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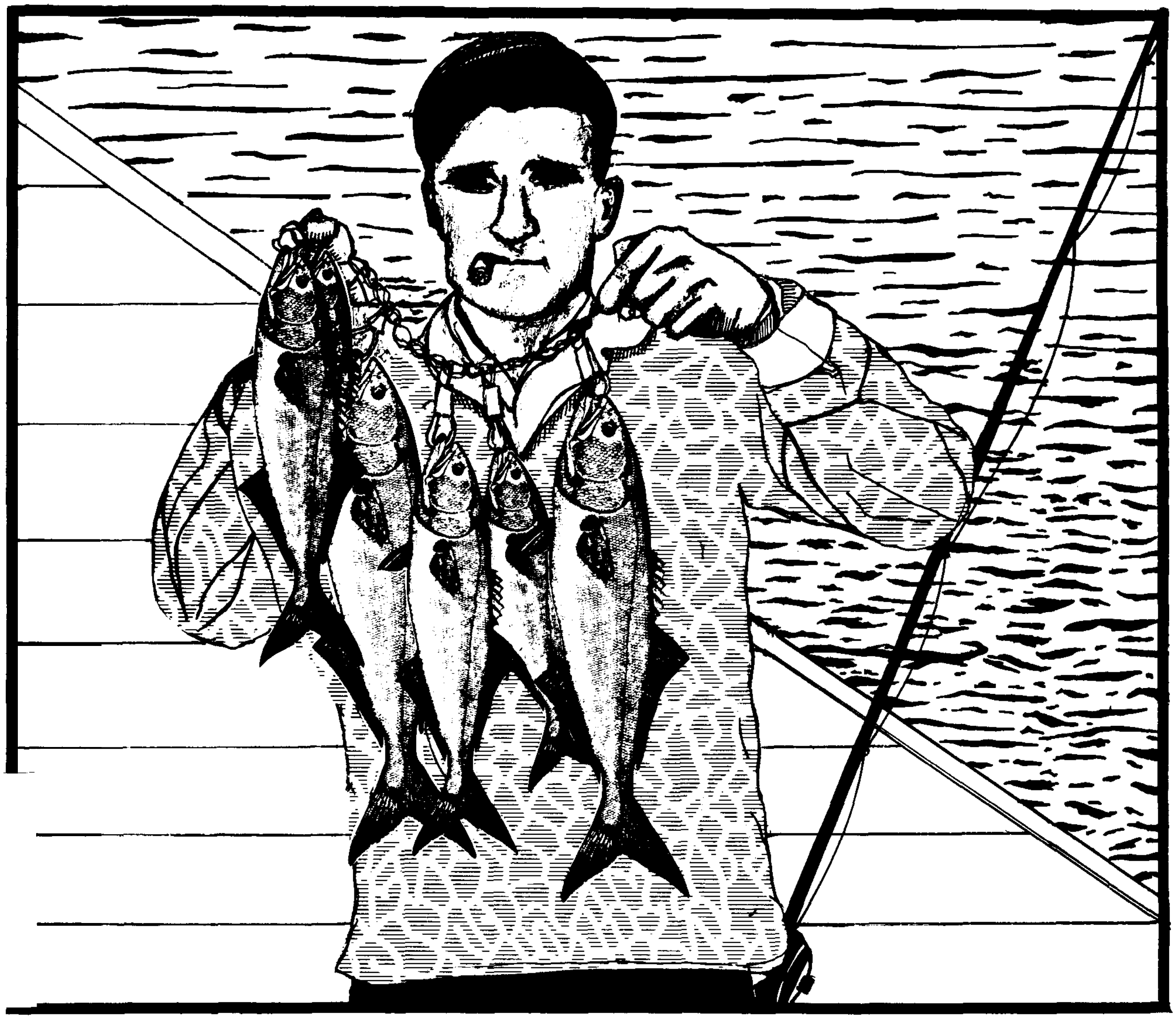

Fish and Wildlife Service

U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station

U.S. Army Corps of Engineers

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

BLUEFISH

by

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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.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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or

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Vicksburg, MS 39180

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km*)	0.3861	square miles
hectares (ha)	2.471	acres
liters (1)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	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
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

The authors gratefully acknowledge the aid of Sandra Landes for her research efforts. Unpublished fishery data were provided by Joan Palmer, U.S. National Marine Fisheries Service, Fishery Statistics and Economics Branch. Information on current bluefish research and management activities was provided by David Keifer, mid-Atlantic Fishery Management Council, and Steve Berkeley, South Atlantic Fishery Management Council. Reviews by Jeff Ross, North Carolina Division of Marine Fisheries, and Stuart Wilk, U.S. National Marine Fisheries Service, are much appreciated.

This work was conducted by members of the North Carolina Cooperative Fishery Research Unit which is supported by North Carolina State University, North Carolina Wildlife Resources Commission, and U. S. Fish and Wildlife Service.

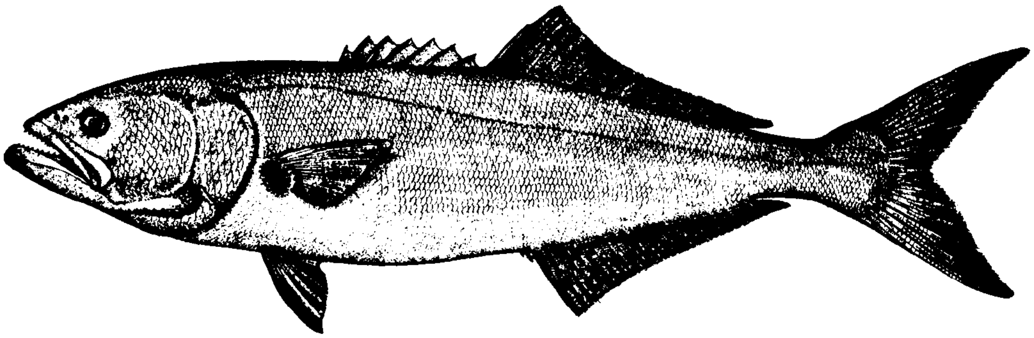


Figure 1. Bluefish (from Jordan and Evermann 1896-1900).

BLUEFISH

NOMENCLATURE/TAXONOMY/RANGE

Scientific name..............Pomatomus saltatrix (Linnaeus)
Preferred common name........ Bluefish (Figure 1)
Other common names . . . .blue. tailor, elf, fatback, snapper, snap mackerel, skipjack, skip mackerel, horse mackerel, greenfish, chopper.
Class . . . .Osteichthyes
Division..................... Teleostei
Order . . . .Perciformes
Family....................Pomatomidae

The bluefish is the only living species in the family Pomatomidae, whose closest relatives are the jacks and pompanos, family Carangidae. Several geographical races of P. saltatrix are recognized (Lund 1961).

Geographic range: Bluefish occur in temperate and tropical waters on the continental shelf and in estuarine habitats around much of the world. In North America they live along most of the Atlantic seaboard from Nova Scotia south, around the tip of Florida, and along the Gulf coast to northern Mexico. Their worldwide range also includes Bermuda, the Bahamas, the northern coast of Cuba, Venezuela, southeastern Brazil, Uruguay, the Azores, the Mediterranean Sea, the Black Sea, northwest Africa, southern Africa, Madagascar, the Malay Peninsula, and the entire coast of Australia (Wilk 1977).

MORPHOLOGY/IDENTIFICATION

Adult

The adult bluefish (Figure 1) is an oblong, laterally compressed, streamlined fish up to 1 m total length (TL), with a large compressed head, large oblique mouth, belly compressed to a blunt edge, and forked caudal fin. Coloration is bluish to greenish dorsally, fading to silver ventrally; a dark blotch at each pectoral fin base is the only distinct marking. Body, cheeks, and opercles are covered with weakly ctenoid scales, 95 along lateral line, but the top of the head and the ridge above the cheeks are unscaled. The anterior spiny dorsal fin, with 8 to 9 spines, is separate from and lower than the posterior soft dorsal, with 24 to 25 rays. The anal fin, with 2 to 3 very small spines and 26 to 28 rays, is slightly behind and about equal in length to the soft dorsal fin. Pectoral fins are rather low set, and the pelvic fins attach directly beneath them. Maxillae extend to the rear of the eyes, the premaxillae are protractile, and the lower jaw projects forward of the mouth. The jaws each have a row of long, unequal, widely spaced teeth; the vomer, tongue, and palatines have several bands of villiform teeth. Vertebrae number 24 to 26. (Compiled from Jordan and Evermann 1896-1900; Bigelow and Schroeder 1953; Miller and Jorgenson 1973).

Eggs and Larvae

Bluefish eggs (Figure 2a) are similar to those of many other pelagic spawning fishes. They are buoyant, spherical, 0.9 to 1.2 mm in diameter, with a smooth transparent membrane, pale amber yolk, and a single darker amber oil globule 0.2 to 0.3 mm in diameter. The bodies of advanced embryos (Figure 2b) have 24 myomeres and do not completely encircle the yolk. (From Oeuel et al. 1966; Lippson and Moran 1974).

Bluefish larvae are 2.0 to 2.4 mm TL at hatching (Figure 2c). The yolk sac is more than half of the body length, an oil globule lies at the posterior end of the yolk, and stellate melanophores are scattered on the head and along the back. Four days post-hatching (Figure 2d), the yolk is mostly absorbed, the mouth is developed, and distinct mid-dorsal and mid-ventral pigment bands are evident. Fin rays are perceptible at 6.0 mm TL (Figure 2e), and fins are fully developed at 13 to 14 mm TL, at which size they resemble adults but with proportionately larger heads (Figure 2f). (From Norcross et al. 1974; Lippson and Moran 1974.)

REASON FOR INCLUSION IN SERIES

Bluefish comprise less than 1% of the U.S. Atlantic coast commercial fishery landings, in terms of both weight and dollar value; but the commercial catch has tripled over the past two decades (Wilk 1977; Thompson 1986), and recent trends in U.S. fish consumption indicate economic incentives for much greater catches: Per capita consumption of edible fish and shellfish in the United States during 1985 was 20% greater than during 1975, and 50% greater than during 1965. "Nutritional demands of consumers, as well as improving methods of catching, handling, and processing seafoods may reasonably be expected to lead to greater consumption levels in future years" (Thompson 1986).

In contrast to its commercial importance, the recreational value of this species is enormous. Bluefish comprise about 15% by numbers and nearly twice as much by weight of Atlantic coast sport fish landings. About 90% of the average 55 million kg of bluefish taken annually over the past 7 years (about 8 times more than the commercial catch) were hooked by anglers in the mid-Atlantic region (Holliday 1984, 1985a, 1985b, 1986).

Because bluefish are abundant along most of the east coast, easy to catch, good to eat, and provide an unusually long fishing season, they have remained popular with sport fishermen since the 1800's. "No other species is as important to all sorts of anglers.... It is unlikely that any other species could completely replace it, were it to disappear" (Wilk 1977).

Periodic disease outbreaks over the past 20 years (Mahoney et al. 1973) suggest that the species is sensitive to coastal water quality degradation, and therefore coastal land use planners and developers should consider the effects of their activities upon bluefish populations.

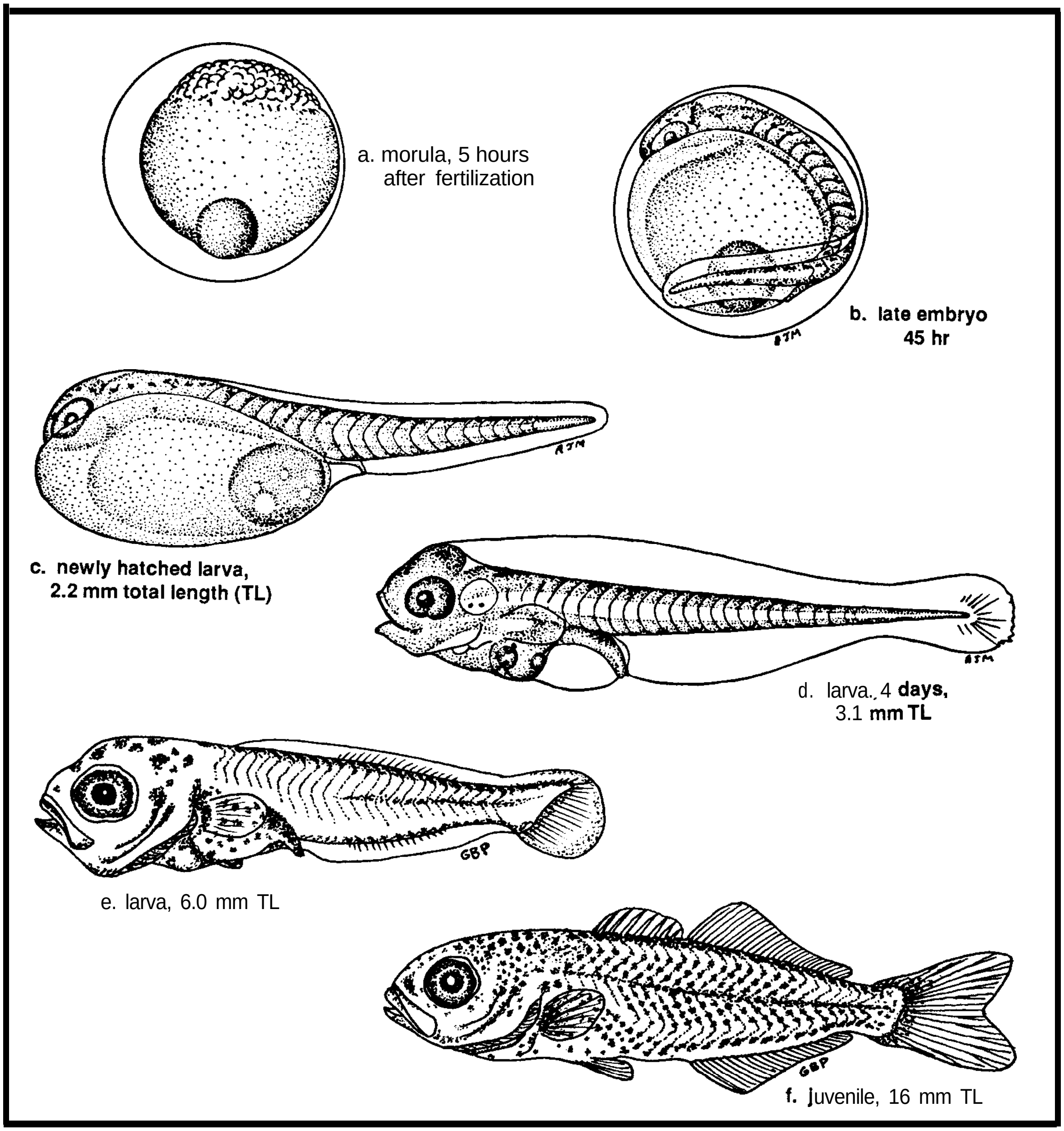


Figure 2. Developmental stages of the bluefish. Drawings a, b, c, and d from Deuel et al. 1966; e and f redrawn from Norcross et al. (1974).

LIFE HISTORY

Reproductive Features

Bluefish are heterosexual and reach sexual maturity during their second year at about 35 cm fork length (FL). Males mature slightly earlier than females, but neither growth rate nor ultimate adult size is sexually dimorphic (Wilk 1977; Wilk et al. 1978). The sexes cannot be distinguished by external features. Lassiter (1962) reported a 2-to-1 female to male ratio in North Carolina, but Wilk (1977) reported a 1-to-1 sex ratio among schools of all ages along the entire Atlantic coast. Fecundity of 3- to 4-year-old females ranged from 0.6 to 1.4 million eggs in a small sample from North Carolina (Lassiter 1962). Fertilization is external; eggs and sperm are shed into the open sea by migrating schools, without further parental care. Larvae drift and feed among the surface plankton until they metamorphose and begin their migrations either south or toward the coastal nursery areas (Kendall and Walford 1979).

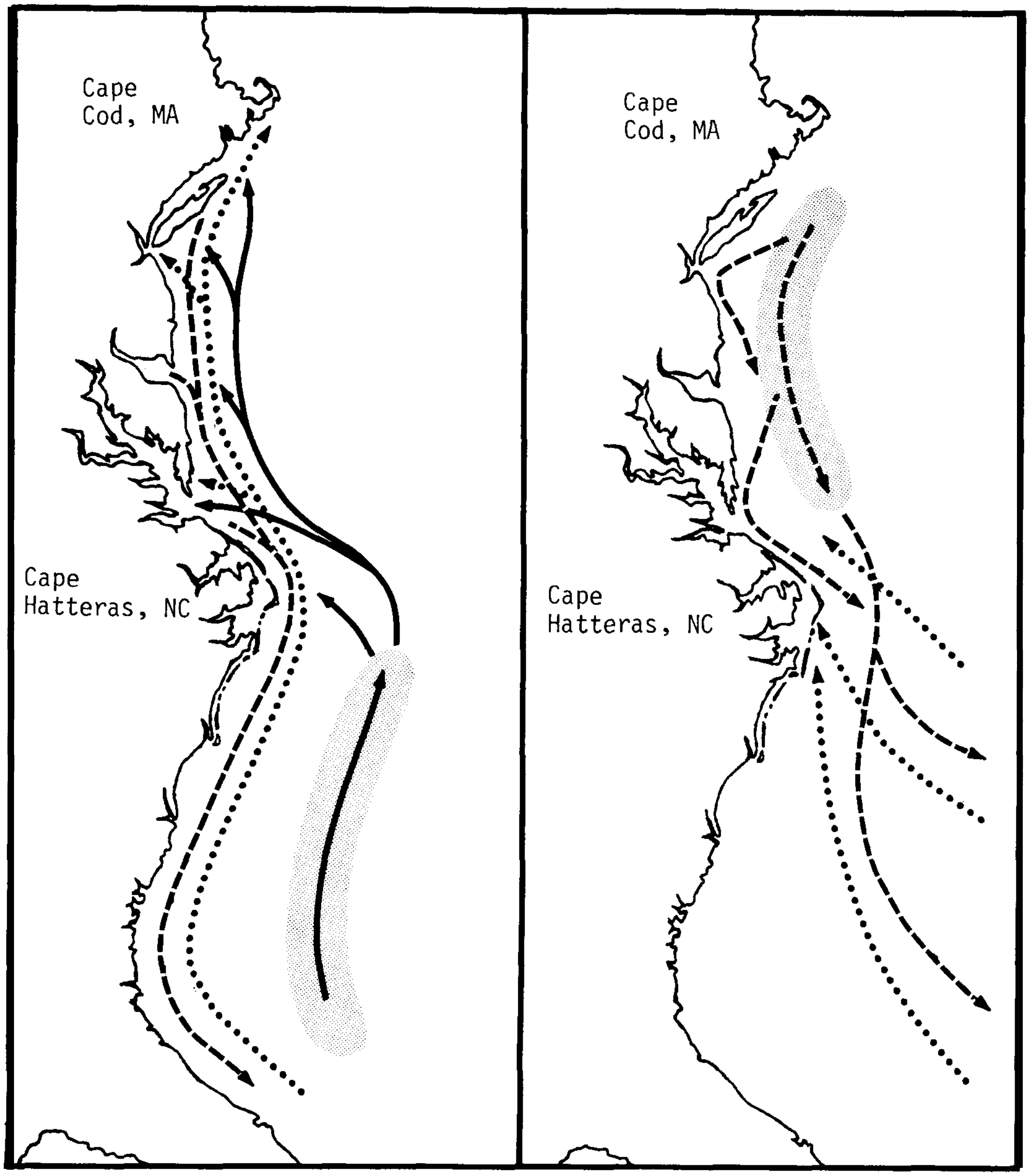
Spawning and Migration Routes

Fisheries data suggest that most North American bluefish are migratory, spending their summers from New England to Cape Hatteras, N.C., and their winters around Florida and the Gulf Stream. Smaller bluefish generally travel close to shore during both the spring and fall migrations, except during spawning. Older fish travel near shore in their northern range, but apparently shift farther offshore in the south with periodic forays toward the coast, since they appear infrequently but in large schools south of Virginia, especially during the fall migration (Lund and Maltezos 1970; Wilk 1977). There also appear to be small non-migratory (or less migratory) populations in the south Florida and Gulf of Mexico regions (Barger et al. 1978; Kendall and Walford 1979). The degree of reproductive isolation of the various Atlantic and gulf coast populations (including those that are migratory and those that appear to be non-migratory) is unclear. Wilk (1977) and Matlezos (1970), however, recognize very small but consistent morphological differences (see Population Dynamics) between the two major spawning aggregations that comprise the mid-Atlantic fishery: a south-Atlantic spring-spawning stock and a mid-Atlantic summer-spawning stock.

Figures 3a and 3b map the migration routes of spring-spawning and summer-spawning bluefish, respectively, during their first year of life. Figures 4a and 4b map the migration routes of bluefish of these two populations older than 1 year. The figures are presented in order of age, but our discussion of this complex and incompletely understood migration necessarily begins with the spawning adults.

The spring-spawning stock arrive at the continental slope/Gulf Stream interface between north Florida and Cape Hatteras, N.C., mainly in April and May, from their wintering areas in south Florida or offshore in the south Atlantic (Figure 4a). Spawning occurs in pulses as the schools travel northward. North of Cape Hatteras the spent adults begin heading toward shore for the remainder of the warm season. Smaller ones generally turn west sooner and find their way into Albemarle Sound, Chesapeake Bay, and Delaware Bay, whereas larger ones follow the continental slope farther north and turn west into Long Island Sound and Narragansett Bay, or continue around Cape Cod to the north Atlantic region. As temperature and photoperiod decline in autumn, the schools orient southward again, young ones close to shore and older ones farther offshore (Wilk 1977; Kendall and Walford 1979).

Summer-spawning bluefish arrive over the outer half of the continental shelf (about 50 to 150 km offshore) between Cape Cod and Cape Hatteras from June through August, probably from the same wintering areas as the spring spawners (Figure 4b). After spawning, adults migrate toward the mid-Atlantic and north Atlantic coasts, especially Long Island Sound (Lund and Maltezos 1970). They depart in autumn along with the spring spawners.



a. Spring-spawning

b. Summer-spawning

spawning area

1-2 months, summer

5-6 months, fall

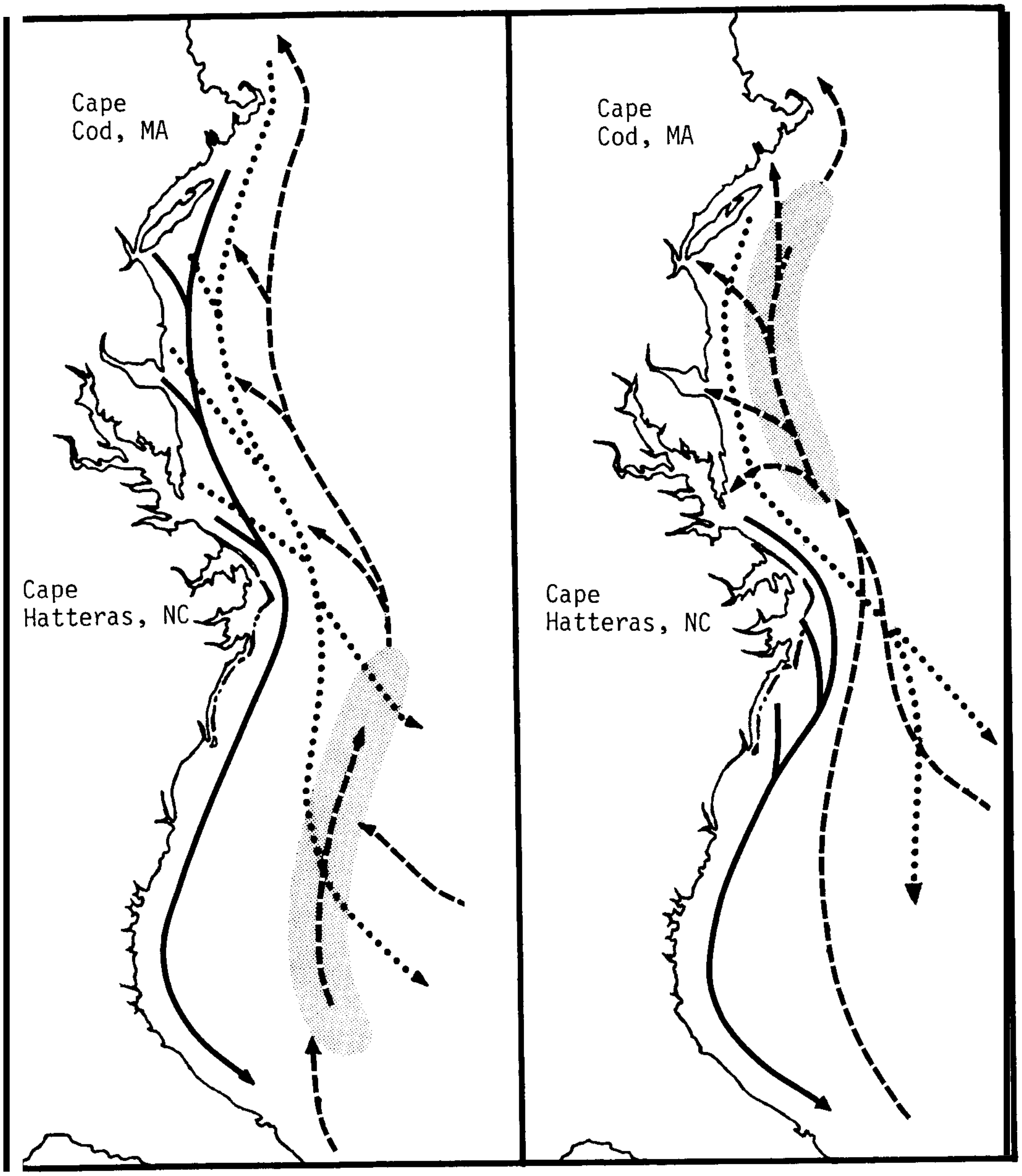
12-13 months, spring

spawning area

2-4 months, fall

9-11 months, spring

Figure 3. Migration routes of bluefish from hatching until 1 year old.



a. Spring-spawning

spawning area
1+ years, fall
≥ 2 years, spring
≥ 2 years, fall

b. Summer-spawning

spawning area
1+ years, fall
≥ 2 years, spring and summer
> 2 years, fall

Figure 4. Migration routes of bluefish over 1 year old.

Juveniles from the spring spawning drift northward with the Gulf Stream past Cape Hatteras and along the continental slope (Figure 3a). When continental shelf waters warm sufficiently by early summer, they cross the shelf and migrate into the mid-Atlantic bays and estuaries. Here they feed heavily and grow rapidly until fall, then migrate south along the coast to their south Florida wintering areas. The following spring the yearlings travel back up the coast, returning mainly to the mid-Atlantic bays, though some stop earlier and spend their second summer in North Carolina (Wilk 1977; Kendall and Walford 1979).

Juveniles from the mid-Atlantic summer spawning remain offshore over the continental shelf for the remainder of the warm season (Figure 3b). Some visit the coastal areas briefly in early fall, but then return seaward for their southern migration. Most young-of-the-year bluefish caught during winter in Florida appear to be from the spring spawning, so summer-spawned young probably remain farther offshore through the winter, and make their first major coastal appearance the following spring, mostly in the south Atlantic and in the sounds of North Carolina (Wilk 1977; Kendall and Walford 1979).

GROWTH CHARACTERISTICS

First Year

Bluefish larvae begin feeding when the yolk supply is exhausted, at 3 to 4 mm TL (Norcross et al. 1974). When the spring-spawned young arrive in mid-June in the mid-Atlantic bays they are 1 to 2 months old and 25 to 50 mm standard length (SL); by migration time in late September these fish have achieved lengths of 175 to 200 mm SL. The following spring they return from south Florida at about 260 mm SL, when their first scale annulus forms in May (Lassiter 1962; Kendall and Walford 1979).

Summer-spawned young lag behind in growth because they are hatched later in the season and because most do not utilize the fertile bays and estuaries until they are nearly a year old. Those that visit the mid-Atlantic coast briefly in September are 40 to 70 mm SL just prior to their southward migration. When they reappear in North Carolina in spring and develop their first scale annulus, they are about 120 mm SL. Growth rates of these summer-spawned fish apparently exceed those of the spring-spawned fish during the second year, since at age 2 or 3 the size difference between the two stocks is much less pronounced than at age 1. (From Lassiter 1962; Norcross et al. 1974; Kendall and Walford 1979.)

Subseauent Years

Beyond yearlings, lengths are usually expressed as fork length (FL), which approximately equals 1.1 x SL. Wilk (1977) summarizes age, length, and weight data for 7,500 bluefish up to 14 years old taken between Rhode Island and Florida over a 6 year period. Richards (1976) measured a sample of 64 bluefish up to 7 years old from Long Island Sound. His data agree closely with those of Wilk (1977), but he remarks that growth is highly variable in the first few years, with much overlap in size between age classes.

Lassiter (1962) presents the only study to date in which the spring spawning and summer spawning populations are modeled separately, based on several hundred bluefish up to 812 mm FL collected off the North Carolina coast. He estimates the relationships of age (t = years) versus fork length (mm) and age (years) versus weight (grams) for bluefish older than 1 year as follows:

Spring spawners:

$$FL = 1,285\ [1 - e^{-0.103(t + 1.366)}]$$

$$Wt = 28,943\ [1 - e^{-0.103(t + 1.366)}]^3$$

Summer spawners:

$$FL = 675\ [1 - e^{-0.342(t + 0.249)}]$$

$$Wt = 4,244\ [1 - e^{-0.342(t + 0.249)}]^3$$

Lassiter's (1962) and Wilk's (1977) age versus length relationships are plotted in Figure 5, and their age versus weight relationships are plotted in Figure 6. Note that Lassiter's equations suggest a slower growth rate beyond 3 years and a smaller ultimate asymptotic size for the summer spawners than for the spring spawners. Subsequent authors have not investigated this discrepancy, and it may be an artifact of his regionally restricted data. Allometric fork length (mm) versus weight (grams) relationships for the pooled populations have been presented by Lassiter (1962) based on 646 North Carolina specimens, and by Wilk et al. (1978) based on 343 New York Bight specimens:

$$\log Wt = 2.903 \log FL - 4.611$$
(Lassiter 1962)

$$\log Wt = 3.036 \log FL - 4.953$$
(Wilk et al. 1978)

FISHERIES

Recreational

The bluefish has ranked first among sport fish in the mid-Atlantic region and in the United States overall in terms of both number and weight nearly every year since it first achieved that distinction in 1970. Table 1 summarizes recreational fishery data compiled from various U.S. National Marine Fisheries Service (NMFS) publications. During recent years, bluefish have comprised about 15% by numbers and nearly 30% by weight of all species in the Atlantic

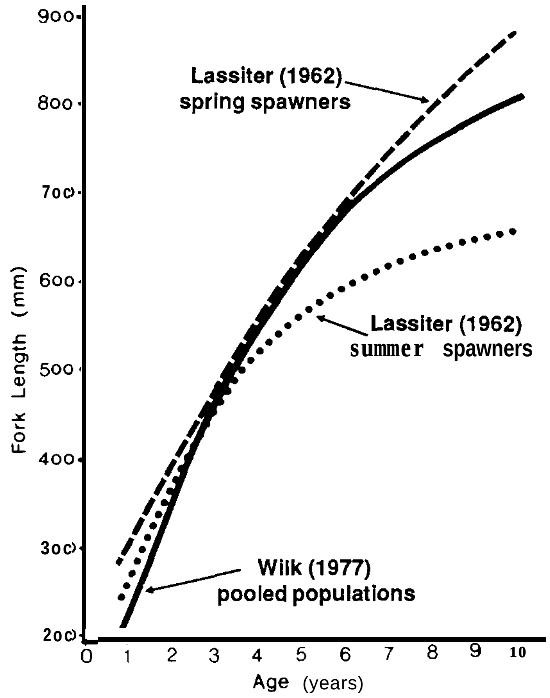


Figure 5. Age versus fork length of bluefish over 1 year old.

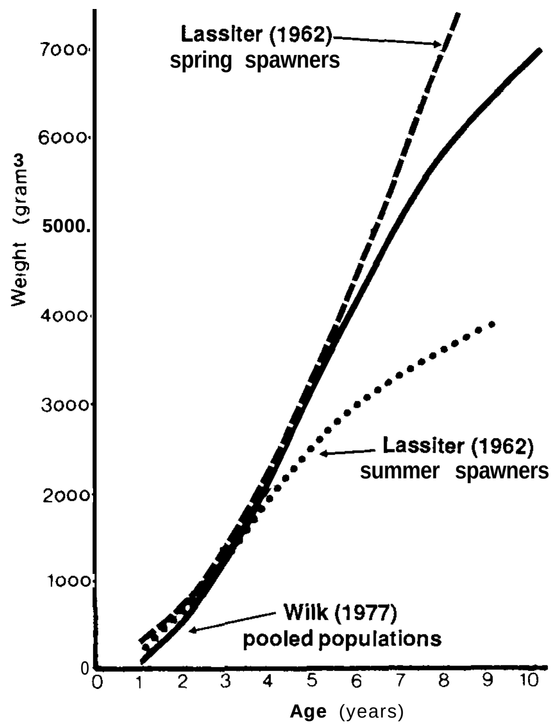


Figure 6. Age versus weight of bluefish over 1 year old.

coast (Maine to Florida Keys) recreational fishery. The mid-Atlantic States (Massachusetts to North Carolina) contribution has increased from about 70% during the 1960's to about 90% of the total U.S. recreational bluefish catch during the 1980's. Average weight of bluefish caught has varied between 1.0 and 1.8 kg over the past 25 years, depending on the relative contributions of northern and southern fishermen to the total catch, but there has been no apparent overall change in the average size of available bluefish. The size distribution of bluefish caught from 1983 to 1985 is bimodal: fish in the 250 to 400 mm FL size class make up the bulk of the recreational catch, with a smaller peak at 750 to 850 mm FL. Inland waters (bays, sounds, estuaries) have contributed slightly less than half of the total catch during the past 7 years. About one-third are taken from shore or from man-made structures along the shore, and the remaining two-thirds are taken from boats. Trolling, chumming, casting, live-bait fishing, jigging, still fishing, and drift fishing techniques are used by various anglers to catch bluefish.

Spring, summer, and especially fall yield most of the recreational catch in the mid-Atlantic, but large

Table 1. Recreational bluefish fishery statistics, 1960-85.

Year	Number (millions)		Weight (million kg)	% of total	Area of fishing (%)		Mode of fishing (%)	
	MA to NC	ME to TX	ME to TX	Atlantic catch[a]	Inland[b]	Ocean[c]	Shore[d]	Boat[e]
1960	17	24	23	11	--	--	21	79
1965	22	31	43	15	29	71	39	61
1970	23	36	55	12	39	61	39	61
1979	33	38	61	13	44	56	25	75
1980	40	43	70	15	62	38	32	68
1981	29	32	60	16	28	72	35	65
1982	30	33	47	15	41	59	30	70
1983	41	44	66	16	48	52	37	63
1984	27	30	40	12	44	56	40	60
1985	25	28	45	12	45	55	32	68

[a]Number of bluefish expressed as % of total finfish taken by recreational fishermen between ME and the FL Keys.
[b]Percent (by number) of ME to TX recreational bluefish catch taken from bays, sounds, and estuaries.
[c]Percent (by number) of ME to TX recreational bluefish catch taken from open ocean waters.
[d]Percent (by number) of ME to TX recreational bluefish catch taken from shore, piers, and jetties.
[e]Percent (by number) of ME to TX recreational bluefish catch taken from private, rented, and chartered boats.
--Data not available

Compiled from the 1960, 1965, and 1970 Saltwater Angling Surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973) and from the 1979-85 Marine Recreational Fishery Statistics Surveys (Holliday 1984, 1985a, 1985b, 1986).

fish are available year-round in the southernmost mid-Atlantic and the south Atlantic for anglers venturing offshore to the Gulf Stream (Wilk 1977). Spring-spawned young-of-the-year caught during the fall migration, and yearlings of both stocks caught during spring, are especially popular with novice anglers since they are plentiful in inshore waters.

Commercial

Bluefish are harvested for human consumption as fresh whole fish or fillets; there is little or no industrial use of this species. During the peak years 1980-83, when an average 7.4 million kg of bluefish were caught annually, this species comprised only about 0.5% of the Atlantic coast commercial finfish and shellfish industry landings (Thompson 1981, 1982, 1983, 1984a). The soft, dark meat of bluefish does not freeze well, so fishermen and seafood distributors are at the mercy of short-term localized market demand. This feature has discouraged large-scale development of the bluefish fishery and kept the price low in the past, but recent advances in fishery methods and freezing and processing technology may soon increase the domestic market and create substantial new export markets as well (Wilk and Brown 1980).

Bluefish landings by U.S. commercial fishermen at ports in the mid-Atlantic states, compiled from various NMFS statistical publications, are summarized in Table 2. During the last decade (1976-85), North Carolina has been the largest supplier, averaging about 28% of the total U.S. bluefish catch, or nearly 1.8 million kg annually. Virginia is ranked second, with 18% of the U.S. catch. New York and New Jersey each have landed about 10%-12% of the U.S. total; Massachusetts, Maryland and Rhode Island each about 3%-5% and Connecticut and Delaware each about 1% or less. All totalled, the mid-Atlantic region accounts for approximately 83% of the total U.S. bluefish catch. About 90% of the combined catch of Maryland and Virginia, or about one-fifth of the U.S. catch, is taken in Chesapeake Bay. Until the late 1970's, nearly 90% of the U.S. commercial bluefish catch was taken less than 3 mi offshore; in more recent years the inshore catch has dropped to about 70% of the total, as offshore catch effort in the U.S. Fishery Conservation Zone has increased, especially off North Carolina.

The commercial fishing season from Cape Cod, MA to Delaware Bay is primarily May though November, with peak catches from July to September. In Maryland and Virginia, bluefish are caught year-round, with peak catches earlier in the summer. In North Carolina, the bluefish fishery is year-round with peak catches in the winter: small fish are taken in the sounds and nearshore waters from April through December, and recently, great quantities of larger fish have been taken offshore during winter (Wilk 1977; Mid-Atlantic FMC 1984). Fishing gear employed varies widely from state to state, as presented in Table 3 for the years 1975 to 1977. Hand lines are used in New England when schools of large fish are feeding; pound nets are common in Chesapeake Bay; traps and seines are generally used in inshore waters; trawls and gill nets are used both inshore and offshore in many states. During the last decade, otter trawls, gill nets, and pound nets have yielded about three-fourths of the mid-Atlantic commercial catch, with seines and hand lines contributing most of the remainder (Mid-Atlantic FMC 1984).

There is no appreciable foreign catch or joint venture catch of bluefish in U.S. waters, and no user conflicts have occurred yet, but fishery stock assessments by Anderson and Almeida (1979) and Anderson (1980) suggest that any "major increase in

Table 2. U.S. commercial bluefish landings in the mid-Atlantic states, 1950-85.

Year	Thousands of kilograms									Millions of kilograms		Millions of dollars
	MA	RI	CT	NY	NJ	DE	MD	VA	NC	MA to NC	US	us
1950	28	25	9	58	589	10	48	141	578	1.48	2.13	0.70
1955	17	i4	15	213	461	1	29	100	198	1.05	1.92	0.59
1960	7	15								0.76	1.58	0.49
1965	65	49	2:	472 188	201 395	' '	5 3	59 93	280 320	1.42	2.28	0.58
1970	31	146					31	289	7	1.75	3.27	0.74
1975	250	174	39	404	483	3	126	1,493	898	3.94	4.65	1.48
1976	205	110	10	273	582	5	233	1,894	616	3.93	4.83	1.09
1977	229	111	6	448	635	14	238	1,440	1.060	4.18	5.24	1.31
1978	296	170	6	793	720	11	131	1,246	-885	4.26	5.26	1.61
1979	193	147	25	733	723	16	145	1,393	1,548	4.92	6.00	2.20
1980	231	166	24	677	637	73	199	1,280	2,475	5.76	7.12	2.43
1981	220	229	3	582	834	89	189	1,038	3,005	6.19	7.57	3.23
1982	455	302	55	783	891	232	121	1.151	1,950	5.94	7.41	3.68
1983	276	236	91	767	875	182	331	-691	3,067	6.52	7.59	2.58
1984	449	463	30	744	769	71	78	526	1.613	4.74	5.77	2.38
1985	387	769	45	969	904	79	194	706	1,638	5.69	6.23	2.36
lo-year % of U.S. total	4.7	4.3	0.5	10.7	12.0	1.2	2.9	18.0	28.3	82.7	100.0	

[a]Ten year total bluefish landings in each state, expressed as % of U.S. total bluefish landings for the period 1976-85.

*Less than 500 kg reported.

Compiled from Wilk (1977); Pileggi and Thompson (1978, 1979, 1980); Thompson (1981, 1982, 1983, 1984a, 1984b, 1985, 1986); Mid-Atlantic FMC (1984); and unpublished NMFS data.

Table 3. Percent of commercial bluefish landings in the Mid-Atlantic states taken by various types of fishing gear.

	Weight % of state catch by gear					
State[a]	Seines (purse, haul)	Trawls (otter, midwater)	Pound net, floating trap	Gill nets (drift, anchor, runaround)	Hand line	Long line, troll line
MA	*	4	10 31	2	66	18
RI			*	*		
CT	* *	47 37		7	22 55	* *
NY NJ	26	13	14	9 43	38	*
DE	10 1	41 *	6 *	85	* 15	1 *
MD	6	17	52	24	6	*
VA		2				
NC	47	42	77 2	15 8	* *	* 1
MA to NC[b]	13	28	25	23	8	3

[a]Based on 3-year (1975-77) commercial landings data.

[b]Based on 8-year (1975-82) commercial landings data.

*Less than 0.5% reported.

Compiled from Pileggi and Thompson (1978, 1980); Thompson (1984b); and Mid-Atlantic Fishery Management Council (1984).

fishery pressure" would likely push the harvest beyond the taking of "surplus production." If so, they contend, recreational fishermen would probably suffer first.

Population Dynamics

The migratory nature of bluefish populations and the differential distribution of age classes make population studies of this species extremely difficult. Schools are segregated by size, and sampling techniques typically reflect that segregation (Wilk, 1977). Tagging studies, such as those by Lund and Maltezos (1970) and Sandy Hook Marine Laboratory (Wilk 1977) during the 1960's, and ichthyoplankton surveys by Clark et al. (1969), Norcross et al. (1974), and Kendall and Walford (1979) have established spawning areas, migration routes, and the existence of distinct spring spawning and summer spawning populations.

Yearlings of the summer spawning stock are distinguished by a slightly larger head, longer maxillae, larger eyes, smaller pelvic fins, larger pectoral fins, smaller soft dorsal and anal fins, and a larger gap between the spiny and soft dorsal fins than the spring spawners. Older fish of the summer spawning stock can sometimes be distinguished from spring spawners by the smaller distance between the center of a scale and its first annulus (Wilk 1977).

Estimates of population density, mortality, natality and recruitment, and age structure are at present weakly based and incomplete. The recreational fishery, our largest available data source, demonstrates a frequency peak of 1-to-2 year olds and a smaller peak of 8- to 12-year-olds during the years 1983 to 1985 (Holliday 1985b, 1986). Wilk (1977) reports that 1- to 4-year-old bluefish comprised the bulk of the samples during the mid-1960's, and that all year classes between 1962 through 1965 were of equal strength. Relative abundance of mid-Atlantic bluefish has apparently increased since the 1960's, based on NMFS offshore and inshore trawl surveys, but fluctuations from year to year are large. Total annual mortality is estimated at 69% to 75% over all ages; annual fishing mortality is estimated at 27% for large fish and up to 70% for small fish (due to their greater vulnerability to inshore fishermen); and annual natural mortality is estimated at 59% to 63% for large fish and 18% to 50% for small fish (Mid-Atlantic FMC 1984).

The two major spawning stocks have not yet been studied separately with respect to population dynamics and age structure; if they are indeed reproductively isolated, then statistics based on pooled data from all bluefish stocks are not very useful for purposes of stock management.

Regulation and Management

Recreational and commercial fishing regulations for bluefish in the mid-Atlantic exist in several states, but lack of enforcement and inconsistency from state to state limit their effectiveness (Wilk 1977). The objective of states that do regulate the fishery is generally to limit the catch of young-of-the-year bluefish, which is thought to promote successful recruitment into larger, more desirable age classes. The Magnuson Fishery Conservation Management Act of 1976 created a series of regional Fishery Management Councils to develop overall management plans for important species and to coordinate the states' management efforts. The Mid-Atlantic (New York to Virginia) Fishery Management Council completed a proposed Fishery Management Plan for bluefish in 1984 in cooperation with the New England FMC and South Atlantic FMC. The council adopted a provisional maximum sustained yield (MSY) of 95 million kg annually based upon MSY estimates by Boreman (1983) and NMFS (1983) and upon the evidence for increasing recruitment from their trawl surveys. The plan proposed an allocation of 20% of the total U. S. bluefish catch for commercial fishermen, mostly in the mid-Atlantic region; the remainder would be allocated to recreational fishermen (Mid-Atlantic FMC 1984). But the plan was disapproved by Congress that same year because the bluefish catch in the federally regulated Fishery Conservation Zone (3 to 200 miles) is only a small fraction of the catch in nearshore (less than 3 miles) state regulated waters, so Federal regulation was deemed inappropriate (David Keifer, Mid-Atlantic FMC, pers. comm.). Currently, the three Fishery Management Councils are working with the Atlantic States Marine Fisheries Commission, a coalition of state agencies, to develop a coast-wide plan to be adopted by all states in lieu of a federal management plan.

ECOLOGICAL ROLE

Food and Feeding

Bluefish are voracious predators throughout their lives, relying primarily on vision to detect prey, although their olfactory sense is also well-developed (Olla et al. 1970; Wilk 1977). Food habits of larvae and early juveniles have not been well studied, but they presumably select various zooplankton, including larvae of other pelagic-spawning fishes (Norcross et al. 1974; Kendall and Walford 1979). Young-of-the-year arriving in the coastal nursery areas feed on small shrimp, anchovies, killifish, silversides, and many other available prey; those remaining at sea probably find small pelagic fishes and crustaceans as forage. As their size increases, so does the list of potential prey. A wide variety of fish and invertebrates have been recovered from bluefish stomachs, including such unlikely items as the sand dollar (Echinarachnius parma), the sea lamprey (Petromyzon marinus), various sharks and rays, and the northern puffer (Sphoeroides maculatus). More typical fare of adults includes the common squid (Loligo pealii), various shrimp and crabs, alewives (Alosa pseudoharengus), and other shad and herrings, Atlantic menhaden (Brevoortia tyrannus), silver hake (pinfish cius bilinearis), (Lagodon rhomboides), spot (Leiostomus xanthurus), butterfish (Peprilus triacanthus), smaller bluefish, and many other species (Wilk 1977; Richards 1976).

Lassiter (1962) noted the elimination of invertebrates from the diet as bluefish increase in size. Among young adults the stomach contents typically include 10% to 20% invertebrates by volume, but larger fish are almost exclusively piscivorous. Young fish also chop their food into smaller pieces, making diet analysis more difficult; large adults typically swallow their prey whole.

Feeding activity peaks in early morning and continues throughout daylight hours (Lund and Maltezos 1970). In studies of captive bluefish, the normally close-knit school breaks up during feeding as individuals break away to chase particular prey. The fish regroup a few minutes after the prey have been consumed. Fish satiated on small prey resume feeding when larger prey of the same species are offered, suggesting that feeding motivation is influenced by prey size (Olla et al. 1970).

Predation, Parasitism, and Competition

Predation upon the planktonic eggs and larvae of bluefish has not been documented. Juveniles are preyed upon by adults of their own species and probably by other large coastal and estuarine predators. Adults are probably eaten by sharks, tuna, and swordfish (Wilk 1977; Mid-Atlantic FMC 1984).

Anderson (1970) presents an annotated list of parasitic crustacea, acanthocephala, cestoda, trematoda, nematoda, and a dinoflagellate protozoan that have been taken from bluefish; the list is also published in Wilk (1977). Meyers et al. (1977) describe a sporozoan that invades the heart muscle of bluefish. Newman et al. (1972) report on the bacterial flora of the bluefish intestine.

Other fish species sharing the same prev resources with bluefish include- striped bass (Morone saxatilis), spotted sea trout (Cynoscion nebulosus), weakfish (C. regalis), and various Carangidae and Scombridae (Manooch 1984: Fav et al. 1983), bu't direct evidence of interspecific competition has not been demonstrated, since bluefish are highly opportunistic and transient feeders. Being a top predator and seasonally very numerous, it is likely that bluefish play a role in structuring communities of prey species.

Physiological Ecology

Bluefish have one of the fastest air bladder secretion/resorption rates known among Perciform fishes, allowing rapid buoyancy adjustment (Bentley and Wiley 1982). Studies of swimming energetics show that bluefish switch from active opercular pumping of the gills to ram (passive) ventilation of the gills at speeds of 4.0 to 4.6 bodylengths per sec (Freadman 1979). Like certain other large pelagic predators, bluefish can maintain their body temperature up to 4 ^{o}C above ambient (Mid-Atlantic FMC 1984).

ENVIRONMENTAL REQUIREMENTS AND STRESS

Temperature

Temperature is probably the single most important environmental parameter determining bluefish distribution, migration, feeding, spawning, and recruitment success (Lund and Maltezos 1970). Olla and Studholme (1975) and Olla et al. (1975) examined responses of bluefish to thermal changes in a 120,000-l aquarium. At the acclimation temperature of 20 ^{o}C, their small group of adult bluefish (45 to 55 cm TL) swam continuously day and night, typically in a close school during the day at a speed of about 50 cm/sec, and individually during the night at speeds of about 15 cm/sec. These speeds and daily rhythms were maintained over a temperature range of 18 to 22 ^{o}C. When temperature was increased or decreased slowly beyond this range, the fish responded to either treatment with increased day and night cruising speeds. At the upper and lower "stress" temperatures (about 30 ^{o}C and 12 ^{o}C, respectively), the daily rhythm was replaced by nearly constant high speed swimming, more than triple the acclimation speeds; also, the school did not break up at night, and the fish showed little interest in food. At 35 ^{o}C, loss of equilibrium was noted. The authors interpret the observed increases in cruising speed as an avoidance strategy. Since the fish are highly transient, with little incentive to remain in a localized area, rapid swimming is an appropriate strategy to transport the fish away from localized patches of unfavorable conditions.

The 18 to 22 ^{o}C temperature range for minimum cruising speed corresponds well with the thermal regimes from which the majority of commercial and recreational bluefish catches are taken, and also with conditions in the mid-Atlantic bight where summer spawning occurs (Norcross et al. 1974). The south Atlantic waters between the continental shelf and the Gulf Stream, where spring spawning occurs, average slightly higher, 20 to 26 ^{o}C. Juveniles drifting north of Cape Hatteras congregate at the Gulf Stream/continental shelf interface in the mid-Atlantic while shelf waters are still much cooler. As the season advances, the shelf waters warm, and the young bluefish make their voyage across the shelf to the estuaries when shelf temperatures reach 18 to 20 °C. These thermal edges apparently serve as important cues to juvenile migration, insuring that the young arrive in suitably warm nursery habitats (Kendall and Walford 1979).

Photoperiod

In a study of daily and seasonal rhythms of bluefish, Olla and Studholme (1972, 1978) found that activity increased sharply, immediately at daybreak, compared to the slow nighttime cruising speed, continued to increase gradually until noon, and then decreased steadily throughout the afternoon until 1 to 2 hrs after dark, when the nighttime swimming speed resumed. This daily rhythm is maintained during all seasons, independent of photoperiod. However, increasing photoperiod causes significant increases in both daytime and nighttime speeds. A photoperiod of 10.3 light hours (corresponding to winter months) induces an average swimming speed 17% less than a 12-hr day (spring and fall months) and 50% less than a 14-hr day (summer months). Photoperiod thus appears to be the cue that keeps bluefish moving during the warm months and keeps them relatively stationary in winter, whereas temperature provides a more proximal cue to distinguish favorable from unfavorable patches of habitat.

Salinity

Juvenile and adult bluefish are moderately euryhaline, occasionally ascending well into estuaries where salinities may be less than 10 ppt (Lippson and Lippson 1984). Eggs and larvae are probably less adaptable: Kendall and Walford (1979) report salinities between 35 and 38 ppt in the south Atlantic continental slope waters where the spring spawners originate, and 30 to 32 ppt in the mid-Atlantic summer spawning waters. Whether salinity gradients can act as barriers to migration, as thermal gradients can, has not been determined.

Oxygen

Pelagic open-ocean fishes are usually not well adapted for low oxygen conditions. Swanson and Sinderman (1979) noted a conspicuous absence of bluefish, among other species, in a large low-oxygen mass of water that developed during the summer of 1976 a few kilometers off the coast of northern New Jersey, where extensive kills of surf clams, ocean quahogs, and some fish were reported. Small bluefish that migrate close to shore and very large fish that migrate far offshore appeared as usual along Connecticut and Long Island that summer, but mid-size fish (1.5 to 5.5 kg) were stopped by the foul water mass and reversed direction, returning to southern New Jersey and Delaware for the remainder of the warm season. Along certain New Jersey beaches, winds and currents periodically brought the low-oxygen water mass against the shore; bluefish, striped bass, and other species were observed swimming lethargically and gasping at the water surface (a typical oxygen-stress response).

Contaminants

Mahoney et al. (1973) found a high incidence of fin rot disease in bluefish, flounder, and other fishes for some period during the summers of every year from 1967 through 1973 in the New York Bight. Bacteria of the genera *Aeromonas*, *Vibrio*, and *Pseudomonas* were isolated from fish showing chronic fin necrosis, skin hemorrhage and ulcers, and blindness. These authors suggest that heavy metal contaminants (copper, zinc, chromium, and lead were measured in high concentrations in the area) weakened the fishes' immune response to these facultative pathogenic bacteria, which were also present in unusually high concentrations because of poorly treated municipal and industrial sewage discharge. Laboratory experiments using municipal sewage without heavy metals did not induce the disease.

Mears and Eisler (1977) examined concentrations of metals in the liver of bluefish, and found it positively correlated with body size. Cross et al. (1973).found a similar relationship for metal accumulation in white muscle of bluefish. New York and New Jersey State governments have issued warnings in recent years against eating bluefish and other predatory fishes because of high concentrations of PCBs in their muscles (Mid-Atlantic FMC 1984). Currently, the National Marine Fisheries Service is conducting a body-burden study of toxic chemical accumulation in bluefish (David Keifer, pers. comm.).

Olla and Studholme (1975) state that the behavioral repertoire of bluefish is well adapted for avoidance of unfavorable conditions, but such avoidance depends upon the fishes' ability to detect contaminants and recognize them as hazardous, and also upon the motivation of the fishes to be in that area. If spawning or nursery waters are contaminated, or migration routes are thermally or chemically "blocked," or if contamination is present in the food supply, then avoidance becomes impossible.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, distribution, life history, and environmental requirements of coastal fishes and invertebrates within a specified range. They are written to assist in environmental impact assessment and decision making by coastal planners and developers. Bluefish are the most important recreational fish in the United States, especially in the mid-Atlantic region. The commercial catch is smaller but has increased during recent years. One population spawns offshore during spring from northern Florida to North Carolina, and these young migrate into mid-Atlantic coastal waters to spend their summer and fall. A second population spawns offshore during summer from North Carolina to Massachusetts, but most of these young remain offshore for the remainder of the season. In late fall, young and adults of both populations migrate south until the following spring. Bluefish are migratory, opportunistic, pelagic predators throughout life, and their seasonal abundance may have profound community structuring effects. Schools of juvenile bluefish may be important forage for many pelagic predators, including adults of their own species. Photoperiod apparently triggers long-range migration, and temperature serves as a proximal cue to short-range migration. Bluefish are sensitive to bacterial infection in polluted water and have little tolerance for low oxygen conditions.

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Estuaries
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