A large group of river herring swimming in a tank, viewed through a glass barrier. The fish are silvery and elongated, moving in various directions. The water is slightly yellowish, and the background shows some structural elements of the tank.

A Review of the Biology and Ecology of River Herring from a Climate Change Perspective

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ALEWIFE

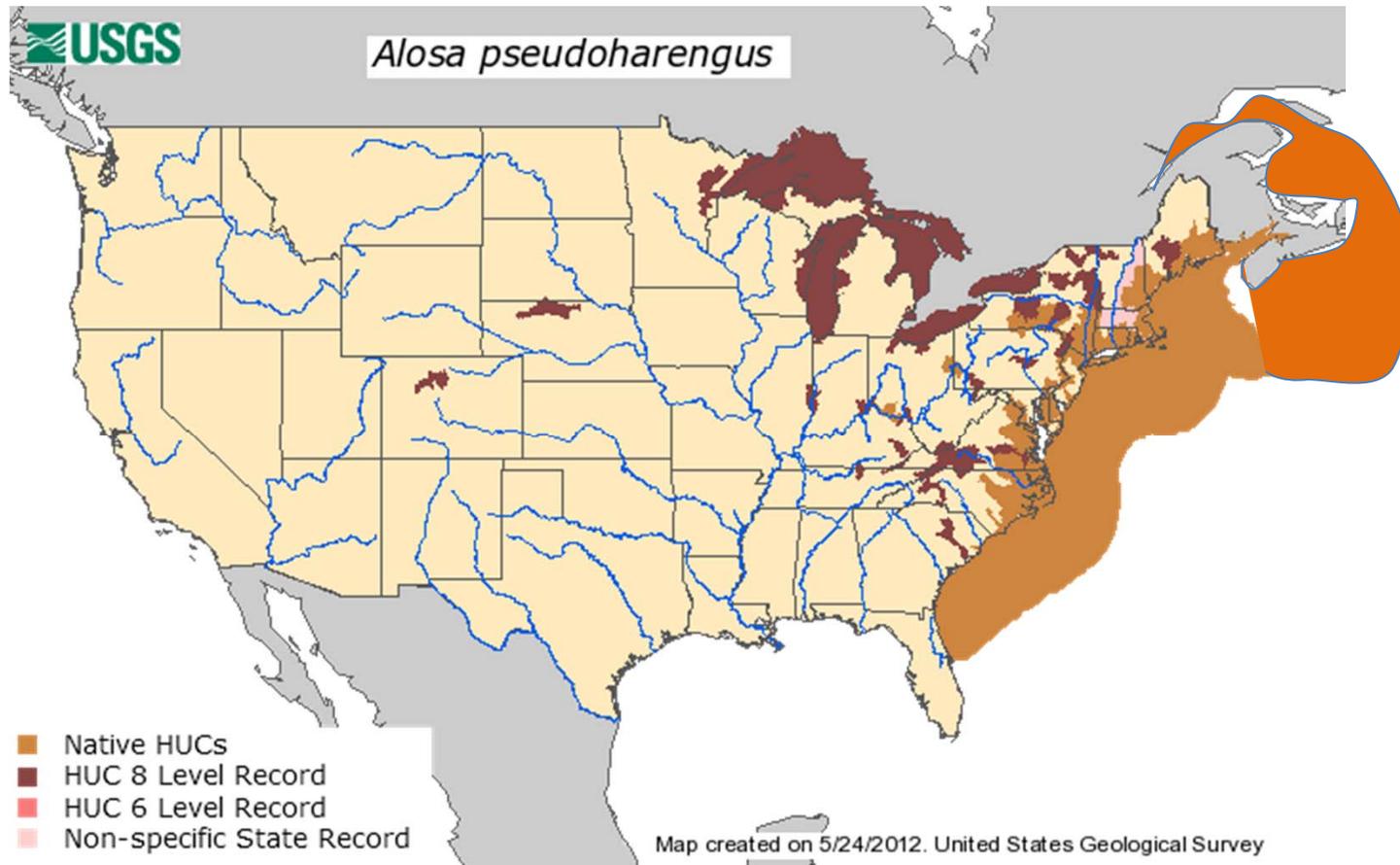
River herring



BLUEBACK HERRING



Alewife



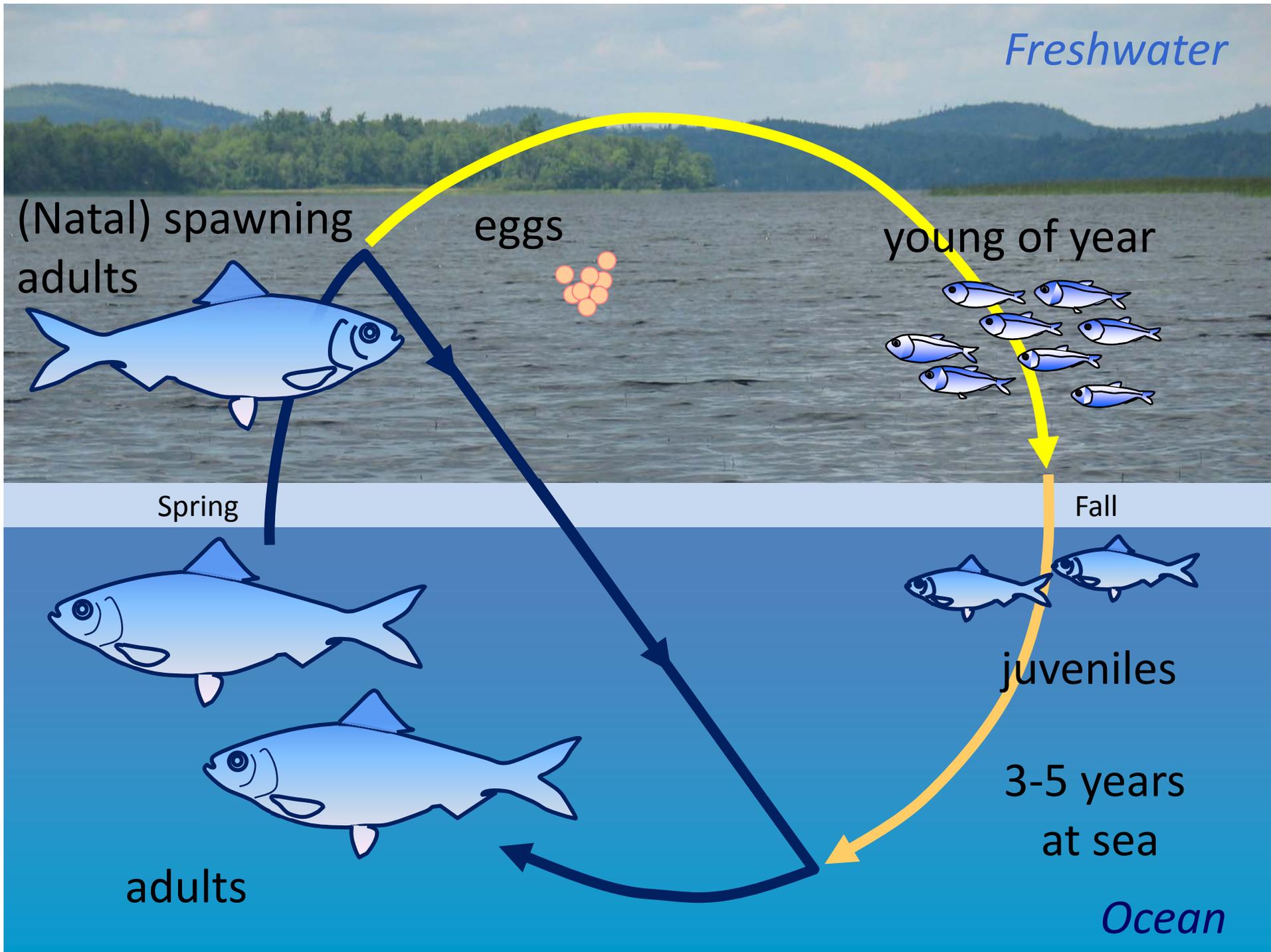
Blueback herring



Population declines

- Stocks depleted relative to 1950, and more depleted relative to historical accounts. (ASMFC River Herring Benchmark Stock Assessment 2012)
- Change in biological data may make residual populations more vulnerable to stochastic events
 - (e.g., loss of repeat spawners, reduction in mean length, mean-length-at-age, and mean age)





Spawning & nursery habitats

Alewife

- Swim up larger river systems to tiny streams
- Spawn in lakes or slow-moving rivers (or impoundments)
- Juveniles grow in lakes until densities/food availability and/or water flows (egress) trigger out-migration
(e.g., Gahagan et al 2012)

Blueback herring

- Spawn in larger, slow moving rivers (but some spawn in lakes & small streams)
- Juveniles appear to move more quickly to estuarine habitats

Considerable variability in life history strategies (and likely considerable variability has been lost).

Reproduction

Alewife

Repeat spawners appear to be more abundant (60%) further north than south (10%) but lit not in agreement

Egg production est. range from 60,000 – 467,000 eggs/female/yr but females often retain some portion of those eggs.

Blueback

Repeat spawners 30-75%

Egg production est. range from 60,000 – 400,000 eggs/female/yr but females often retain some portion of those eggs.

	Alewife	Blueback	Source
Spawning migration	Begins ~ 5 - 10 °C (a) Temps < 8 °C and > 18 °C = little adult movement (b) Light & flows also important (b,c)	Begins ~ 10 – 15 °C (a) NS rivers: 13-21 °C (ee) Later than ALE when sympatric.	(a) Loesch 1987 (b) Richkus 1974 (c) Collins 1952 (ee) Crawford et al 1986
Spawning	10 – 20 °C (d,e) Males arrive before females; larger & older spawn first	Optimal 21-25 °C (aa-cc) Min 14 °C, max < 27 °C (dd) NS Rivers : 20-22 °C (ee)	(d) Rounsefell and Stringer 1943 (e) Carlander 1969 (aa) Cianci 1969 (bb) Marcy 1976b (cc) Klauda et al 1991 (dd) Loesch 1968
Egg incubation	Optimal 17-21 °C 2-3 days @ 22 °C 6 days @ 15.6 °C (d,f,g)	3-4 days @ 20-21 °C (g) 55-58 hrs @ 22.2-23.7 °C (aa,cc)	(f) Mansueti 1956 (g) Jones et al 1978
Hatching success	Max at 20.8 °C, ceases at 29.7 °C (h,i,j)		(h) Edsall 1970 (i) Marcy 1971 & 1973 (j) Kellogg 1982
Larval survival	Minimal above 28 °C (h, i)	Minimal above 28 °C (h, i)	

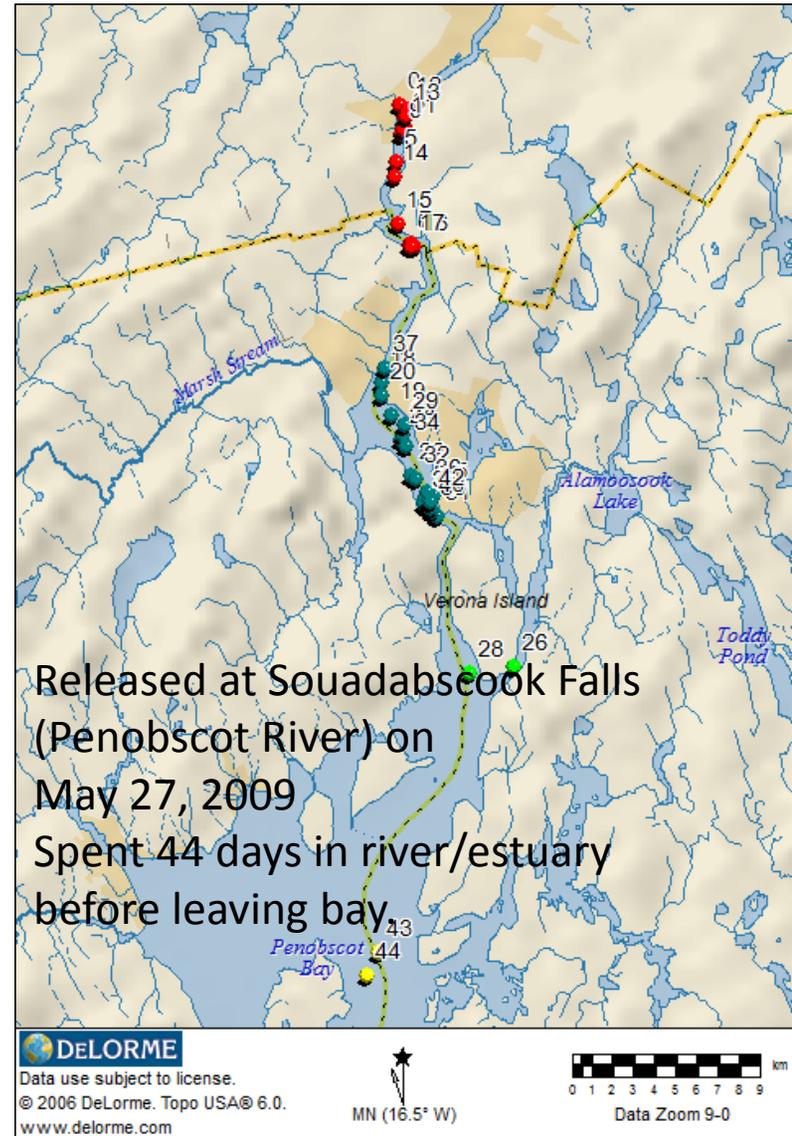
See Collette & Klein-MacPhee, 2002. Fishes of the Gulf of Maine, for review.

Salinity preferences

	Alewife	Blueback	Reference
Larval tolerances	??	<p>Eggs & larvae tolerate up to 18-22 ppt ^(a)</p> <p>Juveniles can use both FW & estuarine habitats up to 28 ppt ^(b)</p>	<p>(a) Johnston & Cheverie 1988</p> <p>(b) Chittenden 1972b</p>
Adult	<p>FW \leftrightarrow salt</p> <p>land-locked populations are common [often introduced]</p>	<p>FW \leftrightarrow salt</p> <p>some land-locked populations reported (e.g., Cooper-Santee river system in SC)</p>	

At sea distributions

- Based on trawl survey, bycatch or directed fisheries data
- Some very nearshore (lake/river/estuary/bay) tracking studies studying spawning migration behavior



At sea distributions

Neves 1981 suggests (adult?) RH are widely distributed in Mid Atl. Bight in spring & move north to Nantucket Shoals, Georges Bank and GOM in summer and fall, then return. [NMFS Bottom Trawl Surveys]

Year round occurrences of RH
Georges Bank to Long Island.

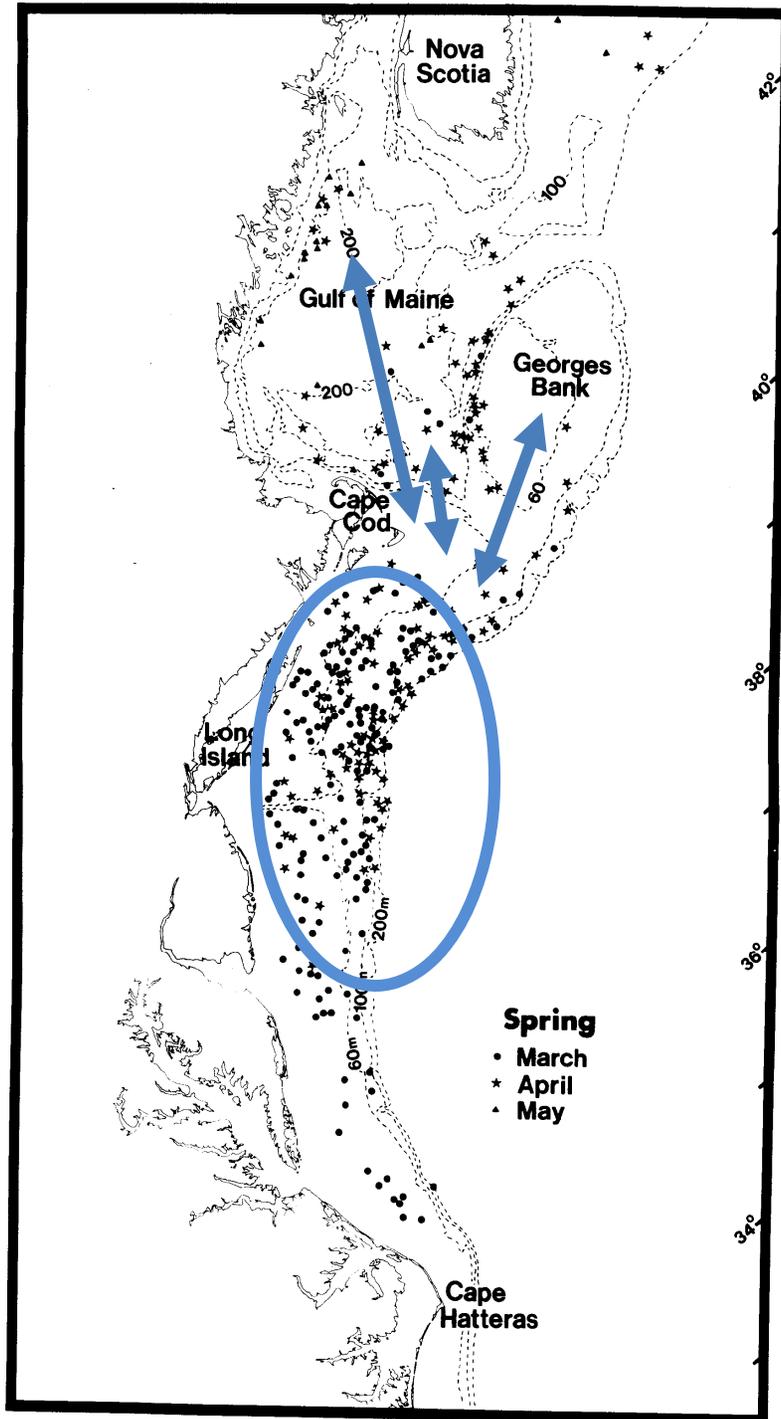


FIGURE 5.— Location of alewife catches during spring bottom trawl surveys, 1968-78, Cape Hatteras, N.C., to Nova Scotia.

At sea distributions

Seasonality inferred from commercial harvests
1970 – 1978 (Neves et al 1981)

Figure Legend:

Foreign vessels

Domestic (spawning migration) fishery

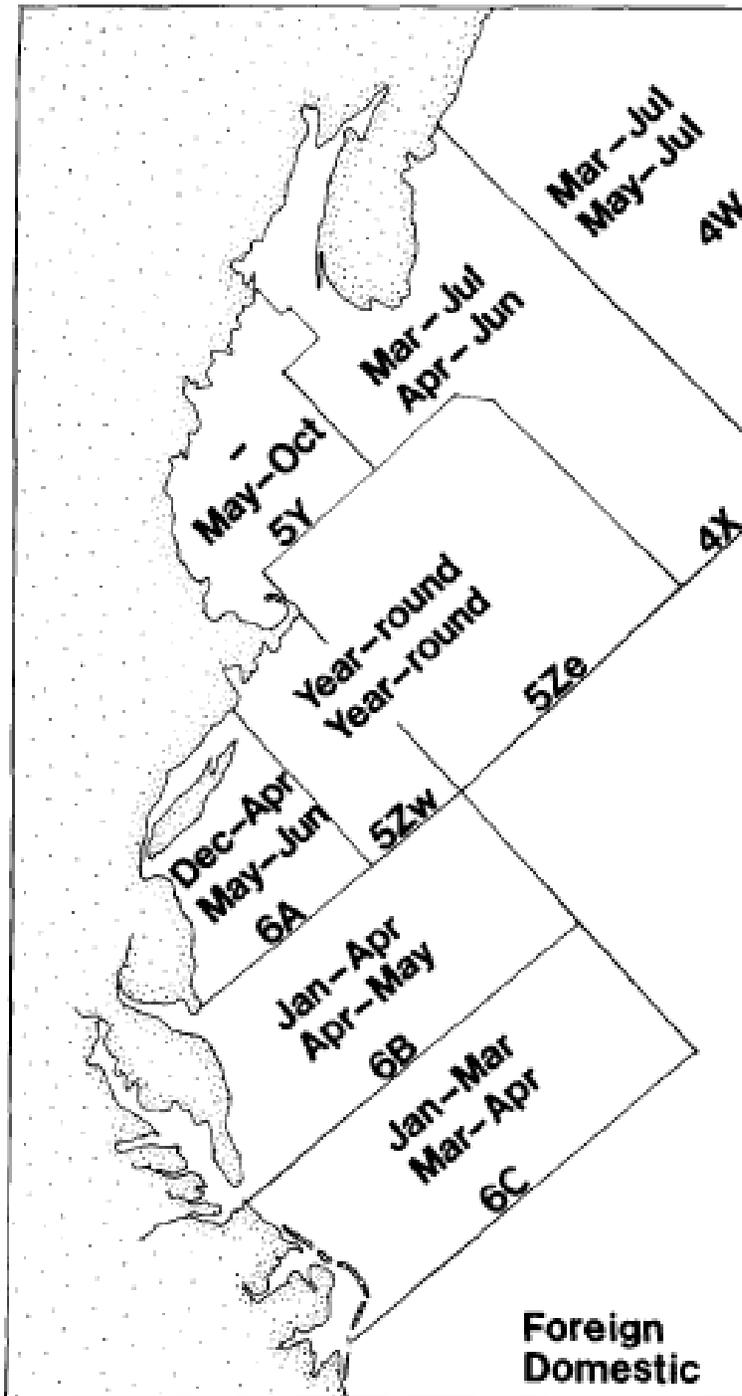


FIGURE 9.—Seasonal distribution of major catches of alewives and blueback herring in divisions of the International Commission for the Northwest Atlantic Fisheries, 1970-78, Cape Hatteras, N.C., to Nova Scotia. Within each division, the months for major catches are shown separately for foreign vessels (upper entry) and the domestic fishery (lower entry).

At sea distributions

Neves (1981) concluded from NMFS bottom trawl survey data (1963-1978):

- RH most common at depths < 100 m (associated with zooplankton concentrations?)
- Water temperatures:
 - Alewife 3 – 17 °C
 - Blueback 2- 12 °C, 16 °C
- Bluebacks found slightly shallower waters than alewife
- Daily migrations (deeper – day, shallower – night)
- Suggested that populations south of Cape Hatteras would migrate from the north along the coast to avoid 17.5 °C thermal barrier located offshore year round.

At sea distributions

Stone & Jessop 1982 [Canadian groundfish bottom trawls 1970-1989]

Spring: Scotian Gulf, GOM, Bay of Fundy

Summer: Bay of Fundy

Fall: Bay of Fundy, Scotian Gulf

Most catches at $> 5^{\circ}\text{C}$

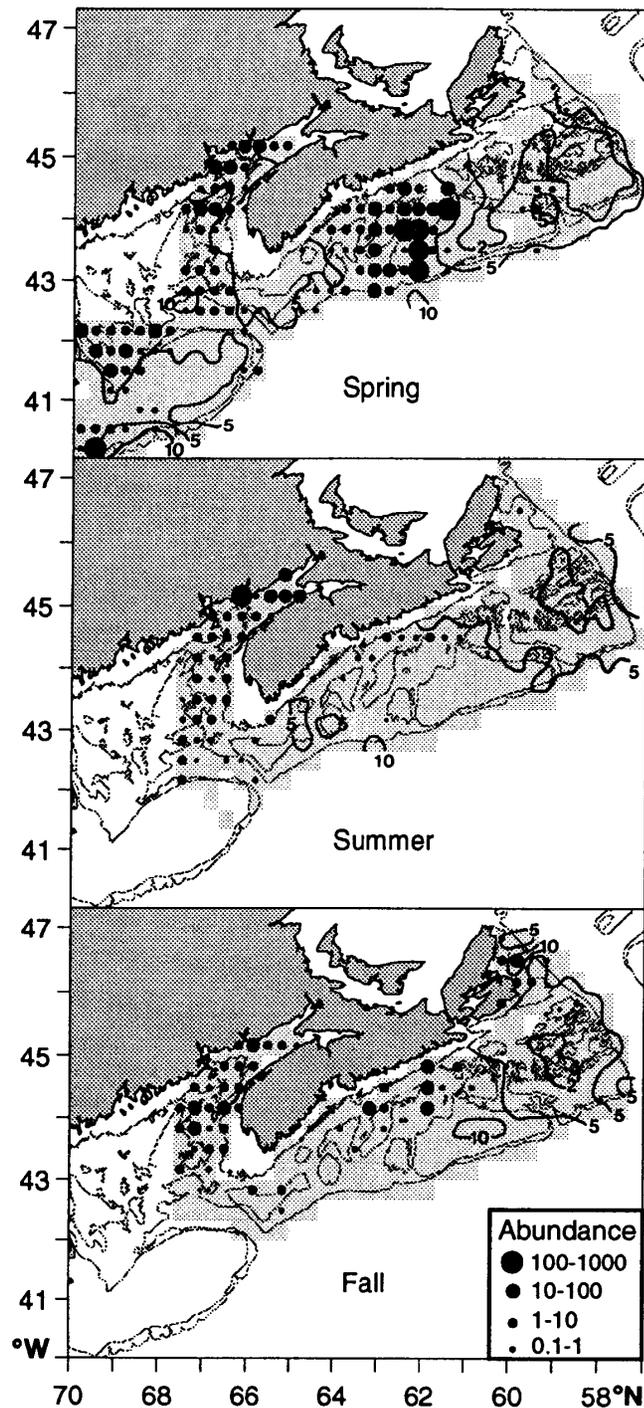


Figure 2

Distribution and relative abundance (\bar{x} catch per 20-min square) of river herring from spring (1979-89), summer (1970-89), and fall (1978-84) groundfish surveys conducted off the Atlantic coast of Nova Scotia. Area sampled is indicated by shading, and mean catch (n/tow) for each 20-min square is represented by a solid circle, scaled to catch level. Isotherms for 2, 5, and 10°C of bottom temperature are also indicated.

River herring food web relationships

- Larvae & juveniles feed on zooplankton and some insects while in FW
- Adults may feed during their spawning run (e.g., bluebacks in the Hudson & Mohawk rivers, Simonin et al. 2007; alewife in Maine Lakes, Willis 2006)
- Heavily consumed by resident predators
- Zooplanktivores at sea (Calinoid copepods, euphausiids & mysids...)
- Prey for numerous marine predators (fish, mammals, birds)



River herring ecosystem impacts

Bi-directional linking of marine & freshwater systems:

- Export phosphorus from lakes (in the form of juveniles)?
- Import marine-derived nutrients into FW systems?
- Trophic subsidies for low productivity (FW or marine) systems?

Warmer temperatures

- Hypoxia in nursery areas?
(e.g., Chesapeake Bay & Delaware River)
- Slow(er) northward range shifts due to natal homing?
 - What habitats become important? What ones are lost?
- More energetically taxing?
- Upper limits?

Changes in magnitude and timing of freshwater flows

- Increased pollution load?
- Interfere with migratory cues?

Fish passage issues:

- Dams and “hardened” old dam sites offer few or no alternate routes for passage
- Fish passage facilities require attraction flows that can be obscured by high water
- Downstream passage issues for adults (impacts % repeat spawners) and juveniles
- Small lake outlet dams, used to regulate lake water levels, are barriers during low water
- Small streams may dry up entirely

Other potential issues

- Parasite load?
- Correlation between hydrograph and temperature may make it difficult to tease out relative importance of abiotic vs. biotic factors influencing growth & mortality of juveniles (Jessop 1990c, 1994 in C&K)
- Ocean acidification: impact prey base?
- Shifts in ocean currents/patterns?
- Temperature/water regime shifts facilitating invasive species spread in freshwater and marine systems
 - competitors, predators, zooplankton community



A Review of the Biology and Ecology of River Herring from a Climate Change Perspective (Summary)
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The term “river herring” refers to two difficult to distinguish species of anadromous Alosid herring, alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). Both spend most of their life in marine habitats, and return to their natal freshwater rivers and/or lakes to spawn. River herring range from Florida to the St. Lawrence River, with blueback herring more dominant in southern rivers, and, generally, alewife more dominant in northern rivers. In their northern range, it is not uncommon to find “repeat spawners” returning to spawn multiple times (i.e., iteroparity), a degree of life history plasticity that allows individuals to try again next year if environmental conditions make spawning difficult. Adult river herring move up coastal rivers in early to late spring in response to water temperature. Alewife typically spawn in lakes (or, in southern ranges, in slow moving stretches of larger rivers); blueback herring are considered a river-spawning species, again, in slower moving reaches. Both males and females return to the ocean after spawning although alewives, at least, can feed in freshwater and may stay in lakes for weeks to months, particularly if dropping water levels prevent egress. In lakes young of the year (YOY) alewives are pelagic, feeding on zooplankton; as they grow they can move inshore and their diet may include benthic invertebrates. YOY alewives emigrate from lakes as early as July or as late as October depending on numerous factors that may include lake productivity, population density, and access to outlet streams. Juveniles spend their first few years in estuaries and the ocean although details are not well known; adults spend their time well off shore. Adults return to their natal rivers to spawn at age 2-4; there are more repeat spawners (i.e., fish who have spawned the previous year) the further north the spawning run. Climate change could affect river herring in a multitude of ways. Those related to the biology and ecology of river herring include:

Temperature: Temperature is an important river herring spawning and migration cue. For example, in the spring of 2012, many spawning runs in northern states began 2-3 weeks earlier than normal, correlated with unusually warm spring temperatures. In addition, temperature has important energetic implications for river herring. The warmer the water, the more energetically costly it is for the fish to linger in that water. In more northerly rivers, it is not uncommon for water temperatures to drop due to spring storms and for fish to “fall back” into estuaries or larger rivers. Changes in the timing of spawning may contribute to “match – mismatch” between predator and prey.

Water flows: Water flows dictate, in large part, the ability of fish to pass both natural and anthropogenic barriers in rivers. Too much or too little flow can render fish passage ineffective, or delay fish at a barrier long enough as to deplete the fish’s energy stores before spawning, or prevent a spawned-out fish from reaching the ocean. Fish passage devices on dams require an “attraction flow” to attract migrating fish – if this flow is too little compared to that coming over the dam or through turbines fish will not “find” the intended passage. Outmigration is also impacted by flows: greater flows may ease outmigration by reducing time spent while minimal flows may block outmigration of young of year in late summer and fall.