NOTE

Blueback Herring (Alosa aestivalis)
in Lake Ontario: First Record, 
Entry Route, and Colonization Potential

Randall W. Owens1,*, Robert O'Gorman1, 
Edward L. Mills2, Lars G. Rudstam2, 
John J. Hasse3, 
Brandon H. Kulik4, 
David B. MacNeil5

1U.S. Geological Survey Biological Resources Division 
Great Lakes Science Center Lake Ontario Biological Station 
17 Lake Street Oswego, New York 13126

2Department of Natural Resources Cornell University 
Biological Field Station 900 Shacketton Point Road 
Bridgeport, New York 13030

3New York Department of Environmental Conservation 
207 Genesee Street Utica, New York 13501

4Kleinschmidt Associates 75 Main Street P.O. Box 576 
Pittsfield, Maine 04964

5New York Sea Grant Morgan III SUNY 
Brockport Brockport, New York 14420

ABSTRACT. Two juvenile blueback herring (Alosa aestivalis) were caught in Lake Ontario in October 1995, the first record of this anadromous marine clupeid in the Great Lakes. Blueback herring most likely gained entry to Lake Ontario via the Erie Barge Canal, a navigation canal that links the Mohawk-Hudson rivers, which drain to the Atlantic Ocean, to Oneida Lake, which drains to Lake Ontario through the Oneida-Oswego rivers. Blueback herring ascend the Hudson River to spawn and were first reported from the upper Mohawk River in 1978. They currently spawn in several of the upper Mohawk's tributaries, including one about 430 km from the ocean but only 25 km from Oneida Lake. They were first found in Oneida Lake in 1982 and, in fall 1994, large numbers of juvenile blueback herring were found moving down the Oswego River. In the southern United States, blueback herring established self-reproducing populations in several reservoirs, and thus they have the potential to colonize Lake Ontario. If blueback herring become established in Lake Ontario, they could spread to other Great Lakes and impede recovery of depressed populations of indigenous fishes, like lake herring (Coregonus artedi) and lake trout (Salvelinus namaycush), through competition with, or predation on, their larvae.

INDEX WORDS: Blueback herring, Lake Ontario, Erie Barge Canal, Oneida Lake.

*Corresponding author.
E-mail: randy_owens@usgs.gov
INTRODUCTION

Blueback herring (*Alosa aestivalis*) and alewives (*Alosa pseudoharengus*) are sympatric clupeids with overlapping native ranges in the western Atlantic Ocean from the Carolinas to the Canadian Maritime Provinces (Bigelow and Schroeder 1953, Winters *et al.* 1973, Loesch 1987). Both are anadromous, often co-occurring when spawning in rivers in spring, and they are similar in appearance (Scott and Crossman 1973). Although alewives established reproducing populations in freshwater lakes, including Lake Ontario, as early as the late 1800s (Smith 1970), blueback herring established reproducing populations in freshwater environments only in the late 1900s and they have not previously been reported from any of the Great Lakes (Prince and Barwick 1981, Guest and Drenner 1991).

Two juvenile blueback herring were caught in southeastern Lake Ontario near Oswego, New York in October, 1995. Blueback herring likely gained access to Lake Ontario via the Mohawk River and Erie Canal (New York State Barge Canal system), the same route which alewives used over 100 years ago (Bean 1884, Smith 1970, Aron and Smith 1971, Smith 1995). If blueback herring become established in Lake Ontario, they could move through the Welland Canal to Lake Erie and colonize other Great Lakes. Alewives used the Welland Canal to gain access to the other Great Lakes in the 1930s (Miller 1957, Ihssen *et al.* 1992) and their subsequent proliferation severely disrupted native fish communities in Lakes Michigan and Huron (O'Gorman and Stewart 1998).

In this paper the chronology of the blueback herring’s range expansion through the Erie Canal to Lake Ontario is documented. To evaluate the potential for the establishment of blueback herring in the Great Lakes, the life history of the blueback herring is briefly compared with that of alewives.

METHODS

Description of Study Areas

The Mohawk-Hudson River watershed in the Atlantic drainage is linked to the Oneida-Oswego River watershed in the Great Lakes drainage via the Erie Canal (Fig. 1). The Erie Canal opened in 1819, was widened and deepened in the mid-1800s, and reconstructed in the early 1900s to utilize existing waterbodies. The Mohawk River joins the Hudson River 0.4 m above sea level and 246.5 km from the Atlantic Ocean. Until completion of the Erie Canal, Cohoes Falls on the Mohawk River, just above the confluence with the Hudson River, restricted upstream passage of anadromous fish.

![FIG. 1. The Erie Canal and Mohawk River connecting Oneida Lake to the Hudson River and the Oswego-Oneida rivers connecting Oneida Lake to Lake Ontario. The confluence of the Oswego River and Lake Ontario is located at 43°28′(N) and 76°31′(W).](image-url)
The section of the Erie Canal which connects the Atlantic and Great Lakes drainages is near Rome, New York and bordered by lock 20 on the east and lock 21 on the west (Fig. 1). This section (hereinafter called the Rome section of the Erie Canal) is 128 m above sea level, 29.5 km long, and 168.5 km from the confluence of the Mohawk and Hudson rivers. Direction of water flow in this section of the canal can be either toward the Atlantic drainage or toward the Great Lakes drainage depending largely on operation of the locks. From lock 21, the canal drops 15.3 m in 9 km to enter Oneida Lake, a shallow (mean depth 6.8 m) eutrophic lake with a surface area of 20,700 ha. Oneida Lake drains into Lake Ontario through the Oneida-Oswego rivers, a distance of about 56 km and a vertical drop of 36 m. Locks and dams (some equipped for hydroelectric generation) on the Oneida-Oswego rivers allow vessels to navigate between Oneida Lake and Lake Ontario.

Collection Methods
Blueback herring were collected in the upper Mohawk River, Oneida Lake, Oswego River, and Lake Ontario using a variety of methods. In the Mohawk River, blueback herring were captured by angling and electrofishing and with scap nets, gill nets, and minnow seines. In Oneida Lake, fish were captured with bottom trawls and vertical gill nets. In the Oswego River, blueback herring were captured with draft-tube sampling nets in the outflow of water from three of the five units of a hydroelectric generating station located near Minetto, about 10 km upstream from Lake Ontario. The draft-tube nets, equipped with 6-mm mesh, stretch measure, cod ends, had the capacity to sample 60% of the total volume of water exiting the powerhouse and were fished from April 1994 to April 1995. In Lake Ontario, blueback herring were caught with a bottom trawl equipped with a 9-mm mesh, stretch measure, cod end.

RESULTS AND DISCUSSION
Chronology of Invasion
Anadromous blueback herring run up the Hudson River from the Atlantic Ocean in spring to spawn in various tributaries. Blueback herring were first reported from the lower Mohawk River in 1934 (Greeley 1935) and then again in the late 1960s and early 1970s (McBride 1985, Smith 1985). Blueback herring were first reported from the upper Mohawk (above Little Falls, New York) at the confluence of West Canada Creek near Herkimer in 1978 (Fig. 1). In 1981, blueback herring, presumed to be spawning, were caught farther upstream in the lower reaches of Nine Mile Creek, a stream which flows into the Rome section of the Erie Canal. During 1981 to 1984 spawning runs in the upper Mohawk River were sporadic, but after 1984 spawning blue-back herring were regularly captured, 220 to 280 mm in total length and 3 to 6 years of age (N > 300), during late May to early June. Based on catches with minnow seines and cast nets, most young-of-year (YOY) blueback herring abandon the area above Little Falls during September to early November. Outmigration of YOY in autumn is associated with declining water temperatures and major precipitation events.

Prior to the mid 1970s degraded water quality likely prevented expansion of blueback herring spawning runs to the upper Mohawk River. Dissolved oxygen (DO) readings were zero in 1912 near Utica, and DO levels remained lethal for fish through the 1940s and into the early 1950s (Anonymous 1952). Water quality in the upper Mohawk River began to improve in the mid-1970s and it continued to improve through the mid 1980s. At a long-term monitoring station near Utica, DO (% saturation) in the Mohawk River was often " 25% during 1965 to 1973, rarely " 25% but often " 50% during 1974 to 1982, and never " 25% and rarely " 50% during 1983 to 1988 (Anonymous 1995). During 1989 to 1993, DO levels "75% were not recorded.

The first record of blueback herring in Oneida Lake is that of a single juvenile fish caught in 1982. Two juveniles were caught in 1983 to 1984 and ten were caught with bottom trawls during 1989 to 1995. In vertical gill nets, juvenile blueback herring were consistently captured during 1995 to 1997 (1995, N = 23; 1996, N = 18; and 1997, N = 33). The timing of the appearance and increase in numbers of juvenile blueback herring in Oneida Lake is consistent with the westward progression and increasing frequency of spawning runs in the upper Mohawk River. The first record of adult blueback herring in Oneida Lake was in 1994 (Scheurell 1996).

In the Oswego River, 9,147 blueback herring (99% juveniles < 175 mm total length) were first captured with draft-tube nets at a hydroelectric power station near Minetto in 1994,
mostly during November, just 10 km upstream from the confluence with Lake Ontario. It was estimated that 345,000 blueback herring, nearly all juveniles, passed through this power station in November 1994 (Niagara Mohawk Power Corporation 1995). A few juvenile blueback herring evidently overwintered in the Oswego River or Oneida Lake as two were caught at Minetto in March, 1995.

In October 1995, two juvenile blueback herring were captured (151 and 154 mm) in Lake Ontario near Oswego. Anadromous blueback herring spawning in Nine Mile Creek which empties into the Rome section of the Erie Canal, straddling the Great Lakes and Atlantic drainages, is the likely source of recruitment to Lake Ontario. Furthermore, it is likely that blueback herring were in Lake Ontario for years before they were detected because adults have been spawning annually in the upper Mohawk River since 1985 and because juveniles were routinely captured in Oneida Lake in the 1990s. Detection of a small population of blueback herring in Lake Ontario would be difficult because of the size of the lake relative to the area routinely sampled. For example, in October 1995, blueback herring were first captured, the bottom trawls swept a total of 38 ha in the 1,947,700 ha lake. Also making detection of a small population difficult is the combination of superficial similarity of blueback herring to alewife (see below) and the large survey catches of alewives, the most abundant clupeid in the lake. To illustrate, in spring 1994, during a routine bottom trawl survey, about 34,000 adult alewives were caught in southeastern Lake Ontario alone. Only a small fraction of the adults were examined closely so a catch of 10s, or even 100s of blueback herring could easily go unnoticed.

**BLUEBACK HERRING AND ALEWIVES:**

**LIFE HISTORY AND BIOLOGY**

**Distinguishing Characteristics**

There are few characteristics which can be used to distinguish blueback herring from alewives. Externally, alewives have a larger eye and greater body depth; internally, color of the peritoneal lining is probably the most reliable distinguishing characteristic, black to sooty in blueback herring and pearly to white, sometimes with gray flecks, in alewives (Bigelow and Schroeder 1953, Leim and Scott 1966, Scott and Crossman 1973).

**Distribution:**

**Geographic, Bathymetric, and Bathythermal**

Both blueback herring and alewives are found off the Atlantic coast from South Carolina to the Maritime provinces of Canada; however, alewives range farther north to Newfoundland, whereas blue-back herring range farther south to Florida (Bigelow and Schroeder 1953, Winters et al. 1973, Neves 1981, Stone and Jessop 1992). Alewives have colonized many freshwater systems from Virginia to the Great Lakes and up to New England and the Maritimes (Scott and Crossman 1973, Smith 1985, Loesch 1987), whereas blueback herring have only colonized a few freshwater systems in the South (Prince and Barwick 1981, Guest and Drenner 1991). In the Atlantic Ocean, from Cape Hatteras to Nova Scotia, Neves (1981) found blue-back herring mostly at depths of 27 to 55 m and alewives mostly at depths of 56 to 110 m. The range of temperatures occupied by both species is similar, 3 to 17°C (blueback herring have also been caught at 2°C), and they are most commonly found at 4 to 11°C (Neves 1981, Stone and Jessop 1992).

**Spawning and Food Habits**

Blueback herring generally enter rivers to spawn one to two weeks later than alewives and consequently spawn at temperatures about 5°C higher (Loesch and Lund 1977, Messieh 1977). Anadromous blueback herring generally spawn in deeper, faster moving water over harder substrate than alewives, but in more southern waters where alewives are less abundant or absent, bluebacks will spawn in lentic waters (Loesch 1987). Among landlocked populations, blueback herring appear to spawn successfully in embayments of the Jocassee Reservoir, South Carolina (H. Barwick, Duke Power Company, personal communication) where riverine habitat is minimal. They also reproduce in Lake Theo, a reservoir in Texas with no tributaries (J. Kraai, Texas Parks and Wildlife, personal communication). Fecundity is similar among anadromous blueback herring (30,000 to 400,000 eggs) and alewife (100,000...
to 467,000), but varies with length, slightly higher for blueback herring (Jessop 1993), and age, slightly higher for alewife, (Loesch 1987) because for a given age, alewives are slightly longer (Mullen et al. 1986).

Both blueback herring and alewives can filter and particulate feed, but blueback herring are apparently more effective at filter feeding (Janssen 1976, 1978, 1982; Neves 1981; Stone and Daborn 1987) because their gillrakers are closer together (Hildebrand 1963) which may give them a competitive advantage over alewives (Svardson 1976). In the ocean, alewives eat more benthic organisms than do blueback herring (Stone and Daborn 1987) but this may simply reflect the deeper depth distribution of alewives; and their larger eye may be a morphological adaptation that allows them to feed at lower light levels (Neves 1981, Jessop 1990). There is some indication of spatial and temporal segregation when feeding (Neves 1981), but there is also overlap in the diet and feeding repertoire, especially among juveniles of both species (Loesch 1987). Landlocked populations of blueback herring (Davis and Foltz 1991, Guest and Drenner 1991) and alewives (Wells 1970, Hutchinson 1971, Kohler and Ney 1980, Brandt et al. 1987, O’Gorman et al. 1991, Krueger et al. 1995) will generally feed on the largest zooplankton available and both will feed on larval fish.

**POTENTIAL FOR COLONIZATION AND ECOLOGICAL CONSEQUENCES**

It is possible that blueback herring have the potential to colonize Lake Ontario because their life history is similar to alewives, a sympatric species that has established reproducing populations in all of the Great Lakes (O’Gorman and Stewart 1998) and because Lake Ontario is apparently receiving juvenile blueback herring annually, via Oneida Lake and Oneida-Oswego rivers, from spawning by anadromous adults in the upper Mohawk River. However, at present, blueback herring face numerous obstacles to forming a sizable population in Lake Ontario. One obstacle is competition for food and space from a dominant alewife population. Alewives are so abundant in Lake Ontario that they structure the zooplankton community (Johannsson and O’Gorman 1991, Johannsson et al. 1991) and grow slowly (O’Gorman et al. 1997). Thus, food resources for pelagic planktivores would seem scarce in Lake Ontario. The key changes that allowed alewives to proliferate in the Great Lakes appears to have been the decline of Atlantic salmon (*Salmo salar*) in Lake Ontario and the collapse of lake trout (*Salvelinus namaycush*) in Lakes Huron and Michigan (Miller 1957, Smith 1970). But piscivorous fishes are now so abundant in Lake Ontario that they place a heavy demand on alewives (Jones et al. 1993) and continued stocking of hatchery-reared salmonids will maintain that demand. Colonizing a lake with a surfeit of piscivores will be difficult. Despite the belief that blueback herring have the potential to establish in Lake Ontario, there is some evidence that blueback herring can not colonize northern latitude lakes. In 1978, juvenile blueback herring were first captured in Lake Champlain (Plosila and LaBar 1981), a large dimictic lake, which is connected to the upper Hudson River by the Champlain canal. Juveniles continued to be captured into the 1990s (L. Durfrey, New York Department of Environmental Conservation, and B. Chipman, Vermont Fish and Wildlife Department, personal communications) and, as mature blueback herring were not present in Lake Champlain, juveniles were thought to originate from spawning by anadromous blueback herring in the upper Hudson River. Water temperatures in Lake Champlain would be much lower in winter than in those water-bodies in the southern United States where blue-back herring are reproducing and this alone may account for the apparent failure of blueback herring to form a detectable reproducing population in Lake Champlain. Alewives in the Great Lakes sometimes suffer mass mortalities from cold water in severe winters (O’Gorman and Schneider 1986, Bergstedt and O’Gorman 1989) and they have failed to establish large populations in Lake Superior, the coldest of the Great Lakes (Bronte et al. 1991). As noted in the Atlantic Ocean the distribution of alewives extends farther northward than that of blueback herring suggesting that alewives may be more tolerant of cold temperatures than blueback herring. Nevertheless, a few age-1 blueback herring were captured in the Oswego River at the Minetto power station in March 1995 demonstrating that blueback herring can overwinter in fresh water at northern latitudes.

Although colonization of Lake Ontario by blue-back herring is problematic, the consequences of colonization of the Great Lakes by another plank-tivorous alosid are not—additional size-selective predation on zooplankton, increased predation on larvae and juveniles of important indigenous fishes like lake trout, and, if blueback herring have levels of thiaminase similar to that of alewife (Fisher et al. 1996), reduced viability of the offspring of lake trout that eat them
due to thiamine deficiency (Fitzsimons 1995). Spawning by anadromous blue-back herring in Nine Mile Creek, 430 km from the Atlantic Ocean, demonstrates that mature bluebacks will use navigation canals to move long distances upstream and suggests that they could easily access the other Great Lakes from Lake Ontario via the Welland Canal. Finally, even if blueback herring fail to establish in Lake Ontario, the occurrence of juveniles in the lake is clear evidence that an old pathway, the Erie Canal, has been reopened for exotic aquatic organisms to enter the Great Lakes watershed, apparently due to an improvement of water quality.

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