to join the migration annually. In contrast, few males of that age were migratory. Berggren and Lieberman (1978) used discriminate function analysis to show that 90.2% of the coastal striped bass fishery from southern Maine to Cape Hatteras was derived from fish spawned in Chesapeake Bay. Two other studies supporting the importance of the Chesapeake Bay-derived striped bass for maintaining observed seasonal abundance in northern waters are Schaefer (1968a) and Austin and Custer (1977).

A portion of the migratory stocks of striped bass enters and overwinters in mid-coastal rivers such as the Hudson, Mullica, and Delaware. However, these fish make up only a small percentage of the total migratory population (Westin and Rogers 1978).

Along with migratory stocks, portions (sometimes large) of adult striped bass stocks of the mid-Atlantic region remain in or near their areas of origin. This is supported by tagging studies in the Hudson River-Long Island Sound area (Raney et al. 1954; Clark 1968; Schaefer 1968b; Texas Instruments, Inc. 1974), southern New Jersey (Hamer 1971), Chesapeake Bay (Mansueti 1961), Upper Chesapeake Bay (Moore and Burton 1975), the Potomac River (Nichols and Miller 1967; Miller 1969), and Virginia rivers (Massman and Pacheco 1961). In almost every study, some tagged bass appeared to remain in the same area all year, while others were recaptured 1000 km (621 mi) or more from the release area. It is not known why some striped bass migrate and others do not.

A recently documented tagging study (McLaren et al. 1981) on the Hudson River indicated that most adult fish remained all year within 50 km (31 mi) of tagging sites. Most fish that moved out of the Long Island Sound area moved northeastward. The most northerly recapture area over 2 years of study was Provincetown, Massachusetts. In contrast to what has been reported for Chesapeake Bay striped bass, no dependence on age, size, or sex was found for the migratory segment of the Hudson River population. Evidence indicated that the Hudson River population was most likely self-perpetuating and self-contained within the river and immediate surrounding coastal area. Little evidence existed for mingling of Chesapeake and Hudson stocks, either during migrations or within overwintering populations (McLaren et al. 1981).

Local movements of adult striped bass also have been investigated. Great numbers of striped bass appear to ride tidal flows from one locality to another (Kerr 1953). Results from sonic tracking in the C-D Canal indicated that movements were made in a "rest and go" manner, often with lengthy rest periods. If currents moved in a desirable direction, the fish swam or drifted with the current. In an opposing current, the fish remained stationary. There was little difference between day and night movements (Koo and Wilson 1972).

Schooling is typical for striped bass as large as 4.5 kg (9.9 lb). Larger fish school at various times, but individuals over 13.6 kg (30.0 lb) are more often found singly or in small groups (Raney 1952; Bigelow and Schroeder 1953). Striped bass appear to school by size rather than age (Westin and Rogers 1978). Vladykov and Wallace (1938) concluded that striped bass school movements were based on schooled prey fish movements, rather than isotherms or salinity variations.

Striped bass females up to 29 years old (29.5 kg or 65.0 lb) (Merriman 1941) and 17 years old (1158 mm or 45.6 inches) (Frisbie 1967) have been reported from natural environments. A female in captivity lived 21 years (Westin and Rogers 1978). Striped bass over 12 years old are rare, and are almost always female (Westin and Rogers 1978; Setzler et al. 1980). The maximum recorded weight for a striped bass was a 56.7-kg (125.0-lb) female taken from North Carolina waters in 1891 (Setzler et al. 1980).

Parasites and diseases of striped bass have been studied and reported by Paperna and Zwerner (1976) and Bonn et al. (1976). Summary tables of parasite and disease literature are provided in Westin and Rogers (1978), Smith and Wells (1977), and Setzler et al. (1980). The most commonly reported diseases of striped bass are fin rot disease, pasteurellosis, columnaris, lymphocystis, and epitheliocystis (Setzler et al. 1980). The most commonly occurring abnormality of striped bass is "pugheadedness," a foreshortening of the head and face area. Researchers have speculated that its cause is genetic or genetic/environmental in origin, rather than a result of mechanical damage to the head in early life stages (Mansueti 1958b; Westin and Rogers 1978).

GROWTH CHARACTERISTICS

Growth Rates

The growth rate for striped bass up to 70 cm (27.6 inches) can be calculated from scales with the formula:

$$l = (L-1)\ l'/\ L' + 1$$

where L = total length of fish (cm), L' = scale radius, l = change in total length, and l' = ratio of radius to annulus in question (Setzler et al. 1980). Other body length to scale relationships are given in Robinson (1960), Mansueti (1961), Lawler et al. (1974), and Texas Instruments, Inc. (1974). Conversion factors between fork length (FL), standard length (SL), and total length (TL) values for striped bass are reported in Mansueti (1961), Trent (1962), Texas Instruments, Inc. (1973), and Westin and Rogers (1978).

Trent (1962) observed a nearly linear growth rate for young-of-the-year striped bass from Albemarle Sound, North Carolina. Observed rates ranged from 0.272 to 0.433 mm/day, for the period June to November, over 5 years of study. Total length at the end of the first growing season averaged 100 mm. Studies by Rathjen and Miller (1957) and Texas Instruments, Inc. (1975b) also reported nearly linear growth rates for Hudson River young-of-the-year striped bass between June and November. Growth rate was greatest during June and July, and averaged 0.45 mm/day over the growing season (Rathjen and Miller 1957). Instantaneous growth in weight for Hudson River young-of-the-year ranged from 0.0311 to 0.0407 for the months of July and August, and -0.0157 to 0.0145 for the months of October and November (Texas Instruments, Inc. 1976). Dey (1981) reported young-of-the-year growth rates in the Hudson

Natural logarithm of ratio of final weight to initial weight, for a unit of time.

River of 0.2 mm/day in May and June, 0.8 mm/day during July and August, dropping off rapidly through September and October. The year classes studied by Dey (1981) generally showed positive correlation between magnitude of instantaneous growth rate and mean water temperature since peak spawning.

Laboratory studies of juvenile striped bass collected from Chesapeake Bay found relative growth rates of 8.8%, 3.8%, 4.6%, and 9.1% for the months of October, November, May and June, respectively. No growth occurred between December and April or below 10 °C (50 °F). Maximum growth occurred at 20 °C (68 °F). Growth of juvenile striped bass in the Patuxent River, Maryland, was highest in July, followed by August, June, September, May, and October. No growth occurred between November and April (Koo and Ritchie 1973).

Nicholson (1964) found that compensatory growth (reduction of size variation within age classes as age increases) occurred for age 2 and some age 3 striped bass in Albemarle Sound, North Carolina. Table 4 summarizes mean lengths and annual increments for striped bass age 1-12 from various areas along the mid-Atlantic coast (data for separate sexes given where available). Males and females generally grow at the same rate until age 4, when females mature and begin to grow faster. This is illustrated in Figure 4 for male and female striped bass from Chesapeake Bay (Mansueti 1961).

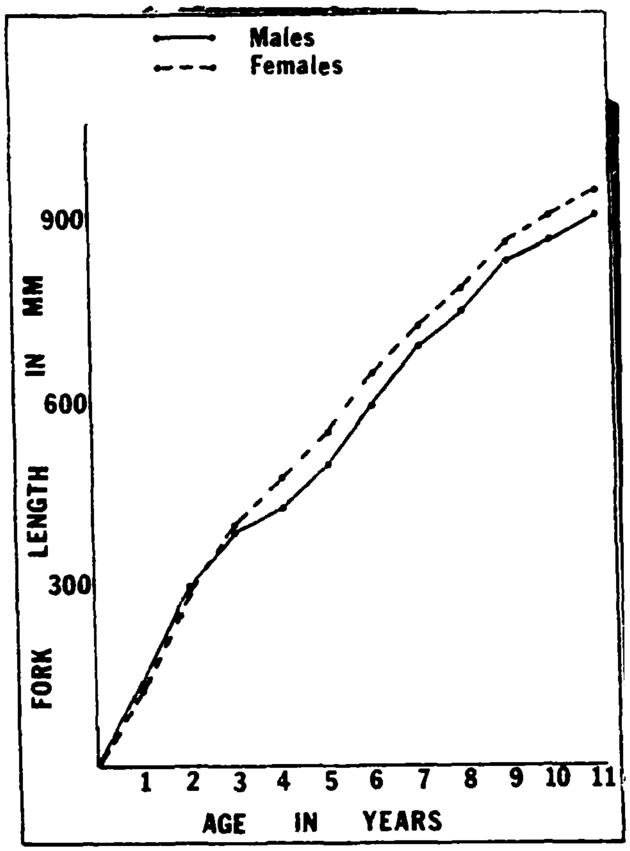


Figure 4. Length (mm FL) of male and female striped bass up to 11 years old, from Chesapeake Bay (Mansueti 1961).

Length-Weight Relationships

Three studies have developed length-weight relationships for young-of-the-year and yearling striped bass combined. These relationships are, for the Hudson River, log10 (wt) = 2.94 log (L) - 4.886, (units, gm and mm TL) (Texas Instruments, Inc. 1973); for the Rappahannock River, Virginia, log10 (wt) = 3.073 log (L) - 5.081, (units, gm and mm FL) (Kerby 1972); and for Albemarle Sound, North Carolina, log (wt) = 2.9198 log (L) - 1.8462, (units, mg and mm TL) (Trent 1962). Length-weight relationships for adult striped bass (males and females separate, when available) from various mid-Atlantic areas are presented in Table 5. Throughout their range, mature male striped bass weigh less than mature females of the same length (Merriman 1941; Mansueti 1961).

Trent (1962) reported that condition factors (K) ranged from 0.984 to 1.471 for young bass 18.5 to 91 mm

Table 4. Mean fork lengths (FL in mm) and annual increments (AI in mm) for striped bass ages 1-12 from various mid-Atlantic areas.

Location[a]	CN		DR		CB		CB		PR		PR		PS	
Sex[b]	B		B		M		F		M		F		B	
Age	FL	AI	FL	AI	FL	AI	FL	AI	FL	AI	FL	AI	FL	AI
1	124	121	102	99	135	132	124	121	--	--	--	--	--	--
2	236	112	218	116	297	162	292	168	324	--	311	--	367	--
3	366	130	319	101	381	84	389	97	399	75	403	92	421	54
4	450	84	430	111	422	41	467	78	435	36	470	67	503	32
5	531	81	530	100	500	78	556	89	533	98	591	121	534	31
6	610	79	630	100	594	94	645	89	634	101	659	68	556	22
7	689	76	708	78	704	110	724	79	742	108	779	120	614	58
8	749	63	795	87	754	50	782	58	784	42	826	47	668	54
9	820	71	869	74	831	77	856	74	864	80	888	62	--	--
10	--	--	919	50	876	45	899	43	839	--	924	36	--	--
11	--	--	992[c]	73	907	31	935	36	--	--	936	12	--	--
12	--	--	1045[c]	53	--	--	1006	71	--	--	973	37	--	--

[a] CN = Connecticut (Merriman 1941), DR = Delaware River (Bason 1971), CB = Chesapeake Bay (Mansueti 1961), PR = Potomac River (Jones et al. 1977), PS = Pamlico Sound, North Carolina (Marshall 1976).

[b] M = males, F = females, B = both sexes combined.

[c] Sample size of one fish.

Table 5. Predictive length-weight regressions for striped bass from various areas of the mid-Atlantic region. All regressions are of the equational form $\log_{10}(wt) = a \log_{10}(L) + b$, except the Potomac River regressions, which are $\ln(wt) = a \ln(L) + b$.

Location	Sample year(s)	Sex[a]	Slope (a)	Intercept (b)	Units[b] L	Units[b] wt	Source
Massachusetts	1956-1959	B	2.9616	-3.2838	inFL	lb	Frisbie (1967)
Rhode Island	1973-1975	B	1.533	-2.321	cmFL	kg	Rogers et al. (1977)
Hudson River	1972	M	2.956	-4.880	mmTL	g	Texas Instruments, Inc. (1973)
Hudson River	1972	F	3.130	-5.340	mmTL	g	Texas Instruments, Inc. (1973)
Hudson River	1971-1972	B	2.839	-1.825	cm?	g	Lawler et al. (1974)
Hudson River	1974	M	3.265	-5.750	mmTL	g	Texas Instruments, Inc. (1975b)
Hudson River	1974	F	3.424	-6.180	mmTL	g	Texas Instruments, Inc. (1975b)
Delaware River	1968	M	3.031	5.028	mmFL	g	Bason (1971)
Delaware River	1968	F	2.948	4.834	mmFL	g	Bason (1971)
Delaware River	1969	M	3.000	-4.950	mmFL	g	Bason (1971)
Delaware River	1969	F	2.911	-4.736	mmFL	g	Bason (1971)
Ches.-Del. Canal	1974	B	3.0501	-5.0001	mmFL	g	Bason et al. (1975)
Chesapeake Bay	1957-1958	M	3.234	-2.406	inTL	lb	Mansueti (1961)
Chesapeake Bay	1957-1958	F	3.153	-2.238	inTL	lb	Mansueti (1961)
Nanticoke River, Maryland	1974-1975	B	2.894	-4.665	cmFL	kg	Rogers et al. (1977)
Potomac River	1974	M	2.9910	-11.0369	mmFL	kg	Wilson et al. (1976)
Potomac River	1974	F	2.9984	-11.0943	mmFL	kg	Wilson et al. (1976)
Potomac River	1975	M	2.8670	-10.2610	mmFL	kg	Wilson et al. (1976)
Potomac River	1975	F	2.9388	-10.6706	mmFL	kg	Wilson et al. (1976)
Potomac River	1976	M	3.0419	-11.3208	mmFL	kg	Wilson et al. (1976)
Potomac River	1976	F	2.7727	-9.5418	mmFL	kg	Wilson et al. (1976)

[a] M = males, F = females, B = sexes combined.

[b] Original units of length-weight regressions.

TL in Albemarle Sound, North Carolina. Texas Instruments, Inc. (1973) calculated condition factors for striped bass 200-800 mm TL from the Hudson River and Chesapeake Bay (using data from Mansueti 1961). These factors ranged from 0.91 to 1.1 for Hudson River bass and 0.87 to 1.35 for Chesapeake Bay bass.

THE FISHERY

Commercial Fisheries

The commercial catch of striped bass during the last decade has fallen off from a record harvest of 6335 metric tons (mt) in 1973 and 5023 mt in 1974, to 1594 mt, 2041 mt, and 1740 mt in 1979, 1980, and 1981, respectively. The values of the 1980 and 1981 commercial catches were $4,902,000 and $5,272,000, respectively. The dominant year class of 1970 was last readily available to commercial gear in 1973 and 1974. Of the annual commercial landings, 98% or more have been taken by United States fishing boats, the remainder by Canada. The majority of the commercial catch (> 90%) has occurred in the northwest Atlantic region (St. Lawrence River to Virginia). In 1981, 97.9% of the commercial catch occurred in waters less than 4.8 km (3 mi) from the coast, while the remaining 2.1% was caught between 4.8 and 320 km (3 and 200 mi) offshore. (National Marine Fisheries Service 1978, 1979, 1980, 1981, 1982a). Since 1930 Maryland and Virginia have produced the highest commercial landings, followed by New York, North Carolina, and in recent years, Massachusetts (Setzler et al. 1980).

A variety of commercial gear has been employed to catch striped bass, depending on geographical area and state regulations, which vary considerably. Stationary gill nets, drift gill nets, haul seines, fyke nets, pound nets, fish traps, and hoop nets are the most commonly used gear types. Stationary gill nets, illegal everywhere except Virginia and the Potomac River, have been very effective. Haul seines in New York, pound nets in New Jersey, and fish traps in Rhode Island are the most popular gear types (Setzler et al. 1980). Pound, fyke, and bow nets are nonselective for striped bass, while gill nets and haul seines are considered size selective (Tiller 1950; Vladykov and Wallace 1952; Mansueti 1961; Trent and Hassler 1968; Grant and Joseph 1969). Setzler et al. (1980) summarized commercial and recreational fishing regulations for most Atlantic Coast States.

The age distribution of commercial landings varies directly with the availability of dominant year classes recruited to the fishery. For example, the Long Island south shore catch in 1936 and 1937 was dominated by 2- and 3-year-olds, respectively, from the dominant 1934 year class (Merriman 1941). In 1942 and 1943, the commercial catch from Chesapeake Bay was dominated by 2- and 3-year-olds from the 1940 year class. In 1944 and 1945, a substantial number of 4- and 5-year-olds from the 1940 year class, plus many 2- and 3-year-olds from the relatively strong 1942 year class, dominated the catch (Tiller 1950). Other examples of this occurrence are given in Frisbie and Ritchie (1963), Davis (1966), Schaefer (1968b), and Johnson et al. (1977). Dominant striped bass year classes, which appeared in subsequent commercial catches, occurred in the years 1934, 1940, 1958, 1964, and 1970 (Merriman 1941; Tiller 1950; Mansueti and Hollis 1963; Koo 1970; Schaefer 1972). Other apparently stronger than average year classes occurred in 1942, 1961, and 1972 (Setzler et al. 1980).

Recreational Fisheries

In 1970, the striped bass ranked third behind bluefish and spotted seatrout in total weight landed by recreational fishermen along the Atlantic and Gulf coasts. From Maine to Cape Hatteras, North Carolina, the striped bass ranked third behind the bluefish and Atlantic mackerel (National Marine Fisheries Service 1979).

The recreational catch of striped bass has declined over the past decade, even more drastically than the commercial catch. Comparison of recreational and commercial landings over the past decade demonstrates that the recreational catch has dropped from four to five times the commercial catch in 1970, to approximate parity with the commercial catch in 1979. In 1970, an estimated 33,015 mt of striped bass were landed by recreational fishermen along the Atlantic coast. By 1974, the catch from Maine to Virginia (constituting the majority of the Atlantic coast catch) dropped to 17,937 mt. In 1979, the last year with complete data available, an estimated 2917 mt of striped bass were landed by recreational fishermen (National Marine Fisheries Service 1982b). Historical records indicate that the mid-Atlantic region has always dominated the recreational catch. In 1979, Maryland (68.4%) and New York (29.1%) contributed greatly to the recreational catch. Also, 71% of the 1979 Atlantic coast recreational harvest was taken within the contiguous coastline (inland coastal waters) (National Marine Fisheries Service 1982b).

Dominant year classes were responsible for large numbers of 2- and 3-year-olds occurring in the sport fishery catch between 1959 and 1961 in the Potomac River, and similarly in the 1974 and 1975 sport fishery catch in Albemarle Sound, North Carolina (Frisbie and Ritchie 1963; Johnson et al. 1977).

Sport fishery regulations differ among States along the Atlantic coast. Minimum length limits vary from no limit in Delaware and South Carolina, to 30.5 cm (12 inches) in Maryland and North Carolina, 40.6 cm (16 inches) in most States, and 45.7 cm (18 inches) in New Jersey. Length limits also differ as to FL or TL specifications. New Jersey, New York, and Connecticut have closed seasons in winter, but most States do not. During the spawning season in Maryland waters, all striped bass over 6.8 kg (15.0 lb) must be immediately released (Setzler et al. 1980). Inconsistencies in regulation have led in part to many of the management, enforcement, and data collection problems encountered with the Atlantic coast striped bass population in recent years. Migratory versus sedentary striped bass stocks also complicate species management. Overall, the regulatory situation is a high-priority problem needing study and analysis.

Population Dynamics

Probably the single most important feature of striped bass population dynamics in relation to management is poor reproductive success interspersed with occasional dominant year classes. Most likely, environmental suitability during the larval stage acts in large part to determine year class success and future striped bass stock abundances (Bain and Bain 1982a).

Sex ratios. During summer and fall in coastal waters, the sex ratio is generally about 9:1 in favor of females, particularly in the north (Bigelow and Schroeder 1953; Holland and Yelverton 1973; Oviatt 1977). In the Potomac River Estuary, age specific sex ratios (proportion of males) were as follows: age 3 - 0.97, age 4 - 0.94, age 5 - 0.81, age 6 - 0.31, and age 7 - 0.19 (Jones et al. 1977). Dominant year classes affect the sex ratio in subsequent years. For example, as females of the 1970 year class began returning to spawn in the Potomac River in 1975 and 1976, the sex ratio (males to females) changed from 4:1 in 1974 to 1:1.3 in 1976 (Jones et al. 1977).

Reproductive rates/life stage abundance. Zankel et al. (1975) estimated a peak spawning population of 1 million adults by using an acoustic survey on the Potomac River in 1974. Striped bass egg, yolk sac, finfold, and postfinfold larval densities and estimates of life stage production from the Potomac River for the years 1974 - 1976 have been given in Mihursky et al. (1974, 1976), Polgar et al. (1976), and Boynton et al. (1977). Data from Boynton et al. (1977) is summarized below.

Stage	1974	1975	1976
Egg production	8.11(9)	1.16(9)	8.85(8)
% mortality	99.20	63.62	92.99
Yolk-sac larvae	7.47(7)	4.21(8)	6.20(7)
% mortality	96.15	94.02	81.70
Finfold larvae	2.49(6)	2.69(7)	1.14(7)
% mortality	81.65	80.59	93.94
Postfinfold	4.60(5)	4.69(6)	7.30(5)

Note: Integer in parentheses represents exponent of 10 multiplied by production estimates.

Estimates from Boynton et al. (1977) are based on a uniform age distribution assumption, which probably causes an underestimation of egg production (Setzler et al. 1980). Polgar et al. (1976) assumed an exponential age distribution and obtained an egg production estimate of 26.9×10^9 for the Potomac River in 1974. McFadden (1977) estimated fall young-of-the-year populations in the Hudson River at 1.68×10^6, 1.29×10^6, and 1.02×10^6, for the years 1973, 1974, and 1975, respectively, using Petersen mark-recapture methods.

Two specific environmental conditions have been hypothesized to be responsible for influencing the spawning success and occurrence of dominant year classes in striped bass populations. First, water flow (both velocity and volume) was found to be an important factor for spawning success in California rivers and the Roanoke River in North Carolina (Van Cleve 1945; Hassler 1958). Higher flows during spawning produced the most successful year classes. Second, subnormal winter temperatures have been highly correlated with the production of strong year classes the following spring. Several studies support a general conclusion that dominant year classes through recent history have always been preceded by a colder than normal winter (Merriman 1941; Koo 1970; Heinle and Flemer 1975; Heinle et al. 1976; Boynton et al. 1977). One proposed mechanism of the severe winter-strong year class association is through the estuarine food chain. Heinle and Flemer (1975) hypothesized a simple food chain consisting of detritus, zooplankters (*Eurytemora affinis* and *Neomysis americana*), and anadromous fish larvae in the Patuxent River, Maryland. Production of *E. affinis* during a spring that led to a strong striped bass year class was four to five times greater than during a spring that led to a poor year class (Heinle et al. 1976).

A review of factors that may determine dominant year class production is presented in Cooper and Polgar (1981). Several investigators have concluded that variance and range in year class strength are controlled almost entirely by density-independent environmental factors (Vladykov and Wallace 1952; Chadwick 1974; Polgar et al. 1975; Ulanowicz and Polgar 1980; Cooper and Polgar 1981). Apparently, there is no evidence of behavioral compensation on the part of spawning striped bass to offset annual variation in optimal life stage survival conditions (Ulanowicz and Polgar 1980;

Cooper and Polgar 1981). Adults spawn over a lengthy period and a variety of environmental gradients, and only a small fraction of the eggs are deposited in suitable environments. The size of the parental spawning stock probably does not affect year class strength and subsequent recruitment, as long as the spawning population meets some minimum requirements in reproductive potential (Cooper and Polgar 1981). Most likely, individuals spawned during a relatively short period of optimal conditions for early life stages make up the majority of survivors for that year class (Setzler et al. 1980; Ulanowicz and Polgar 1980; Cooper and Polgar 1981).

Cooper and Polgar (1981) recommended the following management schemes for striped bass, based on a review of the most recent information available:

1) Do not manage by recruitment relationships, such as the classical Ricker and Berverton-Holt stock recruitment curves.

2) Manage by recognizing dominant year classes, by juvenile abundance indices, protecting the early ages of the year class so as to maximize weight yield and allow sufficient spawning stock to reach maturity.

3) Control and modify seasonal and regional commercial regulations and effort, in accordance with availability and age of a dominant year class.

4) Unify, but not necessarily make uniform, the management strategy and regulations across States and regions.

5) Protect the resource and necessary habitats from the effects of pollutants.

Mortality rates. Sykes et al. (1961) estimated average commercial fishing mortality rate (F) in the Potomac River at 0.40 of the stock available to the gear. Kohlenstein (1981) estimated commercial fishing mortality at 0.35 for 3-year-old males in Chesapeake Bay. Street et al. (1975) estimated total annual mortality (A) in Albemarle Sound, North Carolina, at 51% for fish 3 to 6 years old (1972-74). Total instantaneous mortality rates (Z) for Virginia and North Carolina coastal rivers have been reported between 0.66 and 0.98 (Hassler et al. 1966; Grant and Merriner 1971; Merriner and Hoagman 1973). The only estimate found for instantaneous natural mortality rate on the Atlantic coast was 0.243 for North Carolina striped bass (Holland and Yelverton 1973). Chadwick (1968), Sommani (1972), and Miller (1974) gave estimates of various mortality and survival rate parameters for the years 1958-71 in California waters. Between 1959 and 1971, instantaneous fishing mortality rates ranged from 0.11 to 0.39. Instantaneous natural mortality rates ranged from 0.15 to 0.32.

Saila and Lorda (1977) summarized the following survival probabilities from studies of the Hudson River striped bass population (juvenile stages are of arbitrary classification).

Age class	Stage	Duration (days)	Probability of survival
0	Egg, yolk-sac	10	0.06
0	Post yolk-sac	24	0.04
0	Juvenile 1	30	0.20
0	Juvenile 2	145	0.51
0	Juvenile 3	156	0.16
1	Adult	365	0.40
2	Adult	365	0.60

Stock identification. Documented differentiation of striped bass stocks on the basis of meristic, morphological, and biochemical characteristics is as follows:

(1) Roanoke River-Albemarle Sound, North Carolina: This population separates into two groups in the winter, with smaller fish overwintering in lower areas of the Roanoke River or in Albemarle Sound and larger fish (>2.7 kg, >6 lb) overwintering on the ocean side of the outer banks (Chapoton and Sykes 1961). Albemarle Sound striped bass are distinct from James River, Virginia, bass and closely related to the York River, Virginia, and Rappahannock River, Virginia, populations, based on lateral line scales and morphometric characters (Lund 1957; Murawski 1958).

(2) Chesapeake Bay: Three distinct subpopulations-- the James River, the York and Rappahannock Rivers, and Upper Bay-- are present within the Chesapeake drainage based on meristic studies (Raney 1957), gill raker counts (Lewis 1957), and lateral line scales (Murawski 1958). Lund (1957) concluded that four rivers within the Bay-- the James, York, Rappahannock, and Potomac-- have separate subpopulations based on morphometric characters. Biochemical characterization (by electrophoresis) of adult striped bass collected from five Chesapeake Bay tributaries during spawning indicates probable discrete spawning populations in at least three of the five rivers studied-- the Nanticoke, Elk, and Choptank Rivers (Morgan et al. 1973a). Populations in the Patuxent and Potomac Rivers could not be differentiated by electrophoresis, though both were distinct biochemically from populations in the other three rivers.

(3) Delaware River: The Delaware River population is most closely allied with the James River population based on lateral line scale (Murawski 1958) and gill raker counts (Lewis 1957).

(4) Hudson River: Hudson River striped bass form a distinct population based on meristic counts (Raney and de Sylva 1953), gill rakers (Lewis 1957), lateral line scales (Murawski 1958), and morphometric measurements (Lund 1957).

Population dynamics simulations. Simulation models have been developed for assessing the impact of power plant intake entrainment on striped bass life stages. Seven models were evaluated and discussed by Swartzman et al. (1977). Three of these models have been developed by Lawler, Matusky, and Skelly Engineers for the Hudson River, two by the Oak Ridge National Laboratory for the Hudson River and C-D Canal, and one by Johns Hopkins University for the C-D Canal. Major differences among models were the choice of life stage duration and compensatory mortality regimes. The reader is referred to Swartzman et al. (1977) for review of these models, and to Eraslan et al. (1976) for a sample model (Hudson River). Other available models not discussed by Swartzman et al. (1977) are presented in Chadwick (1969), Saila and Lorda (1977), and Warsh (1977).

ECOLOGICAL ROLE

Food Habits

Larvae/juveniles. In laboratory studies, Doroshev (1970) found that first-feeding larvae preferred *Cyclops* nauplii and copepodites. Beaven and Mihursky (1980) reported positive electivity of larger copepods and cladocerans and negative electivity of copepod nauplii and rotifers in a sample of 605 larvae from the Potomac River. In the Hudson River, striped bass up to 75 mm preferred *Gammarus* spp., calanoid copepods, and chironomid larvae. Bass from 76-125 mm preferred Gammarus and Calanoida, and those from 116-200 mm preferred Microgadus tomcod (Texas Instruments, Inc. 1976).

Young bass (<70 mm) in the York and James Rivers consumed primarily mysids and insects, respectively. Bass between 70 and 150 mm fed primarily on gobies (Gobiosoma bosci) in the York River and decapod shrimp (Palaemonetes spp.) in the James River (Markle and Grant 1970). In the Delaware River, young striped bass (50-100 mm) fed primarily on Neomysis americana and Crangon septemspinosa. In low salinity tidal creeks of the Delaware drainage, fish, decapods, amphipods, and mysids were the most important food items (Bason 1971). Juvenile bass (40-100 mm) from Chesapeake Bay also fed on Neomysis americana, as well as Gammarus and Corophium spp. Bass between 100 and 270 mm fed on bay anchovies (Anchoa mitchilli) and various invertebrates (Bason et al. 1975). Several investigators (e.g., Markle and Grant 1970; Bason 1971) stated that prey selection by young striped bass varies with the salinity of the juvenile environment and the corresponding food item availability.

Adults. Hollis (1952) found that adult striped bass in Chesapeake Bay were primarily piscivorous, with fish making up 95.5% by weight of the total diet. During summer and fall, bay anchovy and Atlantic menhaden (Brevoortia tyrannus) were principal prey, while in winter, spot (Leiostomus xanthurus) and croaker (Micropogonias undulatus) dominated the diet.

Fish, primarily clupeids, constituted 96.2% of the summer diet of striped bass in Albemarle Sound, North Carolina. Engraulids were found most frequently in the diet during the fall. Winter forage included a higher percentage of invertebrates, compared to the summer season. During the spring, blue crabs (Callinectes sapidus) were a major prey item (Manooch 1973). Oviatt (1977) reported that, in general, striped bass feeding inshore ate Atlantic menhaden, while fish captured offshore fed on sand lance (Ammodytes).

A fish-dominated diet does not occur for all adult mid-Atlantic striped bass stocks. Schaefer (1970) found that in Long Island Sound, striped bass between 275 and 399 mm FL primarily fed on Gammarus, Haustorius canadensis, and Neomysis americana. Bass between 400 and 599 mm FL fed equally on fish (Anchoa mitchilli, Menidia menidia, and Stenotomus chrysops) and amphipods. Bass between 600 and 940 mm FL fed more on fish than other size groups (65% of dietary volume), but still consumed amphipods, mysids, and lady crabs (Ovalipes ocellatus).

Other stomach contents recorded from adult striped bass include alewife (Alosa pseudoharengus), blueback herring (Alosa aestivalis), mummichog (Fundulus heteroclitus), striped mullet (Mugil cephalus), rainbow smelt (Osmerus mordax), weakfish (Cynoscion regalis), white perch (Morone americana), silver hake (Merluccius bilinearis), American eel (Anguilla rostrata), American lobster (Homarus americanus), squid (Ilex and Loligo), and various crab, clam, and mussel species (Smith and Wells 1977).

Feeding Behavior

The striped bass is an opportunistic, carnivorous species, swallowing prey whole if possible (Westin and Rogers 1978). Striped bass do not feed steadily; rather whole schools feed together at certain intervals (Raney 1952). Factors initiating feeding behavior have not been investigated. When feeding on schooling prey species, striped bass follow the school, periodically gorge themselves, and then drop down in the water column to digest their prey (Setzler et al. 1980). When a specific preferred food item is abundant, striped bass tend to concentrate on the abundant resource and ignore other available food items (Smith and Wells 1977).

Miller (1980) reported that young-of-the-year striped bass in Chesapeake Bay exhibited feeding activity peaks at twilight. The feeding intensity of adult striped bass varies with time of day and season. Generally, adults feed heavily just after dark and just before dawn (Raney 1952). It has also been noted that feeding rate of adults drops off temporarily in late spring and summer, probably in connection with spawning activities (Hollis 1952; Stevens 1966; Trent and Hassler 1966).

Predators

Little direct information exists concerning predation on striped bass in coastal waters. Most likely, large bluefish (Pomatomus saltatrix) and weakfish prey on small striped bass. Adult and juvenile white perch probably consume large numbers of striped bass larvae. Smith and Kernehan (1981) found significant predation on striped bass larvae by the free-living copepod Cyclops bicuspidatus.

Competitors

Though direct evidence is lacking, other large piscivores like bluefish (Pomatomus saltatrix) and weakfish (Cynoscion regalis) probably compete with adult striped bass for schooling forage species. Larval and juvenile striped bass share common nursery areas with white perch (Morone americana), which are usually more abundant, and some competition for food resources probably occurs (Mihursky et al. 1976).

ENVIRONMENTAL REQUIREMENTS

Habitat Suitability Index Models

A habitat suitability index model for coastal stocks of striped bass was developed by Bain and Bain (1982a). The model uses data on habitat parameters to produce a single index of habitat suitability for each combination of life stage and environmental factor. A summary of reviews and comments by a large number of managers and species experts (Bain and Bain 1982b) indicated that the model was perceived as a useful and easily applied tool. However, some comments suggested that the model was to some extent an oversimplification and too rigid for high site specific accuracy.

Much has been done to delineate environmental requirements and tolerances of striped bass life stages. Five natural environmental factors (temperature, salinity, temperature-salinity interaction, current velocity, and turbidity/total dissolved solids) are most important and will be discussed in separate sections. Additionally, the environmental requirements of the egg and larval stages are most crucial (Bain and Bain 1982a). Summaries of other environmental requirements and more detailed information on those listed above are presented in Tables 6, 7, and 8 for the egg, larval, and combined juvenile/adult life stages, respectively. Impingement on power plant intake screens, thermal pollution discharge, and environmental contaminants, are man-caused factors and are treated separately.

Temperature

Mansueti (1958a) found that striped bass eggs tolerated temperatures between 14° and 23°C (57° and 73°F). Optimum temperatures for egg development were 17°-20°C (63°-68°F) (Mansueti 1958a) and 18°-21°C (64°-70° F) (Rogers et al. 1977). Lethal temperatures found for eggs were below 12°C (54°F) (Shannon and Smith

1968; Morgan and Rasin 1973) and above 24°C (75°F) (Morgan and Rasin 1973).

Davies (1970) reported that striped bass larvae tolerated temperatures between 10° and 25°C (50° and 77°F). Optimum temperatures for larval survival were 15°-22°C (59°-72°F) (Davies 1970) and 18°-21°C (64°-70°F) (Rogers et al. 1977). Lethal temperatures for larvae have been given as below 10°C (50°F) (Davies 1970) and above 28°C (82°F) (Kelly and Chadwick 1971). Rogers and Westin (1981) found that temperature interacted with first larval feeding time to determine survival. Time to death for unfed larvae was longer at lower temperatures within the range of 15°-24°C (59°-75° F).

Juvenile striped bass tolerated temperatures of 10°-27°C (50°-81°F) (20-50 mmTL) and <30°C (<86°F) (50-100 mmTL) (Bogdanov et al. 1967). Juveniles acclimated to higher temperatures exhibited higher lethal limits than those acclimated to lower temperatures (Loeber 1951). Transfers of juvenile striped bass from 12.8° C and 21.1°C (55°F and 70°F) environments to 7.2°C (45°F) were lethal, but the reciprocal transfer (cold to warm) was not (Tagatz 1961). This agrees with the premise that fish acclimate more easily to rising temperatures than to falling temperatures. Adult striped bass were reported to tolerate temperatures from 0°-30°C (32°-86°F) with no apparent ill effects (Tagatz 1961).

Table 6. Tolerance, optimal, and lethal values for selected environmental factors on striped bass eggs.

Environmental factor	Tolerance	Optimum	Lethal	Source
Temperature (°C)	14-23	17-20		Mansueti (1958a)
		18-21	<12[a]	Rogers et al. (1977)
			>23[a]	Shannon and Smith (1968)
Salinity (ppt)	0-10	1.5-3.0		Mansueti (1958a)
	0-9	1.7		Albrecht (1964)
	0-8			Morgan and Rasin (1973)
Dissolved O_2 (mg/ℓ)			<1.5	Mansueti (1958a)
			<5.0[b]	Turner and Farley (1971)
Turbidity (mg/ℓ)	0-500		>1000	Auld and Schubel (1978)
pH	6.6-9.0			Bowker et al. (1969)
Current velocity (cm/s)	30.5-500	100-200		Mansueti (1958a)
			<30.5	Albrecht (1964)

[a] Values were given as lethal only after prolonged exposure.

[b] Value was given as "predisposing to other mortality sources," rather than directly lethal.

Salinity

Salinity tolerance of striped bass eggs has been reported at 0-10 ppt (Mansueti 1958a), 0-9 ppt (Albrecht 1964), and 0-8 ppt (Morgan and Rasin 1973). Optimum salinities for egg development were 1.5-3.0 ppt (Mansueti 1958a) and 1.7 ppt (Albrecht 1964). Yolk sac and post-yolk sac larvae were reported to tolerate salinities of 0-15 ppt (Albrecht 1964; Regan et al. 1968) and 0-25 ppt (Rogers and Westin 1978), respectively. Optimum salinities for yolk sac and post-yolk sac larvae were 5-15 ppt and 5-25 ppt, respectively (Rogers and Westin 1978).

Table 7. Tolerance, optimal, and lethal values for selected environmental factors in relation to striped bass larval stages.

Environmental factor	Experimental conditions	Tolerance	Optimum	Lethal	Source
Temperature (°C)		12-23	16-19		Regan et al. (1968)
		10-25	15-22	<10	Davies (1970)
			18-21		Rogers et al. (1977)
				>28[a]	Kelly and Chadwick (1971)
Salinity (ppt)		0-15	5-10		Regan et al. (1968)
	1-6 days		3.4		Lal et al. (1977)
	7-13 days		6.7		Lal et al. (1977)
	14-20 days		13.5		Lal et al. (1977)
	21-29 days		20.2		Lal et al. (1977)
	30-35 days		33.7		Lal et al. (1977)
	Yolk-sac		5-15		Rogers and Westin (1978)
	Post yolk-sac		5-25		Rogers and Westin (1978)
Dissolved O_2 (mg/ℓ)	Yolk-sac			<2.3	Rogers and Westin (1978)
	Post yolk-sac			<2.4	Rogers and Westin (1978)
Turbidity (mg/ℓ)	Yolk-sac			>500[a]	Auld and Schubel (1978)
	48 hr LD_{50}			3411	Morgan et al. (1973b)
pH		6-9	7-8		Regan et al. (1968)
Current velocity (cm/s)		0-500	30-100		Regan et al. (1968)

[a] Values were given as lethal only after prolonged exposure.

Lal et al. (1977) reported optimum salinities for various-aged striped bass larvae as follows: 3.4 ppt (1-6 day old larvae), 6.7 ppt (7-13 days), 13.5 ppt (14-20 days), 20.2 ppt (21-29 days), and 33.7 ppt (seawater, 30-35 days). Juvenile striped bass tolerated salinities from 0-35 ppt, and optimum salinity for survival was between 10 and 20 ppt (Bogdanov et al. 1967).

Temperature-Salinity Interaction

Significant interaction between salinity and temperature tolerance has been described. Otwell and Merriner (1975) reported that the highest mortality of test groups occurred for the highest salinity-lowest temperature test combination. Fish younger than 28 days had significantly lower mortalities than fish over 28 days old, for a given temperature-salinity combination.

Table 8. Tolerance, optimal, and lethal values for selected environmental factors in relation to striped bass juvenile and adult stages.

Environmental factors	Experimental conditions	Tolerance	Optimum	Lethal	Source
Temperature (°C)	20-50 mm TL	10-27	16-19		Bogdanov et al. (1967)
	50-100 mm TL	<30	18-23		Bogdanov et al. (1967)
	Acclim. at 15.6°C			31.0[a]	Loeber (1951)
	Acclim. at 11.0°C			29.4[a]	Loeber (1951)
Salinity (ppt)	20-50 mm TL	0-20	10-15		Bogdanov et al. (1967)
	50-100 mm TL	0-35	10-20		Bogdanov et al. (1967)
Dissolved O_2 (mg/ℓ)		3-20	6-12		Bogdanov et al. (1967)
	Acclim. at 32.8°C			<2.4[b]	Dorfman and Westman (1970)
pH		6-10	7-9		Bogdanov et al. (1967)
				5.3	Tatum et al. (1966)
Current velocity (cm/s)		0-500	0-100		Bogdanov et al. (1967)
Temperature (°C)	Adults	0-30			Tagatz (1961)
Salinity (ppt)	Adults	0-33.7			Rogers and Westin (1978)
Dissolved O_2 (% saturation)	Adults - avoidance			<44	Meldrim et al. (1974)

[a] LD_{50}.

[b] Value was given as lethal only after prolonged exposure.

Tagatz (1961) found that a transfer of juveniles directly from salt to fresh water was only lethal below an acclimation temperature of 12.8 C (55 F). Morgan et al. (1981) reported that a temperature-salinity interaction affected percent hatch of eggs and percent survival of newly hatched larvae, but not larval length at 24 hr. Equations calculated for percent hatch and percent survival as functions of temperature (T in °C) and salinity (S in ppt) were:

$$\text{Percent hatch} = -0.83T^2 + 30.64T - 0.12(S \times T) + (2.22 \times S) - 205.8$$

and

$$\text{Percent survival} = -1.03T^2 + 35.86T + (0.54 \times S) - 246.63$$

The optimum temperature-salinity combination for percent survival was given as 10 ppt at 18°C (64°F) (Morgan et al. 1981).

Current Velocity

Current velocity has been cited as a key factor for egg survival and hatching success (Mansueti 1958a; Albrecht 1964; Regan et al. 1968). Minimum current velocity needed to keep semibuoyant striped bass eggs off the bottom is 30.5 cm/s (1 ft/s) (Albrecht 1964). Below this rate, the eggs sink to the bottom and can be smothered. Current velocity is a "threshold level" factor. Eggs have tolerated a wide range of current velocities above 30.5 cm/s (31-500 cm/s, 1-16 ft/s), but below the threshold level of 30.5 cm/s (1 ft/s) (prolonged exposure), virtually no eggs will survive (Albrecht 1964; Setzler et al. 1980).

Turbidity/Total Dissolved Solids

Auld and Schubel (1978) found that turbidities greater than 1000 mg/l and 500 mg/l were lethal to striped bass eggs and larvae, respectively. Morgan et al. (1973b) reported a 48-hr LD_{50} of 3411 mg/l for larval striped bass. Total dissolved solids (TDS) concentrations above 350 mg/l have blocked spawning runs of striped bass (Radtke and Turner 1967). Farley (1966) and Murawski (1969) reported that spawning striped bass avoided areas where TDS exceeded 180 mg/l.

Impingement

Striped bass eggs may be able to survive impingement velocities up to 24 cm/s (0.8 ft/s) for 6 min, but test results have been highly variable (Skinner 1974). Skinner (1974) found that survival of striped bass less than 40 mm was significantly affected at impingement velocities over 15 cm/s (0.5 ft/s). Juveniles 40-50 mm long could withstand 6-min periods at 24 cm/s (0.8 ft/s) velocity but not 49 cm/s (1.6 ft/s) velocity. Skinner (1974) concluded that water velocity was a more important factor than time of exposure, though both were related to survival success. A study by Kerr (1953) showed that 80% of striped bass 19-38 mm could avoid an impingement velocity of 30.5 cm/s (1 ft/s). Only 5% of this size class could avoid 43 cm/s (1.4 ft/s). For juveniles 26-76 mm, 95% successfully avoided an impingement velocity of 61 cm/s (2 ft/s), and all juveniles 127-178 mm were able to avoid 84 cm/s (2.7 ft/s).

Thermal Pollution Discharge

Sharp temperature changes have been observed to affect spawning activity of striped bass. A sharp rise in temperature occurring on the spawning run may cause premature spawning in normally unsuitable areas (Farley 1966). Sudden drops in water temperature on the spawning run or during the spawning act have caused complete cessation of spawning activities (Calhoun et al. 1950; Mansueti and Hollis 1963; Boynton et al. 1977).

Most early striped bass life stages show significantly elevated mortality rates when exposed to rapid changes in water temperature (such as that in a thermal discharge plume) (Schubel et al. 1976). Eggs were able to sustain 15° C (27° F) temperature elevation for 4-60 min, but an elevation of 20 °C (36° F) above acclimation temperature killed all eggs in 2 min. Yolk sac larvae survival was significantly affected at a temperature elevation of 15° C (27° F). Chadwick (1974) reported that slightly lower temperature elevations, on the order of 10 °C (18° F), significantly affected survival of 8-mm and 24-mm striped bass. However, mortality was not over 50% unless the absolute test temperature was 32.2 °C (90° F) or higher, regardless of the temperature elevation. Kelly and Chadwick (1971) gave 48-hr LC_{50} values from 30° -33° C (86° -91° F), for various acclimation temperatures.

Larger striped bass, overwintering in thermal discharge areas along the Atlantic coast, given the freedom to avoid the thermal plume, may remain active and provide a winter sport fishery (Marcy and Galvin 1973).

Environmental Contaminants

Summaries of the effects and lethal concentrations of various pesticides, heavy metals, pharmaceutical drugs, and other commonly discharged chemical substances on striped bass eggs, larvae, and juveniles are presented in Bonn et al. (1976) and Westin and Rogers (1978). Three classes of substances have received much study: monocyclic aromatic hydrocarbons (e.g., benzene), chlorinated hydrocarbons (including PCB's), and residual chlorines.

Benville and Korn (1977) reported the following acute toxicities (24-hr LC_{50}) of monocyclic aromatic hydrocarbons (often present in oil spills) to 6-g juvenile striped bass: benzene-6.9 mg/l, toluene-7.3 mg/l, ethylbenzene-4.3 mg/l, metaxylene-9.2 mg/l, orthoxylene-11.0 mg/l, and paraxylene-2.0 mg/l. Korn et al. (1976) tested the chronic effects of exposure to sublethal benzene concentrations of 3.5 and 6.0 μg/l for 4 weeks. The initial reaction was pronounced hyperactivity. Chronic reaction to both levels included inability to locate and consume food properly, lower percent body fat, and lower dry and wet weight at the end of the test period.

Mehrle et al. (1982) examined the relationship between bone strength, bone health and development, and levels of organic and inorganic contaminants in young-of-the-year striped bass from the Nanticoke, Potomac, and Hudson Rivers, and from a North Carolina hatchery. Polychlorinated biphenyls (PCB's) were the most prevelant organic contaminants found. Hudson River fish had the highest PCB levels, and both Potomac and Hudson River bass had significantly higher levels of total organic contaminant residues than the Nanticoke and hatchery groups. Arsenic, lead, selenium, and cadmium were the most prevelant inorganic contaminants found. Levels of organochlorine residues and heavy metals were highly correlated with bone strength, stiffness, toughness, and stress tolerance. Hudson River fish had the highest residue levels and the poorest bone quality and bone health of the four groups examined.

The effect of total residual chlorine levels (TRC) on early striped bass life stages have been examined by Morgan and Prince (1977) and Middaugh et al. (1977), and their results are summarized in Table 9.

Table 9. Effects of total residual chlorine levels on various life stages of striped bass.

Life stage	Total residual chlorine (mg/ℓ)	Effect	Source
Egg	0.21	100% mortality	Middaugh et al. (1977)
Egg	0.07	3.5% hatch, scoliosis	Middaugh et al. (1977)
Egg	0.01	23% hatch, difficult chorion detachment	Middaugh et al. (1977)
Egg	<0.01	No significant effects	Middaugh et al. (1977)
<13 hr old eggs	0.43	100% mortality	Morgan and Prince (1977)
24-40 hr old eggs	0.50	100% mortality	Morgan and Prince (1977)
<13 hr old eggs	0.22	LC_{50}	Morgan and Prince (1977)
24-40 hr old eggs	0.27	LC_{50}	Morgan and Prince (1977)
Yolk-sac larvae	0.20	LC_{50}	Morgan and Prince (1977)
Yolk-sac larvae	0.04	Incipient lethal[a]	Middaugh et al. (1977)
Juvenile	0.04	Incipient lethal[a]	Middaugh et al. (1977)

[a] The incipient lethal level is that level at which mortality is first observed.

LITERATURE CITED

Albrecht, A. B. 1964. Some observations on factors associated with survival of striped bass eggs and larvae. Calif. Fish Game 50: 100-113.

Auld, A. H., and J. R. Schubel. 1978. Effects of suspended sediment on fish eggs and larvae: a laboratory assessment. Estuarine Coastal Mar. Sci. 6:153-164.

Austin, H. M., and O. Custer. 1977. Seasonal migration of striped bass in Long Island Sound. N. Y. Fish Game J. 24: 53-68.

Bain, M. B., and J. L. Bain. 1982a. Habitat suitability index model: coastal stocks of striped bass. Rep. Natl. Coastal Ecosystems Team, U. S. Fish. Wildl. Serv. Rep. No. FWS/OBS 82/10.1, Washington, D. C. 47 pp.

Bain, M. B., and J. L. Bain. 1982b. A habitat suitability index model for striped bass: uses and limitations for impact assessment. Paper presented at the 1982 Northeast Fish and Wildl. Conf., Cherry Hill, N. J. 11 pp.

Barkuloo, J. M. 1970. Taxonomic status and reproduction of striped bass in Florida. U. S. Bur. Sport Fish. and Wildl. Tech. Paper No. 44. 16 pp.

Bason, W. H. 1971. Ecology and early life history of the striped bass in the Delaware Estuary. Ichthyol. Assoc. Bull. No. 4. 122 pp.

Bason, W. H., S. E. Allison, L. O. Horseman, W. H. Keirsey, and C. A. Shirley. 1975. Fishes. In Ecological studies in the vicinity of the proposed Summit power station. Ichthyol. Assoc., Inc. Volume 1, 327 pp.

Beaven, M., and J. Mihursky 1980. Food and feeding habits of larval striped bass: an analysis of larval striped bass stomachs from 1976 Potomac Estuary collections. Rep. Maryland Univ. Chesapeake Biol. Lab. UMCEES 79-45-CBL, PPSP-PRFF 80-2. 27 pp.

Benville, P. E., and S. Korn. 1977. The acute toxicity of six monocyclic aromatic crude oil components to striped bass and bay shrimp. Calif. Fish Game 63: 204-209.

Berggren, T. J., and J. T. Lieberman. 1978. Relative contribution of Hudson, Chesapeake, and Roanoke striped bass stocks to the Atlantic coast fishery. U. S. Natl. Mar. Fish. Serv. Fish. Bull. 76: 335-345.

Bigelow, H. B., and W. C. Schroeder. 1953. The striped bass. In Fishes of the Gulf of Maine. U. S. Fish Wildl. Serv. Fish. Bull. 53: 389-404.

Bogdanov, A. S., S. I. Doroshev, and A. F. Karpevich. 1967. Experimental transfer of Salmo gairdneri and Roccus saxatilis from the USA for acclimatization in bodies of water of the USSR. Vopr. Ikhtiol. 42: 185-187. (Translated from Russian by R. M. Howland, Narragansett Mar. Game Fish Res. Lab., R.I.)

Bonn, E. W., W. M. Bailey, J. D. Bayless, K. E. Erickson, and R. E. Stevens. 1976. Guidelines for striped bass culture. Am. Fish. Soc., Striped Bass Comm. South. Div. 103 pp.

Bowker, R. G., D. J. Baumgartner, J. A. Hutcheson, R. H. Ray, and T. L. Wellborn, Jr. 1969. Striped bass, 1968 report on the development of essential requirements for production. U.S. Fish. Wildl. Serv. Publ. 112 pp.

Boynton, W. R., E. M. Setzler, K. V. Wood, H. H. Zion, and M. Homer. 1977. Final report of Potomac River fisheries study: ichthyoplankton and juvenile investigations. Univ. Md., CEES, Chesapeake Biol. Lab. Ref. No. 77-169 (unnumbered).

Calhoun, A. J., C. A. Woodhull, and W. C. Johnson. 1950. Striped bass reproduction in the Sacramento River system in 1948. Calif. Fish Game 36: 135-145.

Carlson, F. T., and J. A. McCann. 1969. Report on the biological findings of the Hudson River fisheries investigations, 1965 - 1968. Hudson River Policy Committee, N. Y. State Conserv. Dep. 50 pp.

Chadwick, H. K. 1968. Mortality rates in the California striped bass population. Calif. Fish Game 54: 228-246.

Chadwick, H. K. 1969. An evaluation of striped bass angling regulations based on an equilibrium yield model. Calif. Fish Game 55: 12-19.

Chadwick, H. K. 1974. Entrainment and thermal effects on a mysid shrimp and striped bass in the Sacramento-San Joaquin Delta. Pages 23-30 in L. D. Jensen, ed., Second workshop on entrainment and intake screening. Electrical Power Res. Inst., Publ. No. 74-049-00-5, Palo Alto, Calif.

Chapoton, R. B., and J. E. Sykes. 1961. Atlantic coast migration of large striped bass as evidenced by fisheries and tagging. Trans. Am. Fish. Soc. 90: 13-20.

Clark, J. R. 1968. Seasonal movements of striped bass contingents of Long Island Sound and the New York Bight. Trans. Am. Fish. Soc. 97: 320-343.

Cooper, J. C., and T. T. Polgar. 1981. Recognition of year class dominance in striped bass management. Trans. Am. Fish. Soc. 110: 180-187.

Davies, W. D. 1970. The effects of temperature, pH, and total dissolved solids on the survival of immature striped bass. Ph.D. Thesis. North Carolina State University, Raleigh. 100 pp.

Davis, R. H. 1966. Population studies of striped bass in Maine based on age distribution and growth rate. M.S. Thesis. University of Maine, Orono. 51 pp.

Dey, W. P. 1981. Mortality and growth of young of the year striped bass in the Hudson River Estuary. Trans. Am. Fish. Soc. 110: 151-157.

Dorfman, D., and J. Westman. 1970. Responses of some anadromous fishes to varied oxygen concentration and increases in temperature. Water Resour. Res. Inst. Publ. No. PB192312, Rutgers University. 75 pp.

Doroshev, S. I. 1970. Biological features of ' e eggs, larvae and young of the striped bass in connection with the problem of its acclimation in the USSR. J. Ichthyol. 10: 235-278.

Dovel, W. L. 1971. Fish eggs and larvae of the upper Chesapeake Bay. Nat. Resour. Inst. Spec. Rep. No. 4, University of Maryland. 71 pp.

Dovel, W. L., and J. R. Edmunds. 1971. Recent changes in striped bass spawning sites and commercial fishing areas in Upper Chesapeake Bay: possible influencing factors. Chesapeake Sci. 12: 33-39.

Dudley, R. G., A. W. Mullis, and J. W. Terrell. 1977. Movements of adult striped bass in the Savannah River, Georgia. Trans. Am. Fish. Soc. 106: 314-322.

Eldridge, M. B., D. J. King, D. Eng, and M. J. Bowers. 1977. Role of the oil globule in survival and growth of striped bass larvae. Proc. Annu. Conf. West. Assoc. Game Fish Comm. 57: 303-313.

Eraslan, A. H., W. Van Winkle, R. D. Sharp, S. W. Christensen, C. P. Goodyear, R. M. Rush, and W. Fulkerson. 1976. A computer simulation model for the striped bass young of the year population in the Hudson River. Oak Ridge Natl. Lab. Envir. Sci. Div. Publ. No. 766. 208 pp.

Farley, T. C. 1966. Striped bass spawning in the Sacramento-San Joaquin River system during 1963 and 1964. Calif. Fish Game Dep., Fish Bull. 136: 28-43.

Fish, F. F., and E. G. McCoy. 1959. The river discharges required for effective spawning by striped bass in the rapids of the Roanoke River, North Carolina. N. C. Wildl. Resour. Comm., Raleigh. 33 pp.

Forrester, C. R., A. E. Peden, and R. M. Wilson. 1972. First records of the striped bass in British Columbia waters. J. Fish. Res. Board Can. 29: 337-339.

Frisbie, C. M. 1967. Age and growth of the striped bass in Massachusetts coastal waters. M.S. Thesis. University of Massachusetts, Amherst. 58 pp.

Frisbie, C. M., and D. E. Ritchie, Jr. 1963. Sport fishing survey of the lower Potomac Estuary, 1959-1961. Chesapeake Sci. 4: 175-191.

Grant, G. C., and E. B. Joseph. 1969. Comparative strength of the 1966 year class of striped bass in three Virginia rivers. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 22: 501-509.

Grant, G. C., and J. V. Merriner. 1971. Feasibility of increasing striped bass populations by stocking of underutilized nursery grounds. Virginia Anadromous Fish Proj. Rep. No. AFS-6-1. 39 pp.

Hamer, P. E. 1971. Migratory patterns of some New Jersey striped bass. N. J. Dep. Environ. Protect. Misc. Rep. No. 6M. 23 pp.

Hardy, J. D., Jr. 1978. Development of fishes of the mid-Atlantic Bight: an atlas of the egg, larval and juvenile stages, Volume III. U. S. Fish Wildl. Serv., Biol. Serv. Prog. Rep. No. FWS/OBS-78/12. 394 pp.

Hassler, W. W. 1958. The striped bass in relation to the multiple use of the Roanoke River, North Carolina. Trans. N. Am. Wildl. Conf. 23: 378-391.

Hassler, W. W., W. L. Trent, and B. J. Florence. 1966. The status and abundance of the striped bass in the Roanoke River, North Carolina, for 1965. Rep. to the N. C. Dep. of Conserv. and Dev., Div. of Commer. Sport Fish., Raleigh. 52 pp.

Heinle, D. R., and D. A. Flemer. 1975. Carbon requirements of a population of the estuarine copepod, Eurytemora affinis. Mar. Biol. 31: 235-247.

Heinle, D. R., D. A. Flemer, and J. F. Ustach. 1976. Contribution of tidal marshlands to mid-Atlantic estuarine food chains. Pages 309-320 in M. Wiley, ed. Estuarine processes, Volume II. Academic Press, New York.

Holland, B. F., and G. F. Yelverton. 1973. Distribution and biological studies of anadromous fishes offshore North Carolina. N. C. Dep. Nat. Econ. Resour. Spec. Rep. No. 24. 132 pp.

Hollis, E. H. 1952. Variations in the feeding habits of the striped bass in Chesapeake Bay. Bingham Oceanogr. Collect. Bull., Yale Univ. No. 14: 111-131.

Hollis, E. H. 1967. Investigation of striped bass in Maryland. Md. Dep. Game Inland Fish. Rep. No. MD F-003-R-12. 96 pp.

Jackson, H. W., and R. E. Tiller. 1952. Preliminary observations on spawning potential in the striped bass. Chesapeake Biol. Lab. Publ. No. 93. 16 pp.

Johnson, H. B., B. F. Holland, Jr., and S. G. Keefe. 1977. Anadromous fisheries research program, northern coastal area. N. C. Div. Mar. Fish. Rep. No. AFCS-11. 138 pp.

Johnson, R. K., and T. S. Koo. 1975. Production and distribution of striped bass in the Chesapeake and Delaware Canal. Chesapeake Sci. 16: 39-55.

Jones, P. W., J. S. Wilson, R. P. Morgan II, H. R. Lunsford, Jr., and J. Lawson. 1977. Potomac River fisheries study: striped bass spawning stock assessment. Chesapeake Biol. Lab. Rep. No. CEES Ref. No. 77-56-CBL.

Kelly, R., and H. K. Chadwick. 1971. Some observations on striped bass temperature tolerances. Calif. Dep. Fish Game Admin. Rep. No. 71-9: 11 pp.

Kerby, J. H. 1972. Feasibility of artificial propagation and introduction of the Morone complex into estuarine environments, with a meristic and morphometric description of the hybrids. Ph.D. Thesis. University of Virginia, Charlottesville. 172 pp.

Kernehan, R. J., M. R. Headrick, and R. E. Smith. 1981. Early life history of striped bass in the Chesapeake and Delaware Canal and vicinity. Trans. Am. Fish. Soc. 110: 137-150.

Kerr, J. E. 1953. Studies on fish preservation at the Contra Costa Steam Plant of the Pacific Gas and Electric Co. Calif. Dep. Fish Game Fish Bull. No. 92. 66 pp.

Kohlenstein, L. C. 1981. On the proportion of the Chesapeake Bay stock of striped bass that migrates into the coastal fishery. Trans. Am. Fish. Soc. 110: 168-179.

Koo, T. S. Y. 1970. The striped bass fishery in the Atlantic States. Chesapeake Sci. 11: 73-93.

Koo, T. S. Y., and D. E. Ritchie, Jr. 1973. Growth of juvenile striped bass as determined by tagging and recapture. U. S. Dep. Commer., Mid. Atl. Coastal Fish. Cent. Tech. Publ. 1: 124-125.

Koo, T. S. Y., and J. S. Wilson. 1972. Sonic tracking of striped bass in the Chesapeake and Delaware Canal. Trans. Am. Fish. Soc. 101: 453-462.

Korn, S., J. W. Struhsaker, and P. Benville, Jr. 1976. Effects of benzene on growth, fat content, and caloric content of striped bass. U. S. Natl. Mar. Fish. Serv. Fish. Bull. 74: 694-698.

Lal, K., R. Lasker, and A. Kuljis. 1977. Acclimation and rearing of striped bass larvae in sea water. Calif. Fish Game 63: 210-218.

Lawler, J. P., R. A. Norris, G. Goldwyn, K. A. Abood, and T. L. Englert. 1974. Hudson River striped bass life cycle model. Pages 83-94 in L. D. Jensen, ed. Entrainment and intake screening, proc. of the 2nd workshop on entrainment and intake screening. Johns Hopkins University, Baltimore, Md.

Lewis, R. M. 1957. Comparative study of populations of the striped bass. U. S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 204. 54 pp.

Lewis, R. M., and R. R. Bonner, Jr. 1963. Sexual maturity and fecundity studies. U. S. Bur. Commer. Fish. Circ. No. 148. 27 pp.

Lewis, R. M., and R. R. Bonner, Jr. 1966. Fecundity of the striped bass. Trans. Am. Fish. Soc. 95: 328-331.

Loeber, T. S. 1951. A report of an investigation of the temperature and salinity relationships of striped bass and salmon in connection with the Reber plan. Calif. Dep. Fish Game Inland Fish. Bur. Rep. No. 51-27. 40 pp.

Lund, W. A., Jr. 1957. Morphometric study of the striped bass. U.S. Fish Wildl. Serv. Spec. Sci. Rep. Fish. No. 216. 24 pp.

Magnin, E., and G. Beaulieu. 1967. Striped bass of the St. Lawrence River. Nat. Can. (Que.) 94: 539-555.

Manooch, C. S., III. 1973. Food habits of yearling and adult striped bass from Albemarle Sound, North Carolina. Chesapeake Sci. 14: 101-102.

Mansueti, R. J. 1958a. Eggs, larvae, and young of the striped bass. Chesapeake Lab. Biol. Contrib. No. 112. 35 pp.

Mansueti, R. J. 1958b. The development of anal spines and soft rays in young striped bass. Chesapeake Lab. Biol. Contrib. No. 113. 12 pp.

Mansueti, R. J. 1961. Age, growth and movement of the striped bass taken in size selective fishing gear in Maryland. Chesapeake Sci. 2: 9-36.

Mansueti, R. J., and E. H. Hollis. 1963. Striped bass in Maryland tidewater. University Md. Nat. Resour. Inst. Educ. Ser. No. 61. 28 pp.

Mansueti, R. J., and A. J. Mansueti. 1955. White perch eggs and larvae studied in lab. Maryland Tidewater News 12(7): 1-3.

Marcy, B. C., Jr., and R. C. Galvin. 1973. Winter-spring sport fishery in the heated discharge of a nuclear power plant. J. Fish Biol. 5: 541-547.

Markle, D. F., and G. C. Grant. 1970. The summer food habits of young of the year striped bass in three Virginia rivers. Chesapeake Sci. 11: 50-54.

Marshall, M. D. 1976. Anadromous fisheries research program: Tar River, Pamlico River, and Pamlico Sound. N. C. Div. Mar. Fish., Proj. Rep. No. AFCS-10. 90 pp.

Massman, W. H., and A. L. Pacheco. 1961. Movements of striped bass in Virginia waters of Chesapeake Bay. Chesapeake Sci. 2: 37-44.

McFadden, J. T. 1977. Influence of Indian Point Unit 2 and other steam electric generating plants on the Hudson River Estuary, with emphasis on striped bass and other fish populations. Rep. submitted to the Consolidated Edison Co. of N. Y., Inc.

McGill, E. M., Jr. 1967. Pond water for rearing striped bass fry in aquaria. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 21: 331-340.

McIlwain, T. D. 1968. Distribution of striped bass in Mississippi waters. Proc. Annu. Conf. Southeast. Game Fish Comm. 21: 254-257.

McLane, W. M. 1955. The fishes of the St. John's River system. Ph.D Thesis. University of Florida, Gainesville. 361 pp.

McLaren, J. B., J. C. Cooper, T. B. Hoff, and V. Lander. 1981. Movements of Hudson River striped bass. Trans. Am. Fish. Soc. 110: 158-167.

Mehrle, P. M., T. A. Haines, S. Hamilton, J. L. Ludke, F. L. Mayer, and M. A. Ribick. 1982. Relationship between body contaminants and bone development in east coast striped bass. Trans. Am. Fish. Soc. 111: 231-241.

Meldrim, W., J. J. Gift, and B. R. Petrosky. 1974. The effect of temperature and chemical pollutants on the behavior of several estuarine organisms. Ichthyol. Assoc. Bull. No. 7. 75 pp.

Merriman, D. 1941. Studies on the striped bass of the Atlantic coast. U. S. Fish. Wildl. Serv. Fish. Bull. 50: 1-77.

Merriner, J. V., and W. J. Hoagman. 1973. Feasibility of increasing striped bass populations by stocking of underutilized nursery grounds. Va. Comm. Game Inland Fish. Rep. No. AFS-06-02. 66 pp.

Middaugh, D. P., J. A. Couch, and A. M. Crane. 1977 Responses of early life history stages of the striped bass. J. Fish. Res. Board Can. 32: 1864-1866.

Mihursky, J. A., R. N. Block, K. Wood, R. Prince, and E. W. Gordon. 1974. Potomac Estuary fisheries study: ichthyoplankton investigations. University Md. Cent. Envir. Estuar. Stud., Nat. Resour. Inst. Ref. No. 74-127. 160 pp.

Mihursky, J. A., W. R. Boynton, E. M. Setzler, K. V. Wood, H. H. Zion, E. W. Gordon, L. Tucker, P. Pulles, and J Leo. 1976. Final report on Potomac Estuary fisheries study: ichthyoplankton and juvenile investigations. University Md. Cent. Environ. Estuar. Stud., Nat. Resour. Inst. Ref. No. 76-12-CBL. 241 pp.

Miller, L. W. 1974. Mortality rates for California striped bass from 1965-1971. Calif. Fish Game 60: 157-171.

Miller, P. E. 1980. Food habit study of striped bass post yolk sac larvae. Chesapeake Bay Inst. Spec. Rep. No. 68, Ref. 78-8. 59 pp.

Miller, R. V. 1969. Continental migrations of fishes. Underwater Nat. 6(1): 15-23, 44-45.

Moore, J., and D. T. Burton. 1975. Movements of striped bass tagged in Maryland waters of Chesapeake Bay. Trans. Am. Fish. Soc. 104: 703-709.

Morgan, A. R., and A. R. Gerlach. 1950. Striped bass studies on Coos Bay, Oregon in 1949 and 1950. Oreg. Fish Comm. Contrib. No. 14. 31 pp.

Morgan, R. P., II, and R. D. Prince. 1977. Chlorine toxicity to eggs and larvae of five Chesapeake Bay fishes. Trans. Am. Fish. Soc. 106: 380-385.

Morgan, R. P., II, and V. J. Rasin, Jr. 1973. Effects of salinity and temperature on the development of eggs and larvae of striped bass and white perch. Chesapeake Bay Inst. Nat. Resour. Ref. No. 73-110. 21 pp.

Morgan, R. P., II, T. S. Y. Koo, and G. E. Kranz. 1973a. Electrophoretic determination of populations of the striped bass in the Upper Chesapeake Bay. Trans. Am. Fish. Soc. 102: 21-32.

Morgan, R. P., II, V. J. Rasin, Jr., and L. A. Noe. 1973b. Effects of suspended sediments on the development of eggs and larvae of striped bass and white perch. In Hydrographic and ecological effects of enlargement of the Chesapeake and Delaware Canal. U. S. Army Corps of Engineers, Philadelphia District Contract No. DACW 61-71-C-0062. 21 pp.

Morgan, R. P., II, V. J. Rasin, Jr., and R. L. Copp. 1981. Temperature and salinity effects on development of striped bass eggs and larvae. Trans. Am. Fish. Soc. 110: 95-99.

Murawski, W. S. 1958. Comparative study of populations of the striped bass based on lateral line scale counts. M. S. Thesis. Cornell University, Ithaca, N. Y. 80 pp.

Murawski, W. S. 1969. A study of the striped bass foulhooking problem in New Jersey waters. N J. Dep. Conserv. Econ. Develop. Misc. Rep. No. 4M. 40 pp.

National Marine Fisheries Service. 1978, 1979, 1980, 1981, 1982a. Fisheries of the United States. U. S. Dep. Commer. Curr. Fish. Stat. Bull. Nos. 7500, 7800, 8000, 8100, 8200.

National Marine Fisheries Service. 1982b. Marine recreational fishery statistics survey, Atlantic and Gulf coasts. U. S. Dep. of Commer. Curr. Fish. Stat. No. 8063. 139 pp.

Nichols, P. R., and R. V. Miller. 1967. Seasonal movements of striped bass tagged and released in the Potomac River, Maryland, 1959-1961. Chesapeake Sci. 8: 102-124.

Nicholson, W. R. 1964. Growth compensation in four year classes of striped bass from Albemarle Sound, N. C. Chesapeake Sci. 5: 145-149.

Otwell, W. S., and J. V. Merriner. 1975. Survival and growth of juvenile striped bass in a factorial experiment with temperature, salinity, and age. Trans. Am. Fish. Soc. 104: 560-566.

Oviatt, C. A. 1977. Menhaden, sport fish and fishermen. Univ. R. I. Mar. Tech. Rep. No. 60.

Paperna, I., and D. E. Zwerner. 1976. Parasites and diseases of striped bass from the lower Chesapeake Bay. J. Fish Biol. 9: 267-281.

Pearson, J. C. 1938. The life history of the striped bass, or rockfish. U. S. Bur. Fish. Bull. No. 49: 825-860.

Polgar, T., E. Elanowicz, and A. Pyne. 1975. Preliminary analyses of physical transport and related striped bass ichthyoplankton distribution properties in the Potomac River in 1974. Potomac River Fish. Prog. Rep. Ser. Ref. No. PRFP-75-2. 51 pp.

Polgar, T., J. A. Mihursky, R. E. Ulanowicz, R. P. Morgan II, and J. S. Wilson. 1976. An analysis of 1974 striped bass spawning success in the Potomac Estuary. Pages 151-165 in M. Wiley, ed. Estuarine processes, Volume 1. Academic Press, New York.

Radtke, L. D., and J. L. Turner. 1967. High concentrations of total dissolved solids block spawning migration of striped bass in the San Joaquin River, California. Trans. Am. Fish. Soc. 96: 405-407.

Raney, E. C. 1952. The life history of the striped bass. Bingham Oceanogr. Collect., Yale Univ. Bull. 14: 5-97.

Raney, E. C. 1957. Subpopulations of the striped bass in tributaries of Chesapeake Bay. U. S. Fish. Wildl. Serv. Spec. Sci. Rep. Fish. 208: 85-107.

Raney, E. C., and D. P. de Sylva. 1953. Racial investigations of the striped bass. J. Wildl. Manage. 19: 444-450.

Raney, E. C., W. S. Wolcott, and A. G. Mehring. 1954. Migratory pattern and racial structure of

Atlantic coast striped bass. Trans. N. Am. Wildl. Conf. 19: 376-396.

Rathjen, W. F., and L. C. Miller. 1957. Aspects of the early life history of the striped bass in the Hudson River. N. Y. Fish Game J. 4: 43-60.

Regan, D. M., T. L. Wellborn, Jr., and R. G. Bowker. 1968. Striped bass: development of essential requirements for production. U. S. Fish. Wildl. Serv. Bur. Sport Fish., Atlanta, Ga. 133 pp.

Rinaldo, R. G. 1971. Striped bass and white perch spawning and nursery area in the York-Pamunkey River. M. S. Thesis. Virginia Institute Marine Science, Gloucester Point. 64 pp.

Ritchie, D. E., and T. S. Y. Koo. 1968. Movement of juvenile striped bass in the estuary as determined by tagging and recapture. Chesapeake Biol. Lab. Rep. No. 68-31. 1 p.

Robinson, J. B. 1960. The age and growth of striped bass in California. Calif. Fish Game 46: 279-290.

Rogers, B. A., and D. T. Westin. 1978. A culture methodology for striped bass. EPA Ecol. Res. Ser. Rep. No. 660/3-78-000.

Rogers, B. A., and D. T. Westin. 1981. Laboratory studies on effects of temperature and delayed initial feeding on development of striped bass larvae. Trans. Am. Fish. Soc. 110: 100-110.

Rogers, B. A., D. T. Westin, and S. B. Saila. 1977. Life stage duration in Hudson River striped bass. Univ. R. I. Mar. Tech. Rep. No. 31. 111 pp.

Saila, S. B., and E. Lorda. 1977. Sensitivity analysis applied to a matrix model of the Hudson River striped bass population. Pages 311-332 in W. Van Winkle, ed. Proceedings of the conference on assessing the effects of power plant induced mortality on fish populations. Pergamon Press, New York.

Schaefer, R. H. 1968a. Size, age composition and migration of striped bass from the surf waters of Long Island. N. Y. Fish Game J. 15: 1-51.

Schaefer, R. H. 1968b. Sex composition of striped bass from the Long Island surf. N. Y. Fish Game J. 15: 117-118.

Schaefer, R. H. 1970. Feeding habits of striped bass from the surf waters of Long Island. N. Y. Fish Game J. 17: 1-17.

Schaefer, R. H. 1972. A short range forecast function for predicting the relative abundance of striped bass in Long Island waters. N. Y. Fish Game J. 19: 178-181.

Schubel, J. R., T. S. Y. Koo, and C. F. Smith. 1976. Thermal effects of power plant entrainment on survival of fish eggs and larvae. Chesapeake Bay Inst. Spec. Rep. No. 52, Ref. 76-5. 37 pp.

Schultz, L. P. 1931. Hermaphrodism in the striped bass. Copeia 1931: 64.

Scruggs, G. D., Jr. 1957. Reproduction of resident striped bass in Santee-Cooper Reservoir, S. C. Trans. Am. Fish. Soc. 85: 144-159.

Scruggs, G. D., Jr., and J. C. Fuller. 1955. Indications of a freshwater population of striped bass in Santee-Cooper Reservoir, S. C. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 8: 64-70.

Setzler, E. M., W. R. Boynton, K. V. Wood, H. H. Zion, L. Lubbers, N. K. Mountford, P. Frere, L. Tucker, and J. A. Mihursky. 1980. Synopsis of biological data on striped bass. Natl. Mar. Fish. Serv., FAO Synopsis No. 121. 69 pp.

Setzler-Hamilton, E. M., W. R. Boynton, J. A. Mihursky, T. T. Polgar, and K. V. Wood. 1981. Spatial and temporal distribution of striped bass eggs, larvae, and juveniles in the Potomac Estuary. Trans. Am. Fish. Soc. 110: 121-136.

Shannon, E. H., and W. B. Smith. 1968. Preliminary observations on the effect of temperature on striped bass eggs and sac fry. Proc. Annu. Conf. Southeast. Assoc. Game Fish Comm. 21: 257-260.

Skinner, J. E. 1974. A functional evaluation of a large louver screen installation and fish facilities research on California water diversion projects. Pages 225-250 <u>in</u> L. D. Jensen, ed. Second workshop on entrainment and screening. Electrical Power Res. Inst. Publ. No. 74-049-00-5.

Smith, R. E., and R. J. Kernehan. 1981. Predation by the free living copepod <u>Cyclops bicuspidatus</u> on larvae of striped bass and white perch. Estuaries 21(4): 32-38.

Smith, W. G., and A. Wells. 1977. Biological and fisheries data on striped bass. Sandy Hook Lab. Tech. Ser. Rep. No. 4. 42 pp.

Sommani, P. 1972. A study on the population dynamics of striped bass in the San Francisco Bay Estuary. Ph.D. Thesis. University of Washington, Seattle. 145 pp.

Stevens, D. E. 1966. Food habits of the striped bass in the Sacramento-San Joaquin Estuary. Calif. Dep. Fish Game, Fish Bull. 136: 68-96.

Street, M. W., P. P. Potts Jr., B. F. Holland Jr., and A. B. Powell. 1975. Anadromous fisheries research program, north coastal region. N. C. Div. Mar. Fish. Rep. No. AFCS-8. 235 pp.

Swartzman, G., R. Deriso, and C. Cowan. 1977. Comparison of simulation models used in assessing the effects of power plant induced mortality on fish populations. Pages 333-361 <u>in</u> W. Van Winkle, ed. Proceedings of a conference on assessing the effects of power plant induced mortality on fish populations. Pergamon Press, New York.

Sykes, J. E., R. J. Mansueti, and A. H. Swartz. 1961. Striped bass research on the Atlantic coast. 20th Annu. Conf. of Atlantic States Mar. Fish. Comm. (Mimeo.).

Tagatz, M. E. 1961. Tolerance of striped bass and American shad to changes in temperature and salinity. U. S. Fish. Wildl. Serv. Spec. Sci. Rep. Fish. 338. 8 pp.

Tatum, B. L., J. Bayless, E. G. McCoy, and W. B. Smith. 1966. Preliminary experiments in artificial propagation of striped bass. Proc. Annu. Conf. Southeast. Game Fish Comm. 19: 374-389.

Texas Instruments, Inc. 1973. Hudson River ecological study in the area of Indian Point. First Annu. Rep. Consolidated Edison Co., New York. 348 pp.

Texas Instruments, Inc. 1974. Hudson River ecological study in the area of Indian Point. 1973 Annu. Rep. Consolidated Edison Co., New York.

Texas Instruments, Inc. 1975a. First annual report for the multiplant impact study of the Hudson River Estuary. Rep. Consolidated Edison Co., New York. 2 volumes.

Texas Instruments, Inc. 1975b. Hudson River ecological study in the area of Indian Point. 1974 Annu Rep. Consolidated Edison Co., New York.

Texas Instruments, Inc. 1976. Hudson River ecological study in the area of Indian Point. 1975 Annu. Rep. Consolidated Edison Co., New York.

Tiller, R. E. 1950. A five year study of the striped bass fishery of Maryland, based on the analysis of scales. Chesapeake Biol. Lab. Publ. No. 85. 30 pp.

Trent, L. 1962. Growth and abundance of young of the year striped bass in Albemarle Sound, North Carolina. M. S. Thesis. North Carolina State University, Raleigh. 66 pp.

Trent, L., and W. H. Hassler. 1966. Feeding behavior of adult striped bass in relation to stages of sexual maturity. Chesapeake Sci. 7: 189-192.

Trent, L., and W. H. Hassler. 1968. Gill net selection, migration, size and age composition, harvest efficiency, and management of striped bass in the Roanoke River, North Carolina. Chesapeake Sci. 9: 217-232.

Turner, J. L., and T. C. Farley. 1971. Effects of temperature, salinity and dissolved oxygen on the survival of striped bass eggs and larvae. Calif. Fish Game 57: 268-273.

Ulanowicz, R. E., and T. T. Polgar. 1980. Influences of anadromous spawning behavior and optimal environmental conditions upon striped bass year class success. Can. J. Fish. Aquat. Sci. 37: 143-154.

Van Cleve, R. 1945. A preliminary report on the fishery resources of California in relation to the Central Valley project. Calif. Fish Game 31: 35-52.

Vladykov V. D. 1947. Rapport du biologiste du department des pefcheries. Cont. Oue. Dep. Fish. 22: 1-89.

Vladykov, V. D., and D. E McAllister. 1961. Preliminary list of marine fishes of Quebec. Nat. Can. (Que.) 88: 53-78.

Vladykov, V. D., and D. H. Wallace. 1938. Is the striped bass of Chesapeake Bay a migratory fish? Trans. Annu. Am. Fish. Soc. Meet. 67: 67-86.

Vladykov, V. D., and D. H. Wallace. 1952. Studies of the striped bass with special reference to the Chesapeake Bay region during 1936-1938. Bingham Oceanog. Collect. Bull., Yale Univ. 14: 132-177.

Warsh, K. L. 1977. Final summary of estimates of the entrainment rate of spawn of the striped bass into the proposed power plant at Douglas Point. Rep. No. SHU,PPSE-T-2, Applied physics lab, Johns Hopkins Univ., Maryland.

Westin, D. T. 1978. Serum and blood from adult striped bass. Estuaries 1: 123-125.

Westin, D. T., and B. A. Rogers. 1978. Synopsis of the biological data on the striped bass. Univ. R. I. Mar. Tech. Rep. No. 67. 154 pp.

Wilson, J. S., R. P. Morgan II, P. W. Jones, H. R. Lundsford, J. Lawson, and J. Murphy. 1976. Potomac River fisheries study--striped bass spawning stock assessment. Chesapeake Biol. Lab., Univ. Md. Cent. Envir. Ecol. Stud. Ref. No. 76-14. 61 pp.

Zankel, K. L., L. H. Bongers, T. T. Polgar, W. A. Richkus, and R. E. Thorne. 1975. Size and distribution of the 1974 striped bass spawning stock in the Potomac River. Martin Marietta Corp. Envir. Cent. Ref. No. PRFP 75-1

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO. FWS/OBS-82/11.8 *

2.

3. Recipient's Accession No. AD-A180 382

4. Title and Subtitle
Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Mid-Atlantic) -- Striped Bass

5. Report Date
October 1983

6.

7. Author(s)
Clemon W. Fay, Richard J. Neves, Garland B. Pardue

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Department of Fisheries and Wildlife Sciences
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
National Coastal Ecosystems Team
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

13. Type of Report & Period Covered

14.

15. Supplementary Notes
*U.S. Army Corps of Engineers report No. TR EL-82-4

16. Abstract (Limit: 200 words)
Species profiles are literature summaries on the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are designed to assist in environmental impact assessment. The striped bass (Morone saxatilis) is a highly valued recreational and commercial fish species and is surpassed in total recreational catch (weight) only by bluefish and Atlantic mackerel on the Atlantic coast. Males mature at age 2 or 3, and females at age 4 or 5. Striped bass are anadromous, spawning in fresh or nearly fresh water, from April through June in the mid-Atlantic region. Upper Chesapeake Bay, its major tributaries, and the Chesapeake-Delaware Canal are the most important spawning grounds on the Atlantic coast. Eggs are semibuoyant, and require a minimum current velocity of 30.5 cm/s during development to keep them from settling and smothering on the bottom. Environmental conditions during the larval stage are considered most crucial in terms of future year class strength. Juveniles remain in or near areas of origin for 2 or 3 years, at which time a portion of the juveniles may join coastal migratory stocks, moving north in spring and summer and south in fall and winter. Temperature, salinity, current velocity, and turbidity are important environmental factors for striped bass. Eggs require water temperatures between 14°C and 23°C, salinities between 0 and 10 ppt, water currents of at least 30.5 cm/s, and turbidities less than 1000 mg/l for successful development and hatching. Larvae require temperatures between 10°C and 25°C, salinities between 0 and 15 ppt, and turbidities less than 500 mg/l for survival. Juvenile and adult tolerances are generally wider. Keywords:

17. Document Analysis a. Descriptors
Estuaries;
Fishes
Growth Physiology
Feeding

b. Identifiers/Open-Ended Terms
Striped bass
Morone saxatilis
Salinity requirements
Temperature requirements
Nursery areas
Spawning requirements

c. COSATI Field/Group

18. Availability Statement
Unlimited

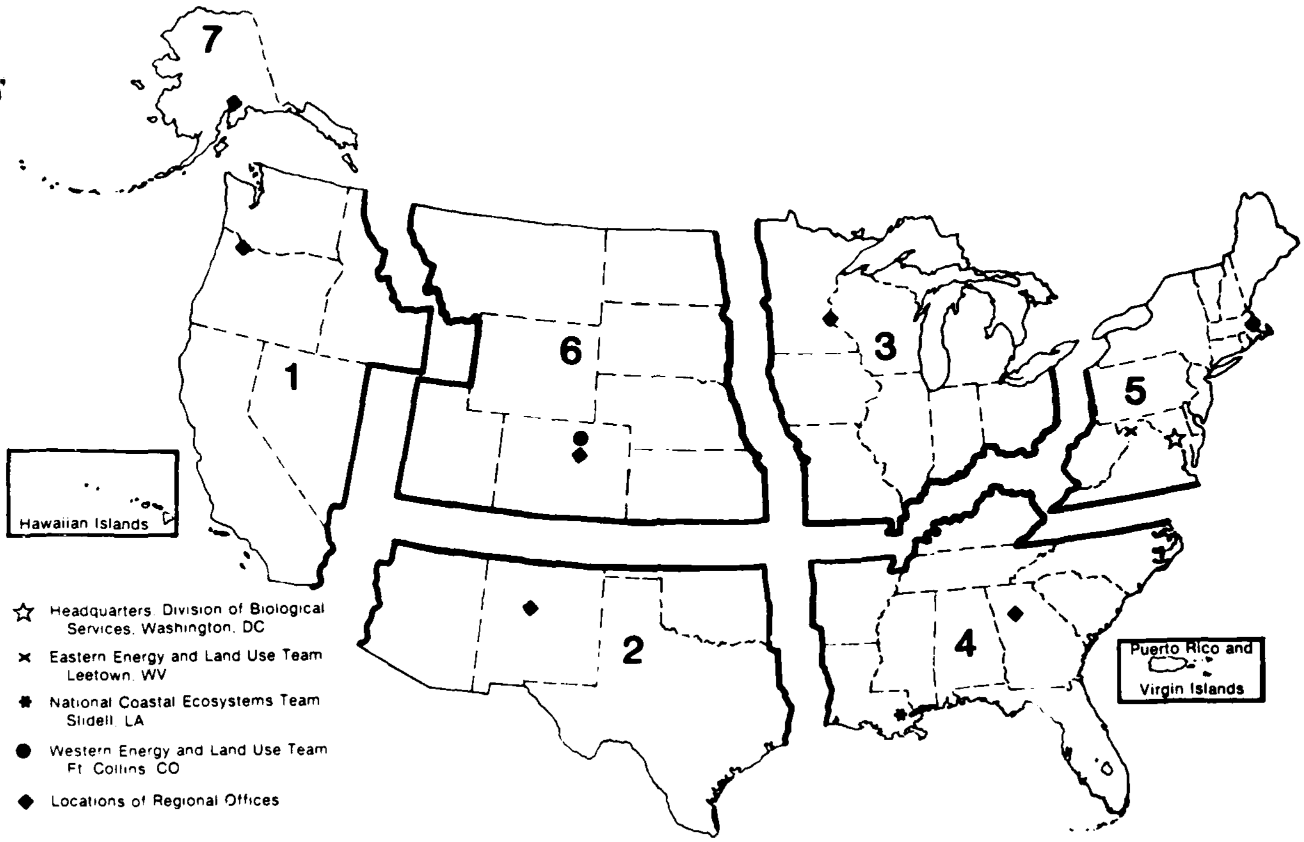
19. Security Class (This Report)
Unclassified

20. Security Class (This Page)
Unclassified

21. No. of Pages
36

22. Price

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce



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Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
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U.S. Fish and Wildlife Service
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Twin Cities, Minnesota 55111

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Atlanta, Georgia 30303

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U.S. Fish and Wildlife Service
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Regional Director
U.S. Fish and Wildlife Service
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Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

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