Biological Report 82 (11.56)
July 1986

TR EL-82-4

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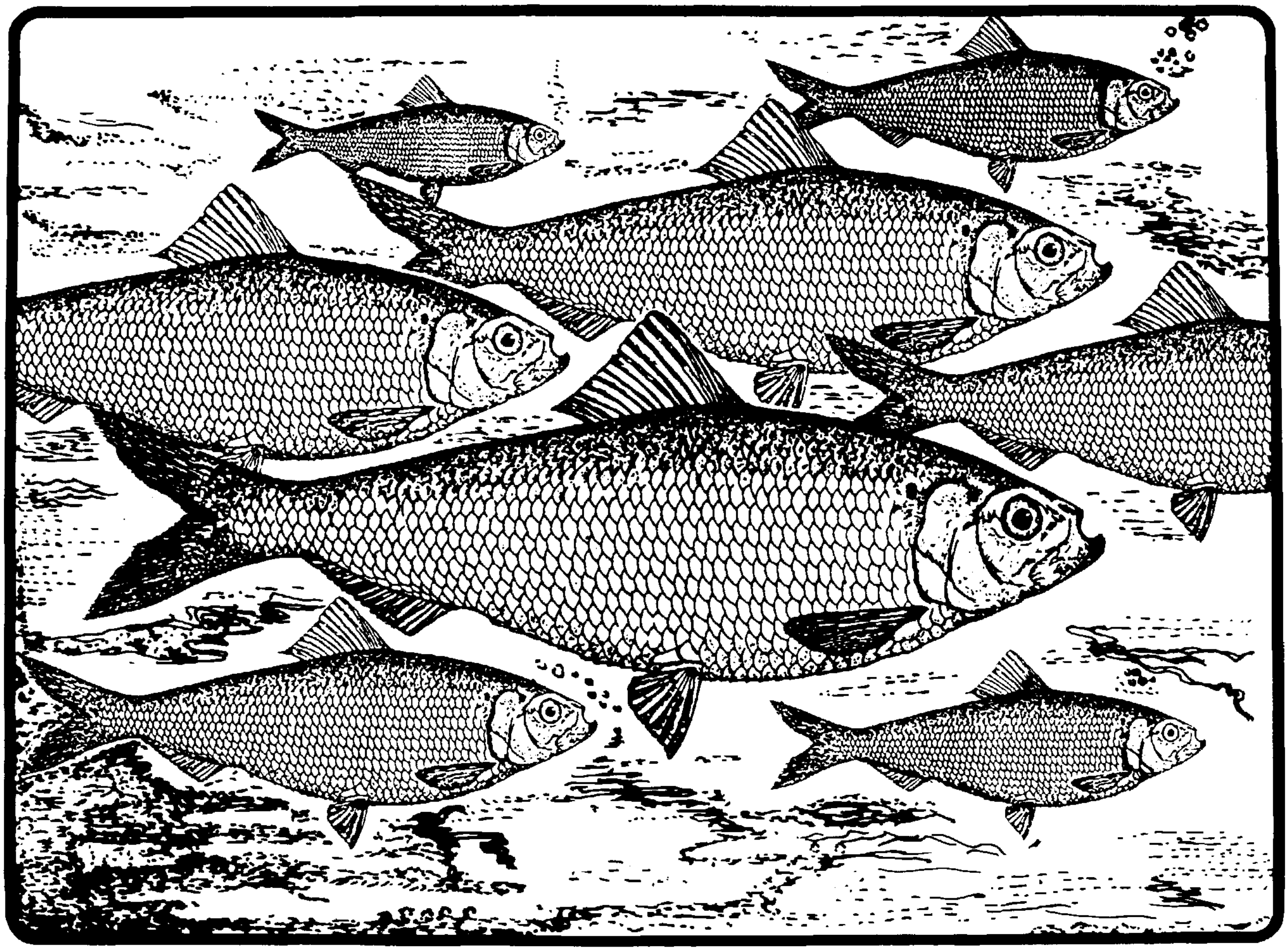
ALEWIFE/BLUEBACK HERRING



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 (North Atlantic)

ALEWIFE/BLUEBACK HERRING

by

Dennis M. Mullen, Clemon W. Fay, and John R. Moring
Maine Cooperative Fishery Research Unit
313 Murray Hall
University of Maine
Orono, ME 04469

Project Officer
John Parsons
National Wetlands Research Center
U.S. Fish and Wildlife Service
1010 Gause Boulevard
Slidell, LA 70458

Performed for
Coastal Ecology Group
Waterways Experiment Station
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Vicksburg, MS 39180

and

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U.S. Department of the Interior
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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.

Information Transfer Specialist
National Wetlands Research Center
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-C
Post Office Box 631
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
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 (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
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
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

We are grateful for the reviews by Joseph Loesch, Virginia Institute of Marine Science, Gloucester Point, and Lewis Flagg, Maine Department of Marine Resources, Augusta, Maine.

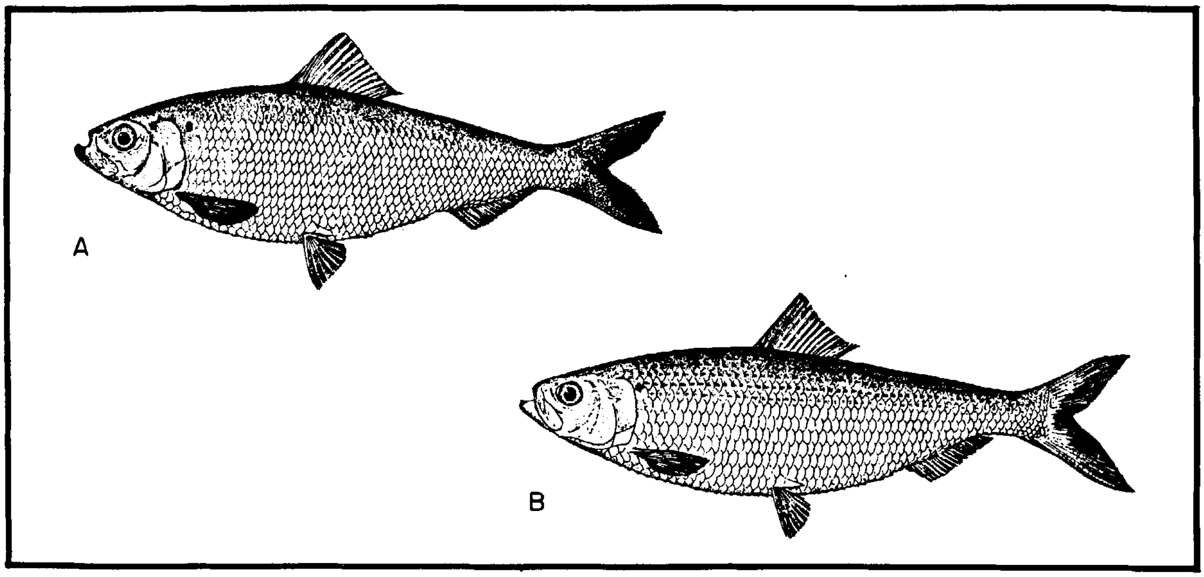

Figure 1. A: alewife; B: blueback herring.

ALEWIFE/BLUEBACK HERRING

PROFILE SCOPE

This profile describes the life history and environmental requirements of the alewife (Alosa pseudoharengus) and the blueback herring (Alosa aestivalis), since their distribution is overlapping and their morphology, ecological role, and environmental requirements are similar. Nevertheless, significant differences in certain physical, physiological, and biological characteristics exist between the two species. When information is available, these differences are addressed by separate statements for each species. In *addition, a special section on the* most readily distinguishing characteristics for separating eggs, larvae, and adults of the two clupeids is presented in the morphology section.

Because most of the information available for the two species concerns the alewife, characteristics of this species are given priority reference in the text. Features should not be considered similar among the two species unless noted as such. In a few reports (particularly those on commercial fisheries statistics), the two species are referred to collectively as "river herring" or "gaspereau" (Canada).

NOMENCLATURE/TAXONOMY/RANGE

Scientific names . . . . . Alosa pseudoharengus (Wilson) or Alosa aestivalis (Mitchill)
Preferred common names. . . . . . . alewife and blueback herring *(Figure 1)*
Other common names . . . . alewife -- freshwater herring, grayback, gaspereau, sawbelly, kyak, branch herring; blueback herring -- glut herring, summer herring, black belly, kyack (Bigelow and Schroeder (1953)
Class. . . . . .Osteichthyes
Order. . . . . .Clupeiformes
Family. . . . . .Clupeidae

Geographical range: The alewife and blueback herring are anadromous species common in rivers, estuaries, and coastal waters of the North Atlantic from Newfoundland (Winters et al. 1973) to South Carolina (Berry 1964). Self-sustaining, landlocked populations have been established in the Laurentian Great Lakes, the Finger Lakes of New York, and several other freshwater lakes (Bigelow and Schroeder 1953; Scott and Crossman 1973). The blueback herring is geographically distributed along the Atlantic coast from Nova Scotia to the St. Johns River, Florida (Hildebrand 1963). The distribution of alewives and blueback herring from Cape Cod north to Maine is illustrated in Figures 2a and 2b.

MORPHOLOGY/IDENTIFICATION AIDS

The following information was taken from morphological summaries prepared by Jones et al. (1978), unless otherwise indicated.

Alewife

Dorsal rays 12-19 (usually 13-14), anal rays 15-21 (usually 17-18), scales in lateral line series 42-54. Belly with scutes forming a keel. Prepelvic scutes 17-21 (usually 19-20), postpelvic scutes 12-17 (usually 14-15), gill rakers on first arch 38-46. Body strongly compressed, deep. Mouth oblique, anterior end of lower jaw thick, heavy; jaw extending to middle of orbit. Eye large, diameter greater than snout length. Color: dorsally, gray to gray-green; laterally, silver with prominent dark shoulder spot; fins pale, yellow, or green.

Blueback Herring

Dorsal rays 15-20, anal rays 15-21, scales in lateral series 46-54. Prepelvic scutes 18-21, postpelvic scutes 12-16, gill rakers on first arch 41-52. Body moderately compressed, elongate, eye diameter small, equal to or less than snout length. Upper jaw with definitive median notch, no teeth on premaxillaries. Color: dorsally, blue to blue-green; laterally, silver with prominent dark shoulder spot; fins pale, yellow, or green. Adults often with rather distinct dusky lines along the back as shown in Figure 1.

Aids for Species Separation

Eggs. Unfertilized blueback herring eggs amber, alewife eggs greenish. Oil droplets of fertilized blueback herring eggs unequal in size and scattered; those of alewife eggs numerous and uniformly small (Kuntz and Radcliffe 1917; Norden 1967).

Larvae. Myomeres between insertion of dorsal fin and anal vent 11-13 for blueback herring and larvae, 7-9 for alewife (this characteristic is definitive according to Chambers et al. [1976]). According to Chambers et al. (1976), larvae less than 15 mm long can be separated by using regressions of vent to tail distance and vent to urostyle distance against standard length (SL).

Adults. The two species are morphologically similar but can be separated by differences in scale imbrication patterns and individual scale markings (Figure 3). Alewives usually have the fewer vertebrae, dorsal rays, and gill rakers on the first arch.

REASON FOR INCLUSION IN THE SERIES

The alewife and blueback herring are important forage and commercial fishes. Ecologically, they are important energy links between zooplankton and piscivores. In New England both species have a long history of commercial exploitation and are important as sources of fish meal,

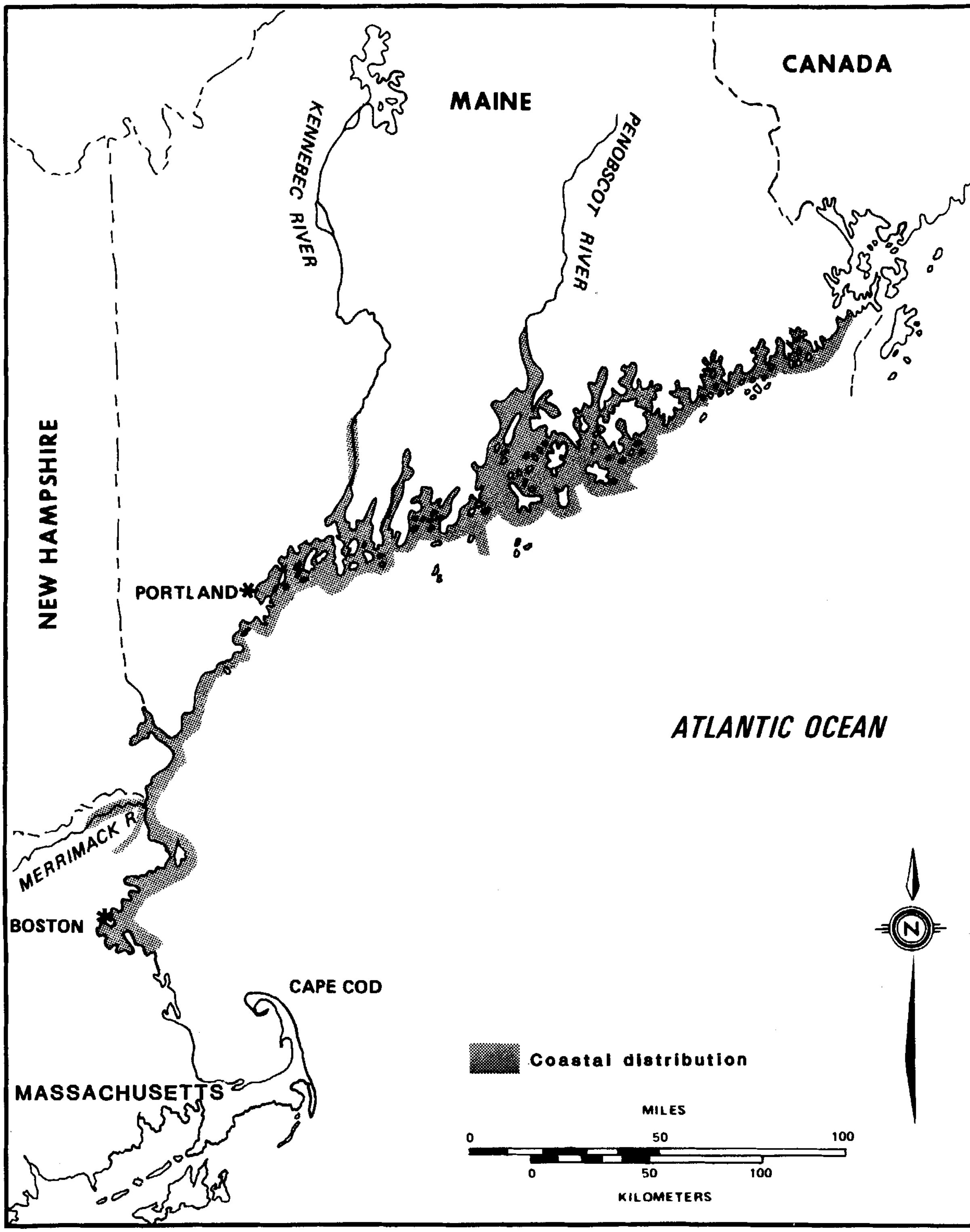

Figure 2a. Distribution of alewives along the U.S. North Atlantic coast.

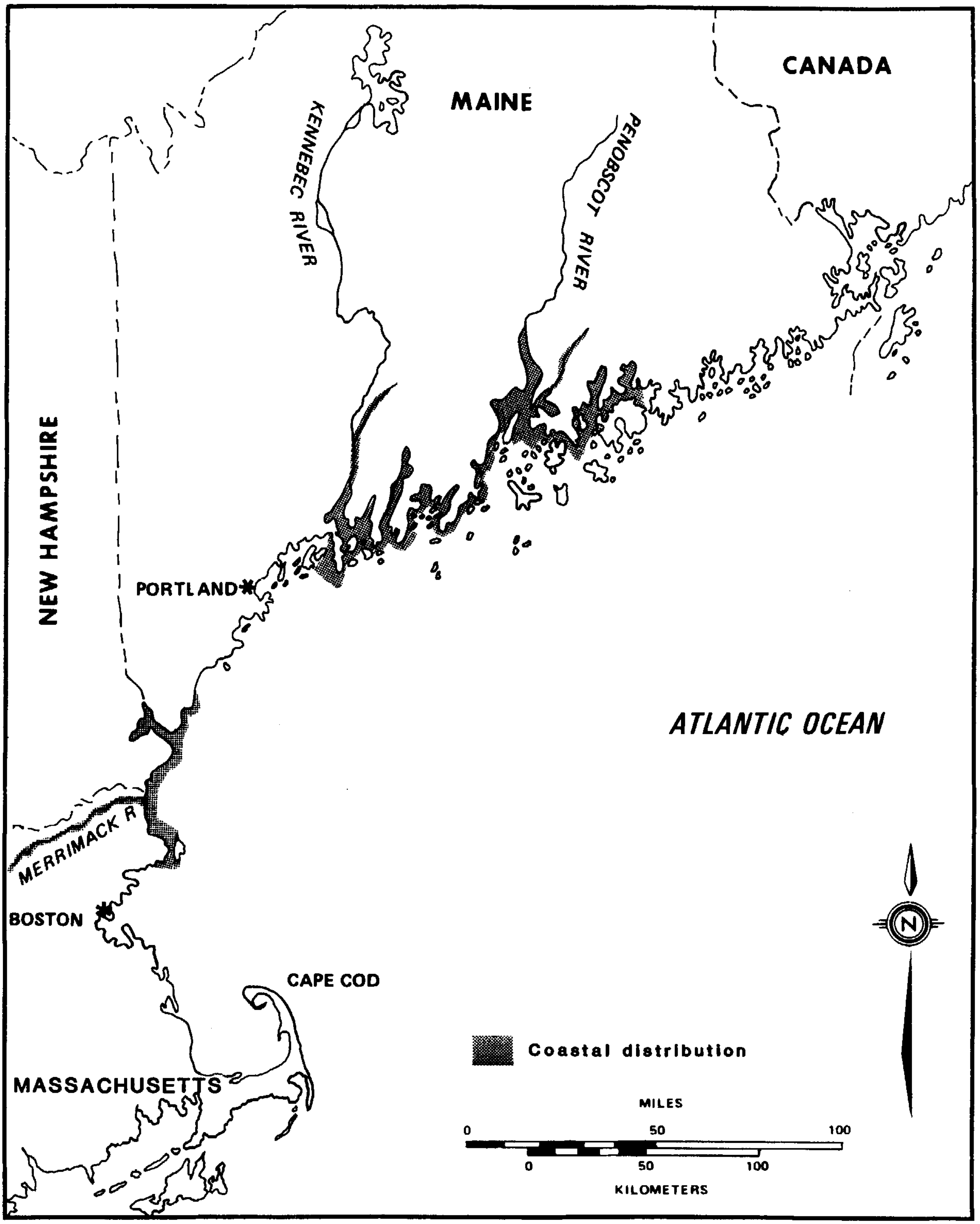

Figure 2b. Distribution of blueback herring along the U.S. North Atlantic coast.

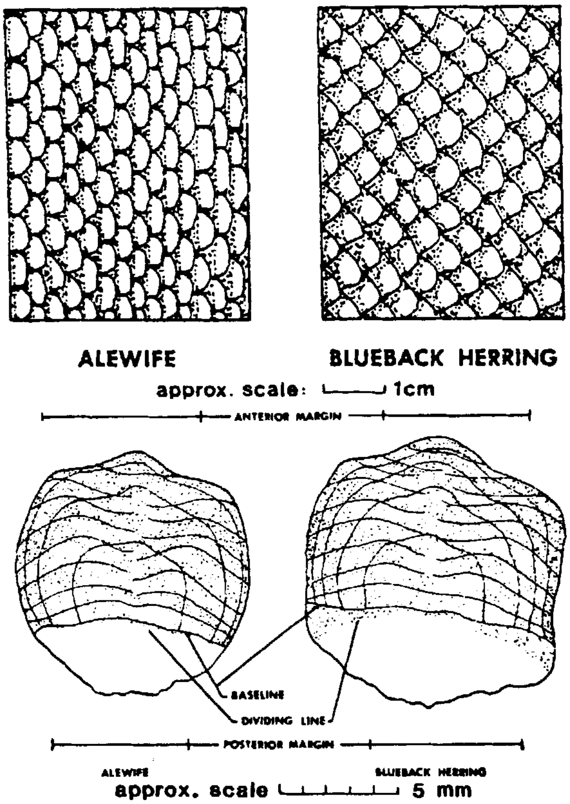

Figure 3. Scale imbrication patterns (top) and individual scale morphology (bottom) used for external discrimination of the alewife and the blueback herring (from MacLellan et al. 1981; used with permission of the Canadian Journal of Fisheries and Aquatic Sciences)

fish oil, and fish protein, particularly for the animal food industry. Alewives also are important as bait in the New England lobster fishery.

LIFE HISTORY

Reproductive Characteristics

A small percentage of anadromous alewives spawn for the first time in their fourth year of life (age group III). During spawning, males numerically dominate fish in age groups III and IV and females dominate among the older fish. This relation suggests that males mature at an earlier age than females but have a shorter life span. The age of first spawning of blueback herring varies more that that of the alewife, yet they mature at about the same age (Joseph and Davis 1965; Loesch and Lund 1977; O'Neill 1980).

Age at first spawning, percentage of repeat spawners, and longevity of alewives tend to decrease from north to south. For example, spawning alewives in southern North Carolina were numerically dominated by Age III fish; none were older than Age IV (Tyus 1974). In contrast, alewife spawning populations consisted of age groups III to VIII in Chesapeake Bay (Joseph and Davis 1965) and in the Connecticut River (Marcy 1969; Loesch and Lund 1977), and of age groups IV to X for both species in Nova Scotia (O'Neil 1980). The percentages of repeat spawners (fish that spawned during two or more years) were 60% for alewives in Nova Scotia (O'Neill 1980); 61% in the York River, Virginia (Joseph and Davis 1965); and less than 10% in southern North Carolina (Tyus 1974). Repeat spawners among blueback herring were 65% in the York River and 75% in Nova Scotia (Joseph and Davis 1965; O'Neill 1980).

The females of alewives and blueback herring are slightly larger and heavier than males of the same age (Cooper 1961; Netzel and Stanek 1966; Marcy 1969; Loesch and Lund 1977).

Fecundity

Fecundity estimates for female alewives in the Parker River, Massachusetts, ranged from about 68,000 to 206,000 eggs per female (Cole et al. 1980). Age group V females averaged 168,000 eggs whereas females of age groups III and VII averaged only about 118,000 eggs (Cole et al. 1980). Fecundity of Chesapeake Bay alewives ranged from 60,000 to 100,000 eggs per female (Foerster and Goodbred 1978).

The age-fecundity relation may be asymptotic for both alewives and blueback herring, and "fecundal senility" may characterize all long-lived stocks of these species (Street 1969; Loesch and Lund 1977).

Females apparently lay nearly all of their eggs during spawning. Spent female alewives leaving the Parker River contained less than 0.1% of the average number of eggs in the females entering the spawning runs. About 7% of the adult female alewives returning to the sea from the Parker River in 1975 and 1976 had not spawned (Cole et al. 1980). Female blueback herring in the Connecticut River retained 10% to 30% of their full complement of eggs after spawning (Loesch and Lund 1977).

Spawning

Historically in Maine, alewives and blueback herring made spawning runs up all or nearly all streams with access to lakes, ponds, and backwaters (Flagg 1977). Even barrier beach ponds with an outlet to the sea were used by alewives as spawning grounds (Bigelow and Welsh 1925).

The two species spawn once a year in spring or early summer in fresh or brackish water (Raney and Massmann 1953). Males enter the mouths of rivers in which they spawn earlier than females (Cooper 1961; Tyus 1971; Richkus 1974a). Blueback herring do not usually swim as far upstream as alewives do to spawn (Jones et al. 1978, cited from Loesch 1968, 1969). Adult alewives move into freshwater only during daylight hours, primarily between 1500 and 1800 h. Beltz (1975) surmised that light acts as a switch, initiating migration in the morning and halting it in the evening.

Downstream movement of adult alewives after spawning is not a random event, nor does it depend on the length of time spent on the spawning grounds. Downstream movement apparently is triggered by an increase in water flow, suggesting that emigration of adults after spawning is a rheotactic response (Huber 1978).

In laboratory tests, adult anadromous alewives from Rhode Island waters were capable of distinguishing water of their natal pond from water collected in nearby ponds. Olfaction was shown to be the major sensory mechanism for homing behavior (Thunberg 1971). Although homing behavior is strong in alewives, considerable mixing of stocks takes place. Discriminant function analyses by Messieh (1977) for fish of the St. Johns River, Florida, indicated that spawning stocks often strayed from home streams, particularly between adjacent spawning areas and stocks. Most of the mixing of stocks was during the prespawning period (late winter, early spring) rather than during the actual spawning runs.

Alewives spawn along the Atlantic coast from late March through July; spawning occurs progressively later from south to north. Alewives spawn from mid-April to mid-May in the Parker River, Massachusetts (Cole et al. 1980), and from early May to early June in Maine (Flagg 1977; Libby 1981). In general, spawning of alewives begins 3 to 4 weeks before that of blueback herring in the same spawning areas. Spawning peaks of the two species usually are 2 to 3 weeks apart (Jones et al. 1978). The minimum water temperatures at which spawning begins is 10.5 °C in alewives (Cianci 1969) and 14 °C in blueback herring (Loesch and Lund 1977). Both species cease spawning when water temperature exceeds 27 °C (Loesch 1969; Edsall 1970).

Blueback herring prefer to spawn in fast currents over hard substrate (Loesch and Lund 1977). In contrast, alewives select a wide variety of spawning sites, using standing water and oxbows, as well as mid-river sites (Kissil 1974). Several investigative studies have described alewife spawning in ponds that have an open connection with the ocean (Havey 1973; Kissil 1974). The spawning of anadromous alewives and blueback herring is spatially and temporally different.

The spawning behavior of blueback herring was described by Loesch and Lund (1977). A spawning group composed of one female and several males swam in circles for several minutes. The males occasionally nudged the vent of the female. Swimming speed increased gradually until a deep dive occurred. Eggs and milt were released simultaneously near the bottom. Both species spawn mostly at night (Graham 1956; Edsall 1964). Both male and female blueback herring migrate rapidly downstream after spawning. Few fish stay in the spawning stream longer than 5 days (Cooper 1961; Loesch and Lund 1977).

Eggs

Until water-hardened, eggs of both species are demersal in still water and adhesive or pelagic in running water (Loesch and Lund 1977; Jones et al. 1978). After water-hardening (less than 24 h), eggs lose their adhesive property and drift in the water column. Egg diameter ranges from 0.8 to 1.3 mm in alewives and from 0.8 to 1.1 mm in blueback herring (Mansueti 1962; Norden 1967). Incubation of blueback herring eggs is about 80 to 94 h at 20 to 21 °C and 55 to 58 h at 22 to 24 °C (Cianci 1969; Morgan and Prince 1976).

An equation for predicting incubation time for alewife eggs from water temperature is

$$T = 6.335 \times 10^{6} \times t^{-3.122}$$

where T = time in days and t = incubation temperature in degrees Fahrenheit (Edsall 1970).

Yolk-Sac Larvae

Total length (TL) at hatching is 2.5 to 5.0 mm and averages 5.1 mm at yolk-sac absorption (Mansueti 1962; Norden 1967). Duration of the absorption stage is 2 to 5 days for alewives and 2 to 3 days for blueback herring (Mansueti 1962; Cianci 1969).

Larvae

The larval stage lasts from yolk-sac absorption until transformation to the juvenile stage. Detailed drawings of the developmental stages of eggs, yolk-sac larvae, and larvae of both alewives and blueback herring were published by Jones et al. (1978).

Alewife larvae in two ponds in the Parker River, Massachusetts, showed a diurnal change in depth distribution and a random pattern of lateral distribution (Cole et al. 1980). Larval *Alosa* in Nova Scotian rivers inhabited waters that were relatively shallow (<2 m), sandy, and warm, and were collected in or near the spawning grounds (O'Neill 1980).

Juveniles

Transformation from the larval to the juvenile stage is usually complete when the fish is about 20 mm TL. Scales first appear on juveniles 25 to 29 mm TL, and are fully developed at 45 mm TL (Hildebrand 1963).

Juvenile alewives and blueback herring in rivers tend to move upstream between June and the start of emigration in October (Burbidge 1974; Warinner et al. 1969). This upstream movement may partly involve juveniles from oxbows and tributaries, which gradually move into the main river during summer (Burbidge 1974).

Juvenile blueback herring in the James River, Virginia, were more concentrated near the surface than at a depth of 5 m throughout their stay in the river (Burbidge 1974). Juvenile alewives in the Potomac River were concentrated in the surface waters in September, and in October became more abundant at depths of 4.6 m or near the bottom (Warinner et al. 1969).

In most Atlantic coastal populations, young-of-the-year alewives and blueback herring emigrate from freshwater and brackish estuaries between June and November (Burbidge 1974; Kissil 1974; Richkus 1975; O'Neill 1980). Juvenile alewives 32 to 152 mm TL emigrated from Maine rivers between mid-July and early December (Flagg 1977). Their size reportedly depends on the availability of food in the river, the total number of young produced in the watershed, and the length of time in freshwater (Flagg 1977).

Factors initiating emigration "waves" (Richkus 1975) that consist of large schools of juvenile alewives are: heavy rainfall (Cooper 1961), high water levels (Kissil 1974; Richkus 1975), and sharp drops in water temperature (Richkus 1975). Richkus (1975) offered three observations: (1) These waves lasted two to three days, regardless of the duration of the environmental changes; (2) migrations peaked in late afternoon; and (3) the magnitude of a wave was not related to the magnitude of environmental change. About 70% of the juveniles completed emigration in only a few days.

Adults

Data on the habits and biology of adult alewife and blueback herring stocks are scarce. More research is needed for identifying inshore and offshore stocks, calculating natural and fishing mortalities, and describing movements, migratory patterns, feeding behaviors, and habitat preferences.

Catch data from National Marine Fisheries Service trawl surveys along the Atlantic coast between Cape Hatteras and Nova Scotia were summarized annually from 1963 to 1978 (Neves 1981). Samples of fish were taken at depths down to 200 m. Most alewives and blueback herring were caught in water less than 100 m deep. Average fork lengths (FL) of alewives and blueback herring ranged from 60 to 350 mm; alewives outnumbered blueback herring about 10:1. Alewives were most abundant at depths of 56 to 110 m, and blueback herring at depths of 27 to 55 m. Trawl catches over a wide area indicated that both species were concentrated in summer and fall in an area north of 40° N, in or near Nantucket Shoals, Georges Bank, and the perimeter of the Gulf of Maine. Winter catches were heaviest between latitudes 40° and 43° N. Spring catches demonstrated that both species were distributed over the entire Continental Shelf (Neves 1981).

In July and October 1964 (the only months sampled), adult alewives and blueback herring inhabited only a small portion of Georges Bank -- specifically the western slope near 41° 29' north latitude and 68° 34' west longitude (Netzel and Stanek 1966). Alewives outnumbered blueback herring in these samples. All mature age groups were represented, but no fish of ages I or II were captured.

Alewives and blueback herring, like other clupeids, are reported to exhibit seasonal movements in conjunction with changes in water temperature or availability of forage (Collins 1952; Leggett and Whitney 1972); however, sound evidence for this conclusion is lacking (Richkus 1974b). Feeding and vertical migration are probably regulated largely by light intensity and water temperature (Richkus and Winn 1979; Neves 1981).

GROWTH CHARACTERISTICS

Growth Rates

Little is known about growth rates of either the alewife or blueback herring from the time they hatch to the time they spawn. Estimates of daily growth of juvenile alewives in two spawning ponds in the Parker River drainage, Massachusetts, ranged from 0.2 to 0.5 mm (Cole et al. 1980).

Average lengths of juvenile emigrants, sampled over three years (1970-72) in Hamilton Reservoir, Rhode Island (Richkus 1975), ranged from 25 to 88 mm SL (30 to 105 mm TL). Yearling male alewives averaged 147 mm TL by the end of their second summer in the Connecticut River Estuary (Marcy 1969). On Georges Bank, fish of age group II of both species were about 180 mm TL by the end of their third summer (Netzel and Stanek 1966).

Mature alewives are usually longer than blueback herring of the same age (Table 1). In both species, males are smaller than females of the same age. Growth rates for both species level off after reaching sexual maturity (compared to growth rates of immature fish). Mean weights of spawning alewives in Damariscotta Lake, Maine, ranged from 153 g (males) and 164 g (females) for age group III, to 325 g (males) and 356 g (females) for age group VII. One female in age group VIII weighed 455 g (Walton 1979).

Length-Weight Relations

Length-weight relations for alewives and blueback herring of the St. John River, New Brunswick, were given by Messieh (1977) as follows:

Male alewives:
$\log W=3.235 \times \log L-5.420$
Female alewives:
$\log W=3.192 \times \log L-5.294$
Male blueback:
$\log W=2.904 \times \log L-4.702$
Female blueback:
$\log W=2.472 \times \log L-3.693$
L = fork length (mm), W = weight (g)

THE FISHERY

Commercial Fisheries

Commercial landings of river herring (both species combined) along the Atlantic coast of the United States were 3,783 t in 1981 and 5,682 t in 1982. These landings were worth $671,000 and $1,021,000, respectively. The 5-year running average of the U.S. river herring landings (1977-82) was 5,037 t/yr. More than 90% of the U.S. commercial catch was made within 4.8 km of the coastline (National Marine Fisheries Service 1983). Commercial fishing for alewives is primarily during spawning runs. Weirs and trap nets are the most commonly used gears in North Atlantic rivers (Flagg 1977), whereas pound nets are commonly used in the Chesapeake Bay area (Joseph and Davis 1965; Pate 1974). More than 90% of the annual Maine harvest is used as lobster bait. The rest is used for trawl bait, human consumption, and for fish meal as a protein supplement in animal feed. Roe from these species is canned and is highly valued (Joseph and Davis 1965; Street and Davis 1976; Merriner 1978).

The foreign catch of river herring (both species) within the U.S. Fishery Conservation Zone (FCZ) was 13.9 t in 1981 and 2.0 t in 1982. About 75% of the foreign catch in 1981 was taken by fishermen from Poland; in 1982 fishermen from Italy took the largest share (75%). All of the 1981 and 1982 foreign catch was taken north of Cape Hatteras (NMFS 1983).

The State of Maine has developed an Alewife Management Plan for anadromous stocks under its jurisdiction (Walton et al. 1976). Historical landings and management were reviewed

Table 1. Ages and fork lengths (mm) of alewives and blueback herring captured during spawning runs in Albemarle Sound, North Carolina (Pate 1974), Chesapeake Bay (Joseph and Davis 1965), the Connecticut River (Marcy 1969), Georges Bank (Netzel and Stanek 1966), and Damariscotta Lake, Maine (Walton 1979).

Species Location and sex	Age group III	IV	V	VI	VII	VIII	IX
Alewife							
Albemarle Sound							
male	236	249	256	259	268	279	-
female	254	261	270	277	283	287	-
Chesapeake Bay							
male	229	239	249	254	259	-	-
female	239	249	259	264	274	282	-
Connecticut River							
male	-	265	278	290	301	-	-
female	-	284	284	299	308	324	-
Georges Bank							
male/female	270	284	294	306	316	327	330
Damariscotta Lake							
male	260	278	301	315	318	-	-
female	273	283	309	324	333	356	-
Blueback herring							
Albemarle Sound							
male	231	241	245	251	258	270	-
female	245	252	258	264	268	280	307
Connecticut River							
male	258	266	280	286	298	-	-
female	261	277	291	301	311	-	-
Georges Bank							
male/female	240	269	281	292	302	313	-

and new management recommendations prepared for the alewife runs of each coastal county. Catch statistics for each New England State from 1977 to 1982 are given in Table 2.

Population Dynamics

Sex ratios/age structure. The sex ratio of spawning adults is near 1:1 in most waters. The percentage of males in spawning populations was 56% for alewives in Bride Lake, Connecticut (Kissil 1974), 54% for alewives and blueback herring in the Connecticut River, and 53% (Marcy 1969) and 58% (Loesch and Lund 1977) for blueback herring in the Thames River. Because males tend to mature at a younger age than females, there is a slight dominance of males in spawning populations (Kissil 1974). The percentages of males (by different age groups) in the 1966 and 1967 spawning populations of alewives from the Connecticut and Thames rivers, Connecticut (data combined), were 72% (age group IV), 64% (V), 50% (VI), 34% (VII), and 0% (VIII). The percentages of blueback herring males by age group were: 80% (age group III), 79% (IV), 65% (V), 37% (VI), and 23% (VII) (Marcy 1969).

Abundance and mortality. In Bride Lake, Connecticut, in 1966, an estimated 184,000 adult alewives spawned 20.5 billion eggs. About 257,000 juveniles were counted as they emigrated seaward during summer and fall. The freshwater mortality rate from egg stage to emigration in this lake was 99.99%, indicating that about three juveniles left the lake for each adult female that spawned. Since some repeat spawning occurs, this level of juvenile production seems to be adequate for sustaining the spawning population in Bride Lake (Kissil 1974). The mortality of spawning adults in Bride Lake was 57% in 1966 and 49% in 1967.

Juvenile production and adult mortality of the alewife population in Love Lake, Maine, were reported by Havey (1973). The number of juvenile emigrants ranged from less than 1,000 (i.e., 220) in 1962 to 439,000 in 1967. Juvenile emigrants produced per spawning female per year numbered from 12 to 3,209. There were significant linear relations between juvenile emigrant abundance and spawning population size 4 years later, and between the log of female escapement and the log of juvenile emigrant abundance. The annual adult mortality in freshwater averaged 91% and ranged from 66 to 100% (Havey 1973). The annual mortality for anadromous alewives in Long Pond, Maine was 79% between ages V and VI, and 74% between ages VI and VII (Havey 1961). Freshwater post-spawning mortality for all ages in 1954-59 averaged 41% and ranged from 32% to 67% (Havey 1961). Results from these two studies in Maine and the study by Kissil (1974) in Connecticut indicated that juvenile production and adult freshwater mortality may vary considerably among spawning areas and among different years in the same spawning area.

Spawning stocks. Although Thunberg (1971) found that olfaction was the basis for homing behavior in alewives, Messieh (1977) reported considerable mixing among spawning stocks during the spawning runs. Although most of the alewives homed, a substantial number (determined by meristic comparisons) from each presumed stock did not (Messieh 1977).

Evidence of a nonlandlocked, nonmigratory, self-sustaining dwarf population of alewives living in the mouth of the Susquehanna River was reported by Foerster and Goodbred (1978).

ECOLOGICAL ROLE

Food Habits

Alewives and blueback herring feed primarily on zooplankton. Other

Table 2. Annual alewife/blueback herring landings (thousands of pounds) and value (thousands of dollars) in New England from 1977 to 1982 (NMFS, unpublished data).

Year	Conn.		R.I.		Mass.		N.H.		Maine	
	Wt.	Value	Wt.	Value	Wt.	Value	Wt.	Value	Wt.	Value
1977	-	-	3	0	112	3	12	1	-	-
1978	61	5	2	0	660	13	11	1	2,781	138
1979	40	3	6	0	38	2	10	1	2,305	124
1980	63	6	2	0	5	3	-	-	2,645	170
1981	-	-	-	-	5	3	-	-	-	-
1982	40	4	2	0	25	2	115	7	552	36

foods, especially for the larger fish, are small fish and insects, and the eggs of fish, insects, and crustaceans (Bigelow and Schroeder 1953). Larvae begin feeding on relatively small cladocerans and copepods immediately after formation of a functional mouth (about 6 mm TL). As they grow, the larvae eat larger species of these zooplankters (Norden 1968; Nigro and Ney 1982).

Stomachs from young-of-the-year blueback herring collected in the James River, Virginia, contained primarily (by volume) the cladocerans, Bosmina spp., copepod nauplii, copepodites, and the adult copepods Eurytemora affinis and Cyclops vernalis. Diaphanosoma brachyurum and Canthocamptus robertcokeri were minor food items. Young-of-the-year alewives in Hamilton Reservoir, Rhode Island, ate primarily chironomid midges in July and cladocerans in August and September (Vigerstad and Cobb 1978).

Studies of the food of juvenile blueback herring in the Connecticut River showed a strong electivity[1] for members of the family Bosminidae, and moderate electivity for daphnids and calanoid and cyclopoid copepods (Domermuth and Reed 1980). Cladocerans made up 47% of the food volume (electivity was neutral). Copepods made up only 18% of the food volume and showed strong positive electivity. Chironomid larvae and pupae made up 19% and 16% of the food respectively, but electivity was strongly negative. Comparisons of these data with similar data for juvenile American shad (Alosa sapidissima) and pumpkinseed (Lepomis gibbosus) showed that neither blueback

[1]Ivlev's electivity index compares relative abundance (percentage of the composition) of a food item in a fish stomach sample with the relative abundance of that item in the feeding environment. For example, if a food item makes up 10% of the food in a fish's stomach, but 90% of the available food, its electivity index is strongly negative. Electivity is neutral when the proportion of a food item eaten is directly proportional to its availability in the environment.

herring nor American shad competed with the benthic-feeding pumpkinseed, and that competition between blueback herring and American shad was inconsequential (Domermuth and Reed 1980).

Little is known about the food of anadromous adult alewives. Generally they are zooplanktivores, eating larger and more diverse prey as they grow. Large landlocked alewives tend to be piscivorous (Kohler and Ney 1981).

Feeding Behavior

In laboratory tests, alewives showed three feeding modes: (1) particulate feeding on individual prey organisms, (2) filter feeding (mouth agape during rapid bursts of swimming), and (3) gulping of several prey organisms at once (but not swimming at the rapid speed used in filter-feeding) (Janssen 1976). Size selectivity of prey was highest in particulate feeding, moderate in prey gulping, and negligible in filter feeding. Adult Lake Michigan alewives and their major food, *Mysis relicta*, make coincidental, crepuscular vertical migrations, from near bottom during daylight to just below the thermocline at night (Janssen and Brandt 1980). This diel vertical migration, not necessarily related to the thermocline, also may occur in anadromous populations living in estuaries or marine coastal habitats.

Competitors

The degree of competition between anadromous alewives and blueback herring is not known. Because of general similarities in their diets and feeding behavior, competition for food is probable. Spatial separation between young alewives and blueback herring in the same habitat, which may lead to reduced competition for food among juveniles, was reported by Loesch et al. (1982a).

Predators

Alewives and blueback herring contribute substantially to the food of many riverine, estuarine, and marine fishes as well as gulls and terns (Commonwealth of Massachusetts 1976). Major predators are bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), and striped bass (*Morone saxatilus*). These pelagic, schooling predators commonly prey on schooling clupeids (Cooper 1961; Tyus 1974).

ENVIRONMENTAL REQUIREMENTS

Some research has been conducted to delineate the specific environmental requirements or preferences of anadromous alewives and blueback herring. However, much of the available information on alewives was derived from tests on landlocked populations, particularly in Lake Michigan. The differences in environmental requirements of landlocked populations and anadromous populations is unknown. Since many of the available data are from studies of landlocked populations, the following environmental requirements refer largely to them.

Temperature

The effects of water temperature on the incubation of alewife eggs from Lake Michigan were studied by Edsall (1970). Eggs hatched at test temperatures between 7 and 29.5 °C. At the optimum temperature for hatching (18 °C) 38% of the eggs hatched. Egg mortality over the first 36 h ranged from 22% (at temperatures of 3.5 to 6.0 °C) to 66% (at temperatures of 25.5 to 28.5 °C). Egg mortality was directly correlated with incubation temperature (Edsall 1970). An upper lethal temperature of 29.7 °C was reported for alewife eggs from the Hudson River, New York (Kellogg 1982). Most eggs hatched at a water temperature of 20.8 °C; only a few hatched at temperatures of 12.7 and 26.1 °C.

Blueback herring eggs collected from the Washademoak Lake, Canaan River, New Brunswick, Canada, were time-temperature tested in a power plant cooling system (Koo and Johnston 1978). These tests proved that larval deformity rates were better than egg mortalities as indicators of the effects of temperature change. Deformity rates of larvae, acclimated at 19 °C and exposed to 20 °C water for 5 to 180 min, ranged from 0 to 25% (control 0-5%). Deformity rate increased to 100% when the temperature was increased to 34 °C. Deformities ranged from minor curvature of the spine to completely abnormal larval form or behavior. Deformities were permanent and few such larvae would have survived in natural environments (Koo and Johnston 1978).

Two effects of temperature on larval alewives from Lake Michigan were reported by Edsall (1970). Survival time of unfed larvae was 3.8 days at 10.5 °C, 7.6 days at 14.5 to 15 °C, and 2.4 days at 26.5 to 28 °C. A functional jaw did not develop in fish from eggs or larvae kept at or below 10 °C, even though some eggs hatched at those temperatures. An upper temperature tolerance of 31 °C for alewife larvae from the Hudson River, New York, acclimated to 14 °C, was reported by Kellogg (1982). Average daily gain in larval weight was directly proportional to water temperature. The maximum larval growth rate was 0.084 g/day at 29.1 °C; net gain in biomass (a function of survival and growth) was highest at 26.4 °C (Kellogg 1982).

Young-of-the-year alewives (19 to 31 mm TL) from the Hudson River, New York, prefer water temperatures near 26 °C when given a choice in a controlled thermal gradient (Kellogg 1982). Young-of-the-year alewives from Lake Michigan exhibited critical thermal maxima (CTM; the mean temperature at which experimental fish lose equilibrium) of 28.3 °C, 32.7 °C, and 34.4 °C at acclimation temperatures of 11 °C, 19 °C, and 25 °C, respectively (Otto et al. 1976). The equation for predicting CTM from acclimation temperature was CTM = 21.9 + 0.5(TA), where TA = acclimation temperature in degrees Celsius (correlation coefficient $r^2 = 0.96$).

For alewives tested at the same acclimation temperatures, CTM values were 3 to 6 °C higher for young-of-the-year than for adults. (Otto et al. 1976).

In laboratory tests, preferred (selected) water temperatures of juvenile alewives and blueback herring (age groups 0 and I) collected from the Delaware River, New Jersey, and acclimated to water temperatures of 15 to 21 °C ranged from 20 to 22 °C at salinities of 4 to 6 ppt (Meldrim and Gift 1971). Davis and Cheek (1966) captured juvenile blueback herring in the Cape Fear River seasonally in areas where water temperatures ranged from 11.5 to 32 °C. Juvenile alewives in the same watershed were captured at water temperatures of 13.5 to 29 °C.

School formation patterns and daily rhythms of adult alewives in Lake Michigan were affected by changes in water temperature in laboratory tanks (Colby 1971). As water temperature dropped below 6.7 °C, normal feeding behavior was disrupted and cruising speed of schooling fish decreased. Below 4.5 °C, normal schooling behavior was significantly reduced. At temperatures between 2.0 and 2.8 °C, alewives lost orientation, swam into the sides of the test chamber, and ceased feeding and schooling.

In laboratory cold shock tests with adult alewives from Lake Michigan, transfers to temperatures of less than 3 °C caused 100% mortality, regardless of acclimation temperatures (Otto et al. 1976). The magnitude of the temperature decrease tolerated by alewives increased gradually with increasing acclimation temperature. Some alewives survived a temperature decrease of 10 °C, regardless of acclimation temperature, if the temperature did not drop below 3 °C (Otto et al. 1976).

The electrolyte balance and osmoregulation of alewives in Lake Michigan changed with a change in temperature (Stanley and Colby 1971). Transfer of fish acclimated at high temperatures to low cold temperatures caused levels of Na+, K+, and Ca++ in blood and muscle to move toward an equilibrium with the salinity of the acclimation environment (body concentrations increased in saltwater and decreased in freshwater). The fish temporarily lost their ability to osmoregulate when exposed to cold, regardless of the salinity of the water.

Salinity

Although supporting data are sparse, anadromous alewives and blueback herring are highly tolerant of salinity changes (Cooper 1961; Chittenden 1972). No mortality of adult blueback herring from either gradual or abrupt changes in salinity, including direct transfers from freshwater to saltwater and vice versa, was observed by Chittenden (1972). Blood and muscle concentrations of Na+, K+, and Ca++ were similar in fish kept in seawater and freshwater of the same temperature -- indicating that, after a period of acclimation, alewives were efficient osmoregulators in either environment (Stanley and Colby 1971).

Other Environmental Factors

The location of appropriate spawning sites and substrates is important not only to the perpetuation of each species but also for natural "reproductive segregation" between two otherwise closely similar species. Blueback herring prefer spawning sites with strong currents and hard substrates (Loesch and Lund 1977). Their spawning requirements are thus more specialized than those of alewives, which use a wide variety of spawning sites. Alewives may spawn in standing river water, oxbows, coastal ponds, small streams, or fast mid-river currents.

Young-of-the-year alewives and blueback herring from the Cape Fear River, North Carolina, were abundant in water where free carbon dioxide ranged from 4 to 22 ppm, alkalinity from 5 to 32 ppm, dissolved oxygen from 2.4 to 10.0 ppm, and pH from 5.2 to 6.8 (Davis and Cheek 1966).

An experiment by Schubel and Wang (1973), designed to test the effects of suspended sediments on the hatching of alewife eggs, was terminated because a naturally occurring fungus in the sediment infected all test eggs before they hatched. Although the extent of infection may have been enhanced by laboratory conditions, the attempt indicated that high levels of suspended sediment during or after spawning may cause high excessive mortality of eggs in some natural waters. In contrast, suspended sediments in concentrations of 100 ppm or less produced no significant effect on egg mortality in either of alewives or blueback herring (Auld and Schubel 1978).

Blood lactic acid concentrations, measured in alewives moving through a pool-and-weir fishway, indicated moderate activity and energy expenditure (Dominy 1971, 1973). The mean levels of blood lactic acid in alewives passing through the fishway were less than half the levels found in heavily exercised fish in the laboratory. The use of resting pools along the course of the fishway allowed blood lactic acid levels in fishes to drop to levels observed in rested fish in the laboratory.

Periodicity of upstream migratory movements of adult alewives through a Rhode Island river fishway was correlated with the magnitude of incident solar radiation (Saila et al. 1972). Richkus (1974a) corroborated this light-dependent migration; however, he also observed that within activity patterns determined by light intensity, changes in water temperature strongly influenced the specific timing of upstream movement of alewives. Juvenile downstream emigration from Hamilton Reservoir, Rhode Island, during summer and fall was inhibited somewhat by the sunlight and shade interface present at a highway bridge at the lower end of the reservoir. More fish passed under this bridge on cloudy than on sunny days (Richkus 1974a).

Environmental Contaminants

The LC_{50} (concentration needed to kill 50% of the test fish) of total residual chlorine for blueback herring eggs ranged from 0.20 to 0.32 ppm. All larvae from eggs exposed to sublethal concentrations of total residual chlorine were deformed (Morgan and Prince 1977). Concentrations of Kepone greater than 0.3 ppm (termed the "action level" for possible closure of a fishery) were found in body tissues of young-of-the-year alewives and blueback herring collected from the James and Chickahominy Rivers, Virginia (Johnson et al. 1978; Loesch et al. 1982b). Kepone (in concentrations less than 0.3 ppm) was present in young alewives and blueback herring from the Mattaponi and Pamunkey Rivers, Virginia, but was not present in detectable quantities in fish from the Rappahannock River, Virginia, or the Potomac River, Maryland (Loesch et al. 1982b).

Entrainment and Turbine Induced Mortality

Young alewives and blueback herring in the Hudson River are susceptible to power plant entrainment for up to 63 days after spawning (older ones usually escape) (Boreman et al. 1981). Entrainment mortality calculated for three power plants on the river was 3.5 to 4.1% in 1974 and 6.1 to 11.2% in 1975. Juveniles had higher mortality than eggs and sac-fry.

The mortality of blueback herring passing through the 17 MW Kaplan turbine at Holyoke Dam, Massachusetts, varied with the level of power generation (Knapp et al. 1982). Mortality was lowest when the operating efficiency of the turbine was highest. Mortality ranged from 62% at an output of 16.5 MW to 82% at outputs of 12.0 and 5.5 MW.

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Dennis M. Mullen, Clemon W. Fay, and John R. Moring

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Maine Cooperative Fishery Research Unit
313 Murray Hall, University of Maine
Orono, ME 04469

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National Wetlands Research Center
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 of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in impact assessment. The alewife and blueback herring (*Alosa pseudoharengus* and *Alosa aestivalis*) are important species in estuarine and marine ecosystems, though both anadromous and landlocked populations exist. Some individuals mature by age 3, and all mature by age 5. Repeat spawning is common. Spawning environments range from streams only a few centimeters deep to large rivers. Alewives will also spawn in ponds with an open connection to the sea. Blueback herring prefer spawning sites with fast currents and associated hard substrates, while alewives select a wider variety of sites, from standing water and oxbows to mid-river areas. Spawning occurs from April to July in the north Atlantic region; the onset and peak of alewife spawning precede those of blueback herring by 2 to 3 weeks. Larvae and juveniles remain in or near areas spawned before emigrating (as juveniles) to coastal areas in their first year. Emigration is apparently triggered by heavy runoff from rain and/or sharp decreases in water temperature. Adults overwinter offshore to depths of at least 110 m. Nantucket Shoals, Georges Bank and the Gulf of Maine are important overwintering grounds. Commercial and limited recreational fisheries for these species occur; total U.S. landings in 1982 were 5,682 t, while foreign landings within the U.S. Fishery Conservation Zone were 2.0 t. Some eggs can hatch at water temperatures between 7° and 29.5°C, but temperatures above 29.7°C are lethal. Larvae need temperatures greater than 10°C for proper development.

17. Document Analysis a. Descriptors

Rivers, Fisheries, Estuaries, Fishes, Growth, Feeding habits, Herrings, Temperature, Salinity, Animal migrations, Contaminants, Life cycles

b. Identifiers/Open-Ended Terms

Alewife
Alosa pseudoharengus
Blueback herring
Alosa aestivalis
Spawning

c. COSATI Field/Group

18. Availability Statement
Unlimited Release

19. Security Class (This Report)
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21

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(See ANSI-Z39.18)

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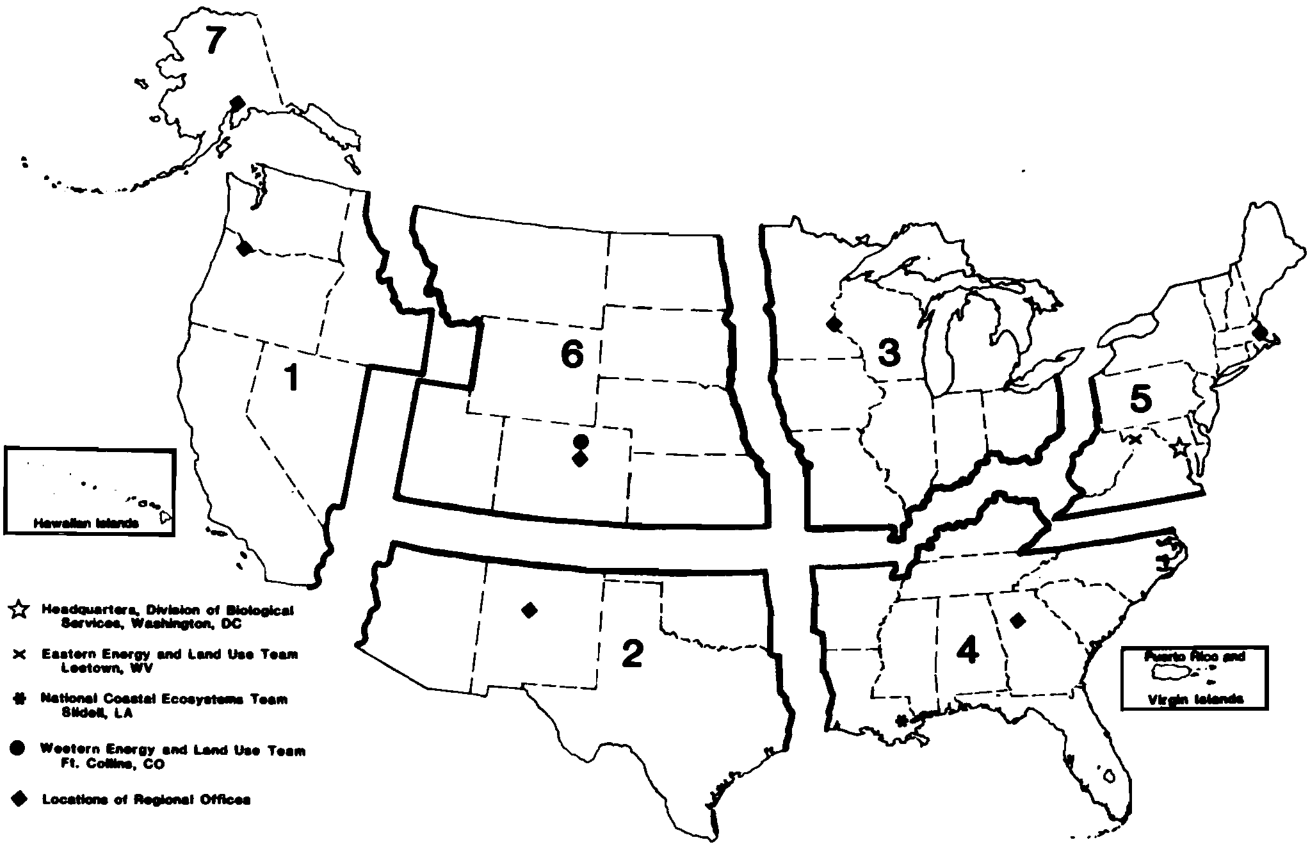

REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

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

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

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