New England Proper
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Dr. David B. Halliwell, Maine Department of Environmental Protection
(david.halliwell@maine.gov,happyh1949@gmail.com)
Maps by Arlene Olivero, The Nature Conservancy (arlene_olivero@tnc.org)










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Preface – Readers should be aware that the author of this treatise is originally from "down south" …a small *island* 'off' the coast of *Connecticut*…that would be the state of *Rhode Island*! Ten years (1967-1977) spent at the *University of Rhode Island* in Kingston (B.S., M.S. and two years post-graduate teaching *Wildlife Populations*), followed by 13 years (1977-1991) with the *Massachusetts Division of Fish & Wildlife*, including a Ph.D. in Fisheries Biology from the *University of Massachusetts*, Amherst in 1989, 28 years (1991-2019) in *Maine* (*US-EPA/FWS EMAP Northeast Lakes*, 20 years (1999-2019) with the *Maine Department of Environmental Protection (Division of Environmental Assessment*), all of which has provided me with a professional career perspective on the New England 'proper' region of the United States, with a directed interest on the natural history of resident fishes – particularly native freshwater and diadromous indigenous fish species and naturally occurring indigenous fish assemblages.

The author also has a comprehensive working knowledge of *Connecticut*, *Vermont* and *New Hampshire* resident fishes and natural history, through regional research projects in addition to the *EMAP-SW Northeast Lakes* project (development of *Indices of Biotic Integrity*, *Bio-Condition Gradient*, *US-EPA Ecoregion* development and more recent northeastern regional stream and lake classification initiatives with *The Nature Conservancy*) in addition to 15+ years of teaching early summer week-long and/or fall weekend NE-FISH seminars and presentations at the *Eagle Hill Institute* in Steuben, *Maine* (inclusive of 20+ years as guest editorship for the *Northeastern Naturalist*).

I dedicate this life-time work to my dearly departed mother ***Doris May Bishop***, who, on my sixth birthday (circa 1955), purchased a sectional cane fish pole with *S&H green stamps* and showed me how to bait a hook with backyard worms to catch 'sunfish & horned pout' at *Olney Pond* in Lincoln Woods, *Rhode Island*. I thank my two lovely children, *Benjamin* & *Briana* <u>*Davies Halliwell*</u> and ex-spouse *Susan Price Davies* for sharing the fishes and for lending their Maine support over the past several decades. A very special thanks to *Dick Byers* (*Dick's Sport & Hobby Shop*) & *Willis Goodwin* (ex-brother-in-law) for teaching me how to angle fishes and fly-fish respectively, when I was growing up across the street from *Spectacle ('Specs') Pond* in the Fairlawn-Lincoln section of Pawtucket, *Rhode Island*.

***New England (Proper)** – Connecticut River drainage east to the Gulf of Maine, <u>exclusive</u> of the Hudson-Hoosic (HH in *VT* & *MA*) and Lake Champlain (LC), St. Francois (SF) & Lake Memphremagog (LM) drainages within the state of *Vermont*. (Halliwell et al. 1999, pg. 314)

Acknowledgments – My sincere thanks to my following friends and colleagues, listed (more or less) in chronological fashion: Bob Seaton, Rick Enser, Ray Hand, Walt Gould (d.), Jim Brown, Frank Golet, Charlie McKiel, Bill Johnston, Jim Parkhurst, Rich Tomsyck, Jerry Taber, Art Screpitis (d.), Warren Kimball, Brian (Kinky) Friedman, Bob Maietta, Greg DeCesares, Nancy Hebert-Stoll, Deb Rudis, Brandon Kulik, Chris Yoder; Maine DEP: Matt Scott, Dave Courtemanch, Linda Bacon, Josh Royte (Maine *TNC*), Barry Mower, Bill Woodward, Rich Baker, Roy Bouchard, John McPhedran, Don Witherill, Jeff Dennis, Leon Tsomides, Melissa Evers, Mary-Ellen Dennis, Mark Holden, Bill Noble, Tom Danielson, Doug Suitor, John Reynolds, Joe Glowa, Karen Hahnel, Becky Schaffner, Josh Noll, Joerg-Henner Lotze (Director – *Eagle Hill Institute* in Steuben, Maine) and pre-contact archaeologists Art Spiess (*Maine HPC*) and Julia Clark (formerly with the *Abbe Museum* in Bar Harbor, Maine).

This compilation and synthesis of the past and present-day distribution of the inland fishes of ***New England proper*** would not have been possible without the valuable recent and past contributions of state-federal and provincial fisheries biologists and ichthyologists throughout the northeastern United States and Atlantic Maritimes of **Canada**, including: **NB** – Allen Curry & Mark Gautreau; **NY** – Bob Schmidt, Bob Daniels, Mark Bain (d.), Doug Carlson, Neil Ringler & Bob Werner; **NJ** – Jim Kurtenbach; **MA** – Karsten Hartel, Doug Smith, Peter Oatis (d.), Jack Finn, Henry Booke, Paul Godfrey, Boyd Kynard; **CT** – Walt Whitworth (d.), Bob Jacobs, Neal Hagstrom, Mike Beauchene, Michael Humphreys; **VT** – Rich Langdon; **RI** – Alan Libby & Bill Krueger (d.); **NH** – David Neils, John Magee, Matt Carpenter & Dianne Timmins; **ME** – Merry Gallagher, Dave Boucher (d.), Kendall Warner (d.), Jeremiah Wood, James Pellerin, Frank Frost, Francis Brautigam, Mike Kinnison, Nate Gray, Gail Wippelhauser, Dave Potter, Fred Kircheis & Ed Baum; **New England** – Arlene Olivero & Mark Anderson (*TNC* Boston - a special thanks for the excellent updated preparation of revised HUC-8 *NatureServe* Maps for New England proper, thanks to *NatureServe* data manager Margaret Ormes), **U-Maine graduate students** Tara Trinko-Lake, Kristin Ditzler-Strock & Quenton Tuckett; **EMAP-SW** (US-EPA, Corvallis, OR) – Bob Hughes, Thom Whittier & Phil Kaufmann.

The following treatise takes into consideration only those fish species that naturally occur within the freshwaters of New England proper – probably like fish assemblages present during *Pre-Contact/Pre-Columbian* times when *Native Peoples* seasonally harvested resident fish species (Spiess & Halliwell 2011, revised 2012). When the early invasive European settlers landed on America's eastern shores in the early 1600's, most new communities did their best to accomplish two things: "they built a church and damned up the river" (Walker & West 2017). The consequences of these two actions were equally destructive to both the livelihood and spiritual wellness of the *Native Peoples* of New England proper. While blocking the flow of rivers and streams made it possible to power up their mills, the dams also shut off the natural migratory journey of diadromous fishes, inclusive of river herring, shad, eel, lamprey, sturgeon, smelt and other fish species that spend most of their life in the ocean, but must return to freshwater rivers to successfully spawn (Poff et al. 1997, Holcomb et al. 2016, Cooper et al. 2017, Walker & West 2017).

Pre-Contact Native Peoples and Fish Harvest Opportunities in New England

Circa 4,500 years past – freshwater fish in the New England region are generally plentiful and relatively easy to catch. It is the spring of the year, when the sun shines, the snow melts and the clear waters glisten. The native peoples are strong and healthy, but are now often feeling hunger pains, having mostly consumed their over-winter supply of native indigenous fish and wildlife foodstuffs (Spiess & Lewis 2001).

It is time for native peoples to gather during the springtime at the multitude of natural waterfalls on New England coastal rivers (e.g., *Great Falls* on the Kennebec River in town of Dresden, *Maine*) and larger streams (e.g., *Benton Falls* on the Sebasticook River and *Stone Brook Falls* on the northwest side of Augusta in central *Maine*) to harvest the abundant runs of ascending river herring, shad, sturgeon, *salmon*, striped bass, eel and sea lamprey (aka lamprey eels '*Seguap Squ Hm*,' Alger **1897**).

"*There occur many pools in these rivers, in which the salmon play after having ascended, which they have trouble doing because of the natural falls which are found there. There are places where the water falls from eight, ten, twelve, and fifteen feet in height, up which the salmon ascends. They dart into the waterfall and with five or six strokes of the tail they get up. To these places the (native peoples) went at night with their canoes and their torches*." (Denys River, Maine, early **1600**'s, in Anderson & Brimer 1976).

They also may have traveled inland through streamside woods to capture brook trout, suckers and possibly nesting fallfish in the smaller rivers and streams and lake trout (togue) or freshwater cod (burbot/cusk) and whitefish – found to be naturally residing in large northern New England cold water lakes and ponds (Spiess & Halliwell 2011, revised 2012).

Through the heat of the summer, native peoples may have concentrated their efforts while fishing from dugout canoes in the coastal bays and open sea, stockpiling catches of swordfish, cod, marine sculpin and various flounder species. Non-migratory tomcod and (white) perch and migratory eels and smelt were traditionally captured in simply made fishing weirs set in coastal river estuaries (Spiess & Lewis 2001, Prins & McBride 2007).

In the fall of the year, when the leaves drop, long before the winter freeze, the native peoples possibly turned to numerous inland warm water lakes and ponds where they may have captured native pickerel, sunfish, yellow perch, and bullhead - fishing with spears and possibly harpoons (Anderson & Brimer 1976) along the shorelines or from their birch bark canoes. Fish were then cooked in the open air on fire hearths and then dried in the hot sun to preserve their storage value for extended periods of time, particularly through the winter months.

During the winter time, fish could have also been captured from beneath the ice by native peoples. However, the bulk of their fish supply was probably harvested from spring, through the summer and fall months. All tribal members may have contributed to the capture of fish, including women and children, who may have harvested large numbers of inland fish (and turtles) while the men may have spent more of their time hunting larger mammals (including beaver, black bear, moose, white-tailed deer and the now extinct *Sea Mink*) coastal seabirds (such as various resident ducks, geese and the now extinct *Great Auk*) and upland game birds (including turkey, grouse, woodcock and the now extinct *Passenger Pigeon* and *Heath Hen*).

In contrast to the current multitude of resident freshwater fish, comprised of both native and introduced species, the diversity of fish species during pre-contact times were relatively limited – particularly fish species that were of a *desirable size and abundance* to be worth the effort to spend the time to catch. Only a single minnow would possibly qualify – the considerably larger ***Fallfish***; and *single* species of bullhead (*horned pout*), pickerel, true (yellow) perch, eel, lamprey, freshwater (burbot) and estuarine (tomcod) codfish; *two* species of sturgeon (Atlantic & shortnose), suckers (white & longnose), whitefish (lake & round), temperate basses (striped & white perch), and sunfish (redbreast & pumpkinseed); *three* Alosids (alewife, blueback herring & shad); and *four* salmonids (brook & lake trout, Arctic char & Atlantic salmon) – for a total of **25** desirable native indigenous freshwater fish species resident to New England proper freshwater environs (Spiess & Halliwell 2011, revised 2012).

The Reshaping of the New England Fish Fauna

New England (USA) is "knit together by a common topography of mountain spine, valley floor, and coastal plain" (Judd 2014) which closely corresponds with both (A) the topology of the continental United States (Rocky Mountains, Mississippi Valley and Atlantic Seaboard) and (B) with the defined naturally occurring 'fish faunal regions' in *Massachusetts* (and New England proper): (1) *Berkshire-Valley* (2) *Central-Uplands* and (3) *Coastal-Lowlands* (Halliwell 1989). Whittier et al. (1997) similarly found that three ichthyogeographic sub-regions effectively differentiated between lakes in the northeastern U.S. (New England Uplands, Coastal Lowlands Plateau and Adirondacks).

The New England geographical region can be further generally described as "a giant peninsula" bounded by the St. Lawrence River valley – northwest of *Maine*, Lake Champlain – west of *Vermont*, and the Gulf of Maine – east of *Maine*, *New Hampshire* and *Massachusetts* (Judd 2014, Cooper et al. 2017).

New England Fish Diversity and Biogeography – western and eastern fish fauna, including suspected Wisconsinan Pleistocene glacial refugia, hypothesized post-glacial drainage networks and probable fish dispersal sequence. Rahel (2007) historically recognized several biogeo-graphic barriers at increasing spatial scales, consisting of major waterfalls/cascades, drainage divides, mountain ranges and saline oceans. This hierarchy of barriers to the movement of fresh-water (fish) faunas has produced quite distinct aquatic biotas at larger drainage units (ibid).

Freshwater environments in the northeastern United States are inhabited by a limited number of resident fish species of various origins (Halliwell 1994). This distribution of fishes is ultimately governed by historical natural geologic events (glaciation) and human-induced events (dams/habitat disturbance and introductions). Approximately **158** and **82** fish species comprise the total faunal pool of fishes in *New York* and *New England* inland waters, respectively, inclusive of native and non-native/introduced species (see Appendix B).

In most lakes in New England proper, a maximum of only 10 to 15 fish species generally co-occur, and even less in wadeable streams (5 to 10). Possible origins of resident fish species include: (1) native resident (*indigenous*); (2) introduced resident (*naturalized*); (3) native non-residents (*transients* – habitat misfits); and (4) introduced non-resident (*stocked*) (Halliwell 1994, Halliwell et al. 1999).

In comparison with mid-western United States fish faunas, the New England region has a depauperate post-glacial freshwater fish fauna, particularly when excluding the Champlain and Hudson-Hoosic drainages in *Vermont* and *Massachusetts*. In New England proper, the minnow family is comprised of only 16 fish species, with an additional 8 minnow species native to the Lake Champlain drainage in *Vermont* (Appendix B) and an additional 19 minnow species native to the Great Lakes region (Hubbs & Lagler 1958).

McCabe (1948) recognized only **12** members of the minnow family recorded from western and central *Massachusetts* streams – a small number in comparison with **38** for the state of *Michigan* and more than **250** for *North America* (ibid). There are only **two** darter species native to New England proper (***Tessellated*** & ***Swamp***), while the Champlain drainage in *Vermont* has an additional **four** native darter species (Appendix B) and the Great Lakes region has an additional **twelve** darter species (Hubbs & Lagler 1958). The state of *Tennessee* alone contains **90** native darter species and *North American* streams in total contain upwards of **145** darter species (Helfman et al. 2000).

The distribution of the native fish fauna of New England proper, as elsewhere in the northeastern *United States* and *Canada*, can be explained by biogeographic theory considering postglacial history (Smith 1983). It is well known that the New England states, during the *Pleistocene* period were completely covered by at least one ice invasion (McCabe 1942) with ice “perhaps a mile thick” (Emerson 1917, Pielou 1979 & 1991). Any fishes which were present prior to the glacial invasion either perished or were forced southward into freshwater retreats (refugia) along coastal drainages (Figure 2).

Per Schmidt (1986), a biogeography should address questions involving both pattern and process, and ideally, the course of research should follow: (1) the analysis of distributions and discovery of patterns; (2) the development of hypotheses of the processes that produced the observed distributional patterns; and last – but not least, (3) the final testing of the hypotheses.

In terms of present day New England proper freshwater fish biogeography, it is important to recognize that post-glacial river drainage systems were no doubt very much different than what exists today (Cooper et al. 2017). Benner et al. (2009) realistically note that the timing of postglacial reinhabitation of New England waterways is a complicated problem. Confounding attempts to theoretically model post-glacial reinhabitation is a complex deglacial history of channel switching, lake impoundment and drainage events, in association with postglacial isostatic rebound (Schmidt 1986, Curry 2007). Past attempts to explain the distribution of native fish in New England proper have utilized various approaches, inclusive of analyzing the present-day geographical distribution of native fish and associated invertebrate populations and extrapolation, using geomorphological data, past refugial areas and hypothesized migration routes (ibid).

Per Schmidt & Whitworth (1979), "accurate post-glacial drainage patterns are traceable" due to "the unique characteristics of the glacier in (southern) New England." New England was covered with a minimum of 300 meters of ice from ca. 17,000 to 12,500 years ago, when the glacier began to recede, but not by a typical rapid melting process (ibid). Apparently, the glacier melted in a stagnant manner, from high (northern) to low (southern) elevations (ibid). Melt-water carried sediments were deposited on down-stream ice blocks providing insulation – hence, ice blocks in river valleys (terminal moraines) lasted for thousands of years. Reportedly, the Ronkonkoma ice block remained intact until the sea entered *Long Island Sound* ca. 3,500 years ago (ibid). The channels of the major post-glacial river systems are shown in Figure 2 (as modified from Schmidt & Whitworth 1979 and Benner et al. 2009).

Knowledge of present and past connections among drainage basins is important in understanding the current distributional patterns of fishes (Gilbert 1980, Hocutt & Wiley 1986, Hughes et al. 1987). With the recession of the ice, over 12,000 years ago, the glacial waters overflowed the preglacial routes, making many glacial lakes which formed an interlacing pattern of waterways between postglacial drainage systems in New England proper. Griffiths (2017) has concluded that "spatial trends in beta diversity and nestedness in freshwater fish, in both North America and Europe, result primarily from observed differences in postglacial recolonization opportunity across realms and in dispersal ability across species".

In the western *Massachusetts* Berkshire Mountains, it has been theorized that the glacial waters of the Housatonic and Hoosic river valley drainages were probably bridged via the (West Branch) of the Westfield River – where a low divide separates its headwaters from those of the Housatonic in the town of Washington (McCabe 1942). This "crossover connection" may be responsible for the occurrence of western fish species from the north (e.g., ***Northern Redbelly Dace, Lake Chub*** and ***Burbot***) which could follow glacial streams, bogs and flooded lakes linking the precursors of the upper Hudson and St. Lawrence basins to today's Connecticut River drainage and other areas of northern New England. Once into the upper headwaters of the Connecticut River, their route into *Massachusetts* would have been easily accomplished (Hartel et al. 2002).

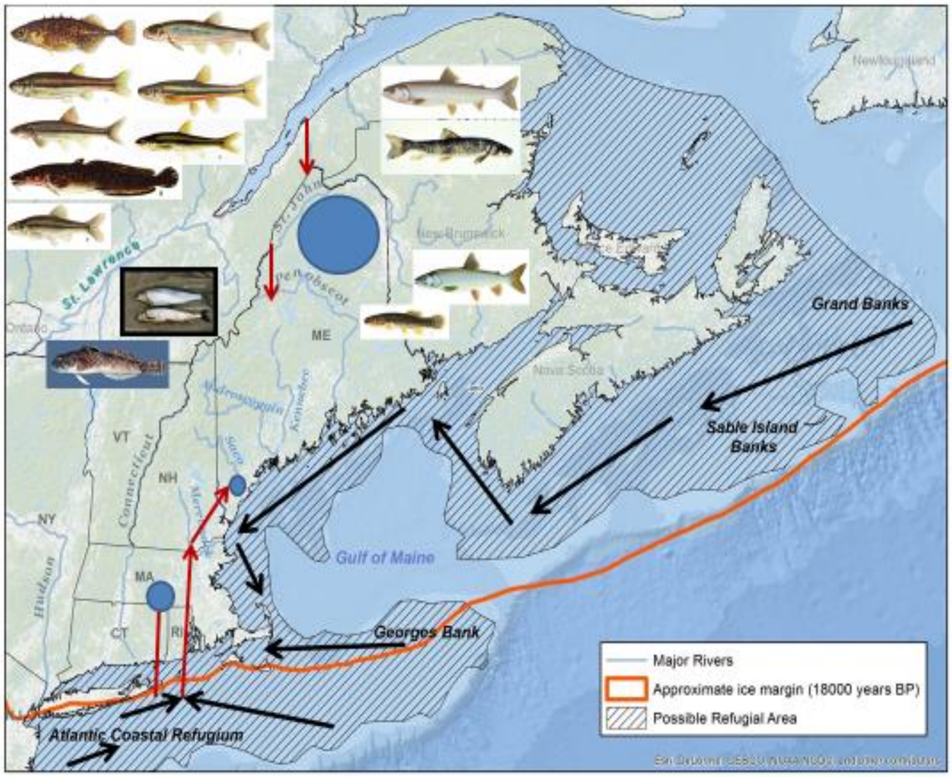
In central *Massachusetts*, a post-glacial connection may have existed between the Millers and Chicopee river systems near the Swift and Ware rivers – glacial lake areas (ibid). Similarly, the Merrimack (River) system in northeastern *Massachusetts* and southeastern *New Hampshire* may have been historically bridged with the Millers River via the ice blockage and overflow of the Conticook River in *New Hampshire*, just above Concord, *Massachusetts* (Wright 1911).

At least two major isostatic-rebound geological post-glacial changes should be highlighted. To the northwest, the St. John River is currently the international boundary between *New Brunswick* (Canada) and *Maine* (USA), but post-glacially is theorized to have been hydrologically connected (Figures x-x) with the St. Lawrence River (Bailey 1938 – pg. 150), Kite & Stuckenrath 1989, Rappol 1989, Curry 2007, Curry & Gautreau 2010). Following deglaciation, the St. John River initially flowed through the Madawaska Valley into Lac Temiscouata and from there drained towards the St. Lawrence Valley "differential isostatic rebound appears to have forced the river back into its original course" (Rappol 1989, pg. 192).

Figures x-x show a *Google-Earth* image of this former connection, as well as a possible 0.72-mile proximal connection between ***Lac du Dentiste*** (St. Lawrence drainage) and ***Lac Long*** (St. John drainage) in *Quebec* – approximately 20 ground miles distant. Figures x-x depict likely low-gradient watershed divides which may have historically connected the St. Lawrence river drainage with the upper St. John river drainage (Schaffner 2017).

Curry (2007) has hypothesized that the eastern (Canadian) provinces <u>and</u> state of *Maine* were not re-populated by fishes from the offshore (Atlantic Coastal) refugia. Rather, fishes re-invaded the east from the lower St. Lawrence River valley into northern Maine/Canadian drainage valleys from 11,000 to 12,000 years before present (ibid). When eventually breached, aquatic organism's residence to the Lake Madawaska watershed were probably able to completely disperse by 6,000 years before present (ibid).

It is quite apparent that northwestern *Maine* has an enriched assemblage of native coldwater fish species, primarily cyprinids, which do not generally occur to the south in New England proper (Bailey & Oliver 1939, Whittier et al. 1997, Curry & Gautreau 2010). There is strong evidence in support of a re-colonization origin for *Maine* from the upper Saint John River watershed via a postglacial connection with the St. Lawrence River (Curry 2007). The only plausible re-colonization route for *obligate freshwater fish* is from the Mississippian refuge southwest of present-day Ontario (ibid). ***Northern*** fishes probably moved down the St. Lawrence River valley (outflow to the northeast, possibly through the present-day Madawaska River valley), entering the <u>Atlantic Maritime Ecozone</u> through the present-day, *upper Saint John River* between 11,000-12,000 YBP (Curry & Gautreau 2010). This western connection may have served to enrich the freshwater fish fauna of northern *Maine* and *New Brunswick*, permitting northwestern fishes into New England and Atlantic Canada (ibid).



Secondarily, it is also hypothesized (Schmidt & Whitworth 1978, Schmidt 1986) that the Blackstone River drainage in *Massachusetts* and *Rhode Island* may have played an important role in fish species dispersal during post-glacial times, when the Atlantic Coastal Plain refugium south of Block Island was connected by 'a large tributary to the east', draining into Narragansett Bay in *Rhode Island*. This major south-flowing tributary (Figure 2) appears to have encompassed both the present-day Blackstone and Merrimack rivers – inclusive of the Nashua River drainage – from *New Hampshire*, through *Massachusetts* and *Rhode Island*. It is hypothesized that geologic warping (isostatic rebounding) in the area south of central *Massachusetts* eventually channeled the Merrimack River eastward into the *Gulf of Maine* (Veatch & Smith 1939, Schmidt 1986). Hence, the Merrimack River was historically exposed to <u>two</u> post-glacial dispersal routes, one along the southern Coastal Plain and the other through the *Gulf of Maine*, permitting the northward dispersion of not only the Coastal Plain fishes (Schmidt 1986): ***Banded Sunfish, Bridle Shiner, Swamp Darter, American Brook Lamprey, Redfin Pickerel*** and ***Eastern Creek Chubsucker***), but also possibly ***Blacknose*** and ***Longnose Dace*** (*Rhinichthys* species), as well as ***Tessellated Darter*** (Halliwell 1989a).

Historical Studies of the Freshwater Fish Fauna in New England Proper

In **1896**, Edward Knobel published a 40-page document listing *"The Freshwater Fishes of New England…and those ascending the streams from the sea,"* including **40** species – exclusive of only five minnows and five larger fish species – based on current assessments.

Based on the original **1908** listing by Warner C. Kendall, New England 'proper' native freshwater fishes total **49** species: comprised of *thirteen* minnows; *four* salmonids; *three* herring, suckers, stickleback and sunfish; *two* sturgeon, whitefish, pickerel, temperate bass, cod and darters; and a *single* lamprey, bullhead, eel, smelt, killifish, sculpin, perch and last, but not necessarily least, a diminutive coastal flatfish species – the ***Hogchoker*** (Table x). The native freshwater (non-parasitic) ***American Brook Lamprey*** was not listed in 1908 by Kendall – possibly being easily confused with the larval stage (ammocoetes) of the ***Sea Lamprey***.

The only non-native fish species included in Kendall's **1908** New England fish listing (Table 1) were the two black basses (***Largemouth*** and ***Smallmouth***). In the preface of his **1914** *"Fishes of Maine,"* Kendall states that "only one (non-native), the ***Smallmouth black bass***, has become sufficiently established to be admitted as a Maine fish." Accordingly, non-native ***Smallmouth Bass*** ranked **1st** (and ***Largemouth Bass*** 6th) in total overall fish abundance (see Appendix A Table 4) during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

In **1917**, Henry W. Fowler published his *"Notes on New England Fishes,"* inclusive of **34** fish species indigenous to New England freshwaters (Appendix A, Table 1).

Non-native fish species introduced by Europeans in the latter half of the 19th and through the 20th centuries include: three large minnows **(*Common Carp, Goldfish* & *European Rudd*); *Yellow Bullhead, White* & *Channel Catfish; Northern Pike* & *Muskellunge; Walleye; Largemouth, Smallmouth* & *Rock Bass, Bluegill, Green Sunfish, Black* & *White Crappie;*** and ***Brown*** & ***Rainbow Trout*** – which comprise a total of 18 non-native species introduced for sport fishing purposes (Halliwell 2005).

A pair of ***Northern Pike*** electrofished from the Kennebec River by Chris Yoder in Waterville, Maine (2010).

Per Belding (**1920**), on August 1, 1917, no less than 37 ***Brown Trout*** were taken by Deputy Peter J. Monahan from beneath Littleville Dam (Middle Branch of the Westfield River drainage, *MA*), weighing from 1 to 5.5 pounds, the largest was 27.5 inches long.

Reeve M. Bailey (*Iowa State College*, project biologist Earl E. Hoover **1938**), while conducting a comprehensive biological study of the Merrimack (River) watershed within *New Hampshire*, classified native resident fish species into the following types (Table x): northern types – four of which were only found to reside within the Androscoggin River (Gordon **1937**) drainage system (***Fathead Minnow, Lake Chub, Northern Redbelly & Finescale Dace***). These latter two daces were also found to occur in the Connecticut (River) watershed in *New Hampshire* during the following summer (Joseph R. Bailey & James A. Oliver – *University of Michigan*, project biologist Herbert E. Warfel **1939**). Notably, ***Brook Stickleback*** & ***Northern Pearl Dace*** were not collected. ***Blacknose Shiner*** was reportedly sampled from the Androscoggin, Saco and Coastal drainages in *New Hampshire* (Gordon **1937**), however they were later deemed to be mis-identified (Matthew Carpenter, NH-F&W, personal communication 2016); warmwater types – including fish species of general statewide distribution; eastern types – the ranges of which lie east of the Appalachian Mountains and inclusive of the New England coastal lowland group, except for the inclusion of non-native ***Margined Madtom*** and exclusion of the ***American Brook Lamprey*** – as listed by Scarola 1973); and lastly, diadromous types, exclusive of ***Blueback Herring, Shortnose Sturgeon*** and ***Striped Bass***.

Three additional fish species were only found to occur in the Connecticut (River) watershed in *New Hampshire*, including ***Eastern Silvery Minnow*** and ***Spottail Shiner*** – although Scarola (1973) reports its occurrence in the Merrimack River drainage system – and ***Tessellated Darter*** – which notably only "a few specimens have been found" in the Merrimack River drainage system in *Massachusetts*, however are common to the Blackstone River drainage and absent from northeastern drainages (Hartel et al. 2002).

Robert Rupp (1955a, 1955b) studied the ***Brook Trout*** fishery, water quality and fish assemblages of a tributary to the Penobscot River (coastal lowland Sunkhaze Stream in *Maine*) and reported no less than 16 resident species, only one of which (***Smallmouth Bass***) was a non-native fish species: ***White Sucker, Fallfish, Creek Chub, Blacknose*** & ***Northern Redbelly Dace, Golden*** & ***Common Shiners, American Eel, Ninespine Stickleback*** & ***Brook Trout***. ***Brown Bullhead, Chain Pickerel, Yellow Perch, Pumpkinseed*** & ***Redbreast Sunfish*** were all found to only inhabit the lower, warmwater sections of the stream, as greatly influenced by resident beaver (*Castor canadensis*). Halliwell (1989, pg. 120) also found that upland trout streams with warmwater habitats were usually associated with the presence of beavers and upland wetland habitats in Massachusetts wadeable streams.

The first comprehensive individual *statewide* surveys of New England freshwater fishes were published for: *Maine* (Williamson **1832**, Holmes **1862**, Kendall **1908** and **1914**, Cooper **1939-1942**, Cooper & Fuller **1945**, Fuller & Cooper **1946**, Everhart **1950**, and Maine DEP/DIF&W **2014-2016**, unpublished); *Connecticut* (Linsley **1844**, Deevey & Bishop **1941**, Behnke & Wetzel **1960**, Whitworth **1968** and **1996**, Jacobs & O'Donnell **2009**); *New Hampshire* (Gordon **1937**, Bailey **1938**, Bailey & Oliver **1939**, Scarola 1973); *Massachusetts* (Storer **1839**, McCabe **1942-**

1943, Mugford **1969**, Halliwell **1984**, Hartel **1994**, Hartel et al. **2002**), *Vermont* (Langdon et al. **2006**), and *Rhode Island* (Krueger, in August et al. **2001**, Libby **2013**). Yoder (**2008** and **2014**) and associates have been working on the development of a comprehensive fish assemblage assessment for *non-wadeable* larger rivers throughout New England (see Appendix A, Table 4).

To the author's knowledge, this present type of compilation and synthesis of existing historical records for the native freshwater fishes of New England proper, inclusive of biogeographical considerations (Jackson & Harvey 1989), has only been previously attempted, in part, for the "*The Fishes of Eastern New Hampshire*" (Gordon 1937), *Merrimack* (Bailey 1938), and *Connecticut* (Bailey & Oliver 1939) river watersheds in *New Hampshire*. Interestingly, this current effort, although independently researched, is quite similar ichthyologically to what was naturally found in these three major *New Hampshire* drainages, directly following the *Great Depression* and prior to the onset of *World War II*. Cooper & Fuller (1945) state that, "except for the possible rare occurrence of sunfish, the fish fauna of *Moosehead Lake* (in Maine) is noteworthy in the complete absence of the warm-water game fishes, particularly the pickerel, perches (yellow and white), and (black) basses (smallmouth and largemouth)." ***Yellow Perch*** were introduced to *Moosehead Lake* in the mid-1950s, ***Smallmouth Bass*** in the mid-1970s and ***White Perch*** in 1984 (Maine DIF&W 2003).

Following is a summary historical account of the ***Maine*** native freshwater fishes based on the **1939 – 1946** survey work of Cooper & Fuller, inclusive of rare fish occurrences. Note that these "studies primarily followed each watershed back into Maine's interior wilderness just as far as the streams and lakes are heavily fished" (Cooper 1939). Hence, the distribution of the native fish species inhabiting the northern St. John, Allagash, Aroostook, St. Croix, and upper Kennebec and Penobscot River drainages are not generally represented.

Sea Lamprey – found to historically occur at only a single occurrence record site in the Salmon Falls drainage in the southern part of the state (Atlantic coastal tributary).

Round Whitefish – was only recorded from Moosehead Lake (headwaters of Kennebec River drainage system.

Longnose Dace – historically limited in distribution to only a single location in the Salmon Falls (Atlantic coastal tributary) drainage system. (now historically extirpated)

Swamp Darter – the smallest and rarest of all New England freshwater fish were found to occur at only two sampling sites in the Piscataqua-Salmon Falls drainages and Atlantic tributaries, where they are now considered to be historically extirpated.

Lake Whitefish – found at three locales including Sebago Lake (Presumpscot River drainage), Moosehead Lake and the lower Androscoggin River drainage (South Pond).

Arctic Char – found at three locales, two in the Penobscot River drainage (Green Lake and Floods Pond) and one on Mt. Desert Island (Jordan Pond). Also known as Golden or Silver Trout, they are only truly native to Floods Pond in Otis (Fuller & Cooper 1946).

Blacknose Shiner – found to occur at only three sampling sites, two sites in the upper Androscoggin River drainage (Rangeley Lake and Dodge Pond Stream), and one site in the Union River coastal drainage system (Beech Hill Pond).

Longnose Sucker – found at four locales, two sites in the upper Androscoggin River drainage, one in the Presumpscot River drainage (Sebago Lake) and Moosehead Lake.

Fathead Minnow – found at four locales, three sites in the upper Androscoggin River drainage (Rangeley Lakes) and 1 site in the Allagash River drainage (Haymock Lake).

Finescale Dace – found at four locales, two sites in the upper Androscoggin River drainage (Rangeley Lakes) system (upper Richardson Lake and Beaver Brook), Moose-head Lake and one (along with ***Northern Redbelly Dace***) in the Maine north coastal system (Mixer Pond – Passadumkeag drainage system).

Northern Pearl Dace – historically limited in distribution to five occurrence sites, three in the upper Androscoggin River (Rangeley Lakes) drainage and one in the upper Kennebec River drainage (Moosehead Lake) and one in the Allagash River drainage (Haymock Lake).

Burbot – historically limited in distribution to five occurrence sites, three in the lower Androscoggin River drainage (Thompson Lake, Parker Pond, Flying Pond), upper Kennebec River drainage (Moosehead Lake) and the Allagash River drainage (Haymock Lake).

Slimy Sculpin – limited in distribution to six locales, including two each in the Saco (Union Falls and Little Ossipee Rivers) and upper Androscoggin River drainages (Little Magalloway River and South Bog Stream), Moosehead Lake and Haymock Lake.

Eastern Creek Chubsucker – limited in distribution to eight locales in southern Maine, two in the Salmon Falls coastal drainage, four in the lower Saco River drainage and two in the Presumpscot River drainage.

Bridle Shiner – found at ten locales in southern *Maine*, one in the Salmon Falls coastal drainage, five in the upper Saco River drainage and four in the Presumpscot River drainage. Historically extirpated from the southern *Maine/NH* Salmon Falls drainage.

The 12 most commonly captured native fishes (122 to 36 locales), per frequency of occurrence (total of 207 sampling locales – 1939 to 1946, *Maine* lakes only) were ***Pumpkinseed, White Sucker, Chain Pickerel, Yellow Perch, Golden Shiner, White Perch, Fallfish, Banded Killifish, Brown Bullhead, Redbreast Sunfish, Brook Trout*** and ***Common Shiner*** – hence, the primary emphasis of this early *Maine* fish survey was on sampling primarily coastal warmwater habitats – and/or heavily fished waters!

Probable Fish Refugia and Post-Glacial Dispersal Routes

The present native fish fauna of the northern Appalachians, inclusive of the New England area, is a result of dispersal from Pleistocene refugia as the Wisconsinan glacier receded and as sea-level rose – approximately 16,000 to 7,500 years ago (Schmidt 1986). The last retreat of ice began about 15,000 years ago, with ice leaving northern New England about 12,000 years ago, followed by a climatic optimum time of maximum warmth 6,000 to 4,000 years ago (ibid, Thomson 1977). Hence, relatively little time was available for the dispersal of primary division fresh-water-fishes – which have very low salinity tolerance (ibid, Myers 1949). The relative paucity (low diversity = depauperate nature) of fishes in the northern Appalachian region suggests that dispersal into this area was a difficult process, unavailable to many species. During the colonization of Ontario, Canada and New England, USA by fishes following the last Ice Age, the <u>coldwater</u> species (trout/salmon & sculpin) probably arrived first, followed by the <u>coolwater</u> species (e.g., perch & minnows), and finally the <u>warmwater</u> species (sunfish & bullhead) - (Holm et al. 2009).

Today, freshwater fish species distribution is generally limited by stream drainage patterns (Smith 1985, Halliwell 1989a) in that "primary (salt intolerant) fish species that are confined to headwaters are essentially island species" …as it is not possible for them to travel downstream through the saline ocean and back up into an adjacent river. Aside from human intervention, the primary means by which freshwater fish are naturally distributed between drainage systems is by the process of stream 'capture' and stream 'swamping.' ***Stream capture*** occurs when two streams flowing down opposite sides of a hill constantly erode their beds toward the topographic high point, with one stream intersecting the other and "capturing" the upper reaches of the second (along with resident fish assemblages). In contrast, ***stream swamping*** is a process by which the upper reaches of two streams which drain opposite sides of a lowland divide are joined during times of excessive high waters due to flooding events (Halliwell 1989a).

Northeastern Freshwater Fish Species Richness – the *New York* fish fauna has **141** native fish species, which is nearly twice as rich as that of the *Lake Champlain* drainage (*VT-West*) and nearly three times greater than the native freshwater fish fauna of *New Jersey* or *New England proper* (Table pg-14 and Figure 12.3 in Halliwell et al. 1999).

This treatise primarily focuses on the **56** indigenous freshwater fish natives to New England proper (Table 1 and Fish Distribution Maps 1-56). Introduced non-native freshwater fishes listed in **Appendix A** comprise an additional **26** freshwater fish species, inclusive of ***Rainbow Trout***/Salmon, originating from the pacific northwest (*Steelhead*) and ***Redear Sunfish***, originating from the southern United States and introduced into two ponds in *Vermont* proper

(Langdon et al. 2006). **Appendix B** provides a full listing of Lake Champlain (**33** native) and Great Lake (**54** native) fishes and **7** European exotic introductions (***Common Carp, Goldfish, Grass Carp, Brown Trout, Rudd, Tench*** and ***Ruffe***), for a total of **165** freshwater fish species currently found to inhabit the freshwaters of the northeastern United States (inclusive of *New York* – Kapuscinski et al. 2012, and the six *New England* states).

Fisheries biologist Brandon Kulik holding an exotic ***Common Carp*** electrofished from the Sebasticook River in Benton, south central Maine.

- ***The 56 native freshwater fishes of New England proper*** are placed into six biogeographical-based fish assemblage groups (see Appendix A, Table 2) including: **A. *Northern*** *(coldwater western) species* (n = 15); **B. *Common*** *(warmwater eastern) species* (n = 15); **C. *Coastal Plain*** *fish species* (n = 6); **D. *Anadromous*** and ***Catadromous (Diadromous)*** *migratory fish species* (n = 10); **E. *Estuarine*** *(non-migratory) species* (n = 4); and **F. *Uncommon*** or ***Miscellaneous*** freshwater fish species (n = 6).

- New England proper fish species distributional accounts are presented sequentially from *Connecticut* to *Rhode Island* to *Massachusetts* to *New Hampshire* to *Maine* to *Vermont*, reflecting interstate drainage systems and fish dispersal patterns (from east to west) following the glacial retreat, from southwestern *Connecticut* to northern *Maine*.

- Scientific nomenclature and progression of fish names within fish assemblage groups follows the 7th edition of the American Fisheries Society "*Common and Scientific Names of Fishes from the United States, Canada, and Mexico"* (Page et al. 2013). This listing closely follows the author's professional fish specimen reference/teaching collection.

- Native indigenous fish species naturally occur as assemblages of associated species having similar distributions and ecological requirements (Halliwell 1989a, Figure xx). The ordination method of *detrended correspondence analysis* (DCA) was originally used to effectively portray wadeable stream fish assemblages in *Massachusetts* (ibid). Although DCA does not force samples into discrete groups, as does cluster analysis, correspondence between spatial patterns in fish assemblages and habitat gradients can be inferred (ibid, Hughes et al. 1987, Jackson & Harvey 1989). Five fish assemblage – stream gradient groups were recognized, like the current distribution of native freshwater fishes in New England proper (Appendix A, Table 2).

- One end of the DCA gradient (Figure 1) is comprised of a northern coldwater assemblage of fishes (*juvenile salmonids*, ***Slimy Sculpin, Longnose Sucker …*** and ***Creek Chub***) and a second downstream assemblage comprised of *adult trout* in association with ***Blacknose*** and ***Longnose Dace***. A third fish assemblage is comprised of a cool-water fish assemblage, including ***Common Shiner, Fallfish, White Sucker, Redbreast Sunfish*** and ***Tessellated Darter***. A fourth, warm water fish assemblage included ***Golden Shiner, Brown Bullhead, Chain Pickerel, Pumpkinseed*** and ***Yellow Perch***. Finally, at the other end of the DCA gradient, the fifth group is a coastal lowland assemblage of fish inclusive of ***American Eel, Eastern Creek Chubsucker, Redfin Pickerel*** and ***Banded Sunfish. American Brook Lamprey, Bridle Shiner*** and ***Swamp Darter*** were also observed to be closely associated with this latter coastal fish assemblage group (Halliwell 1989a).

- Native fish distribution maps are based on Hydrological Unit Codes (HUC) at the level 8 resolution, following the original ***NatureServe*** coverage (TNC 2008), as modified for New England 'proper' drainage systems. This approach is, no doubt, problematic in the accurate portrayal for depicting the current distribution of migratory diadromous species. Such species are primarily limited to coastal drainages and can be found inland within any HUC8 to an extent offering open access and suitable spawning habitat.

New England Proper Native Fish Group Assemblages

Group A-1 to **A-15** **Eastern** fish assemblage include the following commonly encountered widespread native warm and coolwater fish species: ***Golden Shiner, Common Shiner, Blacknose Dace, Longnose Dace, Creek Chub, Fallfish, White Sucker, Brown Bullhead, Chain Pickerel, Banded Killifish, Ninespine Stickleback, Redbreast Sunfish, Pumpkinseed, Yellow Perch*** and ***Tessellated Darter***.

The most direct and probable post-glacial re-invasion route for **Group A Eastern** fishes is from the Northeastern (Atlantic) Coastal refuge, located in the vicinity of present-day Cape Cod, *Massachusetts* (Curry 2007). However, the inshore waters forming the *Gulf of Maine* were saline, therefore presenting a barrier for obligate freshwater fish (ibid). Per Schmidt (1986), no obligate freshwater fish from the Atlantic Coastal refugium are found east of the Connecticut River drainage (i.e. ***Longnose Sucker*** & ***Creek Chub*** in *Massachusetts* and ***Creek Chub*** in *Connecticut*). It is hypothesized that several of these primary fish species could disperse north to varying degrees of success, via the north/south hydrologic connection between the post-glacial Merrimack, Nashua and Blackstone river drainages (e.g., ***Blacknose*** & ***Longnose Dace***).

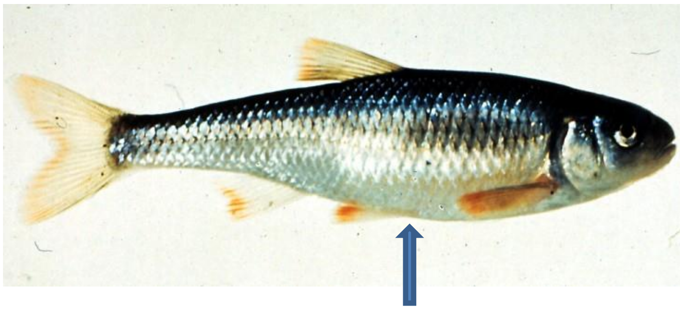
The great majority of these warm/coolwater eastern (northeastern coastal) native fishes are commonly found to occur within all six New England states (Table 1), except for ***Tessellated Darter*** (absent in *Maine* and eastern *New Hampshire*), ***Longnose Sucker*** & ***Creek Chub*** (absent in *Rhode Island* and eastern drainages in *Connecticut*, *Massachusetts* and *New Hampshire*). ***Longnose Dace*** are rarely found to occur in *Maine* and ***Redbreast Sunfish*** are rare to eastern *Vermont* drainage systems (absent from Ontario). ***Chain Pickerel*** (and probably ***Brown Bullhead, Yellow Perch*** and ***Golden Shiner***) are indigenous to the Kennebec River and southern drainages in *Maine*. ***Banded Killifish*** have a patchy distribution in freshwaters throughout New England proper, which may simply reflect non-beach daytime historical sampling collection methods.

A-1 Golden Shiner (*Notemigonus crysoleucas*) aka '*pond shiner*' **Map 1**

Most closely resembles (introduced European ***Rudd***) and the ***Common Shiner*** – but latter does not have an upturned, pointed mouth. Key Identification characteristics: decurved lateral line; 9-12 scales dorsally above lateral line (7-8 in ***Rudd***); naked keel between pelvic fin and vent (scaled in ***Rudd***); adults smaller and typically golden, without reddish fins all over (dorsal and caudal in ***Rudd***); large eye and up-turned pointed mouth. ***Golden Shiner*** lay adhesive eggs that stick to stands of aquatic vegetation, laying thousands of eggs multiple times during the growing season (NH-F&G 2016). ***Golden Shiner*** are capable of both filter feeding and catching small invertebrates and fish (ibid).

Golden Shiner are a ubiquitous species which has been introduced through the bait trade throughout *New England proper*, including northern *Maine* (St. John, Allagash, Dead and Meduxnekeag river drainages). In contrast to northern lakes, cyprinids are generally sparse and/or absent to most southern New England warmer and more developed lakeshores, where the ubiquitous non-indigenous native baitfish minnow ***Golden Shiner*** is often the dominant forage fish species present (e.g., *East Pond*, headwater Belgrade Lakes, Oakland-Smithfield, *Maine*). Widespread introductions of ***Golden Shiner*** may have reduced the diversity of minnow species in lake and pond habitat throughout the *Northeastern United States* (Whittier et al. 1997, NH-F&G 2016). ***Golden Shiner*** were the **3rd** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2000) and ranked **12th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

A-2 Common Shiner (*Luxilus cornutus*) aka '*redfin shiner*' **Map 2**



Common Shiner most closely resembles ***Fallfish***, which are not as deep-bodied and have smaller scales and a longer snout, overhanging the mouth. Key identification characteristics: origin of dorsal fin directly over pelvic fin origin; nine anal fin rays (rarely 8 or 10); diamond-shaped, easily shed body scales; elevated lateral-line scales; banded olive-bronze horizontal stripes (top view, looking down into a bucket of swimming fish). Spawning occurs in late spring to early summer and are known to lay their eggs in the nests of other fish species (i.e., ***Fallfish***). Fins of mature males become reddish during spawning and their heads become covered with horny tubercles (NH-F&G 2016). Maximum lengths of 8 inches – 203 mm (Wick 2007).

Common Shiner are commonly found throughout *New England proper* and are sold commercially as "redfin shiners" in the baitfish trade. They are found to occur only in streams in *Rhode Island*, limited to the Blackstone, Thames and Pawcatuck River drainages (Libby 2013). ***Common Shiner*** can be considered a moderate-gradient, coolwater fish species in *Massachusetts* wadeable streams (Halliwell 1989) and in northern New England states. In *Maine*, ***Common Shiner*** are also found to reside in numerous larger coldwater lakes, conspecific with ***Brook Trout***, ***Creek Chub, Fallfish*** and ***Lake Chub*** (Whittier et al. 1997). ***Common Shiner*** was the **13th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2000) and ranked **9th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

A-3 Blacknose Dace (*Rhinichthys atratulus*) aka '*brook minnow*' **Map 3**

Most closely resembles the ***Longnose Dace***. Key identification characteristics: band of tissue connecting upper lip to snout; upper jaw non-protractile; snout length short, not projecting well beyond mouth (long, as in ***Longnose Dace***); eye and highest point of upper jaw at same level (well above in ***Longnose Dace***).

Blacknose Dace are primarily a commonly encountered stream fish species throughout New England proper. They may also be found in lakes near the mouths of tributary streams. Kraczkowski & Chernoff (2014) found large genetic differences between *R. atratulus* and *R. obtusus*, with the former (eastern ***Blacknose Dace***) inhabiting streams to the east of the Appalachian Mountains from Nova Scotia to *Virginia* and the latter (western ***Blacknose Dace***) inhabiting streams to the west of the Appalachians – to *Minnesota*, eastern *Nebraska* and north to *Manitoba, Canada* (ibid).

Blacknose and ***Longnose Dace*** (*Rhinichthys* spp.) are generally found to occur statewide in *Connecticut*, however, ***Longnose Dace*** are "oddly absent" from the Yantic River drainage and the upper Shetucket River drainage above Willimantic (Jacobs & O'Donnell 2009). Tipton et al. (2011) note that ca. 20,000 years ago, as the glaciers retreated, the hydrologic landscape changed dramatically creating waterways for fish dispersal, serving as "*the Gateway of New England*" and providing rapid access north following glacial retreat. They hypothesize that the earliest deglaciated region (modern-day *Connecticut*), was recolonized by ***Blacknose Dace*** via a single founding event by a single population from a single offshore refugium. In contrast, Curry & Gautreau (2010) suggest that the current natural distributions of many fish species are undoubtedly from more than a single refugium or source, including some commonly occurring fish species which are indigenous to freshwaters throughout New England proper (e.g., ***Common Shiner***, ***Blacknose Dace, Creek Chub, Fallfish, Brook Trout*** and ***White Sucker***).

Blacknose Dace in *Rhode Island* currently reside in only 14 locales (widely scattered streams) in several northwestern drainages of the state, conspecific in some streams with ***Longnose Dace*** (Libby 2013). They are both uncommonly found to occur in the *Rhode Island* portion of the Narragansett Bay drainage (personal communication, Alan Libby 2018).

Within *Massachusetts*, ***Blacknose Dace*** occur within only five streams tributary to the Merrimack River and four streams draining the Concord (Assabet) rivers system. These latter streams are aligned along the western drainage of the Assabet River near the adjacent Nashua River watershed (in which ***Blacknose Dace*** are commonly found to occur). Their distribution in the Merrimack and Assabet river systems may be due to the mixing of fish fauna via *stream swamping* (Halliwell 1989a, Hartel et al. 2002).

In *Massachusetts*, ***Longnose*** and ***Blacknose Dace*** share a common distribution in two-thirds of the state – absent from the eastern part of the state except historically in the Concord-Assabet River drainage and upland tributaries to the Nashua River, but rare in the lower Merrimack drainage. In *New Hampshire* and *Vermont*, ***Longnose*** and ***Blacknose Dace*** are found to occur in all major river drainages (Scarola 1973, Langdon et al. 2006). In *Maine*, ***Blacknose Dace*** are commonly found statewide, however, ***Longnose Dace*** are rarely found to occur in only one-half dozen lotic sites in the Androscoggin River drainage system (Maine DEP/DIF&W 2014-2016). ***Longnose Dace*** prefer larger and faster streams than ***Blacknose Dace*** and both *Rhinichthys* species, particularly ***Longnose Dace***, are rarely found to primarily inhabit lakes and ponds (Scarola 1973). ***Blacknose Dace***, unlike ***Longnose Dace***, are commonly found in lakes and ponds in and around the mouths of tributary streams.

Blacknose and ***Longnose Dace*** appear to have shared a south to northern river conduit (hydrologic connection between the Merrimack-Nashua and Concord-Assabet-Blackstone rivers) for eastern post-glacial dispersal. Based on their current distribution, ***Tessellated Darters*** may also have utilized this Blackstone-Concord-Nashua-Merrimack post-glacial hydrologic connection, like ***Blacknose*** and ***Longnose Dace***, in concert with the existing assemblage of coastal plain fishes.

Today, ***Blacknose Dace*** in Massachusetts occur from the Housatonic to the Blackstone drainage and north thru western portions of the Merrimack River drainage (Hartel et al. 2002). In the eastern portion of *Massachusetts*, ***Blacknose Dace*** are now found only in five streams tributary to the Merrimack River and in four streams in the Concord-Assabet River drainage (ibid). They ranked 21st in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

A-4 Longnose Dace (*Rhinichthys cataractae*) aka 'rapids fish' **Map 4**

Tom Danielson, Maine DEP 7-27-17, Bull Branch, Sunday River, Androscoggin Drainage

Most closely resembles the ***Blacknose dace***. Key identification characteristics: band of tissue connecting upper lip to snout; upper jaw non-protractile; snout length long, projecting well beyond mouth; eye well above highest point of upper jaw.

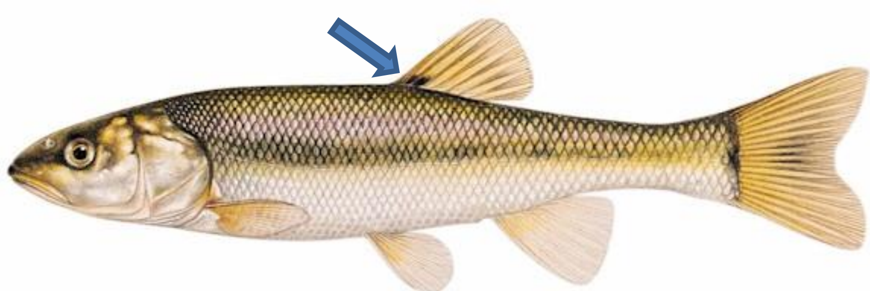
Longnose Dace are strictly a stream fish species which is frequently found to co-occur with ***Blacknose Dace*** (and exotic ***Margined Madtom***, *Noturus insignis*, in New Hampshire – NH-F&G 2016). In *Rhode Island*, ***Longnose Dace*** are widely distributed at 26 locales (gravelly stream riffles) in six northwestern drainages including the Pawcatuck, Thames, Hunt, Pawtuxet, Moshassuck and Blackstone rivers (Libby 2013).

Massachusetts populations of ***Blacknose*** and ***Longnose Dace*** are sympatric from the Housatonic to the Blackstone and north through portions of the Merrimack River drainage in northeastern *Massachusetts* – where they are primarily found in upland tributaries to the Nashua River. They are rarely found to occur in a single stream in Andover (1987) and known historically from the town of Lawrence (1897 record). It's occurrence in the Concord River drainage is based on historical records only (Hartel et al. 2002). ***Longnose Dace*** ranked **23rd** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

Longnose Dace may have been more common along the Merrimack River in *New Hampshire*, before industrial pollution and dams (Scarola 1973). Except for a single unconfirmed historical fishery record from headwaters of the upper Taunton River drainage, ***Longnose Dace*** (as well as ***Blacknose Dace***) are absent from all other eastern *Massachusetts* coastal drainages (Hartel et al. 2002). Scarola (1973) and NH-F&G (2016) report both ***Blacknose*** and ***Longnose Dace*** as being common to most/all major watersheds in *New Hampshire*, and note that the presence of ***Longnose Dace*** can be used as an indicator of healthy, free-flowing river systems.

Longnose Dace have an extremely wide distribution range throughout North America, except for northern *Maine*, Nova Scotia and Prince Edward Island in Canada (Scott & Crossman 1973). Also, historical reports of its occurrence in *New Brunswick* were shown to be unverified by Scott & Crossman 1959 (in Scott & Crossman 1973). Radforth (1944) has suggested an eastern postglacial refugium, as well as a Mississippi one. ***Longnose Dace*** absence from northern Maine would tend to support an eastern vs. western postglacial refugium.

A-5 Creek Chub (*Semotilus atromaculatus*) aka '*horned dace, brook chub'* Map 5



Most closely resemble ***Northern Pearl Dace*** and ***Fallfish***. Key identification characteristics: dark blotch at base of dorsal fin; flap-like maxillary barbel (***Fallfish***); juveniles with dark lateral band (***Fallfish***); crowded darker scales on anterior sides of body.

Creek Chub are a commonly encountered native freshwater fish species, often found in association with closely related ***Fallfish***, both of which display characteristic tubercles on the head during their late spring spawning season. They also both build gravel spawning mounds – considerably higher by ***Fallfish***, which are frequently utilized by ***Common Shiner*** and ***Blacknose Dace*** (Raney 1969). ***Creek Chub*** are quite unusual – they spawn in a vertical position, with both sexes "standing" on their tails while their eggs and sperm are extruded into the gravel nest (Wick 2007).

Creek Chub (and ***Slimy Sculpin***) are absent from Rhode Island and both are distributed mainly in northwestern *Connecticut* and western *Massachusetts* drainage basins. They may have originated (possibly along with ***Cutlip Minnow***) from *refugia directly south* of the southwestern third of *Connecticut* (Whitworth 1996). ***Creek Chub*** probably entered glacial Lake Connecticut close to 12,500 years ago, and could spread east to the Quinnipiac River drainage basin (ibid). Because ***Creek Chub*** entered the Housatonic River when water flows were reasonably high, it could cross the fall line at Falls Village and enter *Massachusetts* (ibid).

In *New Hampshire*, ***Creek Chub*** occurs in abundance in the Connecticut River watershed, is rare in the Androscoggin and Merrimack watersheds, and are absent in the Coastal and Saco River drainages (Scarola 1973). In *Maine* and *Vermont* proper, ***Creek Chub*** are commonly found statewide (Maine DEP/DIF&W 2014, Langdon et al. 2006), often in association with ***Fallfish*** in numerous northern lakes, as well as lotic waters. ***Creek Chub*** ranked **22nd** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

A-6 Fallfish (*Semotilus corporalis*) aka *silver, white or river 'chub'* **Map 6**

Fallfish most closely resemble ***Common Shiner***. Key identification characteristics: absence of dark blotch at base of dorsal fin; adults with dark marks at scale base; juveniles with dark lateral stripe; scales large and silvery, not crowded.

Fallfish are the largest native eastern North American minnow, occasionally reaching a length more than 18 inches and a weight of over two pounds (Raney 1969). The Maine state record ***Fallfish*** weighed 3 pounds 12 ounces (Wick 2007). They are more common to rivers and lakes and are generally absent in higher elevation waters in the northeastern United States.

Fallfish were the **12th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2000) and were ranked **4th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

Fallfish are commonly found to occur statewide in most *Connecticut* streams (Jacobs & O'Donnell 2009), and uncommonly found to occur in coastal (Narragansett Bay) tributaries in *Rhode Island* (Libby 2013) and *Massachusetts* (Hartel et al. 2002). Recent records of ***Fallfish*** from Cape Cod are lacking (ibid), however, ***Fallfish*** are one of the most common minnows statewide in *New Hampshire* rivers and lakes, where it is used extensively for bait, particularly for winter ***Lake Trout*** fishing (Scarola 1973). In *Maine*, ***Fallfish*** nests are comprised of stones averaging as much as two inches in diameter, piled up as high as three feet and with a diameter of up to six feet (Everhart 1976, Figure xx). ***Fallfish*** & ***Creek Chub*** are widespread in both *Vermont* (Langdon et al. 2006) and *Maine* and often co-occur in northern coldwater lakes (Whittier et al. 1997).

Tunk Stream, Maine

Fallfish gravel mound used for spawning.

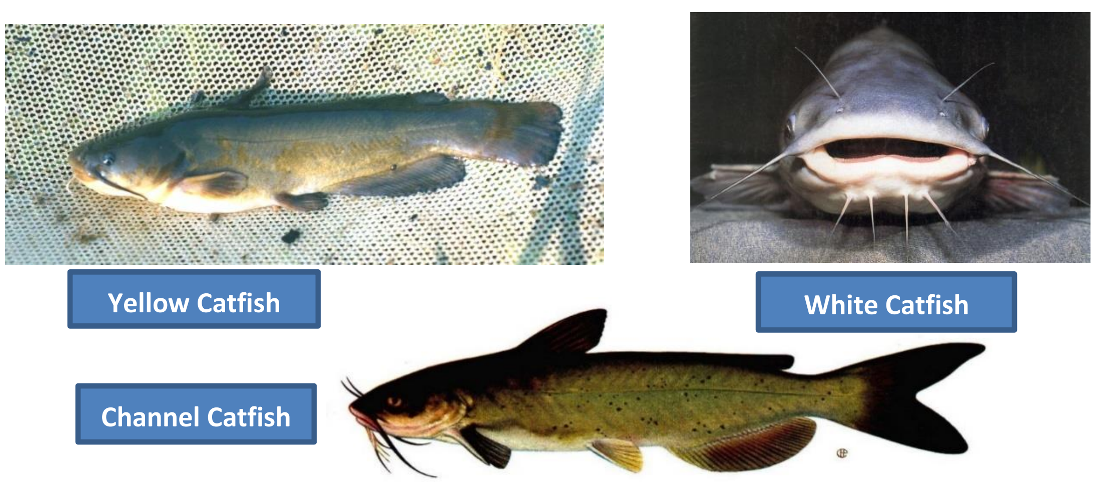
A-7 White Sucker (*Catostomus commersonii*) aka '*common sucker*' Map 7

White Sucker is the most commonly encountered native fish species to be observed throughout New England proper freshwaters. It was the **5th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2001) and ranked **2nd** in total fish abundance (see Table xx) during the New England large (non-wadeable) river surveys (Yoder et al. 2015). It is frequently found to prosper within environmentally degraded waters and is most tolerant to habitat disturbances. It has been successfully used as a surrogate metric (for ***Green Sunfish***) in the northeastern development of the *Index of Biotic Integrity* (Miller et al. 1988, Halliwell et al. 1999). Mostly all lakes and perennial streams in all New England river drainages are home to ***White Sucker*** – generally the most commonly encountered native New England freshwater fish species.

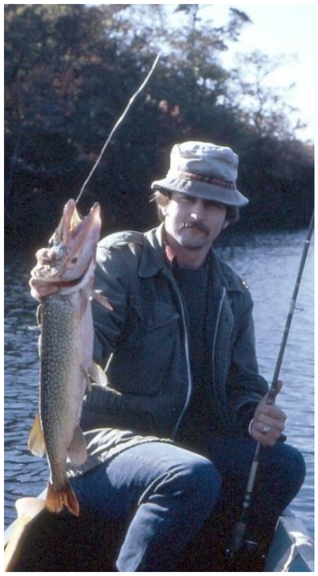
A-8 Brown Bullhead (*Ameiurus nebulosus*) aka '*horned pout*' **Map 8**

The only member of the catfish family (Ictaluridae) indigenous to New England proper is the ***Brown Bullhead***. It was the **4th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2001) and ranked **17th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015). ***Brown Bullhead*** (*Ameiurus*) characteristically have non-forked caudal fins and dark-colored chin barbel.

Madtoms (***Tadpole*** & ***Margined***), which are respectively found to reside in the Chicopee drainage in *Massachusetts* and the Merrimack drainage (Halliwell 1988) in *Massachusetts* and *New Hampshire*, are here considered to be non-native, introduced species, along with ***Yellow Bullhead*** and ***White*** & ***Channel Catfish*** (Appendix A).



A-9 Chain Pickerel (*Esox niger*) aka '*lake pickerel', 'juvenile clothespin'* **Map 9**



Dr. Francis 'Frank' Golet
Professor of Wetlands
University of Rhode Island
Kingston

Barr (1963) notes that the original range of ***Chain Pickerel*** was east of the Allegheny Mountains from southwestern *Maine* to *Florida*…and that through introductions by man, the northern extreme of the range has been extended throughout *Maine* and into *New Brunswick*, Canada. ***Chain Pickerel*** was the **7th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 1999) and ranked **11th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

The native origins of ***Chain Pickerel*** recently came into question during a review of the 2014 publication *"The Origin, Formation & History of Maine's Inland Fisheries Division."* The authors (Auclair & Vail) note (page 97) that "In **1818**, the U.S. quest for expansion included the cross-continental introduction of new species, including chain pickerel and even the European carp into Maine. Spiess and Halliwell (2011 – revised 2012) previously noted that "chain pickerel are native to *Maine*, but are truly indigenous to only southern Maine river drainages (Kennebec River drainage and south).

By **1867** pickerel were widely introduced into many *Maine* rivers, lakes and ponds. ***Chain Pickerel*** introduction than leap-frogged from the Androscoggin drainage to Annabessacook Lake in Winthrop, into the Belgrade lakes, and the Carrabassett and Dead rivers (Foster & Atkins 1867). That year, pickerel were also introduced in Penobscot County and transferred to the St. Croix drainage. Later they spread to the waters of the East Machias River." But, see Williamson **1832**, Holmes **1862**, and Foster & Atkins **1867** – "In many of our (*Maine*) lakes and ponds in the settled section where trout were plentiful within the recollection of the inhabitants, they are now almost extinct" …following the introduction of ***Chain Pickerel***.

Per Auclair & Vail (2014), the decrease of (***Brook***) ***Trout*** (in *Maine*) is owing to three main causes: First, overfishing; second, the erection of dams which have cut them off from their breeding grounds; and thirdly, the introduction of ***Chain Pickerel***." Warner (1973) found ***Yellow*** & ***White Perch*** and ***Rainbow Smelt*** to be the three most abundant fish species identified in the stomach contents of ***Chain Pickerel***.

Pickerel introductions were made in the early 1800's in the Androscoggin drainage north of the outlet of *Wayne Pond*, and it was in **1817** or **1818** that pickerel from *Androscoggin Lake* were introduced in *Annabessacook Lake* in Winthrop. From *Annabessacook Lake* they were later introduced to most other waters of that system, including *Cobbosseecontee Lake* and *Cochnewagon Pond* (Foye 1968).

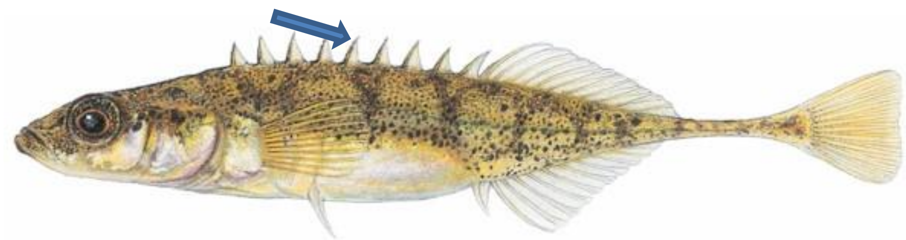
Chain Pickerel from Nehumkeag Pond in Pittston were introduced in *Cobbossee Stream* in **1823 or 1824** and then into the *Belgrade Lakes* and waters of the *Carrabassett River* and the *Dead River*. In **1818**, ***Chain Pickerel*** were introduced to Penobscot County where they were stocked in *Davis Pond* in Eddington and a few years later in waters of the Upper Penobscot. ***Chain Pickerel*** were introduced into northern *Maine* drainages as early as **1819** (*Penobscot River*, Williamson **1832**, Vol. 1:150-164). From the Penobscot, ***Chain Pickerel*** were transferred to the St. Croix drainage and from there to *Meddybemps Lake* on the *Dennys River*. Later they were spread to waters of the *East Machias River* (Foye 1968).

Hybrid *Chain Pickerel* x ***Northern Pike*** from Connecticut River, CT. Displaying very similar vermiculations to the '*Tiger Trout*' (***Brook Trout*** x ***Brown Trout***).

A-10 Banded Killifish (*Fundulus diaphanus*) '*beach' or 'barred' killifish* **Map 10**

Banded Killifish presence in routine freshwater fish surveys is not recorded at many locales due to the fishing gear types most commonly utilized. ***Banded Killifish*** are most likely to be captured using <u>beach seines</u> and particularly during sampling events after dark. It has been shown through daytime vs. nighttime sampling studies that the abundance and diversity of fish species presence is much greater during the nighttime hours (Whittier et al. 2001). ***Banded Killifish*** were the **10th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2001) and ranked **14th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

A-11 Ninespine Stickleback (*Pungitius pungitius*) aka '*lake stickleback*' Map 11



Ninespine Stickleback commonly inhabits inland lakes, ponds and slow-moving streams throughout its northern range (*Maine*), however, moves only a short distance above brackish water in *New Hampshire* (Scarola 1973), similar to their coastal (salt marsh) distributions in *Connecticut*, *Rhode Island* and *Massachusetts*. ***Ninespine Stickleback*** were the 20th most abundant finfish species (out of a total of 46 finfish species captured) in a recent survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018).

In *Ontario* (Canada), ***Ninespine Stickleback*** are found to inhabit the cool, shallow waters of stream, lakes and wetlands (Aldenhoven et al. 2010), and is also found in the deep waters of the Great Lakes – in association with ***Brook Stickleback*** (Holm et al. 2009).

A-12 Redbreast Sunfish (*Lepomis auritus*) aka '*yellowbelly sunfish*' Map 12

Redbreast Sunfish prefer clear water and rocky areas of larger streams and lakes and are not typically associated with vegetation (Jacobs & O'Donnell 2009) – as is the ***Pumpkinseed***. In southern New England, they are typically common in rivers and large streams and uncommon to rare in lakes (ibid). In northern New England, they are found to co-occur with ***Pumpkinseed***

in cooler clear-water lakes with rocky shorelines. ***Redbreast Sunfish*** appear to be more tolerant of current than other sunfishes and are often the dominant sunfish in larger rivers (Jacobs & O'Donnell 2009).

Redbreast Sunfish have a non-arched, extended opercular ear flap which is usually darkly pigmented, in contrast to ***Pumpkinseed*** – which have a much shorter, circular opercular ear flap with a red-pigmented spot on the edge (red color turns white after routinely hardening in 10% formalin solution and preservation in 70% alcohol).

Redbreast Sunfish occur only in eastern North America and in *Canada* are known only from southwestern New Brunswick (Scott & Crossman 1973, Gautreau & Curry 2012) – and are absent from Ontario (Holm et al. 2009). They are native to Atlantic coastal areas from *New Brunswick*, Canada (east of the Appalachian Mountains) to central *Florida* (Jacobs & O'Donnell 2009). ***Redbreast Sunfish*** were the **17th** most widespread resident fish species in the EMAP-SW north-eastern lakes survey (Whittier et al. 1999) and ranked **7th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

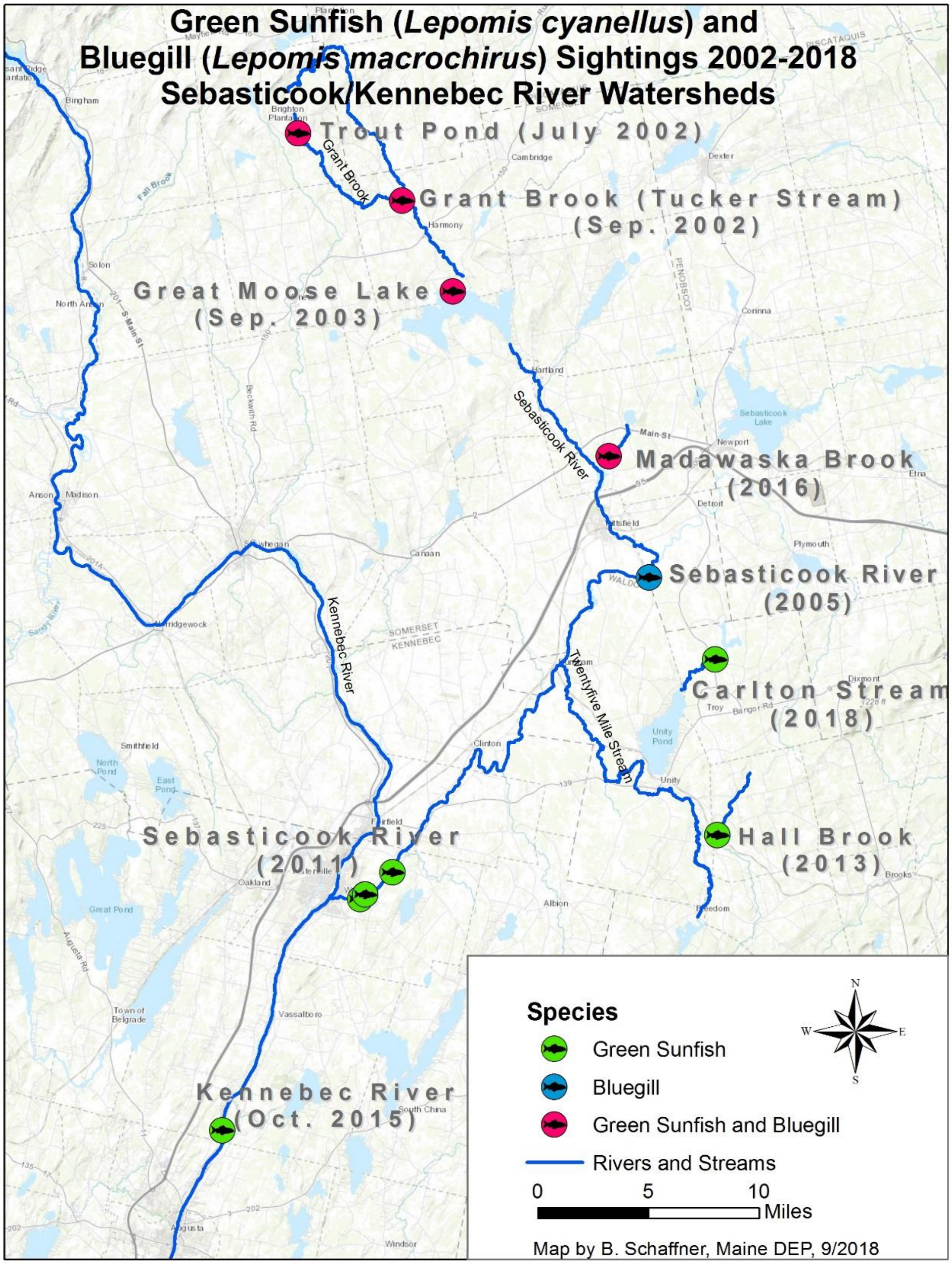
In *Connecticut*, ***Redbreast Sunfish*** have a patchy distribution across the state and are typically common in rivers and larger streams and *uncommonly found to rare in lakes* (Jacobs & O'Donnell 2009). In *Rhode Island*, ***Redbreast Sunfish*** were only collected in the western areas of the state from the Moosup River, south to the lower Pawcatuck and Wood river drainages (Libby 2013). ***Redbreast Sunfish*** were not collected in the Pawcatuck River watershed above Shannock Falls on the Richmond-Charlestown border – where the falls may have acted as a natural barrier to ***Redbreast Sunfish*** recolonizing the upper Pawcatuck following glacial retreat (ibid).

Redbreast Sunfish are known to have a scattered distribution in *Massachusetts* and are commonly found in only a few locations, including the upper Charles and Sudbury rivers, *Quabbin Reservoir* and the main stems of the Connecticut and Merrimack rivers – in both *Massachusetts* (Hartel et al. 2002) and *New Hampshire* (Scarola 1973). ***Redbreast Sunfish*** are common to most drainage systems in *Maine*, usually occurring conspecific with ***Pumpkinseed*** in lakes and ponds throughout the state (Maine DEP/DIFW 2014). In *Vermont* proper, this popular and easy to catch native game fish is found to occur only in *two rivers* (Connecticut and Black) and *three lakes* – Morey, Fairlee and CCC Pond (Langdon et al. 2006).

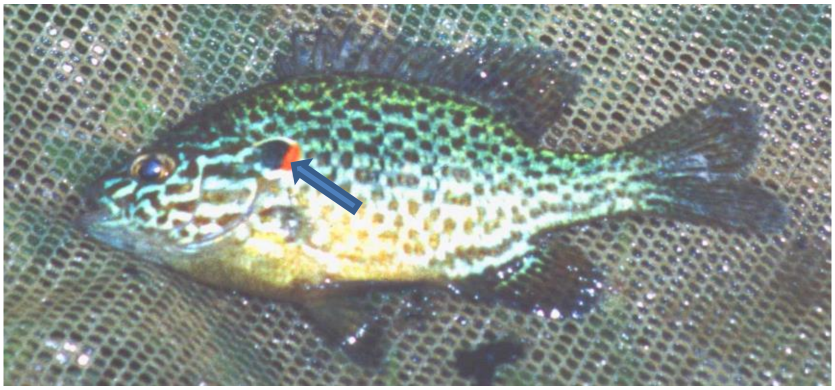
Redbreast Sunfish and ***Pumpkinseed*** are known to readily hybridize in freshwaters throughout *New England* proper, particularly in *Connecticut* (Jacobs & O'Donnell 2009), *Massachusetts* (Hartel et al. 2002) and *Maine* (Maine DEP/DIFW 2014). In north-central *Maine*, non-native ***Green Sunfish*** (*Lepomis cyanellus*) and ***Bluegill*** (*Lepomis macrochirus*) were illegally introduced into the headwaters of the Sebasticook River drainage (Trout Pond – Harmony) in July 2002 and have spread south into the Kennebec River in the Augusta area.

There is recent evidence of possible hybrids between ***Green Sunfish*** and ***Redbreast Sunfish*** in the town of Troy (Unity Pond watershed) – see figure below.

Redbreast Sunfish photos contributed by Dr. Thomas Danielson, from Maine streams. Maine DEP 2018


Green Sunfish (Lepomis cyanellus) and
Bluegill (Lepomis macrochirus) Sightings 2002-2018
Sebasticook/Kennebec River Watersheds
Trout Pond (July 2002)
Grant Brook (Tucker Stream)
(Sep. 2002)
Great Moose Lake
(Sep. 2003)
Madawaska Brook
(2016)
Sebasticook River
(2005)
Carlton Stream
(2018)
Hall Brook
(2013)
Sebasticook River
(2011)
Kennebec River
(Oct. 2015)
Grant Brook
Sebasticook River
Kennebec River
Twentyfive Mile Stream
Species
Green Sunfish
Bluegill
Green Sunfish and Bluegill
Rivers and Streams
0
5
10
Miles
N
S
E
W
Map by B. Schaffner, Maine DEP, 9/2018

A-13 Pumpkinseed (*Lepomis gibbosus*) aka '*sunny' or 'common sunfish*' **Map 13**

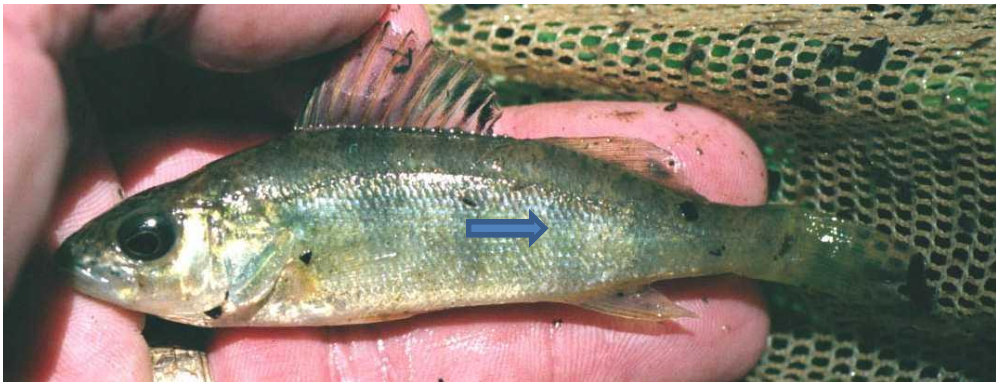


The native distribution of the ***Pumpkinseed*** is restricted to the freshwaters of eastern North America, where it occurs from *New Brunswick* (Canada) south along the Atlantic seaboard to northeastern *Georgia* (Scott & Crossman 1973). It was the **most** widespread resident native fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 1999) and ranked **8th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

Pumpkinseed **(sunfish)** are found to occur statewide in all six New England states, except for Martha's Vineyard in *Massachusetts* and the St. John River mainstem in northern *Maine* (non-indigenous to and uncommonly found in the Allagash, Fish River, Aroostook and Meduxnekeag systems). ***Pumpkinseed*** is often found in association with ***Redbreast Sunfish*** in New England freshwaters and are commonly found to hybridize in *Connecticut* (Jacobs & O'Donnell 2009), *Massachusetts* and *Maine* freshwaters (see figures below).

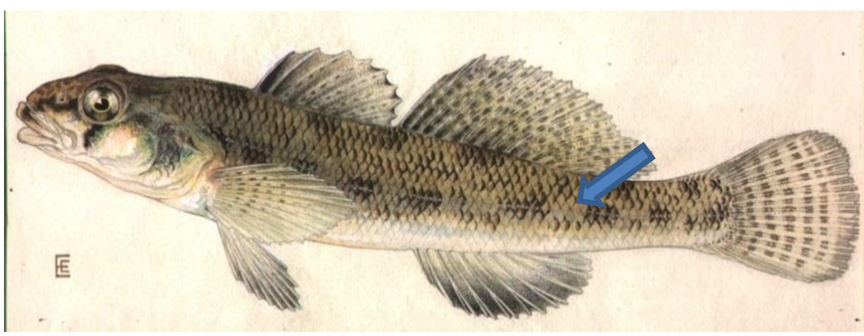
Pumpkinseed prefer moderate to heavy vegetation in still waters of lakes and ponds or slow-moving streams while spawning in gravelly/sandy shoreline shallows. Male spawners dig small depressions in late spring and defend them thru mid-summer (Hartel et al. 2002).

A-14 Yellow Perch (*Perca flavescens*) aka '*brindle perch'*, ME '*tiger trout*' **Map 14**



Yellow perch are an easily identified (black vertical bars), well-distributed and native fish species throughout New England proper, but are only indigenous to the southern New England states (*MA*, *RI*, *CT*), as well as southern portions of the northern New England states (like ***Chain Pickerel, Brown Bullhead*** and ***Golden Shiner***). ***Yellow Perch*** was the **2nd** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 1999) and were ranked **5th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

A-15 Tessellated Darter (*Etheostoma olmstedi*) aka 'eastern Johnny darter' Map **15**



Truly benthic fishes found to inhabit New England's freshwaters include ***Tessellated Darter*** in moderate-gradient rocky streams, ***Swamp Darter*** in low-gradient muddy streams and ponds, as well as the coldwater, primarily high-gradient ***Slimy Sculpin***. Darters in New England are somewhat drab in coloration, and do not exhibit the reds, greens, yellows and blues so common to many of the other approximately 140 darter species as endemics to North America (Helfman et al. 2000). ***Tessellated Darter*** have characteristic "W" spots with a noticeable groove just above the upper lip, lacking in ***Swamp Darter***, which have short, smooth snouts (NH-F&G 2016).

Tessellated Darter, originally described from the Connecticut River near Hartford (*Connecticut*) by D.H. Storer in 1842 (Hartel et al. 2002), are found from Canada to Florida, but (along with ***Banded Sunfish***) have not yet been found to reside in the state of *Maine*. Once considered a subspecies of the Johnny darter, ***Tessellated Darter*** prefers moving waters and, unlike ***Swamp Darter***, are seldom found to occur in lakes and ponds. They ranked **20th** in total fish abundance during the New England large (non-wadeable) river survey (Yoder et al. 2015).

It is probable that glacial refugia for ***Tessellated Darters***, and other primary fish species, were in the middle Atlantic coastal plain. Schmidt & Whitworth (1979) postulated that ***Swamp Darter*** entered New England via the eastern tip of Long Island very late in postglacial time – however, prior to entry of the congeneric ***Tessellated Darter*** – and that their distribution in *Connecticut* and elsewhere in New England is primarily a result of postglacial drainage patterns and dispersal through extinct and extant intersystem drainage connections. In *Connecticut*, ***Swamp Darter*** are primarily limited to ponds and streams east of the mainstream Quinebaug River and does not co-occur with ***Tessellated Darter*** within the lower Thames River drainage. Similarly, in *Massachusetts*, the distribution of ***Swamp Darter*** is restricted to the western-situated *Quinebaug River* headwaters and the distribution of ***Tessellated Darter*** is restricted to the eastern-situated *French River* headwaters (see Figure x).

Tessellated Darter most commonly occur in moderate gradient rocky streams throughout New England, where they can be observed sitting motionless, propped up on their pelvic fins, on the sandy bottom or on small rocks. Relative to food habits, ***Tessellated Darter*** feed mainly on the larvae of midges and other aquatic dipterans, but may switch to other food such as caddisflies later in the season. ***Tessellated Darter*** are found statewide in most *Connecticut* streams, where they are typically common to uncommon in abundance (Jacobs & O'Donnell 2009). In *Rhode Island*, ***Tessellated Darter*** are widely dispersed statewide, occurring at 77 locales in all drainages, but are conspicuously absent in the Hunt & Pawtuxet river watersheds (Libby 2013).

In *Massachusetts*, ***Tessellated Darter*** are common to most streams in the Connecticut and Blackstone river basins, in the southeastern parts of the state, and on Martha's Vineyard. They are rarely found in northeastern drainages, where only a few specimens were found by MDF&W as late as 1998 from Merrimack-Shawsheen river drainages (Hartel et al. 2002). ***Tessellated Darter*** are absent from the Hoosic, upper Deerfield, Charles and Nantucket drainages in *Massachusetts* (ibid). In *New Hampshire*, ***Tessellated Darter*** are absent from the Androscoggin, Saco and Coastal drainages and rarely occur in tributaries to the Merrimack River (NH-F&G 2016). They are primarily found in the Connecticut River watershed, where it can be found throughout the drainage, except at the extreme northern reaches (Scarola 1973). Notably, ***Tessellated Darter*** are *absent* from freshwaters throughout the state of *Maine* (Maine DEP/DIFW 2014).

Tessellated Darter serve as an important host species for the Federally Endangered *Dwarf Wedge Mussel* (NH-F&G 2016). Mussel larvae (*glochidia*) are distributed by attaching to the gills of the host fish species (ibid). Hence, the maintenance of healthy populations of ***Tessellated Darter*** are a critical component for regional efforts to protect and restore *Dwarf Wedge Mussel* populations – particularly in the Connecticut River watershed (ibid).

Group B-1 to **B-15** ***Mississippi Valley*** (St. Lawrence River via post-glacial connections to the upper St. John, Penobscot and possibly Aroostook river drainages) includes the following native primarily <u>coldwater</u> fish species: ***Lake Chub, Northern Pearl Dace, Blacknose Shiner, Northern Redbelly Dace, Finescale Dace, Fathead Minnow, Longnose Sucker, Lake Whitefish, Round Whitefish, Arctic Char, Brook Trout, Lake Trout (Togue), Burbot (Cusk), Brook Stickleback*** and ***Slimy Sculpin***.

Most these fish species of <u>western</u> origin can be characterized as northern obligate coldwater fish species whose ranges lie mainly to the northwest of the Merrimack River valley (*New Hampshire* and *Vermont*), in *Canada* and across the northern tier of states inclusive of the Adirondack Mountains of *New York* (Figure xx). These native fishes probably recolonized shortly following the retreat of the last glacial ice sheet and/or invaded through no longer existing historical post-glacial northwestern hydrological connections. These forms are, without exception, coldwater fishes restricted to deep cold lakes and/or cool upland brooks (Bailey 1938), highly vulnerable to the detrimental habitat impacts of current and future climate change (Jacobson et al. 2009, Rypel et al. 2019).

All <u>Group B</u> coldwater native fish species are primarily found to occur in *Maine* and to a much lesser extent in northern portions of *New Hampshire* and *Vermont*. All of them are absent from *Rhode Island* (Table 1). The biodiversity of species declines with distance across the New England states holds true for species believed to have used the Mississippi Valley refuge (Schmidt 1986, Curry 2007). The present-day distribution patterns of freshwater fish in northern New England support a dispersal point in the upper St. John River area (Curry 2007). Also, the distribution of typically non-bait minnow species such as ***Blacknose Dace, Northern Redbelly Dace*** and ***Creek Chub***, support a north to south dispersal (ibid).

Many small-bodied, obligate freshwater fishes that are absent from central and southeastern Maine (and throughout southern New England), are found to be present in the Saint John, Penobscot and Aroostook river drainages (Whittier et al. 2000 and 2001), in further support for a re-colonization origin for northern Maine, possibly from the upper Saint John River watershed – via the hypothesized St. Lawrence postglacial connection (Curry & Gautreau 2010).

Upper St. John River drainage fish surveys in both lotic and lentic habitats (Maine USA and Quebec, Canada border waters) were carried out during 1999 to 2002, when **14** northern native coldwater fish species dominated the catch (Halliwell & Royte, TNC 2003, Table xx). ***Brook***

Trout, Slimy Sculpin, Blacknose Dace and ***Burbot*** were *lotic residents* found to occur primarily in flowing waters, while ***Blacknose Shiner, Fallfish*** and ***dace (Northern Redbelly, Finescale*** and ***Northern Pearl***) were *lentic residents* found to occur primarily in lakes and ponds. Intermediate *lotic-lentic resident* fish species, found to occur equally in lakes and streams, included ***Common Shiner, Creek*** and ***Lake Chub*** and ***White*** and ***Longnose Sucker***. Very low fish species occurrences were found for ***Banded Killifish, Fathead Minnow*** and ***Brook Stickleback*** in lotic habitats, while several non-indigenous (warmwater) fish species were collected – inclusive of historically introduced ***Yellow Perch, Golden Shiner*** and ***Brown Bullhead*** (Halliwell 2005) – for richness measures of **15** native coldwater fish species present.

B-1 Lake Chub (*Couesius plumbeus*) aka '*northern chub, leaden minnow'* **Map 16**

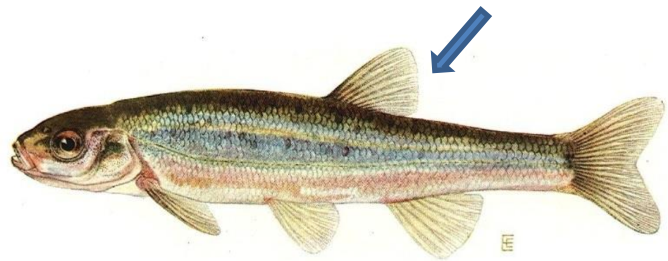
Lake Chub are elongate, round-bodied (terete) minnows characterized by the presence of a small, but well developed, conical barbel in the corners of the upper jaw (Scarola 1973). During the breeding season (early July in Connecticut Lakes region), males develop patches of red about the head and inner bases of the paired fins (ibid). Most closely resembles the ***Northern Pearl Dace***.

In *New Hampshire* (and *Maine*), ***Lake Chub*** are restricted to clear, cold lakes, ponds and streams that are normally good ***trout*** waters (Scarola 1973). *Massachusetts* has several disjunct populations of ***Lake Chub*** in the upper reaches of the West and East branches of the Westfield River – the nearest ***Lake Chub*** populations are in the northern Connecticut River basin of *Vermont* and *New Hampshire* (Hartel et al. 2002). Lake Chub have a northerly distribution and in *New Hampshire* it occurs only in the northern Merrimack River drainage (Pemigewasset River and its tributaries) and the northern Connecticut River and Androscoggin River drainages (Scarola 1973).

Interestingly, ***Lake Chub*** were not reported to occur in the *Lake Champlain* drainage in *Vermont* (Langdon et al. 2006), however, a single occurrence was recorded from the Winooski River during the New England large rivers (non-wadeable) fish assemblage assessment 2002-2009 (Yoder et al. 2015), when they ranked **25th** in total fish abundance (ibid). In *Maine*, ***Lake***

Chub were found to inhabit the Presumpscot River drainage (Cooper 1939), and the Rangeley Lakes region (Cooper 1940). North of New England, the ***Lake Chub*** is the most widely distributed of all *Canadian* fishes and is found in every province and territory (Holm et al. 2009).

B-2 Northern Pearl Dace (*Margariscus nachtriebi*) aka '*northern dace*' Map 17

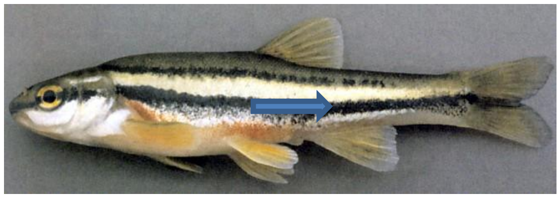


Northern Pearl Dace are characterized by having a rounded dorsal fin which originates behind the pelvic fin origin; pinkish hue below lateral stripe in breeding males; and a relatively small and sub-terminal mouth. They most closely resemble ***Creek Chub***, however, does not have the black blotch at the base of the dorsal fin (Jacobs & O'Donnell 2009). ***Northern Pearl Dace*** are also very difficult to distinguish from ***Lake Chub***; however, the former has a rarely visible barbel, a rounded dorsal fin (***Lake Chub*** with concave posterior edge), and spawning males have a characteristic red/pinkish stripe on the lower side of the body (Holm et al. 2009).

Northern Pearl Dace are found to reside in small, cool streams to small rivers in pools and sections with moderate current – it also inhabits (cold) lakes and (vegetated) boggy ponds (Langdon et al. 2006, Holm et al. 2009). ***Northern Pearl Dace*** is absent from *New Hampshire* and has a sporadic distribution in *Maine*, primarily residing in northwestern drainages (Maine DEP/DIF&W 2014), conspecific with ***Blacknose Shiner*** (Whittier et al. 1997, 2000).

Two *Pearl Dace* species occur in Vermont (Page et al. 2013), the southern ***Allegheny*** Pearl Dace (*Margariscus margarita*) and the ***Northern*** Pearl Dace (*Margariscus nachtriebi*), neither of which are found in Vermont proper. The former (*Allegheny*) species is primarily restricted to a dozen or so tributaries in the (southern) Lake Champlain drainage in Vermont (Langdon et al. 2006). In contrast, the Vermont presence of the latter (*Northern*) species is based on a single record from an unnamed stream in Franklin County (ibid) on the Canadian border of northwestern Vermont – outside of the New England proper (Connecticut River) region. A count of the number of scales on the lateral line distinguish between these two ***Pearl Dace*** species, with the *Allegheny* having 50 to 60 and the *Northern* having 65 to 75 (Hubbs & Lagler 1947).

B-3 Northern Redbelly Dace (*Chrosomus eos*) aka '*yellow-bellied dace*' **Map 18**



Northern Redbelly Dace have two distinctive horizontal upper body stripes; smaller mouth, terminating in front of eye; lateral line entirely or almost lacking; most closely resembles ***Finescale Dace*** (females and non-breeding males), with whom it readily hybridizes with – the hybrids are always females and in some areas, may out-number their parental species (Page & Burr 1991). Hybrids show characteristics which are intermediate to the two-parent species (Holm et al. 2009). Hybrid chrosomids have been documented from 16 locales in northern *Maine*, including a dozen during the EMAP-SW lakes survey (1991-1994) and 4 more waters in the St. John River drainage (TNC 2003). ***Northern Redbelly Dace*** has also been reported to possibly hybridize with the ***Northern Pearl Dace*** (Langdon et al. 2006).

Northern Redbelly Dace are absent from *Connecticut* and *Rhode Island* waters, while *Massachusetts* has only a single population in the Deerfield River drainage in Greenfield – geographically isolated from the nearest New England population in the Sugar River system in the Connecticut River watershed in *New Hampshire* (Bailey & Oliver 1939, Hartel et al. 2002). It also has been reported to be limited in occurrence to only north of the White Mountains, upper waters of the Connecticut River drainage and in the Dead River area of the Androscoggin River drainage (Scarola 1973). ***Northern Redbelly Dace*** are more commonly found to occur in ponds and streams in *Maine* and *Vermont*.

Northern Redbelly Dace prefers cool, heavily vegetated shallow waters of lakes and slow-moving streams with silt and detritus substrates (Holm et al. 2009). They have been observed to spawn in stream filamentous algal mats in both *Vermont* and *Massachusetts*, but may be able to spawn on other substrates also (Langdon et al. 2006). ***Northern Redbelly Dace*** apparently can be long-lived for such small fishes – a Canadian study showed that some individuals live up to eight years (Hartel et al. 2002).

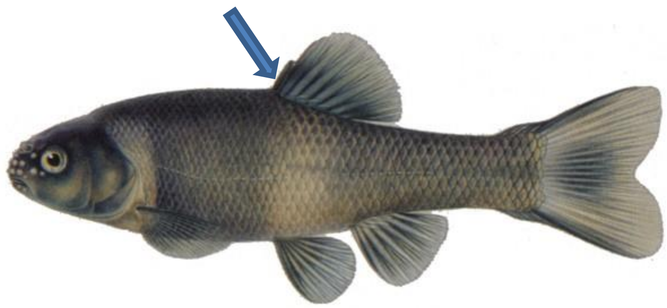
B-4 Finescale Dace (*Chrosomus neogaeus*) aka '*bronze minnow*' **Map 19**

Finescale Dace have a single horizontal upper body stripe; larger mouth, extending past front of edge of eye; and lateral line developed anteriorly. Most closely resembles ***Northern Redbelly Dace*** (females and juvenile males), with whom it readily hybridizes with (see above account).

Finescale Dace (and ***Northern Redbelly Dace***) are found to reside in a wide range of habitats including boggy, acidic (tea-colored) waters to non-boggy clear streams in association with spring-fed seepage pools (Hartel et al. 2002). ***Finescale Dace*** are not found to occur in southern New England waters and is a rarely found fish species in *New Hampshire* – historically found to occur only in meadow-spring holes in the towns of Pittsburg, Errol and Dummer (Scarola 1973). It has a sporadic distribution in Maine and is extremely rare in eastern Vermont, occurring in only a few locales in the Northeast Kingdom (Langdon et al. 2006).

B-5 Fathead Minnow (*Pimephales promelas*) aka '*northern fathead*' **Map 20**



Fathead Minnow are a commonly used baitfish as well as historical bioassay specimen used in water quality testing studies (US-EPA standard methods). These hardy fish are tolerant of a wide range of environmental conditions, including high temperatures, high nutrient concentrations, low oxygen levels, high turbidity, and stagnant conditions (Kircheis & Eliot 1989). In *Maine* waters, ***Fathead Minnow*** are not as common or as widely distributed as are ***Golden Shiner***, historically occurring in only 85 waters (700 Maine waters for ***Golden Shiner***), mostly in the northwestern parts of the state (ibid). It is possible that ***Fathead Minnow*** originally entered New England via the post-glacial St. Lawrence River drainage (Group B northern fishes) and has historically been introduced into southern New England waters (Housatonic, Connecticut, Thames and Concord river drainages). Related non-native ***Bluntnose Minnow*** (*Pimephales notatus*) were surprisingly found to be the most commonly collected minnow from the 1989 shoreline sampling of Quabbin Reservoir in *Massachusetts* (Hartel et al. 2002).

B-6 Blacknose Shiner (*Notropis heterolepis*) aka '*black-nosed minnow*' **Map 21**

Blacknose Shiner, not to be confused with more commonly encountered ***Blacknose Dace*** (which also have a dark lateral stripe), have 8 anal fin rays; a row of crescents within lateral dark band; sharp snout, equal to eye diameter length; chin and upper lip without pigment. Most closely resembles the ***Bridle Shiner,*** which has 7 anal fin rays, but are not conspecific in their distributions. ***Blacknose Shiner*** are absent from the southern New England states, as well as *New Hampshire*. Historical *New Hampshire* records (Hoover 1937, Scarola 1973) were apparently mis-identifications (Matthew Carpenter, NH-F&W, personal communication, 2016).

In *Vermont*, ***Blacknose Shiner*** are primarily restricted to the western Lake Champlain drainage, with just a single historical record of occurrence in the eastern Connecticut River drainage (Langdon et al. 2006), located in Windsor County (HUC-8 Upper Connecticut-Mascoma drainage system). ***Blacknose Shiner*** are conspecific with ***Northern Pearl Dace*** in *Maine*, commonly sharing small-stream and lake habitats, primarily in northwestern drainages (Wick 2007, Maine DEP/DIF&W 2014).

Blacknose Shiner are found to reside in clear, cool waters of shallow, vegetated areas of lakes and slow-moving areas of smaller streams, over silt, sand or gravel bottoms (Holm et al. 2009). They are intolerant of continuously turbid water conditions (Langdon et al. 2006). Like its close relative, the ***Bridle Shiner***, their populations have declined in southern portions of their range in Canada and the northern United States, due to habitat degradation by human development (ibid, Holm et al. 2009).

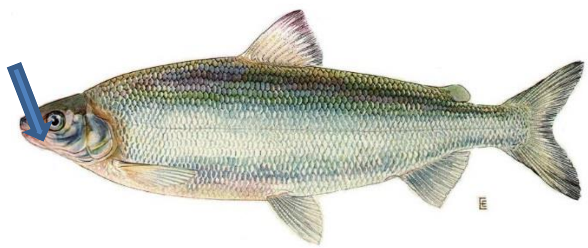
B-7 Longnose Sucker (*Catostomus catostomus*) aka '*finescale' sucker* **Map 22**

Longnose Sucker was once referred to as the 'Adirondack fine-scaled sucker' and characteristically have a larger number of smaller scales in contrast to its closest New England relative, the ***White Sucker***. These two species are found to be conspecific in undisturbed tributaries to the Deerfield River in *Massachusetts* (Hartel et al. 2002). In contrast to the highly tolerant and cosmopolitan ***White Sucker***, the ***Longnose Sucker*** is primarily found to inhabit higher elevation, cooler streams and lakes and is generally intolerant to degraded aquatic habitat conditions. ***Longnose Sucker*** are listed as a fish species of special concern in *Massachusetts* and *Connecticut*.

Longnose Sucker are known to historically occur in *Connecticut* in only a single stream – the Konkapot River – Housatonic River drainage (Jacobs & O'Donnell 2009). ***Longnose Sucker***

are absent from *Rhode Island* freshwaters and are limited in distribution to higher gradient waters to the west of the Connecticut River in *Massachusetts* (Hoosic, Housatonic and Deerfield river systems) – Hartel et al. 2002. *Massachusetts* records from 1940 through 1956 show its historical occurrence in the Connecticut and (western) Westfield rivers and at the mouth of the (eastern) Chicopee River (ibid). In *New Hampshire*, it is strictly northern in its distribution, occurring in the Androscoggin and upper Connecticut and Merrimack river drainages (Scarola 1973). In northern New England proper, ***Longnose Sucker*** distribution is limited in *Vermont* and *New Hampshire* to the northwestern Connecticut River drainage and only rarely occurs and/or is absent from all eastern lowland coastal *Maine* waters – primarily distributed in the northern tier of the state (Wick 2007).

B-8 Lake Whitefish (*Coregonus clupeaformis*) aka '*gizzard fish*' Map 23



Lake Whitefish are mostly found to occur in deeper, coldwater lakes in northern *New England*, particularly within the state of *Maine* (Weaver et al. 2018). They are a slightly deep-bodied, silvery fish with 2 flaps of skin between the nostrils and no notch in the lower posterior section of the eyelid (Holm et al. 2009). In *Ontario*, Canada, spawning occurs in the fall when the water temperature drops below 8 degrees C – eggs and sperm are randomly deposited over the stony bottom, and fertilized eggs are left unattended (ibid).

The presence of unusually smaller, early maturing ***Lake Whitefish*** populations found to be residing in 22 lakes in northwestern *Maine* from 1957 to 1962 were thought to provide possible evidence for dwarf-formed sub-populations (Fenderson 1964). This variation may be due, at least in part, to *postglacial convergence* of two forms of whitefish that had once diverged from a common progenitor (ibid). However, that this is an example of actual divergence was thought to be highly unlikely since the process would have had to occur simultaneously in several lakes in which the two forms were not physically isolated (ibid). Fenderson (1964) concluded that the small size, slow growth and early maturity of the dwarfed ***Lake Whitefish*** form probably did not represent a genetically fixed phenotype.

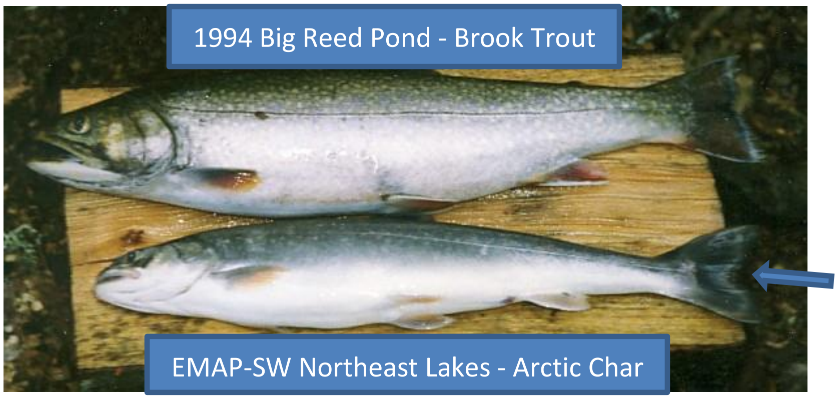
Lake Whitefish are absent from all three southern New England states. In *New Hampshire*, ***Lake Whitefish*** were locally known as "shad" and were once historically considered one of the most eagerly sought gamefish (superb tablefish) in the state and New England (Scarola 1973). Native only to Lake Winnipesaukee and (historically) Lake Umbagog (also in *Maine*), they are now limited to six waterbodies, inclusive of Big Squam and Wentworth lakes (NH-F&G 2016). In *Vermont*, ***Lake Whitefish*** are <u>not</u> found to occur in New England <u>proper</u>, currently existing only in westerly Lake Champlain (Langdon et al. 2006).

B-9 Round Whitefish (*Prosopium cylindraceum*) aka '*Pilot fish*' '*Billfish*' **Map 24**

Round Whitefish are found to populate both riverine and lake habitats in Maine. They are also found to occur in deeper coldwater lakes in Maine and <u>northern</u> *New England*. Round Whitefish' are a very elongate silvery fish with only a single flap of skin between the nostrils and a notch in the lower posterior section of the eyelid (Holm et al. 2009). In *Ontario*, Canada, spawning occurs in the fall in shallow waters when the water temperature drops below 5 degrees C – no parental care is given to fertilized eggs or young (ibid). The only record of ***Round Whitefish*** from <u>southern</u> New England waters is from Twin Lakes in *Connecticut*, originally stocked in the 1870's (Whitworth 1996).

In *New Hampshire*, ***Round Whitefish*** are primarily a river fish, but do well in deep, cold clear lakes – where they frequently inhabit comparatively shallow waters (Scarola 1973). In *New Hampshire*, this species now occurs only in the upper Connecticut River and Newfound Lake (NH-F&G 2016, Carpenter 2018). In *Vermont*, ***Round Whitefish*** distribution is limited to two *Northeast Kingdom* lakes, Willoughby & Seymour, located in New England <u>proper</u> (Langdon et al. 2006).

B-10 Arctic Char (*Salvelinus alpinus*) aka 'Sunapee' or 'Blueback trout' **Map 25**



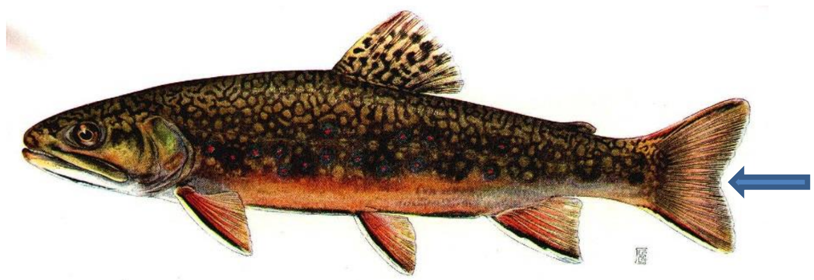
Arctic Char were historically represented (Warner 1965, Scarola 1973, Everhart 1976) by several close relatives, including *Blueback* (Rangeley Lake, Maine), *Sunapee* and *Golden* trout in *New Hampshire* (Sunapee Lake & Big Dan Hole Pond) and northern *Vermont* (Averill Lake). Following the introductions of ***Lake Trout*** (and/or landlocked ***Atlantic Salmon***), ***Arctic Char*** disappeared (from *New Hampshire* & *Vermont*) through both cross-breeding or direct competition and predation (Scarola 1973, Everhart 1976). Relict populations of ***Arctic Char*** in *Maine* were originally described from the Rangeley Lake(s) by Girard (1853), however, are now considered to be extinct from that waterbody (Everhart & Waters 1965).

Arctic Char in *Maine* are currently found to occur in 14 Maine lakes: 4 lakes in the St. John (Fish River – Deboullie drainage – originally surveyed in 1954 and one in Aroostook County – Big Reed Pond), Penobscot River (four lakes in East and West Branch drainages), and *Maine* Coastal (two lakes in the Union River drainage – Floods Pond and Green Lake). The city of Bangor water supply, Floods Pond in Otis *Maine*, was once considered as being the last known 'pure' genetic strain of ***Sunapee Trout* = *Arctic Char*** (Fuller & Cooper 1946, Kornfield et al. 1981), and has served as the source for historically introducing this species into Long Pond (aka Beaver Mountain Lake) in the Upper Androscoggin drainage and Enchanted Pond in the Dead River drainage of the Upper Kennebec River. Historical records of ***Arctic Char*** exist from Jordan Pond (Mount Desert Island – Fuller & Cooper 1946) as well as Harriman and Branch lakes (Everhart 1976) in the Coastal Maine HUC-8 region.

The presence of illegally introduced landlocked ***Rainbow Smelt*** was addressed through the reclamation of Big Reed Pond (Maine DIF&W and Maine DEP in 2010) to restore healthy populations of native ***Arctic Char*** and ***Brook Trout*** (Spiess & Halliwell 2011, revised 2012). The more deeply-forked tail of the ***Arctic Char*** helps to readily distinguish it from ***Brook Trout*** (Scarola 1973). They are also generally a smaller salmonid, averaging 7-15 inches total length in the Fish River drainage (Warner 1965).

Today, ***Arctic Char*** can be considered as 'regionally endemic' to the state of *Maine*, which is the only region in the United States (except *Alaska* – Kircheis 1989) that still have relict populations of the Laurentian (*Canadian*) lineage of ***Arctic Char*** (Bernatchez et al. 2002). ***Arctic Char*** likely dispersed from a now submerged Atlantic coastal refuge and are now mainly composed of landlocked populations that became isolated from the sea during the last glacial retreat (ibid). The ***Arctic Char*** is thought to be one of the first fish species to populate freshwater areas when they became available to habitation following deglaciation (Hammar 1986, Kircheis 1989).

B-11 Brook Trout/Char (*Salvelinus fontinalis*) aka '*speckled trout*' Map 26



For the most part, wild ***Brook Trout/Char*** (originally an anadromous species) are *not* found to naturally populate *lakes and larger rivers* in the New England states other than *Maine*. However, diminutive-sized native ***Brook Trout/Char*** are commonly found to prosper in a great multitude of smaller wadeable streams in all six New England states (Hartel et al. 2002, Langdon et al. 2006, Halliwell & Gallagher 2009, Jacobs & O'Donnell 2009, Beauchene 2011, Libby 2013) and elsewhere in the northeastern United States (Ecret & Mihuc 2013). Adult ***Brook Trout*** naturally inhabiting smaller streams reach maximum lengths of 6-9 inches, living only 2-3 years (Halliwell 1989a). In contrast, native/wild ***Brook Trout*** populations inhabiting larger coldwater lakes and rivers, primarily in *Maine*, will generally reach 3-5 pounds and attain lengths of 18-22 inches' total length and live to be 4-5 years of age (Bonney 2006, Collins 2016).

The ***Eastern Brook Trout Joint Venture*** currently exists as a partnership between state and federal agencies and conservation organizations (e.g. *Trout Unlimited*). This group regards *Maine* as the last true stronghold for lake resident native/wild ***Brook Trout*** in the eastern *United States* (Fleming 2017). In *Maine*, there are 578 lakes or ponds with wild ***Brook Trout*** populations that have never been stocked, or not stocked in the last 25 years, amounting to 97 percent of the remaining wild ***Brook Trout*** lakes and ponds in the species' native range (ibid). By comparison, *New Hampshire* has only three wild trout ponds, *Vermont* has only one, while *New York* has around 20, mostly situated in the Adirondack Mountains' area (Jeff Reardon, New England Director, *Trout Unlimited*, pers. comm.).

Coastal streams in New England commonly support '*salter*' ***Brook Trout***, which undergo a distinct life-history strategy by migrating downstream to feed in the sea during the spring and returning to the streams during mid-late summer to spawn (Morinville **&** Rasmussen 2003, Havird et al. 2011, Dauwalter et al. 2014, Snook et al. 2016).

Hynes (1970) has concluded that **66** degrees (Fahrenheit) represents the optimum water temperature for ***Brook Trout*** with respect to oxygen relations in streams. Current speed is also an important abiotic factor relative to the mixing of water and air in terms of oxygen saturation and availability. As water temperature increases, the amount of dissolved oxygen necessary to maintain a constant (100%) partial pressure decreases, while the metabolic oxygen demand by fish increases (Welch 1980, Halliwell 1989a).

A statewide classification system discriminating between wild trout and non-trout wadeable stream habitats was formulated in *Massachusetts* based on the development of a simple bivariate thermal-gradient model (Halliwell 1989a). This wadeable stream habitat templet is grounded on two key abiotic factors (average stream gradient and maximum summer water temperature) which are meaningful aggregate variables representative of known or suspected processes regulating stream fish species assemblages (Orians 1980, Zalewski & Naiman 1985, Halliwell 1989a).

From a biological viewpoint, stream gradient is an important parameter to consider, in that it reflects both current speed and flow volume, which than determines the oxygen regime (Persoone 1979). Also, stream gradient has been shown to be positively correlated with biotic community diversity (Winget & Magnum 1979) and is related to the relative ability of a watercourse to maintain substrate quality (Halliwell 1989a).

High-gradient coldwater native trout habitats in Massachusetts averaged more than **75** feet/mile, with maximum summer water temperatures less than or equal to **74** degrees Fahrenheit. Moderate-gradient coldwater native trout habitats averaged between **26** to **75** feet/mile, with maximum summer water temperatures less than or equal to **68** degrees F. Low-gradient coldwater native trout habitats averaged less than **26** feet/mile, with maximum summer water temperatures less than or equal to **64** degrees F – often found in association with ground-water springs and shady overhead forested canopy conditions (Halliwell 1989a).

In higher-gradient, coldwater streams, the limiting factor of available dissolved oxygen saturations is generally not a problem. However, any conditions which even slightly decrease oxygen tensions in warm weather can be deleterious for trout and associated coldwater organisms (Hynes 1970, Halliwell 1989a). In lower-gradient situations, characterized by slower flows and higher water temperatures, oxygen may indeed become limiting to trout, even in situations where cold, groundwater flows predominate (Hansen 1975, Halliwell 1989a, Snook et al. 2016, Nuhfer et al. 2017).

The major point of consideration is to recognize that the ability of any stream-reach to support native/wild trout differs with respect to its thermal-gradient properties, which vary along a longitudinal gradient from upland to lowland habitats. This concept is important for aquatic resource managers to recognize when developing bio-habitat criteria and/or water quality standards, particularly when applied to coldwater (stenothermal) organisms (e.g., sculpin, trout/chars and burbot), including ***Brook Trout*** (Carlson et al. 2017, Hildebrand & Kazyak 2017, Piccolo 2017, Kirk et al. 2018).

B-12 Lake Trout/Char (*Salvelinus namaycush*) aka '*togue*' **Map 27**

The ***Lake Trout*** (called "togue" in Maine), like the ***Brook Trout*** and ***Arctic Char***, belong to the char branch (genus *Salvelinus*) of the family Salmonidae. For clarification, the exotic ***Brown Trout*** and native ***Atlantic Salmon*** belong to the 'true trout' branch (genus *Salmo*), while the western United States salmon, along with the ***Rainbow Trout***, all belong to the Pacific salmon branch (genus *Oncorhynchus*). The largest ***Lake Trout*** on record weighs about 40 kg (102 pounds).

Ryan Burton, Grand Lake, Maine

Jamie Carr, Wachusett Reservoir, MA-DEP

Lake Trout require deep, cold and well-oxygenated oligotrophic lakes and are only native to northern New England states, primarily in northwestern *Maine*. ***Lake Trout*** are absent from *Rhode Island*, historically introduced in *Connecticut* and currently limited to Quabbin and Wachusett reservoir non-native/wild fisheries in *Massachusetts* (Stolarski 2019). ***Lake Trout*** originally occurred and are considered native to only seven *New Hampshire* lakes, however have been stocked into many other coldwater lakes (Scarola 1973). In *Maine*, ***Lake Trout*** thrive best in lakes with irregular bottom contours and with shore lines covered with boulders and gravel (Everhart 1976). ***Lake Trout*** spawn in fall on rocky reefs and hatch in the spring, while their overwintering eggs are subject to intense predation by ***Brown Bullhead*** and ***Slimy Sculpin***. The latter have been found to be highly adapted to forage on ***Lake Trout*** eggs, including the novel capacity to compress their skulls to access rocky interstices (Marsden & Tobi 2014).

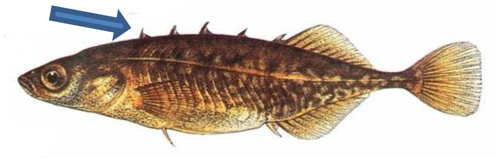
In *Vermont*, ***Lake Trout*** populations, like those of (landlocked) ***Atlantic Salmon***, were severely affected by overfishing and habitat destruction during the 1800's (Langdon et al. 2006). Populations of ***Lake Trout*** from several dozen lakes in *Vermont* are either augmented or totally sustained by hatchery stockings (Baillie et al. 2015).

B-13 Burbot (*Lota lota*) aka '*cusk*' or '*lawyer*' **Map 28**

Burbot are strictly freshwater members of the burbot family Lotidae (Bob Schmidt, personal communication, 2018), with a characteristic single prominent barbel on the underside of the chin near its tip (Everhart 1976). They are absent from *Rhode Island* and only rarely or historically found to occur in southern New England freshwaters – restricted to northern tributaries to the Housatonic and Connecticut river drainages in *Connecticut* and *Massachusetts* (Hartel et al. 2002, Jacobs & O'Donnell 2009). ***Burbot*** are widely found to occur in *New Hampshire* (Scarola 1973) and *Maine* lotic and lentic environments, but are primarily restricted to only rivers and streams within the northern portion of *Vermont* (Langdon et al. 2006). ***Burbot*** ranked 18th in total fish abundance during the New England large (non-wadeable) river survey (Yoder et al. 2015).

In *Maine*, ***Burbot*** are taken in routine sampling of cooler deep lakes and coldwater stream populations. They spawn during the winter and usually complete spawning by the time the ice is gone (Everhart 1976). ***Burbot*** have been observed spawning in riffle areas of streams and juveniles have been found on shallow sandy bottoms of lakes – indicative that some spawning may also occur in lakes (ibid). In mid-summer, ***Burbot*** appear to become lethargic and seem to go into partial hibernation, retreating to the cooler depths of lakes until surface waters cool in the autumn months (Scarola 1973). ***Burbot*** have extremely small embedded scales covering the body (ibid) and appear to be quite 'slimy' when being measured – second only to the ***American Eel*** in respect to the ease of handling and measuring individuals for body lengths and weights.

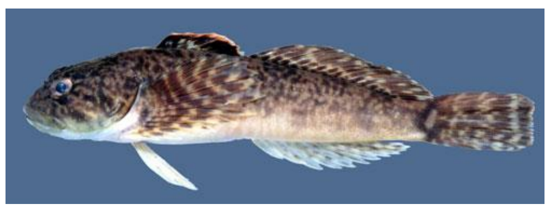
B-14 Brook Stickleback (*Culaea inconstans*) aka '*fivespine stickleback*' **Map 29**



Brook Stickleback characteristically have five dorsal spines and is strictly a freshwater fish species – which are only rarely found to reside in a small number of coldwater streams and lakes in northwestern *Maine* (Maine DEP/DIF&W 2014). They have been historically reported to occur in *Connecticut* waters (Behnke & Wetzel 1960) but none have been sampled since the 1960's, and are probably no longer present (Jacobs & O'Donnell 2009).

There are no sticklebacks in *Vermont* proper, however, ***Brook Stickleback*** are found to reside in clear, cool, weedy areas of lakes, ponds and slow-moving streams in the western Lake Champlain drainage (Langdon et al. 2006).

B-15 Slimy Sculpin (*Cottus cognatus*) aka '*miller's thumb*' **Map 30**



There exists, in western Massachusetts, a single stream in which all three-resident trout (brook, brown and rainbow) were found to populate (co-inhabit) a similar, however, unique habitat of very unusual substrate. In this very same stream, we found an unusually large ("monster") **Slimy Sculpin** *measuring* ***4.7 inches'*** *total length (average adult length usually* ***3 inches****) from a tributary to the Housatonic River in Pittsfield.*

Slimy Sculpin range from northeastern Siberia, through much of Canada, and southeast to Virginia in suitable coldwater habitats. To the west, their southern limits reach *British Columbia, Washington,* and *Montana*. ***Slimy Sculpin*** occur in deep, coldwater lakes in the northern portion of their range, however, are restricted to flowing coldwaters when found to occur in southern New England (Beauchene 2011) and elsewhere in the United States (Poole et al. 2004, Lyons et al. 2009). ***Slimy Sculpin*** feed primarily on invertebrate benthic fauna, particularly aquatic insect larvae and nymphs. They were ranked **24th** in total fish abundance during the large (non-wadeable) river surveys (Yoder et al. 2015).

Slimy Sculpin occurs statewide, often in association with native ***Brook Trout***, in all major *New Hampshire* and *Maine* watersheds, except the Coastal drainages, as well as in most coldwater *Vermont* watersheds (Scarola 1973, Langdon et al. 2006, Maine DEP/DIFW 2014). In *Connecticut*, ***Slimy Sculpin*** has a fragmented distribution, limited to coldwater streams primarily in the *northwestern* part of the state – upper Housatonic and Farmington River watersheds (Jacobs & O'Donnell 2009). ***Slimy Sculpin*** (and ***Creek Chub***) are absent from the waters of *Rhode Island* (Libby 2013). In *Massachusetts*, ***Slimy Sculpin*** are common and widely distributed in coldwater streams, primarily in drainage systems to the west of the mainstem Connecticut River (Johnson et al. 2018, ***Slimy Sculpin-Rainbow Trout*** interactions in NY).

Geographically isolated *Massachusetts* populations of ***Slimy Sculpin*** persist in the Millers, Chicopee and Nashua river basins, but have been extirpated from the lower Merrimack River in Lawrence – last reported in 1953 (Halliwell 1991, Hartel et al. 2002). Geographically isolated 'relict' populations of ***Slimy Sculpin*** inhabiting small headwater streams in eastern *Massachusetts* (12 locations within four drainages east of the Connecticut River) were historically proposed for listing as critical fish habitats (Halliwell 1991). A mysterious reporting of ***Slimy Sculpin*** collected from two locales on an unnamed (low-gradient, spring-fed) tributary to the Eel River (upstream of Forge's Pond) on Cape Cod, in Plymouth *Massachusetts* – currently exist as remnant introduced populations, possibly from historical (1900) upstream trout hatcheries (Maietta 2007).

Past reports of ***Mottled Sculpin*** (*Cottus bairdi*) from *Massachusetts* may stem from the fact that they often have four pelvic fin rays on one side or the other, but are true *C. cognatus* in all other characteristics (Hartel et al. 2002). The author has several large collections of sculpin from populations to the west and east of the Connecticut River in *Massachusetts*, to possibly serve as an available data base (at the *Eagle Hill Institute*, Steuben – Maine) for future taxonomic studies.

Group C-1 to **C-6** ***Atlantic Coastal Plain*** native fish species are primarily limited in distribution to lowland coastal habitats in New England proper. Coastal plain fish species include the following fish species: ***American Brook Lamprey, Bridle Shiner, Eastern Creek Chubsucker, Redfin Pickerel, Banded Sunfish*** & ***Swamp Darter***.

These coastal lowland fish species are all native to and commonly found in all the southern New England states (*Connecticut-Rhode Island-Massachusetts*), as well as *New Hampshire*, however, are particularly rare to totally absent from the state of *Maine*. To the south of *Maine*, these low-gradient (swampland) fish species are well-distributed throughout the low-land coastal plain regions in the remaining New England states, with the natural exception of inland situated (non-coastal) *Vermont*. Interestingly, most of these coastal plain fish species, with the notable exceptions of ***Banded Sunfish*** and ***Swamp Darter***, are also found to occur within the Lake Champlain drainage in western *Vermont* (Langdon et al. 2006).

This component of the extant New England proper fish fauna has a close affinity to the Atlantic Coastal Plain and was probably derived from a refugium south of the glacial margin, possibly as far south as *Virginia* or *North Carolina* (Schmidt 1986). All the fish species within this group are primary division freshwater fishes (Myers 1949) and have very low salinity tolerances. It is hypothesized that dispersal from this southern refugium occurred through freshwater drainage connections (Schmidt 1986).

Group C ***Atlantic Coastal Plain*** lowland fish species, inclusive of ***Bridle Shiner***, probably dispersed into northern sectors of its range relatively early during glacial recession (Jenkins & Zorach 1970). Further dispersal to the south (and northeast) was possibly via extended main rivers during the late Pleistocene, stream capture, and lateral meanders (ibid) and/or swamping (Halliwell 1989a).

These six-coastal plain obligate freshwater fish species probably dispersed northerly through the post-glacial (south flowing drainage into Narragansett Bay = Blackstone River corridor) Merrimack drainage, but spread only a little further along the *Maine* coast. Warping and eustatic rebound in the area south of central *Massachusetts* eventually channeled the Merrimack River eastward to the Gulf of Maine, cutting off this drainage as a dispersal route for salt-intolerant coastal plain fishes (Schmidt 1986).

Schmidt (1986) also includes ***Tessellated Darter*** as a Northern Appalachian fish with Atlantic Coastal Plain affinities whose dispersal was probably through Coastal Plain freshwater habitat on the exposed Continental Shelf. Dispersal from this southern refugium primarily occurred after glacial recession began about 12,000 years ago, and continued to about 3,500 years ago, when the sea reached its present level (ibid). The absence of ***Tessellated Darter*** from the state of *Maine* and eastern *New Hampshire* drainages, inclusive of the Merrimack, Androscoggin and Saco drainages, provides evidence that this darter species did not successfully disperse northward in New England proper. The other six Group C-1 to C-6 coastal plain freshwater fishes, inclusive of ***American Brook Lamprey, Bridle Shiner, Eastern Creek Chubsucker, Redfin Pickerel, Banded Sunfish*** and ***Swamp Darter***, were only somewhat barely successful in their northward dispersal, as evidenced by their rare to absent status in lowland coastal portions of *New Hampshire* and *Maine*.

All members of this coastal plain freshwater fish assemblage typically inhabit similar heavily weeded coves of lowland lakes and quiet weedy backwaters of lowland tea-colored acidic streams (Scarola 1973, Collette 1976). ***Tessellated Darters***, on the other hand, live in a variety of aquatic habitats in both ponds and streams, but is commonly found to occur in mid-gradient rocky clear-running streams with minimal aquatic vegetation (Halliwell 1989a). ***Tessellated Darters*** prefers moving water and, unlike ***Swamp Darters***, are seldom found to occur in lakes and ponds (Hartel et al. 2002).

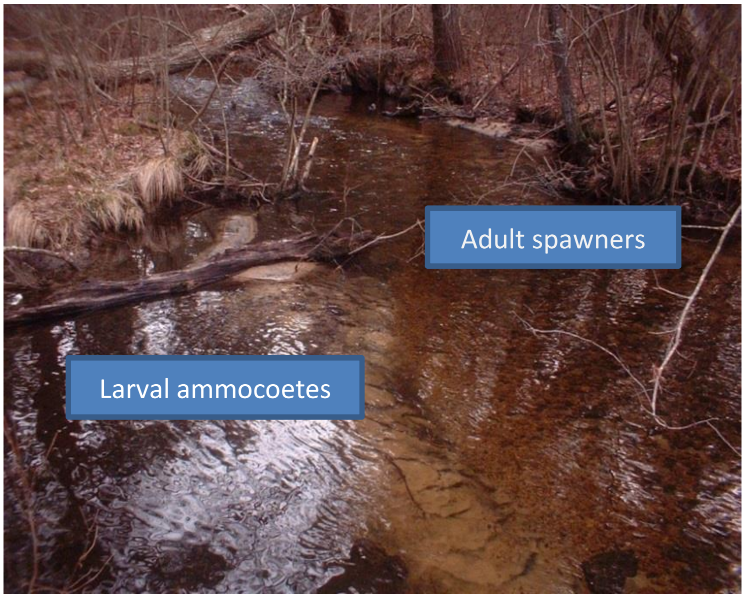
South of the glacial margin, along the exposed coastal plain, was characteristically near-tundra or park tundra where the climate was too severe for extant Atlantic Coastal Plain freshwater fishes (Schmidt 1986). The habitat on the exposed Continental Shelf on the middle Atlantic coast (near southern *Virginia* or *North Carolina*) was probably very like the extant Atlantic Coastal Plain – characterized by slow, acid-stained streams supporting heavy vegetation (ibid). Virtually no taxonomic differences exist between those northern Appalachian fishes and their Atlantic Coastal Plain populations, hence, there apparently existed contact and genetic exchange between the ancestors of these southeastern (coastal lowland) New England proper fish populations (ibid). The current distribution of ***Swamp Darters*** in the state of *New York* is limited to ponds and medium-sized streams on Long Island (Carlson et al. 2016).

Notably, in October 2016, the U.S. Fish and Wildlife Service announced the creation of the "***Great Thicket National Wildlife Refuge***," including grass and shrub habitats in coastal-lowland regions of New England (*Maine, New Hampshire, Massachusetts, Rhode Island* and *Connecticut*) and eastern *New York* (Wood 2016). This area of conservation concern appears to encompass the native group C species along the coastal plain of New England proper (coinciding with Level IV 59 ***Northeastern Coastal Zone*** Ecoregion, Griffith et al. 2009).

C-1 American Brook Lamprey (*Lethenteron appendix*), '*stone sucker*' Map 31

American Brook Lamprey are non-fish like creatures and, like the ***Sea Lamprey***, have a primitive skeleton of cartilage, lack jaws and paired fins and possess seven pairs of external gill openings (Halliwell 1979, White 2014).

Adult ***American Brook Lamprey*** are historically found to inhabit areas where the river channel meanders through open wetlands, while larval ammocoetes are often found where wood from fallen trees or abandoned beaver dams has trapped gravel and fine sediment (Halliwell 1979, Hartel et al. 2002, NH-F&G 2016), in association with accumulated woodland organic debris. ***American Brook Lamprey*** requires two closely associated, however distinctive stream habitats for their two life stages: (1) flowing large gravel coldwater streams (often in association with ***Brook Trout***) for adult spawning (single season only, adults are non-feeding) and (2) adjacent backwater pools of mixed sand and organic matter (detritus) for larval ammocoete development (6-8 years). Figure xx show these two types of stream habitat from a non-fish-sampled southern *Rhode Island* locale.



American Brook Lamprey status is uncertain in *Connecticut* – limited to only a few stream populations in the Connecticut River drainage (Sawyer 1960, Whitworth 1996) – and whether they are native to the state is disputed amongst *Connecticut* fisheries scientists (Jacobs & O'Donnell 2009). ***American Brook Lamprey*** is currently listed as a *Connecticut* State Endangered Species (ibid) – and is also listed as 'fish species of special concern' in *Massachusetts*, *New Hampshire* and *Maine* coastal watersheds.

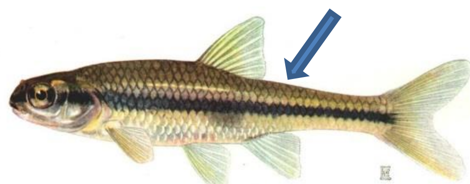
American Brook Lamprey are found to occur in *Rhode Island* only in the northeastern part of the Blackstone River drainage (Libby 2013) – where they also occur over the state border in *Massachusetts* (Halliwell 1979), along with populations on Martha's Vineyard and Cape Cod, where ammocoetes are found to occur in sympatry with parasitic ***Sea Lamprey*** (Hartel et al. 2002). ***American Brook Lamprey*** populations in the Mashpee River (Cape Cod, *Massachusetts*) were originally studied by Hoff from 1966 to 1988 (ibid).

In *New Hampshire*, the ***American Brook Lamprey*** have been historically found to inhabit Chesley Brook and a small fraction of the upper portions of the Oyster River (Scarola 1973, NH-F&G 2016) – located within the Piscataqua River watershed, however, ecologically isolated from Maine by estuarine-rich marine waters (Aman et al. 2017). In *New Hampshire*, ***American Brook Lamprey*** are now restricted to three main populations within a small portion of the Oyster River watershed (Sawyer 1960, NH-F&G 2016).

The presence of ***American Brook Lamprey*** in *Maine* was only recently documented by Aman et al. (2017). They were originally captured during the summer of 2011, by a stream survey team from the *Wells National Estuarine Research Reserve* from a single (Shorey's) brook located in the south coastal *Maine* towns of Eliot and South Berwick, within the Piscataqua River watershed (Aman et al. 2017). Four specimens from this latter sample were positively identified as ***American Brook Lamprey*** using e-DNA genetic analyses at a Canadian laboratory in Manitoba (ibid).

In *Vermont*, ***American Brook Lamprey*** are currently limited to seven tributaries to Lake Champlain only (Langdon et al. 2006), well to the west of the New England proper fish faunal area. To the north of New England in *Canada*, the non-parasitic diminutive ***American Brook Lamprey*** exists as Ontario's most common native lamprey, where it is commercially used as bait for anglers (Holm et al. 2009).

C-2 Bridle Shiner (*Notropis bifrenatus*) aka '*bridled minnow*' **Map 32**



Bridle Shiner depend upon dense communities of submerged aquatic vegetation for their survival (Harrington 1947) – the type of habitat found along the shorelines and coves of smaller ponds and slow-flowing streams, usually associated with adjacent wetlands (NH-F&G 2016). They have only 7 rays in their anal fin (compared to 8 in ***Blacknose Shiner***) and grow to a maximum size of only 2 inches – 51 mm (Wick 2007).

Bridle Shiner are native to five of the six New England proper states, only occurring within the Champlain drainage in *Vermont* (Langdon et al. 2006). They have a scattered range throughout *Connecticut* and *Massachusetts* lakes and streams, where their populations appear to be declining statewide (Jacobs & O'Donnell 2009), particularly in eastern *Massachusetts* (Hartel et al. 2002). In *Rhode Island* (Libby 2013), ***Bridle Shiner*** are found at only 10 locales within four drainage areas: Blackstone, Pawcatuck, Pawtuxet and Narragansett – where they are uncommonly found to occur (personal communication, Libby 2018). In *New Hampshire*, ***Bridle Shiner*** were found to reside at only 8 of 30 sites where they were historically recorded (Harrington 1947). *Bridle Shiner* are now known from 57 scattered sites in *New Hampshire*, with many new records from previously undocumented locations (NH-F&G 2016), including tributaries to the Merrimack River and Coastal drainages, and a chain of lakes in the Saco River drainage (Scarola 1973).

Bridle Shiner in *Maine* are rarely found to occur (two lotic sites), restricted in distribution to the coastal (Saco and Presumpscot River drainage) regions of southern *Maine* (Wick 2007, Maine DEP/DIFW 2014). To the north of New England (*Ontario, Canada*), ***Bridle Shiner*** are found to occur only in the cool, clear, heavily vegetated areas in tributaries to the St. Lawrence River (Holm et al. 2009).

C-3 Eastern Creek Chubsucker (*Erimyzon oblongus*) aka '*sweet sucker*' **Map 33**

Juvenile ***Eastern Creek Chubsuckers*** (as shown above) have a characteristic black lateral band and can be easily mis-identified in the field as a ***Bridle Shiner*** or associated cyprinids (i.e. ***Fallfish***).

Another native coastal plain species, ***Eastern Creek Chubsucker*** have a *statewide*, however, patchy distribution in *Connecticut* (Jacobs & O'Donnell 2009), *Rhode Island* – found at 27 sampling locales in six drainages - Pawcatuck, Pawtuxet, upper Quinebaug, Blackstone, and Narragansett Bay – where they are uncommonly found to occur, Woonasquatucket and Moshassuck (Libby 2013, personal communication 2018), and *Massachusetts* – more common east of Quabbin Reservoir, but not known from Cape Cod and the Islands (Hartel et al. 2002).

In *New Hampshire*, ***Eastern Creek Chubsucker*** are restricted mainly to the southern half of the state, occurring in the lower Connecticut River drainage, Saco and Merrimack River drainages, and Coastal drainage (Scarola 1973). This fish species is rarely encountered in *Maine*, limited to several warmwater ponds in the southern coastal lowland part of the state (Maine DEP/DIFW 2014). ***Chubsuckers*** are absent from all *Canadian* freshwaters, as are ***Banded Sunfish*** and ***Swamp Darter*** (Scott & Crossman 1973, Holm et al. 2009).

The only sucker in Maine without a lateral line, ***Eastern Creek Chubsucker*** have been found to historically populate 21 waterbodies in three southern drainages – lower Saco, Presumpscot and Androscoggin (Wick 2007).

C-4 Redfin Pickerel (*Esox americanus*) aka '*grass, mud, banded pickerel*' **Map 34**

Redfin Pickerel have a spotty distribution in *Connecticut*, where they are found in all major drainages, but are most common in the coastal and Connecticut River drainages, and absent from most of the Housatonic, Thames and western coastal watersheds (Jacobs & O'Donnell 2009). Similarly, ***Redfin Pickerel*** are also absent from the Thames drainage in *Rhode Island*, but are well-distributed in most other stream drainages statewide (Libby 2013).

In *Massachusetts*, ***Redfin Pickerel*** are commonly found throughout the eastern coastal lowlands and often are found to occur in spring-fed native ***Brook Trout*** habitats (Hartel et al. 2002). Like ***Bridle Shiner*** and ***Swamp Darter***, ***Redfin Pickerel*** distribution in *New Hampshire* includes the southernmost part of the Merrimack drainage system and the Coastal watershed (Scarola 1973, NH-F&G 2016). Similarly, these same three fish species are a rarely occurring native fish species in southeastern coastal *Maine* (Lower Kennebec/St. George-Sheepscot) and are listed as a fish species of special concern (Gallagher 1998, Maine DEP/DIFW 2014). ***Redfin Pickerel*** are not found to occur in eastern *Vermont*, but are limited to several swampy stream habitats in the western *Vermont* Lake Champlain drainage (Langdon et al. 2006), outside of New England proper. This fish species is not found to occur in Ontario (Holm et al. 2009), however is native to the St. Lawrence River drainage, like the ***Bridle Shiner*** distribution in Canada.

C-5 Banded Sunfish (*Enneacanthus obesus*) aka '*barred, spotted sunfish*' **Map 35**

Notably, ***Banded Sunfish***, were first described from specimens collected at Hingham and Holliston (*Massachusetts*) by Charles Girard in 1854 (Hartel et al. 2002). In *New Hampshire*, this diminutive sunfish was only found to occur in the Millers River (Connecticut River drainage system) above the *Massachusetts* state line (southeastern section in *New Hampshire*). ***Banded Sunfish*** are found in a few coastal lakes west of the Thames River and extending into the lower Connecticut River drainage basin east of the Connecticut River, with most populations in the Thames basin or further east (Whitworth 1996). Jann (2001) studied ***Banded Sunfish*** distribution and habitats in *Connecticut* and did not find them to reside in water temperatures exceeding 24 degrees centigrade and with aquatic vegetation coverage of less than 60%.

Banded Sunfish probably migrated from the southeastern refugia into glacial Lake Connecticut a few hundred years prior to ***Swamp Darter***, and moved further west in the lake before the penetration of salt waters forced them into freshwaters (ibid). Based on its overall distribution, ***Banded Sunfish*** probably also utilized both headwater and lowland transfers to obtain access to the upper Quinebaug River drainage basin from the basin of the Pawcatuck River in *Rhode Island* and *Connecticut* (ibid). ***Banded Sunfish*** are found in 40 locales throughout *Rhode Island* in all river drainages except for the Woonasquatucket, Moshassuck and the Saugatucket (Libby 2013).

In *Massachusetts*, ***Banded Sunfish*** are widespread in the north- and south-eastern parts of the state, including a few locales on Cape Cod and Martha's Vineyard, but not on Nantucket, nor in the Thames (Quinebaug and French) River drainage (Hartel et al. 2002). ***Banded Sunfish*** populations in the Chicopee and Millers drainages are most likely the result of stream capture with the Merrimack River basin (ibid). In *New Hampshire*, ***Banded Sunfish*** are found in the southern portions of both the Connecticut (Millers River drainage) and Merrimack River drainages and the coastal watershed (Scarola 1973). To date, ***Banded Sunfish*** have not yet been found to reside within the state of *Maine*, but are likely to show-up in the not too distant future.

C-6 Swamp Darter (*Etheostoma fusiforme*) aka '*mud* or *fussy darter*' **Map 36**

Swamp Darter are the smallest species of freshwater fish found in New England proper (seldom exceeding 2 inches in total length) and in the absence of an air bladder, spends its life resting on the bottom or in clumps of aquatic plants (Collette, in Everhart 1976). ***Swamp Darter***

was originally described from tributaries of the Charles River near Framingham (*Massachusetts*) by Charles Girard in 1854 (Hartel et al. 2002). ***Swamp Darter*** are distributed along the coastal plain from extreme southern *Maine* (rarely found) to *North Carolina* and are found to inhabit lower gradient and warmer-water streams and ponds in New England.

Swamp Darter are primarily a vegetated pond and detrital sediment species, and individuals found to inhabit associated streams are thought to be dependent on pond populations for recruitment (Schmidt & Whitworth 1979). Apparently ***Swamp Darter*** are not limited in their distributions to lower pH/colored waters, but are also found to commonly inhabit clear and sandy lake waters in New England, including 15 ponds on Cape Cod, *Massachusetts* (Hartel et al. 2002). Maine ***Swamp Darter*** populations appear to have two distinct annual size classes, while southern New England populations live for only one (Collette, in Everhart 1976, Schmidt & Whitworth 1979).

Detailed studies of the food habits of ***Swamp Darter*** have not been conducted, but copepods seem to be the most common prey item (Collette, in Everhart 1976). ***Swamp Darter*** are still common in many areas of eastern *Massachusetts*; however, their overall New England distribution has been reduced due to development of existing large northeastern cities and towns (Hartel et al. 2002, Jacobs & O'Donnell 2009).

Schmidt and Whitworth (1979) postulated that ***Swamp Darter*** entered New England via the eastern tip of Long Island very late in postglacial time, however, prior to the entry of congeneric ***Tessellated Darter***. The distribution of ***Swamp Darter*** (and ***Banded Sunfish***) is best explained by refugia south of *Rhode Island* and their New England distribution is probably a result of post-glacial drainage patterns and dispersal through extinct and extant intersystem (drainage) connections (ibid).

In *Connecticut*, ***Swamp Darter*** are restricted to lowland areas in drainage basins *east* of the Thames and Quinebaug Rivers and probably entered glacial Lake Connecticut from that refugium just before salt waters began flooding the lake about 12,000 years ago (Whitworth 1996). Because flows from the Thames River were still reasonably high, ***Swamp Darter*** probably were not able to migrate up the main stem of the Thames River system, and were only able to move into only a few areas near the coast in eastern *Connecticut*. Based on its overall distribution, ***Swamp Darter*** probably utilized both lowland and headwater transfers from the east, through the Pawcatuck River drainage basin to migrate into the upper Quinebaug (= Thames, eastern French River) drainage system (Schmidt & Whitworth 1979, Hartel et al. 2002, Jacobs & O'Donnell 2009).

Swamp Darter in *Rhode Island* are widely distributed (45 locales) in *all river drainages* except for the Thames and the Moshassuck (Libby 2013). In *Massachusetts*, ***Swamp Darter*** are common to all major drainages in the *eastern* part of the state, on Cape Cod, Nantucket and

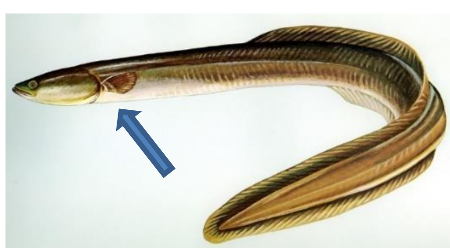
Martha's Vineyard (Hartel et al. 2002). Also in *Massachusetts*, Thames River ***Swamp Darter*** occur only in the (eastern) French River drainage system (like the **Banded Sunfish** distribution in *Massachusetts* and *Connecticut* – Jann 2001), while ***Tessellated Darter*** occur only in the (western) Quinebaug River drainage system (Hartel et al. 2002). Both ***Swamp*** and ***Tessellated Darter*** are notably absent from the Concord River drainage in *Massachusetts* – based on 59 collections (ibid). In *New Hampshire*, ***Swamp Darters*** are found only in the lower portion of the Merrimack watershed and in the Coastal watersheds (Scarola 1973) and are only rarely encountered in a few southern *Maine* coastal streams (Maine DEP/DIFW 2014). The ***Swamp Darter*** spread northward into southern *Maine* (York County: Ogunquit and Cape Neddick river systems – Collette, in Everhart 1976) may have been facilitated through post-glacial Merrimack – Narragansett Bay drainage connections (Schmidt & Whitworth 1979, Schmidt 1986).

Group D-1 to **D-10** ***Diadromous*** – inclusive of the following truly <u>migratory</u> fish species: ***American Eel*** (***Catadromous***)***, Sea Lamprey, Atlantic Sturgeon, Shortnose Sturgeon, Blue-back Herring, Alewife, American Shad, Atlantic Salmon, Rainbow Smelt*** and ***Striped Bass***.

Introduced ***Alewife*** and native ***Atlantic Salmon*** and ***Rainbow Smelt*** are represented as both migrants and inland pond and lake <u>landlocked</u> populations (Lackey 1969). In *Maine*, these migratory native fish species voluntarily moved in the Kennebec River from Augusta upstream to Winslow/Waterville (17 river miles distant) following the removal of the **Edward's Dam** in 1999 (Gail Wippelhauser, Maine DMR, pers. comm.). Most are present, to varying degrees, in the Connecticut River in *Connecticut* and *Massachusetts* and southern portions of the Connecticut River in *New Hampshire* and *Vermont* proper. These two diadromous fish species are also present, to varying degrees, in the *Massachusetts* and southern portions of the Merrimack River in *New Hampshire*.

The removal of dams is becoming a common and effective tool for restoring diadromous fish species in New England proper (Morning Sentinel 2008, Magilligan et al. 2016, Livermore et al. 2017, Liebich et al. 2018). *Diadromous* fish include those migratory *anadromous* fish species that live in the ocean and ascend freshwater rivers-streams-lakes to spawn during the springtime, as well as *catadromous* fish species that live and grow-up in freshwaters and descend to the ocean to spawn (i.e., limited to ***American Eel*** in North America).

D-1 American Eel (*Anguilla rostrata*) aka '*freshwater eel*' **Map 37**



Unlike lampreys, fishlike ***American Eel*** have true jaws, a single gill opening on each side of the head, and paired (pectoral) fins (Libby 2013). ***Diadromous*** native fish species include the facultative *catadromous* ***American Eel*** (US-FWS 2005), which migrates from coastal freshwaters to the vicinity of the *Sargasso Sea* to spawn (Kahn 2019). The remaining nine *anadromous* fish species are known to be anadromous (migratory), ascending rivers in the spring to spawn and returning to the ocean in the fall.

American Eel are a migratory fish species, to say the least, but are *catadromous* in nature – adults spawning in the open *Sargasso Sea* (south of Bermuda), producing leaf-like *leptocephalus larvae* which migrate to rivers in *North America* while developing to nearly transparent tiny *glass eels* and then small, yellow-green juvenile *elvers*, and spending their adult lives in freshwater before returning to sea (Oliveira 1999). They may reach 40 inches' total length, however, are very difficult to measure due to the slippery nature of their slimy skins.

The ***American Eel*** is the only species of freshwater eel found in North America, where people have fished and farmed single population (panmictic) eels for thousands of years (US-FWS 2015). The species has survived multiple ice ages and seems to be equipped to withstand the cycles and fluctuations inherent in ocean dynamics (Oliveira 1999). Surprisingly, ***American Eel*** were tied with ***White Perch*** as the least abundant (only single specimens captured) finfish species (out of a total of 46 finfish species) in a recent survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018).

American Eel are commonly found in most every coastal water along the Atlantic coast and larger <u>female</u> adults travel well inland and inhabit many if not all lotic and lentic environments in New England proper. ***American Eel*** were the **14th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 2001) and ranked **3rd** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder 2015). ***American Eel*** were not found in the Deerfield River proper in *Vermont*, but are rarely found to occur in its Green River tributary (Rich Langdon, VT-DEP, pers. comm.). Several HUC-8 localities in northern *Vermont* were not found to be historically inhabited by ***American Eel*** (Langdon et al. 2006), as well as the Housatonic, Quinebaug-French and Blackstone river drainages in *Massachusetts* (Hartel et al. 2002), but are known to occur in lower portions of these two latter drainage systems in *Connecticut* and *Rhode Island* (Oliveira 1999, Libby 2013).

American Eel are a coastally ubiquitous fish species in *Connecticut* and *New Hampshire*, even journeying the 400 miles of the Connecticut River to the Connecticut Lakes (Scarola 1973). It is well known that adult ***American Eel*** can move across land on rainy nights and wriggle their way up and over high dams and stream/river barriers (Jacobs & O'Donnell 2009). ***American Eel*** are rarely observed in the northwestern drainages of *Maine* (St. John, Allagash, Upper Kennebec and upper West Branch Penobscot) as well as the Fish River drainage in northern

Maine (Warner 1965) and are rarely found in the Dead and upper Androscoggin river systems (latter in *Maine* and *New Hampshire*).

The current conservation status of ***American Eel*** in New England proper is overall stable and not in danger of extinction (endangered) or likely to become threatened within the foreseeable future (US-FWS 2015, Kahn 2019).

D-2 Sea Lamprey (*Petromyzon marinus*) aka '*lamper eel*' by native peoples. **Map 38**

In the absence of paired fins and with multiple gills and ammocoete larval stages, lampreys comprise their own *Class Petromyzontida* in contrast to typical ray-finned bony fishes (*Class Actinopterygii*) and cartilaginous fishes (*Class Chondrichthyes* – sharks and rays). The parasitic ***Sea Lamprey*** (Davis 1967) is commonly found in the lowland portions of coastal rivers and streams located throughout New England proper. They were ranked **19th** in total abundance during the New England large (non-wadeable) river survey (Yoder et al. 2015).

Spawning populations of ***Sea Lamprey*** do not occur in *Rhode Island* freshwaters, as no adult ***Sea Lamprey*** have ever been collected – "only observations of smaller 12-inch long ***Sea Lamprey*** parasitic on ***American Shad*** in the Pawcatuck River" (Libby 2013). Non-parasitic ***American Brook Lamprey*** is much smaller (8-10 inches) as adults, but is found to co-inhabit with ***Sea Lamprey*** in the ammocoete/larval stage. Both lamprey species have been collected while electrofishing on Cape Cod (*Massachusetts*) streams in non-sandy backwater detritus pools which have cold and clean flowing waters (Figure xx). Adult ***Sea Lamprey*** spawn in late spring and, unlike any other East Coast anadromous fish species, experience 100% in-situ post-spawning mortality (Saunders et al. 2006, Gardner et al. 2012).

Williamson (1832) considered 'lamprey eels' to be comprised of two species in his *History of the State of Maine*, while providing an extensive description of only the anadromous and parasitic ***Sea Lamprey*** (pp. 153-154). It is strongly suspected that the 'second' species of lamprey referred to is probably the larval (Clemens 2019) freshwater stage of the ***Sea Lamprey***, and not ammocoete of the ***American Brook Lamprey***.

Recently, the successful spawning of anadromous ***Sea Lamprey*** was documented in a naturally restored stream channel of the Mill River (tributary to the Taunton River) in *Massachusetts* following (Hopewell Mills) dam removal (Livermore et al. 2017). Other restoration projects in New England proper have focused primarily on the recovery of associated diadromous fish species (ibid, Hogg et al. 2014, McMenemy 2004).

D-3 Atlantic Sturgeon (*Acipenser oxyrinchus*) aka '*spring-time breacher*' **Map 39**


Credit: U.S. Fish & Wildlife Service

Sturgeon species are generally characterized by the heterocercal caudal fin, rows of bony plates (scutes) along the body and a mouth located ventrally, for benthic feeding (Wick 2007). ***Atlantic Sturgeon*** are commonly observed during spring months, jumping above the surface of the water (breaching). They both have also been recently observed (2010-17) as seasonal transients in the Piscataqua/Salmon Falls drainages in *Maine* and *New Hampshire* (Kieffer et al. 2018). ***Atlantic Sturgeon*** (historically found in the Charles River drainage, Boston) are only found in the lower Connecticut River in *Connecticut* and lower Merrimack River in *Massachusetts*, and occur on Cape Cod in *Massachusetts*, where ***Shortnose Sturgeon*** historically occurred (Hartel et al. 2002). The reconnection of generally fragmented sturgeon populations in *New England* (and North American) rivers is an important line of investigation in recent years (Jager et al. 2016).

In 2012, *NOAA Fisheries* listed the *Gulf of Maine* distinct population segments (DPS) of ***Atlantic Sturgeon*** as threatened – from lower portions of the Kennebec, Androscoggin and Penobscot rivers (Wick 2007). The *Atlantic States Marine Fisheries Commission* (ASMFC 2017) stock assessment overview for ***Atlantic Sturgeon*** (last completed in 1998) was released in October 2017, noting that archaeological evidence shows *Native Americans* harvested sturgeon in pre-contact times. Historically, ***Atlantic Sturgeon*** reached maximum lengths of 14 to 18 feet, however, individuals over 10 to 12 feet are now rarely encountered (ibid). Per ASMFC (2017), there are signs that ***Atlantic Sturgeon*** populations have started a slow recovery, relative to 1998 levels.

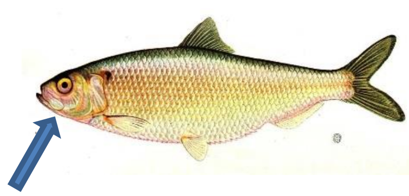
D-4 Shortnose Sturgeon (*Acipenser brevirostrum*) aka '*surface glider*' **Map 40**

Shortnose and ***Atlantic Sturgeon*** differ in respect to their relative size differences, habitat preferences and the surface morphology of their body and head scutes (Halliwell & Spiess 2017). Smaller-sized (4-feet or less) adult Shortnose sturgeon are primarily riverine freshwater inhabitants, with ***tubercular***-patterned (characteristically ***stumped***) body and head scutes – noticeably like Lake Champlain ***Lake Sturgeon***, while ***Atlantic Sturgeon*** are larger-sized (6-8 feet lengths) and are primarily marine/estuarine inhabitants, with ***alveolar***-patterned (characteristically ***pitted***) surfaces on their body and head scutes (ibid).

Shortnose Sturgeon are known to inhabit four major river systems in the *Gulf of Maine*, restricted to lower sections of the Penobscot River, Kennebec River (inclusive of Sheepscot and Androscoggin Rivers), the Saco River in *Maine* (Little et al. 2012) and the Merrimack River in *Massachusetts* (Altenritter 2015). ***Shortnose Sturgeon*** are rarely encountered in the lower reaches of the Saco and Androscoggin in *Maine* and the Housatonic and Thames coastal drainages in *Connecticut* and are more commonly encountered in the Connecticut River (*CT* and *MA*) and free-flowing lower sections of the Merrimack River in *Massachusetts*. A landlocked population of ***Shortnose Sturgeon*** exists above the Holyoke Dam on the Connecticut River in *Massachusetts* (Boyd Kynard, personal communication). In August 2017, a fisherman caught and released an adult-sized ***Shortnose Sturgeon*** below the Vernon Dam in *Vermont* – the first documented report of a ***Shortnose Sturgeon*** in the Connecticut River upstream of the Turners Falls Dam in *Massachusetts* (NOAA Fisheries 2017 report, Julie Crocker).

Shortnose Sturgeon have been "endangered" prior to and since the passage of the *Endangered Species Act* in 1973, however, appears to be on the rebound in larger rivers tributary to the Gulf of Maine (Gail Wippelhauser, Maine Department of Marine Resources, *Bangor Daily News* 2018). Sturgeon are generally bottom feeders, sucking plants and animals disturbed by their movement into their tube-like mouths – including shellfish, fish eggs and worms buried in the river sediment (*Maine Rivers*, ibid).

D-5 Blueback Herring (*Alosa aestivalis*) aka '*river herring*' w/ **Alewife** **Map 41**



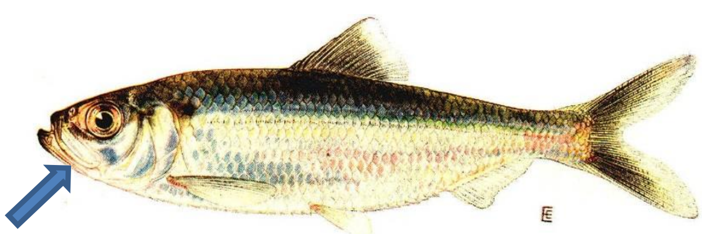
Alosines (Olney 2003), inclusive of 'river herring' (***Blueback Herring*** and ***Alewife***) and ***American Shad***, are commercially significant fish species, often used for baitfish for lobster traps, particularly in *Maine* coastal waters. *Alosines* are laterally compressed silvery fish with deeply forked tails, large, easily detached scales and a belly with a saw-like keel (Jacobs & O'Donnell 2009). The most reliable way of distinguishing between juvenile alosines is the relative shape of the (unscaled) cheek patch (ibid).

Blueback Herring are an anadromous fish species which migrate in the spring, along with ***Alewife***, however, typically spawn in swift-flowing sections of streams with gravel or rocky substrates (Hartel et al. 2002). Like ***Alewife***, the cheek patch is wider than deep in ***Blueback Herring***, however, eye width is usually less than snout length. The color of the gut lining (peritoneum) is the most certain way to tell an ***Alewife*** (light colored) from a ***Blueback Herring*** (dark colored – dusky gray to black).

Like ***Alewife***, adult ***Blueback Herring*** are usually 10-12 inches' total length (Hartel et al. 2002), but unlike ***Alewife***, they are not found to establish landlocked populations in New England freshwaters. Like other alosine and associated anadromous (migratory) fish species, their populations have been historically reduced throughout New England by historical damming and pollution. These anadromous fish species are currently facing dramatic declines, possibly due to changes in climate and increases in North Atlantic Ocean water temperatures (Limburg & Waldman 2009, Palkovacs et al. 2013).

American Shad, Alewives and ***Blueback Herring*** were historically plentiful on the Penobscot River in *Maine* (Carpenter 2016). 'Seven-thousand ***American Shad*** and 100 barrels of ***Alewives*** were taken in one haul of the seine in May **1827**,' per one historian (ibid). Following the removal of the two lower dams in 2012 (Great Works) and 2013 (Veazie), more than 500 ***Atlantic Salmon*** returned in the spring of **2016**, along with 7,846 ***American Shad*** (ibid) and over 1.8 million ***Alewives*** and ***Blueback Herring*** (TNC 2016). This is probably the first time that this many (anadromous) fish have migrated upriver past Indian Island (Old Town) since before the *Civil War* (ibid).

D-6 Alewife (*Alosa pseudoharengus*) aka '*buckies*' and '*river herring*' **Map 42**



Alewives are an anadromous zooplantivorous fish species which migrate in the spring, along with ***Blueback Herring***; however, they typically spawn in upstream freshwater lakes and ponds.

The cheek patch is wider than deep on ***Alewife***, like ***Blueback Herring***; however, eye width is usually greater than snout length, in contrast to ***Blueback Herring***.

Alewives are the only alosine fish species found to be landlocked in New England lakes and ponds, particularly in *Connecticut* and *Maine* inland waters. ***Alewife*** were the 4th most abundant finfish species (out of a total of 46 finfish species captured) in a recent survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018). They were ranked **13th** in total fish abundance during the large (non-wadeable) river survey (Yoder et al. 2015).

In *Connecticut*, dam construction beginning in the 17th century, appears to have caused some sea-run populations to evolve a landlocked (freshwater resident) life history (Palkovacs et al. 2015). Adult landlocked ***Alewife*** are considerably smaller, 3-6 inches' total length (Jacobs & O'Donnell 2009), while anadromous forms are 10-12 inches' total length (Hartel et al. 2002). It has been shown that landlocked ***Alewife*** populations show parallel divergence in foraging traits from their anadromous ancestors – which have larger gapes, wider-spaced gill rakers, and are highly selective for large-bodied prey items, in contrast to landlocked ***Alewife*** populations that have smaller gapes, narrower-spaced gill rakers, and show reduced prey selectivity (Palkovacs & Post 2008, Palkovacs et al. 2008).

Landlocked ***Alewife*** has been introduced as a forage fish for salmonids in several southern New England lakes. They generally have a propensity for overgrazing zooplankton and can cause adverse environmental impacts to water quality as well as to growth and survival of the young of other (resident) fish species (Jacobs & O'Donnell 2009, Brooks & Dodson 1965). Per Post et al. (2008), anadromous ***Alewife*** populations have effects on lake ecosystems that are strong but distinct from those of landlocked alewives (Walters et al. 2009). In (*Connecticut*) lakes with anadromous alewife populations, large-bodied zooplankton are present in early spring, prior to the annual ***Alewife*** spawning migration. However, during summer, large-bodied species are absent and average zooplankton body size is reduced below that seen in landlocked ***Alewife*** lakes (Palkovacs et al. 2015). The success of biomanipulation (***White Perch*** removal) studies on lakes in *Maine* appear to have been confounded by the intermittent presence of significant landlocked ***Alewife*** populations (Halliwell & Evers 2008, Halliwell et al. in preparation).

Notably, both river herring species are common to the lower Connecticut River throughout the state of **Connecticut** (Marcy 1976), however, only ***Blueback Herring*** (along with ***American Shad***) are found to the north in the Connecticut River in *Massachusetts* (per Hartel et al. 2002). The fact that ***Blueback Herring*** and ***American Shad*** are both riverine spawners vs. pond spawning in ***Alewife***, may have been problematic for the latter to be restored in *Massachusetts*. Some fish biologists consider ***Alewives*** to be "*sprinters*" and ***Blueback Herring*** as "*long-distance runners*" (personal communication, Steve Gephard, CT-DEP 2018), in terms of their differential abilities to migrate longer distances in search of suitable spawning habitats in lotic and lentic environments (Hall et al. 2010).

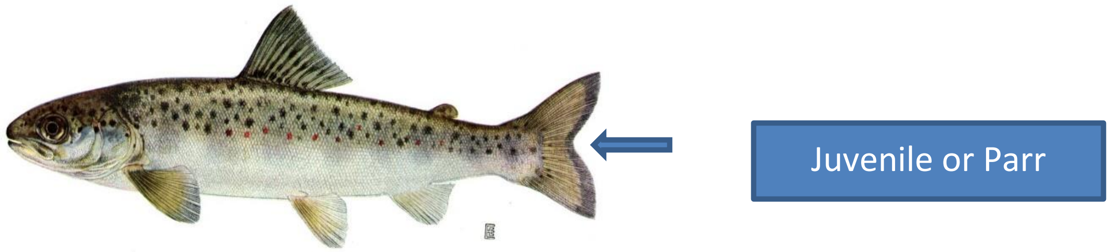
D-7 American Shad (*Alosa sapidissima*) aka '*common shad*' **Map 43**

My most remarkable encounter with this 'poor man's salmon' was at the 'Shad Factory' on the Palmer River in Rehoboth, Massachusetts in the mid-1960's. Willie, my brother-in-law at that time, was an avid angler and taught me (at 15 years of age) how to fly fish for a mixture of coastal fish species including American Shad, Striped Bass and Pollock. We first visited this site over the weekend and I managed to hook and lose several shad, but was not successful in bringing any to shore. Soon after, I decided to play 'hooky' one fine spring day during my senior year at Lincoln High School and returned to the Palmer River 'Factory' to fish for shad with my saltwater fly rod, using a red/white buck-tail shad-dart. After several hours of fishing, I finally was successful at 'snagging' a fish…which turned out to be a five-pound female shad. Unfortunately, I had managed to hook it on the caudal peduncle (tail base) which resulted in an hour's long struggle trying to land this magnificent catch on a fly rod! The shad was taken home and consumed for dinner, but the eggs/roe were very hard to eat – probably overcooked?

American Shad adults grow to be much larger than river herring, reaching total lengths of 20+ inches and weighs 5+ pounds when migrating back to their coastal natal streams. Juvenile alosines (shad, blueback and alewife) are generally difficult to distinguish – the cheek patch is deeper than wide in juvenile ***American Shad***.

American Shad first spawn at the age of 4-5 years and adults may live to 10 years of age (Hartel et al. 2002). Historically, in New England, the ***American Shad*** entered most coastal streams; however, damming, dredging, pollution and other habitat alterations caused large declines in the mid-1800s (ibid). ***American Shad*** (and most other anadromous fish species) were eliminated from the Connecticut, Blackstone and Charles rivers in *Massachusetts* and the Merrimack River in *Massachusetts* and *New Hampshire*.

D-8 Atlantic Salmon (*Salmo salar*) aka '*salar…the leaper*' **Map 44**



I left my coldwater fisheries biologist position with the Massachusetts Division of Fish and Wildlife in the winter of 1991 (after 13 years) to raise my new family in Maine. I was very much aware by then that wild ***Atlantic Salmon*** *populations were non-existent in southern New England; however, I was under the mistaken impression that they were still strong in the state of Maine. Historically, 34 rivers and streams in Maine had naturally reproducing* ***Atlantic Salmon*** *populations* (Saunders et al. 2006). *However, such was not still the case during the waning years of the 20th century* (Moring 1995, NAS 2004).

Sea run anadromous ***Atlantic Salmon*** restoration programs throughout New England were finally discontinued in recent years, following more than two centuries of work dedicated to the restoration of dwindling stocks (Shaw et al. 1824, Moring 1995, Baum 1997, Robinson et al. 2009, Gibson 2017, Gayeski et al. 2018). The Connecticut River was originally one of the finest ***Atlantic Salmon*** streams in New England, until the erection of a dam in **1797** at the mouth of the Millers River in *Massachusetts* (Bailey & Oliver 1939). Migratory ***Atlantic Salmon*** are now officially extirpated in all New England states, except for *Maine* – where dwindling populations persist, primarily in the Penobscot River and a half-dozen or so downeast rivers (Baum 1997, NAS 2004, Boucher & Warner 2006, Gayeski et al. 2018).

The Penobscot River in *Maine* hosts the nation's largest run of the endangered anadromous (migratory) ***Atlantic Salmon*** (Carpenter 2016). Historically, salmon runs may have numbered 60,000, but recent returns fell to less than 1,000 and as low as 250 in 2014 (ibid). Following removal of the two lowest dams on the Penobscot River in 2012 and 2013, more than 500 adult ***Atlantic Salmon*** have returned to spawn. ***Atlantic Salmon*** returns to the Penobscot River are now the highest since 2011, numbering 615 fish, along with 1,583 ***American Shad*** and 29 ***Striped Bass*** at the now lowermost Milford dam (Jason Valliere, Maine Department of Marine Resources – *Bangor Daily News*, 6-27-19).

Atlantic Salmon populations in Maine have declined over previous decades and remain critically low. Despite extensive hatchery supplementation (Moring 1995) and habitat improvement efforts made by management agencies over the last four decades, there has been no clear population response and (eventual) extinction of this species remains an immediate threat

(Sponarski et al. 2017). Among the salmon's current challenges is changing climate, bringing warmer waters and (resulting) unfavorable conditions at sea (Carpenter 2016).

Atlantic Salmon (the 'leaper') ascending a fishway on a Maine river. Note the presence of a parasitic ***Sea Lamprey*** attached to its side! (Photo credit to Sponarski et al. 2017)

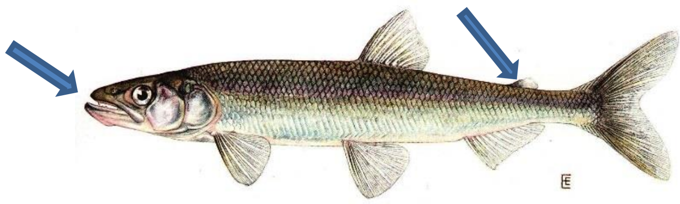
The *Gulf of Maine Distinct Population Segment* was listed as endangered in 2000 with the *Endangered Species Act* (ESA) listing authority jointly shared by the *National Oceanic and Atmospheric Administration* (NOAA) and the *U.S. Fish and Wildlife Service* (FWS). Because regulators and managers working in federal U.S., State of Maine, and *Penobscot Nation* tribal government contexts operate with independent authority, effective recovery related decisions depend on effective communication and coordination among these entities (Carpenter 2016).

Anadromous ***Atlantic Salmon*** have a fairly complex life cycle, including the following stages (Baum 1997, NAS 2004): **eggs** are buried in gravel for 2-6 weeks in mid-October to mid-November; **eyed eggs** over-winter in gravel; **alevin** or **sac-fry** hatch in March or April; pigmented **fry** emerge from gravel in mid-May; stocky **parr** with vertical black marks over summer/winter; streamlined and silvery **smolts (**in April to July), **post-smolts (**from July thru December); and **adult *Atlantic Salmon*** in their first year at sea.

Landlocked ***Atlantic Salmon*** (*Salmo salar*, same species as sea-run ***Atlantic Salmon***) are naturally indigenous to just four drainage systems in *Maine* (Warner & Harvey 1985): ***Presumpscot*** – Sebago Lake; ***St. Croix*** – East/West Grand Lakes; ***Penobscot*** – Sebec Lake; and the ***Union*** – Green Lake. These four-native landlocked Atlantic salmon populations were possibly established following the recession of the Pleistocene glacier 12,000 to 14,000 years ago, along with their primary forage fish, ***Rainbow Smelt***, probably in the same four *Maine* drainage systems. However, landlocked ***Atlantic Salmon*** have been introduced (stocked) as sportfish into hundreds of waters in *Maine* (Boucher & Warner 2006) and throughout New England proper, in suitable deeper coldwater lakes (e.g., Quabbin and Wachusett Reservoirs in *Massachusetts* – existing drinking water supplies for Boston).

Recommendations for management (and conservation) of wild anadromous ***Atlantic Salmon*** include the following: retention of adequate natural riparian buffer strips; dam removal or installation of suitable fishways; maintenance of natural genetic backgrounds of wild salmon by non-introductions of hatchery-raised salmon; and all effluents reducing water quality should be controlled, as best possible (Gibson 2017). The additions of limestone, such as marine mollusc shells, have been recently shown to be beneficial to combat acidified waters in the coastal areas of downeast Maine (Whiting 2015).

D-9 Rainbow Smelt (*Osmerus mordax*) aka '*icefish* ''*cucumber scented'* **Map 45**



Although generally considered an anadromous fish species, ***Rainbow Smelt*** are primarily an inshore marine/estuarine fish species (Behnke & Wetzel 1960, Fried 2006, Dodson et al. 2015, Maine Sea Grant 2017). They move into estuaries and rivers during autumn and remain there throughout the winter months (Saunders et al. 2006), where they have historically supported a popular ice fishery. In late spring, adult ***Rainbow Smelt*** (up to 14 inches in length) move up into fast, cold, and clean freshwater streams to spawn and lay their eggs on submerged rocks and other surfaces (Maine Sea Grant 2017). However, "as a rule, smelt do not journey far upstream; many, indeed, go only a few hundred yards above tidewater" (Bigelow & Schroeder 1953). ***Rainbow Smelt*** were the 10th most abundant finfish species (out of a total of 46 finfish species captured) in a recent survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018).

<u>Landlocked</u> populations of ***Rainbow Smelt*** are the primary forage fish species for non-anadromous ***Atlantic Salmon*** in *Maine* (Rupp 1959) and presumably elsewhere in New England (Halliwell & Boucher 2012). Hence, they are thought to be indigenous to the same <u>four</u> *river basins* which are known to have historically supported *landlocked* ***Atlantic Salmon*** – *St. Croix* (West Grand Lake, Washington County); *Union* (Green Lake, Hancock County), *Penobscot* (Sebec Lake, Piscataquis County), and *Presumpscot* (Sebago Lake, Cumberland County).

Both anadromous and landlocked ***Rainbow Smelt*** exhibit sexual dimorphism, with females being longer lived and having larger sizes at age than males (O'Malley et al. 2017). A latitudinal gradient has been observed in anadromous ***Rainbow Smelt***, which may show signs of population stress at the southern extent of their distribution (ibid).

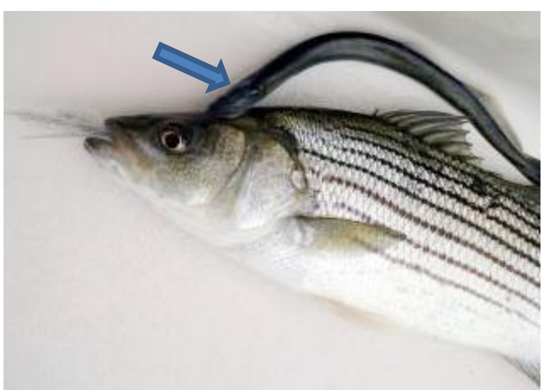
Landlocked ***Rainbow Smelt*** populations in Quabbin and Wachusett Reservoirs in *Massachusetts*, city of Boston water supply – have been found to readily adapt to successful shoreline spawning in direct response to historical acidification in spawning tributaries (personal communication Bill Eastes, MA-DFW, Halliwell 1985 and 1989a).

Anadromous ***Rainbow Smelt*** populations throughout New England and the North-eastern/Mid-Atlantic United States have historically declined due to the creation of coastal river dams, commercial and recreational fishing, and industrial water pollution (Wood et al. 2012). Currently, ***Rainbow Smelt*** are generally considered a species of special concern due to declining populations in the *Gulf of Maine* (Maine Sea Grant 2017). Spawners have not been collected from *southern New England* freshwaters in recent/many years (Jacobson & O'Donnell 2009, personal communication, Libby 2018).

D-10 Striped Bass (*Morone saxatilis*) aka '*rockfish*' '*striper*' '*schoolie*' **Map 46**

Growing up and learning to fish on 'a small island off the coast of Connecticut,' I spent many enjoyable early mornings fishing for 'stripers' with both spinning and fly fishing gear. Patiently watching for seagull and 'bunker' activity on the ocean surface beyond the waves on the beaches of southern Rhode Island was a great way to clear my mind and welcome in the day, prior to attending classes at the University in Kingston. The current Rhode Island state record (over 20-year old) striper is a 52-inch, 77.4-pound fish caught in 2011 (Lengyel 2016).

Striped Bass **hosting a parasitic *Sea Lamprey* attached to the top of its head**



Benjamin, son of author, with a schoolie striper catch from Kennebec River in Augusta, Maine

Striped Bass and ***White Perch*** are closely related members of the family Moronidae – along with White (*M. chrysops*) and Yellow Bass (*M. mississippiensis*), which are not found to occur in *New England* freshwaters (Page et al. 2013). ***White Perch*** differ from ***Striped Bass*** in their preference for active migrations; with the former choosing to spawn in estuarine ponds open to the ocean (see *Fish Group E*). Differentiation of juvenile ***Striped Bass*** from adult ***White Perch*** in archaeological collections can be made based on the relative size and ruggedness of their vertebral centra (Spiess & Halliwell 2011, revised 2012). Adult ***White Perch*** centra are characteristically smaller and less ruggedly built, possibly similar in nature to the observed differences between juvenile ocean ***Atlantic Cod*** (*Gadus morhua*) and adult ***Atlantic Tomcod***.

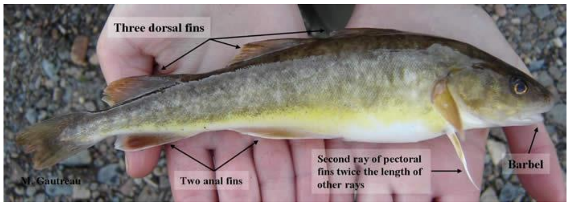
Striped Bass are an inshore schooling coastal species which typically spawn in *New England* rivers during June and are broadcast spawners, with no special courtship sequence (Bigelow & Schroeder 2002). They ranked **15th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015). ***Striped Bass*** run up into estuaries and into river mouths and may remain in the rivers year-round, most notably in the Thames River, *Connecticut* (Jacobs & O'Donnell 2009). Spawning usually takes place to the south of *Rhode Island* in New England (Libby 2013), although ***Striped Bass*** spawning has yet to be positively verified in *Connecticut* freshwaters (Jacobs & O'Donnell 2009). In *Massachusetts*, early accounts (Nelson 2018) note that *Native Americans* traded fish among tribes (Karr 1999) and witnessed their use of a fish weir to catch ***Striped Bass*** in the town of Raynham (Morison 1956) – Wampanoag tribe, probably from the Taunton River. Calcined dorsal spines, vomer and vertebra fragments from ***Striped Bass*** have been found from a 2002 pre-contact inland archaeological site in Newport (Sebasticook Lake outlet), *Maine* (Spiess 2009), downstream from the Sebasticook Lake fish weir (Petersen et al. 1994).

Group E-1 to **E-4** ***Estuarine Species*** – inclusive of the following non-migratory fish species: ***Atlantic Tomcod, Threespine Stickleback, White Perch*** and ***Hogchoker***. ***Threespine Stickle-back*** *and* ***White Perch*** are represented as both coastal pond migrants and inland pond landlocked populations. These non-migratory fish species are known to utilize estuarine coastal habitats and either do not have the physical (swim) capability or voluntarily choose *not* to migrate upstream following dam removal (Nate Gray, Maine DMR, pers. comm.).

Furey & Sulikowski (2011) studied the fish assemblage structure of the Saco River estuary in southern *Maine* and found 24 resident fish species (primarily juveniles), 12 of which were native freshwater fishes – inclusive of estuarine ***Atlantic Tomcod*** and ***Threespine Stickleback***. Also, present in this study were five diadromous fish species – ***Atlantic Sturgeon, American Eel, Blueback Herring, Alewife*** and ***Rainbow Smelt***. ***Blueback Herring*** and ***Rainbow Smelt*** comprised two of the five most dominant fish species, in association with three estuarine/marine fish species (ibid).

Shumchenia et al. (2015), working in a New England estuary, constructed the first estuarine biological condition gradient (BCG) framework that examines changes in resident species habitat structure through time.

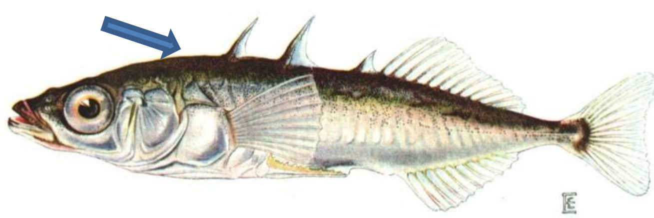
E-1 Atlantic Tomcod (*Microgadus tomcod*) aka '*frostfish*' **Map 47**



Atlantic Tomcod are included in this treatise on New England freshwater fishes primarily based on their recorded appearance as an integral part of the diet of pre-contact native peoples (Smith 1940, Largy 1995, Spiess & Lewis 2001, Spiess & Halliwell 2011 – revised 2012). Also, called "frostfish" because they produce special antifreeze proteins in their blood. Bottom dwellers, ***Atlantic Tomcod*** commonly enter the upper regions of tidal areas along the New England coastal areas during the late fall and early winter to spawn. They remain inland over the winter before returning to cooler, saltier parts of estuaries come spring. ***Atlantic Tomcod*** were the 14th most abundant finfish species (out of a total of 46 finfish species captured) in a recent survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018).

A small (6-10 inch, up to 15 inches) member of the codfish family (Gadidae), ***Atlantic Tomcod*** have recently experienced a precipitous decline in Connecticut and throughout much of their range – Atlantic coast from southern Labrador to the Chesapeake Bay (Jacobs & O'Donnell 2009). Their status is currently uncertain (Bigelow & Schroeder 1953 – revised 2002, Fried 2006).

E-2 Threespine Stickleback (*Gasterosteus aculeatus*) aka '*estuarine fish*' Map **48**

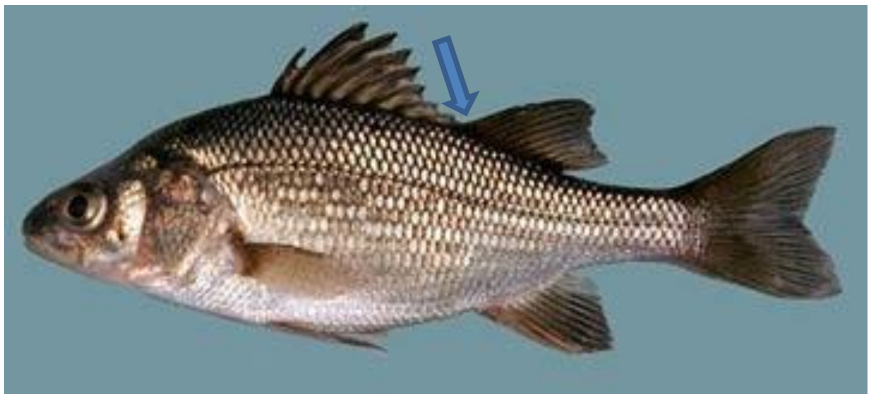


Threespine stickleback are primarily a coastal estuarine fish species which spawn in freshwaters during the spring and early summer (Scarola 1973). ***Threespine Stickleback*** were the most abundant finfish species (out of a total of 46 finfish species captured) in a recent survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018).

Freshwater ***Threespine Stickleback*** populations are not known to occur in *Connecticut* – collected in a dozen coastal streams (Jacobs & O'Donnell 2009) and *Rhode Island* – collected in only five coastal streams (Libby 2013). In *Massachusetts*, only a single landlocked 'threatened' population is in Boston's Olmstead Park (Hartel et al. 2002). In *New Hampshire*, ***Threespine***

Stickleback is also restricted to coastal areas (Scarola 1973). In *Maine*, they are commonly found along coastal estuaries (Vieser et al. 2018), but are also found to reside as landlocked populations in inland streams and ponded waters (Maine DEP/DIFW 2014). *Vermont* only has freshwater ***Brook Stickleback*** populations, which are however, restricted to the western *Lake Champlain* drainage (Langdon et al. 2006).

E-3 White Perch (*Morone americana*) aka '*striped perch*' '*silver perch'* **Map 49**



White Perch are not truly perch, but members of the temperate bass family, which includes the famed ***Striped Bass*** (Aziz 1992). ***White Perch*** are now landlocked in numerous ponds and lakes throughout New England, primarily due to historical introductions as a sportfish during the 1920s and 1930s, however, they are truly indigenous only to river estuaries and coastal ponds which are open to the sea (Bailey 1938, Aziz 1992, Kerr et al. 2009). Surprisingly, ***White Perch*** ranked last in abundance (only a single specimen captured) in a recent finfish survey of Cobscook (boreal macrotidal) Bay in 'down-eastern' *Maine* (Vieser et al. 2018).

When the lowermost *Edwards Dam* on the Kennebec River in Augusta (*Maine*) was removed in 2000, truly migratory (diadromous) fish species (e.g., ***Alewife, Striped Bass*** and ***Shortnose Sturgeon***) moved upstream to the *Fort Halifax Dam* (Sebasticook River confluence) in Waterville/Winslow. Reportedly, resident ***White Perch*** populations chose to remain in the estuarine downstream brackish waters (Gail Wippelhauser, Maine DMR).

It is interesting that Bailey (1938) considered the ***White Perch*** as an <u>introduced</u> species in *New Hampshire*, on the basis that "it was not definitely known to have lived in the Merrimack River originally, and the present lake populations in *New Hampshire* are known to have been stocked." Holmes (1862) recognized early on that ***White Perch*** "are much esteemed by many sportsmen (for fish chowder) and they are easily transferred from their native (estuarine) haunts, and become easily habituated to their new (freshwater) location and soon multiply rapidly."

White Perch were the **15th** most widespread resident fish species in the EMAP-SW northeastern lakes survey (Whittier et al. 1999) and was ranked **16th** in total fish abundance during the New England large (non-wadeable) river surveys (Yoder et al. 2015).

Non-native ***White Perch*** were found to be the dominant resident fish in the great majority of the 33 *Maine* lakes which were US-EPA 303(d) listed in non-attainment of water quality standards (Halliwell 2005, unpublished). With US-EPA 319 project funding for several graduate students (Trinko-Lake, Ditzler-Strock, Tuckett) at the University of Maine in Orono, a long-term biomanipulation study was initiated in 2004 on headwater Belgrade Lakes (*East* and *North*) inclusive of 6 years of pre- and post- removal of targeted fish species (Halliwell & Evers 2008). Over the 6-year period (2007-2012) a grand total of 46.5 tons of fish were removed, 92% of which was comprised of ***White Perch*** (42.6 tons), 5% ***Yellow Perch*** (2.4 tons) and 3% ***Black Crappie*** (1.5 tons). Landlocked ***Alewife*** was only truly abundantly present during the fifth year of removal (2011) and did not significantly contribute to the total weight of targeted fish removed from *East Pond*.

The bycatch of annually captured and released non-targeted native resident fish species in *East Pond* was comprised of ***Golden Shiner*** (50%), ***White Sucker*** (16%), sunfish species (***Pumpkinseed*** and ***Redbreast Sunfish*** with *Lepomid* hybrids – 13%), ***Chain Pickerel*** (13%), ***Brown Bullhead*** (1%) and non-native ***Largemouth Bass*** (6%). Water quality, in terms of the prevalence, intensity and duration of summertime nuisance blue-green algal blooms, appeared to gradually improve, coincident with fish removal (Halliwell 2017, unpublished). The angling quality of resident ***White Perch*** in *East Pond*, as measured by the *Fulton* condition factor (Froese 2006), also showed considerable improvement during the 6-year fish removal period.

Following this biomanipulation project (2004-2015) the water quality of *East Pond* returned to a state of nuisance algal blooms during the summer months (2016-2017). So, the goal of this biomanipulation project to possibly reset the trophic state of the pond in favor of the ability of large-bodied zooplankton to possibly harvest the phytoplankton (blue-green algae) was not met.

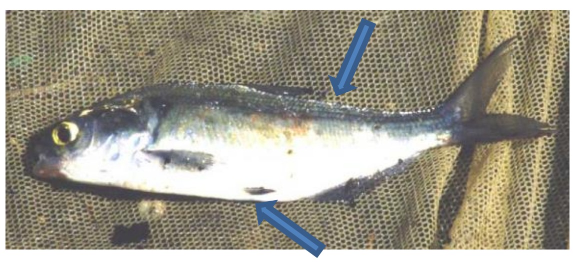
E-4 Hogchoker (*Trinectes maculatus*) aka '*most advanced freshwater fish*' Map 50

This is a diminutive flatfish (American Sole) which seldom reaches total lengths more than 6-8 inches (Hartel et al. 2002). The ***Hogchoker*** is the only local, right-eyed flatfish that lacks pectoral fins (ibid). This fish's strange name originates from colonial times – apparently, when hogs fed on discarded fishes, they had difficulty swallowing this fish because of its hard, rough scales (Bigelow & Schroeder 2002 – revised 1953 edition).

The most advanced freshwater fish, the ***Hogchoker*** is found in coastal streams in southern New England (*Connecticut*, *Rhode Island* and *Massachusetts*), however it is rarely found in *New Hampshire* and is absent to the northwest (*Maine* and *Vermont*). Common to abundant in most *Connecticut* coastal streams (Jacobs & O'Donnell 2009), however, appears to be on the decline in *Rhode Island* brackish waters (Libby 2013). This species is rare north of Cape Cod in *Massachusetts*, however, Louis Agassiz reportedly procured several ***Hogchoker*** from the mouth of the Charles River in 1874 (Hartel et al. 2002).

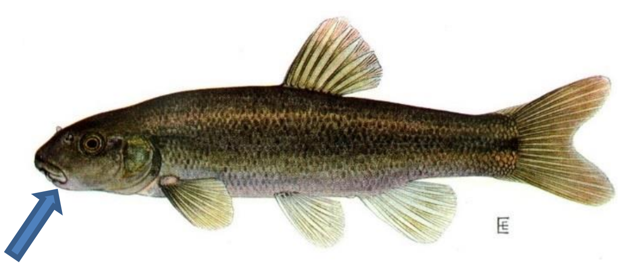
Group F-1 to **F-6** ***Uncommonly Encountered Species*** – inclusive of the following fish species: ***Gizzard Shad, Cutlip Minnow, Eastern Silvery Minnow, Spottail Shiner, Central Mudminnow*** and ***Trout-perch***.

F-1 Gizzard Shad (*Dorosoma cepedianum*) aka '*herbivorous species*' Map 51



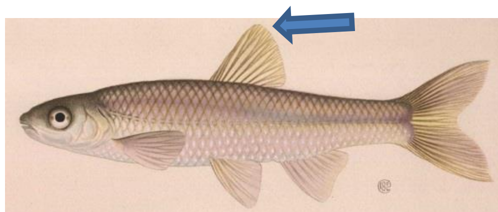
Gizzard Shad are the only known freshwater fish species that has naturally expanded its range into New England (Connecticut River in *Massachusetts*, O'Leary & Smith 1987). ***Gizzard Shad*** also appear to be more abundant in *Rhode Island* fish collections (personal communication, Libby 2018). Individual ***Gizzard Shad*** specimens have been recorded from the Merrimack River in *Massachusetts* (Hartel et al. 2002) and the Kennebec River in Waterville, *Maine* (personal communication, Brandon Kulik 2000).

F-2 Cutlip Minnow (*Exoglossum maxillingua*) aka '*eye-picker*' Map 52



Cutlip Minnow probably did not enter the freshwaters of *Connecticut* until closer to 11,000 years ago, because no ***Cutlip Minnow*** populations were established above the fall line of the Housatonic River, or in drainage basins east of the Housatonic River (Whitworth 1996). A single ***Cutlip Minnow*** specimen was collected from a tributary to the West Branch of the Farmington River in *Connecticut*, possibly the result of a bait bucket release (Jacobs & O'Donnell 2009). However, ***Cutlip Minnow*** are known from the Farmington River in western *Massachusetts* since 1997, where a resident population was found in 2001 (Hartel et al. 2002).

F-3 Eastern Silvery Minnow (*Hybognathus regius*) aka '*bluenose*' *'hunt'* **Map 53**

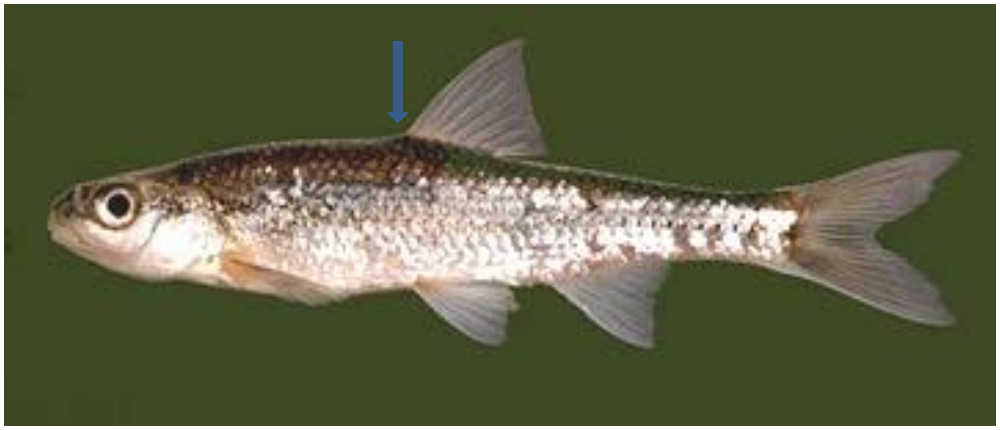


The ***Eastern Silvery Minnow*** – having a pointed dorsal fin, elongated gut and specialized pharyngeal teeth for eating algae – may have survived the last *Ice Age* east of the Appalachian Mountains, as evidenced by its limited Canadian presence, restricted to the southeastern portion of *Ontario* (Holm et al. 2009). This minnow species is known by the name "*hunt*" in Vermont, where it is commonly used by anglers as bait (Langdon et al. 2006). The colloquial name 'bluenose' may refer to the characteristic presence of a lower jaw with a fleshy knob at the tip (Hartel et al. 2002).

Apparently, baitfish dealers in *Maine* have historically sold '***Emerald Shiners***,' which have been positively identified as ***Eastern Silvery Minnow***, collected from the Cobbossee drainage of central *Maine* (Annabessacook Lake and tributary Jug Stream) – Jason Seiders Maine DIF&W, Region B, pers. comm. (3 June 2016). Notably, the introduced ***Emerald Shiner*** has a dorsal fin origin which is set further back than in most shiners, well behind the pelvic fin base. Yoder (2015) also has reported several ***Eastern Silvery Minnow*** large river records from the Lower Kennebec River drainage in *Maine*. (Lower Kennebec – Fish Brook, Fairfield center)

The distribution of ***Eastern Silvery Minnow*** in *Massachusetts*, where it is state-listed as a *Species of Special Concern*, is limited to the main stem of the Connecticut River north of the Holyoke Dam and near the mouth of the Deerfield River (Hartel et al. 2002). ***Eastern Silvery Minnow*** has not been found to occur within *Connecticut* (Whitworth 1996, Jacobs & O'Donnell 2009) and *Rhode Island* (Libby 2013) waters, and (like *Massachusetts*) are restricted to main stem Connecticut River tributaries in *New Hampshire* (Scarola 1973) and *Vermont*, where it is rarely found to occur (Langdon et al. 2006, Rich Langdon, VT-DEC, pers. comm.). This minnow is unique among northeastern cyprinids in that females lay non-adhesive eggs directly on bottom ooze in areas where emergent grasses and reeds provide shelter (Hartel et al. 2002).

F-4 Spottail Shiner (*Notropis hudsonius*) aka '*spottail minnow*' **Map 54**



Spottail Shiner are thought to be native to the Connecticut River mainstem drainages in *Vermont*, *New Hampshire, Massachusetts* and *Connecticut*, however, are possibly introduced as baitfish in *Maine* (Kircheis 1994) and along the eastern coastal lowlands in Rhode Island (Libby 2013). In Massachusetts, this minnow is abundant in the Connecticut, Deerfield, Chicopee and Westfield drainages, and is commonly found in the Merrimack and Housatonic river drainages.

Steven Shapiro, who studied the species in 1976, thought that the *Massachusetts* populations outside of the Connecticut River basin most likely resulted from bait-fish introductions. This may be true, since they are absent from the Blackstone and Taunton river drainages, where this species might be expected to occur, and ***Spottail Shiner*** were not mentioned by early authors such as Storer (1836, 1839, 1867) and Goode & Bean (1879).

Spottail Shiner are found throughout *Canada* and are the most important species in the commercial baitfish industry in northern *Ontario*, particularly during ice-fishing season (Holm et al. 2009). They ranked ***10th*** in total fish abundance in the New England large (non-wadeable) river surveys (Yoder et al. 2015).

F-5 Central Mudminnow (*Umbra limi*) aka '*mudfish*' **Map 55**

The Mudminnow family (Umbridae) is a small group of fishes closely related to the pickerel and pike (Hartel et al. 2002). Mudminnows have the ability to breathe atmospheric oxygen using a modified swim bladder, which enables them to survive in habitats that become seasonally anoxic (ibid, Martin-Bergmann and Gee 2011). ***Central Mudminnow*** are stout-bodied, with rounded dorsal and anal fins, set far back on the body (ibid). A characteristic dark vertical bar is usually found at the base of the tail.

Central Mudminnow is non-native to *Connecticut* (first reported in 1980), where they are primarily restricted to backwater areas of the Connecticut River and the lower ends of some of its tributary streams (Jacobs & O'Donnell 2009). They are also considered to be non-native to *Massachusetts*, where they have been found in only a few locations (Mill River vicinity, first reported in 1975 in Sunderland, near the *University of Massachusetts*) in the southern portion of the Connecticut River drainage (Hartel et al. 2002).

There exists an outside chance that ***Central Mudminnow*** may be native to the St. John River in north-central *Maine* (via a hypothesized post-glacial connection with St. Lawrence River), where a single specimen was collected in August 2005 (Yoder et al. 2008). Twenty-one specimens were collected from a private pond in Grand Isle, Maine – that is flooded out by the St. John River during extreme highwater events (Necropsy Report, G. Russell Danner, Fish Pathologist, Maine DIFW 2010). ***Central Mudminnow*** also have been found to populate *Pushaw Pond* near the *University of Maine*, in Orono (Schilling et al. 2006) and have been recently collected from that locale within the Penobscot River drainage – *Capehart Brook* in Bangor by the author (Maine DEP July 2016).

F-6 Trout-perch (*Percopsis omiscomaycus*) aka '*silver chub*' **Map 56**

Omiscomaycus is the Native American (*Algonquin*) word for this fish species (Holm et al. 2009, Langdon et al. 2006). The ***Trout-perch*** family of fish is characterized by an unusual combination of both primitive and advanced features (Hartel et al. 2002). An adipose fin is present, as in trout and catfishes, however, they also have true spiny fin rays – an advanced feature found, for example, in sunfishes and perch (ibid). ***Trout-perch*** were originally reported from the Housatonic River in *Connecticut* in 1879 – specimens deposited in the *Museum of Comparative Zoology* at Harvard University in *Massachusetts* (McCabe 1943, Hartel et al. 2002).

A juvenile specimen of ***Round Whitefish*** captured (Yoder et al. 2010) from the St. John River in *Maine* appears to resemble a ***Trout-perch*** (see below), complete with having an adipose fin and several rows of black spots or markings on the sides of the body (Figures 10a and 10b). ***Trout-perch*** differ in having ctenoid scales – cycloid in whitefishes, which have pelvic fins origins located behind the pectoral fins, vs. below the middle of the pectoral fins in ***Trout-perch*** (Holm et al. 2009).

Trout-perch are no longer found to occur in New England proper, having been extirpated from the Housatonic River in western *Connecticut* and *Massachusetts* (Green River), as well as in the Hoosic River in northwestern *Massachusetts* (Hartel et al. 2002). Populations of ***Trout-perch*** can still be found downstream in the upper Hoosic drainage in *New York* and *Vermont* and are also commonly found to occur in tributaries to Lake Champlain and to the north in *Canadian* freshwaters (Langdon et al. 2006).

Summary and Conclusions

This treatise on the current distribution and biogeography of the freshwater fishes of New England proper is a historical compilation of information from source literature and reviews, with edits from regional state fisheries biologists, ichthyologists and naturalists. A total of 56 native fish species within six groupings are presented and their distributions within the six New England states are annotated, along with native fish species occurrence maps and regional discussions of their biogeographical associations. Both native and non-native fishes found to reside in larger streams and non-wadeable rivers throughout New England are also taken into consideration (Yoder et al. 2008), as well as migratory diadromous fish species (Maine DMR 2016). An additional 26 non-native (introduced) freshwater fish species are listed and their Northeastern regional distributions and voucher specimen numbers are included in **Appendix B**.

Appropriate recognition of fish species origin and residency status is critical in the monitoring and bioassessment of aquatic habitats (Halliwell 1994, Halliwell et al. 1999 – pg. 316, Halliwell 2007). Major questions to address are: (1) are all observed fish species representative of a viable population in any given aquatic habitat? (2) are all the observed fish species apt to be encountered again during replicate sampling efforts? (3) are the observed fish species interacting in a positive, negative, or neutral manner? and lastly, (4) is the presence of the observed fish species indicative of the relative quality of the aquatic habitat in which it is found to occur?

There is a total of **56** native freshwater fishes in New England proper (Table 1), 22 non-native fishes (78), 6 introduced exotics of European origin (84), 33 freshwater fish species native to the Lake Champlain drainage in *Vermont* and *New York* (117) plus an additional 54 freshwater fish species native to the Great Lakes (Northeast United States total = **171**).

In terms of regional indigenous freshwater fish biodiversity, *Maine* leads the New England states with a total of **51** native fish species present.

Absent from *Maine*: ***Tessellated Darter, Banded Sunfish, Hogchoker, Cutlip Minnow*** and ***Trout-perch***). *New Hampshire* and *Massachusetts* are second, with a total of **45** native fish species present.

Absent from *New Hampshire*: ***Northern Pearl Dace, Blacknose Shiner, Central Mud-minnow*** (non-native), ***Arctic Char*** (extirpated), ***Brook Stickleback, Atlantic Salmon*** (extirpated), breeding ***Sturgeon (Atlantic*** and ***Shortnose), Striped Bass***, ***Gizzard Shad, Cutlip Minnow*** and ***Trout-perch***).

Absent from *Massachusetts*: ***Northern Pearl Dace, Blacknose Shiner, Finescale Dace, Central Mudminnow*** (non-native), ***Lake*** and ***Round Whitefish, Arctic Char, Lake Trout*** (non-native), ***Brook Stickleback, Atlantic Salmon*** (extirpated) and ***Trout-perch*** (extirpated).

With the exception of resident native ***Brook Trout*** in all states, rare populations of ***Northern Redbelly Dace*** and ***Lake Chub*** in western *Massachusetts*, rare populations of ***Burbot*** and western populations of ***Slimy Sculpin*** in *Connecticut* and *Massachusetts*, the three southern New England states do not support populations of any of the other ten northern coldwater native fish species (inclusive of ***Northern Pearl Dace, Blacknose Shiner, Finescale Dace, Whitefish (Lake*** & ***Round), Arctic Char, Atlantic Salmon, Brook Stickleback,*** *native* ***Lake Trout*** and *native* ***Central Mudminnow***.

Massachusetts has a total of **40** native fish species and *Connecticut* has a total of **37** native fish species (also absent extirpated ***Atlantic Salmon, Longnose Sucker*** and non-breeding ***Striped Bass***). On the lower end of the regional freshwater fish biodiversity spectrum, *Rhode Island* and eastern *Vermont* 'proper' have a total of **31** and **28** native fish species respectively.

Absent from *Rhode Island*: ***Creek Chub, Slimy Sculpin***, 13 out of the 15 coldwater native fish species (only ***Brook Trout*** and ***Ninespine Stickleback*** present), extirpated ***Atlantic Salmon*** and absence of breeding ***Sea Lamprey*** and ***Sturgeons***.

The state of *Vermont*, inclusive of the western *Lake Champlain* drainage system, would naturally have a much richer native fish fauna of **77** freshwater fish species (Langdon et al. 2006,

Table 3, pages 14-21). In consideration of New England 'proper' coverage, *Vermont* is naturally missing all six-coastal plain and all four estuarine, along with most of the nine diadromous native fish species. Migratory fish species in the Connecticut River (e.g., ***Sea Lamprey, Blueback Herring, American Shad*** and ***Striped Bass*** are found to occur in southern *Vermont*, in addition to introduced land-locked non-native populations of ***Alewife*** and ***Rainbow Smelt***. Northern coldwater native fish species are also missing or rarely found in western tributaries to the Connecticut River in *Vermont*.

Absent from Vermont (proper): ***Central Mudminnow, Lake*** and ***Round Whitefish, Brook*** and ***Ninespine Stickleback;*** extirpated ***Arctic Char*** and ***Atlantic Salmon***). ***Redbreast Sunfish*** is the only common warmwater native fish species which is rarely observed in eastern *Vermont*. There are only five (one-third) of the northern coldwater native fish species which are found to currently populate eastern *Vermont* waters, inclusive of ***Brook Trout, Lake Chub, Northern Redbelly Dace, Burbot*** and ***Slimy Sculpin***. Another three are only rarely observed to occur, inclusive of ***Northern Pearl Dace, Blacknose Shiner*** and ***Finescale Dace*** (Langdon et al. 2006).

Family Cyprinidae fish species diversity, inclusive of **Group A** widespread species (e.g., ***Common Shiner, Creek Chub*** and ***Fallfish***), are considerably richer and much more robust (greater condition factor) in northwest *Maine's* undeveloped (shoreline) woodland coldwater lakes (Whittier et al. 1997, Halliwell 2000, Halliwell & Bouchard 2008). These northern coldwater minnows are also much more robust and longer-lived in woodland *Maine* lakes, whose watersheds are historically utilized and (apparently) properly managed by the forest products industry (Gawler et al. 1996, Gawler & Cutko 2010, Morning Sentinel 2011, Maine Forest Service 2017, Dustin & Vondracek 2017).

Non-native predators-competitors (e.g., ***Smallmouth Bass, Largemouth Bass, Black Crappie*** and ***White Perch***), commonly introduced by humans to developed lakes elsewhere in New England and New York (Harig 1995) – are not generally found in these relatively undeveloped northwestern *Maine* woodland lakes (Whittier et al. 1997, Whittier & Kincaid 1999, Halliwell 2006). Effective future conservation planning for potential large scale human development in the north *Maine* woods should continue to: (1) recognize the intrinsic value of this unique freshwater fish assemblage (aquatic ecosystem); and (2) ensure provisions to maintain existing valuable lake-shoreline fish habitat conditions. Land-use regulations may need revision to protect and sustain these valuable aquatic ecosystems (Halliwell 2006, Halliwell & Bouchard 2008, Maine Forest Service 2017).

Past Federally supported lake biomonitoring pilot studies (EMAP-SW: EPA/USFWS 1991 - 1994) show that coldwater woodland lakes in northwestern *Maine* support a diverse assemblage of native minnow species – richer than southern *Maine* and other New England states (Whittier 1999) and the *Adirondack Mountain* lakes region of *New York* (Whittier et al. 1997, Whittier & Kincaid 1999). This high native minnow diversity in northwestern *Maine* lakes, due mostly to biogeographic factors as previously discussed, is also associated with the relative absence of human development and related land disturbances, including climate change (Olden et al. 2010).

H-istorical *Maine* commercial forest management practices have apparently provided suitable riparian buffers that serve to protect lake shorelines, while maintaining excellent littoral fish habitat (Whittier et al. 1997, Halliwell 2007a/b, *Morning Sentinel* 2011, Maine Forest Service 2017). Abundant large woody debris provides overhead and in-lake cover from mammalian and avian predators; while minnow populations appear to be in excellent condition – much larger, more robust individuals are found to be resident in *Maine* 'wilderness' lakes.

Freshwater fish biodiversity – Critical aquatic habitats - New England Proper

Several native primary fish species (***Lake Chub***, ***Northern Redbelly Dace***, ***Burbot*** and ***Trout-perch*** are rarely found to occur in <u>southern</u> New England and lead a precarious existence along the southern limits of their biogeographical ranges. Other native fresh-water fish species not considered rare on a regional basis, have geographically disjunct populations. As previously mentioned, ***Slimy Sculpin*** are widely distributed in suitable upland coldwater stream habitats within most drainage systems <u>west</u> of the Connecticut River (in *CT, MA, NH,* and *VT*). However, to the east of the Connecticut River drainage, ***Slimy Sculpin*** populate only a handful of relatively isolated waters of suitable habitat – which should be further targeted for protection efforts (Maietta 2007). Abell et al. (2015) have argued that "high conservation value areas (HVCAs) need to be expanded from forests to freshwaters to enhance resident species biodiversity."

Similarly, ***Blacknose*** and ***Longnose Dace*** populate a limited number of geographically disjunct streams along the eastern biogeographic boundaries of their distributions in *NH, MA* and *RI* – Nashua River south through Blackstone drainages. Further habitat loss, effects of ongoing climate change (Lynch et al. 2016) and stream fragmentation in these aquatic environs could result in the loss of these relict fish populations. In the interest of fish biodiversity conservation in New England, it is imperative that the critical habitats of locally isolated fish species populations be recognized and protected as unique aquatic environments (Halliwell 1991), including official conservation listings as <u>New England</u> 'proper' species of special concern.

Postscript: As a teacher and researcher of the natural history of New England freshwater fish, I am often asked which of the numerous currently published books on fishes that I would most highly recommend to possibly purchase? If I had to go with a single fish book in my possession, it would be the ***Field Guide to Freshwater Fishes of Ontario***, published in 2009 by the *Royal Ontario Ministry* (ROM) and authored by Erling Holm, Nick Mandrak and Mary Burridge. 462-paged, pocket-sized (4.25 x 7.75 inch), colorfully formatted for quick and accurate fish species identification (particularly for difficult to identify 'black-line' shiners) with live fish color photographs, check-listing, inclusive of most New England fish species, with the notable exception of ***Redbreast Sunfish***…along with ten others (***Eastern Creek Chubsucker, Redfin***

Pickerel, Banded Sunfish, Swamp Darter, Shortnose Sturgeon, Atlantic Sturgeon, Blueback Herring, Striped Bass, Atlantic Tomcod and ***Hogchoker***). (2010 Cost: $29.99 in Canada/U.S.)

My second choice would be ***A Pictorial Guide to Freshwater Fishes of Connecticut*** (Jacobs & O'Donnell 2009) and a tie for third are ***Fishes of Vermont*** (Langdon et al. 2006) and ***Inland Fishes of Massachusetts*** (Hartel et al. 2002) – currently out-of-print, however, digitally available at no cost from Harvard University through the Museum of Comparative Zoology located in Cambridge, Massachusetts (Patchett, Ann 2007, *Run)*

Author at work sampling lake fish with baited minnow traps during Maine DEP EcoReserve monitoring at Nahmakanta (Debsconeag) in northwestern Maine, 2008

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APPENDIX A

Table 1. Fishes of New England proper: historical listings – New England, ME & NH

	Fishes of New England	Ken-	Fow-	New	Hol-	Ken-	ME	Gor-	Bai-	Oli-	NH
	HISTORICAL LISTINGS:	dall-1	ler	Eng.	mes	dall-2	State	don	ley	ver	State
	Year of Publication:	1908	1917	Total	1862	1914	Total	1937	1938	1939	Total
GRP	Fish Species NE STATE:	NE	NE	NE	ME	ME	ME	NH	NH	NH	NH
A	*Common Warm-Cool Water*										
A-1	Golden Shiner	X	x	x	x	x	x	x	x	x	x
A-2	Common Shiner	X	x	x	x	x	x	x	x	x	x
A-3	Blacknose Dace	X	x	x	--	x	x	x	x	x	x
A-4	Longnose Dace	X	--	x	--	--	x	--	x	x	x
A-5	Creek Chub	X	x	x	--	x	x	x	x	x	x
A-6	Fallfish	X	x	x	--	x	x	x	x	x	x
A-7	White Sucker	X	x	x	x	x	x	x	x	x	x
A-8	Brown Bullhead	x	x	x	x	x	x	x	x	x	x
A-9	Chain Pickerel	x	x	x	x	x	x	x	x	x	x
A-10	Banded Killifish	x	x	x	x	x	x	x	x	x	x
A-11	Ninespine Stickleback	x	x	x	x	x	x	x	--	--	x
A-12	Redbreast Sunfish	x	x	x	x	x	x	--	x	x	x
A-13	Pumpkinseed	x	x	x	x	x	x	x	x	x	x
A-14	Yellow Perch	x	x	x	x	x	x	x	x	x	x
A-15	Tessellated Darter	x	--	x	--	--	Abs.	--	--	CT-R	x
	Year of Publication:	1908	1917	Total	1862	1914	Total	1937	1938	1939	Total
GRP	Fish Species NE STATE:	NE	NE	NE	ME	ME	ME	NH	NH	NH	NH
B	*Northern Coldwater*										
B-1	Lake Chub	x	--	x	--	x	x	x	x	x	x
B-2	Northern Pearl Dace	x	--	x	--	x	x	--	--	--	Abs.
B-3	Northern Redbelly Dace	x	--	x	--	x	x	x	--	x	x
B-4	Finescale Dace	x	x	x	--	x	x	x	--	x	x
B-5	Fathead Minnow	x	--	x	x	x	x	x	--	--	x
B-6	Blacknose Shiner	x	--	x	--	x	x	**	--	--	Abs.
B-7	Longnose Sucker	x	--	x	--	x	x	x	x	x	x
B-8	Lake Whitefish	x	--	x	x	x	x	x	x	--	x

	Year of Publication:	1908	1917	Total	1862	1914	Total	1937	1938	1939	Total
	Fish Species NE STATE:	NE	NE	NE	ME	ME	ME	NH	NH	NH	NH
B-9	Round Whitefish	x	--	x	x	x	x	--	x	x	x
B-10	Arctic Char	x	x	x	x	x	x	x	--	x	x
B-11	Brook Trout	x	x	x	x	x	x	x	x	x	x
B-12	Lake Trout	x	x	x	x	x	x	x	x	x	x
B-13	Burbot	x	--	x	x	x	x	x	x	x	x
B-14	Brook Stickleback	x	x	x	--	x	x	--	--	--	Abs.
B-15	Slimy Sculpin	x	x	x	--	x	x	x	x	x	x
C	*Coastal Lowlands*										
C-1	American Brook Lamprey	--	--	Rare	--	--	Rare	--	--	--	Rare
C-2	Bridle Shiner	x	--	Rare	--	x	Rare	x	x	--	x
C-3	Eastern Creek Chubsucker	x	--	x	x	x	x	x	x	x	x
C-4	Redfin Pickerel	x	--	x	--	--	Rare	x	x	--	x
C-5	Banded Sunfish	x	x	x	--	--	Abs.	x	x	x	x
C-6	Swamp Darter	x	--	x	--	--	Rare	x	x	--	x
D	*Diadromous Migrants*										
D-1	American Eel	x	x	x	x	x	x	x	x	x	x
D-2	Sea Lamprey	x	x	x	x	--	x	x	x	--	x
D-3	Atlantic Sturgeon	x	x	x	x	--	x	--	x	x	x
D-4	Shortnose Sturgeon	x	--	x	--	--	x	--	--	x	x
D-5	Blueback Herring	x	x	x	x	--	x	--	--	--	x
D-6	Alewife	x	x	x	x	--	x	x	x	--	x
D-7	American Shad	x	x	x	x	--	x	--	x	x	x
D-8	Atlantic Salmon	x	x	x	x	x	x	x	x	x	x
D-9	Rainbow Smelt	x	x	x	x	x	x	x	x	x	x
D-10	Striped Bass	x	x	x	x	--	x	--	--	--	x
	Year of Publication:	1908	1917	Total	1862	1914	Total	1937	1938	1939	Total
	Fish Species NE STATE:	NE	NE	NE	ME	ME	ME	NH	NH	NH	NH

GRP	Fish Species	NE STATE:	NE	NE	NE	ME	ME	ME	NH	NH	NH	NH
E	***Estuarine Non-Migrants***											
E-1	Atlantic Tomcod		**x**	x	**x**	x	--	**x**	--	--	--	**x**
E-2	Threespine Stickleback		**x**	--	**x**	x	x	**x**	x	--	--	**x**
E-3	White Perch		**x**	x	**x**	x	x	**x**	x	x	x	**x**
E-4	Hogchoker		**x**	x	**x**	--	--	--	--	--	--	**x**
F	***Uncommonly Encountered***											
F-1	Gizzard Shad		**x**	**x**	**x**	--	--	--	--	--	--	--
F-2	Cutlip Minnow		--	--	--	--	--	--	--	--	--	--
F-3	Eastern Silvery Minnow		--	--	--	--	--	--	--	--	**x**	--
F-4	Spottail Shiner		--	**x**	**x**	--	--	--	--	--	**x**	**x**
F-5	Central Mudminnow		--	--	--	--	--	--	--	--	--	--
F-6	Trout-perch		--	--	--	--	--	--	--	--	--	--
	Year of Publication:		1908	1917	Total	1862	1914	Total	1937	1938	1939	Total
GRP	Fish Species	NE STATE:	NE	NE	NE	ME	ME	ME	NH	NH	NH	NH
	Total Number of Fish Species		49	34	**51**	30	35	**42**	36	34	35	**45**

Table 2. **(pg. 14)** Number of established freshwater fish species by northeastern U.S. state and combined New England 'proper' (Halliwell et al. 1999, pg. 315)

NE-FISH	Native	Introduced	Total	% Introduced
NH	49	19	68	28
ME	48	12	60	20
MA	44	27	71	38
CT	41	20	61	33
RI	36	14	50	28
VT-E	33	19	52	37
New England	**56**	**24**	**80**	**30**
NJ	58	20	78	26
VT-W	72	12	84	14
NY	**141**	**6**	**147**	**4**

Table 3. Native freshwater fishes of New England proper, arranged by vouchered Bottle number (B #), biogeographical group assemblage, and New England state.

B #	A - COMMON Native Warm/Coolwater Species	Map	ME	NH	VT	CT	MA	RI
74	Golden Shiner (*Notemigonus crysoleucas*)	1	X	X	X	X	X	X
62	Common Shiner (*Luxilus cornutus*)	2	X	X	X	X	X	X
116	Blacknose Dace (*Rhinichthys atratulus*)	3	X	X	X	X	X	X
118	Longnose Dace (*Rhinichthys cataractae*)	4	X	X	X	X	X	X
122	Creek Chub (*Semotilus atromaculatus*)	5	X	X	X	X-W	X-W	A
124	Fallfish (*Semotilus corporalis*)	6	X	X	X	X	X	X
130	White Sucker (*Catostomus commersonii*)	7	X	X	X	X	X	X
152	Brown Bullhead (*Ameiurus nebulosus*)	8	X	X	X	X	X	X
174	Chain Pickerel (*Esox niger*)	9	X	X	X	X	X	X
204	Banded Killifish (*Fundulus diaphanus*) + Estuarine	10	X	X	X	X	X	X
220	Ninespine Stickleback (*Pungitius pungitius*)	11	X	X	A	X	X	X
242	Redbreast Sunfish (*Lepomis auritus*)	12	X	X	R-4	X	X	X
246	Pumpkinseed (*Lepomis gibbosus*)	13	X	X	X	X	X	X
282	Yellow Perch (*Perca flavescens*)	14	X	X	X	X	X	X
276	Tessellated Darter (*Etheostoma olmstedi*)	15	A	X	X	X	X	X
B #	**B - NORTHERN Coldwater Native Fish Species**	**Map**	**ME**	**NH**	**VT**	**CT**	**MA**	**RI**
40	Lake Chub (*Couesius plumbeus*)	16	St. L	X-N	X	A	R-3	A
68	Northern Pearl Dace (*Margariscus nachtriebi*)	17	St. L	A	R-2	A	A	A
108	Northern Redbelly Dace (*Chrosomus eos*)	18	St. L	X	R-1	A	A	A
110	Finescale Dace (*Chrosomus neogaeus*)	19	St. L	R-4	X	A	R-1	A
114	Fathead Minnow (*Pimephales promelas*)	20	St. L	N-N	N-N	N-N	N-N	A
94	Blacknose Shiner (*Notropis heterolepis*)	21	St. L	A**	R-2	A	A	A
128	Longnose Sucker (*Catostomus catostomus*)	22	St. L	Ct-R	X	R-1	X-W	A
182	Lake Whitefish (*Coregonus clupeaformis*)	23	St. L	R-3	A	A	A	A
184	Round Whitefish (*Prosopium cylindraceum*)	24	St. L	R-3	A	A	A	A
192	Arctic Char (*Salvelinus alpinus*)	25	St. L	EX	EX	A	A	A
194	Brook Trout (*Salvelinus fontinalis*) + Coast 'salters'	26	St. L	X	X	X	X	X
196	Lake Trout - togue (*Salvelinus namaycush*)	27	St. L	X	EX	A	N-N	A
202	Burbot - cusk/freshwater codfish (*Lota lota*)	28	St. L	X	X	R-1	R-1	A
214	Brook Stickleback (*Culaea inconstans*)	29	St. L	A	W	A	A	A
224	Slimy Sculpin (*Cottus cognatus*)	30	St. L	X	X	X-W	X-W	A

B #	C - COASTAL PLAIN Native Fish Species	Map	ME	NH	VT	CT	MA	RI
2	American Brook Lamprey (*Lethenteron appendix*)	31	R-1	R-2	A	X	X	X
84	Bridle Shiner (*Notropis bifrenatus*)	32	R-5	X-S	A	X	X	X
132	Eastern Creek Chubsucker (*Erimyzon oblongus*)	33	R-3	X-S	A	X	X	X
164	Redfin Pickerel (*Esox americanus*)	34	R-3	X-S	A	X	X	X
240	Banded Sunfish (*Enneacanthus obesus*)	35	A	X-S	A	X	X	X
270	Swamp Darter (*Etheostoma fusiforme*)	36	R-3	X-S	A	X-E	X	X
B #	**D - DIADROMOUS Native Fish Species**	**Map**	**ME**	**NH**	**VT**	**CT**	**MA**	**RI**
24	American Eel (*Anguilla rostrata*)	37	X	X	X	X	X	X
12	Sea Lamprey (*Petromyzon marinus*)	38	X	X	Ct-R	X	X	N-S
18	Atlantic Sturgeon (*Acipenser oxyrinchus*)	39	X	N-S	A	Ct-R	X	N-S
14	Shortnose Sturgeon (*Acipenser brevirostrum*)	40	X	N-S	A	X	X	A
26	Blueback Herring (*Alosa aestivalis*)	41	X	X	Ct-R	X	X	X
28	Alewife (*Alosa pseudoharengus*) + Landlocked	42	X	X	N-N	X	X	X
30	American Shad (*Alosa sapidissima*)	43	X	X	Ct-R	X	X	X
188	Atlantic Salmon (*Salmo salar*) + Landlocked	44	X	EX	EX	EX	EX	EX
178	Rainbow Smelt (*Osmerus mordax*) + Landlocked	45	X	X	N-N	X	X	X
230	Striped Bass (*Morone saxatilis*)	46	X	N-S	Ct-R	N-S	X	X
B #	**E - ESTUARINE/COASTAL Native Fish Species**	**Map**	**ME**	**NH**	**VT**	**CT**	**MA**	**RI**
203	Atlantic Tomcod (*Microgadus tomcod)*	47	X	X	A	X	X	X
216	Threespine Stickleback (*Gasterosteus aculeatus*)	48	X	X	A	X	X	X
226	White Perch (*Morone americana*) + Landlocked	49	X	X	N-N	X	X	X
300	Hogchoker (*Trinectes maculatus*)	50	R	R	A	X	X	R
50	**TOTAL Number of Native Fish Species - A**		**48**	**42**	**28**	**37**	**40**	**31**
B #	**F - MISCELLANEOUS (Uncommon) Fish Species**	**Map**	**ME**	**NH**	**VT**	**CT**	**MA**	**RI**
32	Gizzard Shad (*Dorosoma cepedianum*)	51	N-N	N-N	Ct-R	X	Ct-R	R
54	Cutlip Minnow (*Exoglossum maxillingua*)	52	A	A	A	X-W	Ct-R	A
58	Eastern Silvery Minnow (*Hybognathus regius*)	53	N-N	Ct-R	Ct-R	A	Ct-R	A
96	Spottail Shiner (*Notropis hudsonius*)	54	N-N	Ct-R	Ct-R	X	Ct-R	A
174	Central Mudminnow (*Umbra limi*)	55	St. L	A	A	N-N	N-N	A
198	Trout-perch (*Percopsis omiscomaycus*)	56	A	A	A	EX	EX	A
			ME	**NH**	**VT**	**CT**	**MA**	**RI**
56	**TOTAL Number of Native Fish Species - B**		**48**	**44**	**31**	**40**	**44**	**32**

Listing of Tabulated Fish Occurrences

X or A	**Present = X Absent = A**
X-W	**X-West** - primarily in-state western distribution
X-N	**X-North** - primarily in-state northern distribution
X-S	**X-South** - primarily in-state southern distribution
X-E	**X-East** - primarily in-state eastern distribution
R-4	**Rare (x)** - number of historical locales (1 to 5)
St. L	**St. Lawrence** River origins via St. John River
Ct-R	Distribution limited to **Connecticut R**. mainstem
N-N	**Non-Native**, Sportfish or Baitfish introductions
A**	Fish species historically **miss-identified** (NH 2016)
EX	**Extirpated** - historically established populations
W	**VT-Western** (Lake Champlain drainage)
N-S	**No Spawn** - adults only, no reproduction…

Table 4. Freshwater fishes of large (non-wadeable) rivers in New England (Yoder et al. 2015).
(12 dominant native and *non-native* fish species – 75% of total number captured)

1. ***Smallmouth Bass***	2,670	22%	22%	***Non-native***
2. White Sucker	2,030	17%	39%	Native
3. American Eel	1,396	11%	50%	Native
4. Fallfish	1,201	10%	60%	Native
5. Yellow Perch	950	8%	68%	Native
6. ***Largemouth Bass***	886	7%	75%	***Non-native***
7. Redbreast Sunfish	774	6%	81%	Native
8. Pumpkinseed	720	6%	87%	Native
9. Common Shiner	486	4%	91%	Native
10. Spottail Shiner	409	3%	94%	Native
11. Chain Pickerel	395	3%	97%	Native
12. Golden Shiner	390	3%	100%	Native

13. Alewife	367	26. Blueback Herring	71
14. Banded Killifish	265	27. Atlantic Salmon	71
15. Striped Bass	216	28. Brook Trout	61
16. White Perch	197	29. Longnose Sucker	60
17. Brown Bullhead	188	30. Redfin Pickerel	27
18. Burbot (Cusk)	172	31. Threespine Stickleback	17
19. Sea Lamprey	171	32. Fathead Minnow	17
20. Tessellated Darter	128	33. Eastern Creek Chubsucker	16
21. Blacknose Dace	127	34. Ninespine Stickleback	15
22. American Shad	89	35. Round Whitefish	14
23. Longnose Dace	87	36. Blacknose Shiner	14
24. Slimy Sculpin	83	37. Northern Redbelly Dace	13
25. Lake Chub	72	38. Rainbow Smelt	8

Sub-total Number (Top 12)	**12,307**	**75%**	**16,382**	**Total Fish**

Table 5. Dominant freshwater sport fishes in Northeastern LAKES (EMAP-SW 1994).
(US-EPA Region 1, New England and US-EPA Region 2, New York and New Jersey)

1. Brown Bullhead	**11.** American Eel
2. Pumpkinseed	**12.** Redbreast Sunfish
3. ***Largemouth Bass***	**13.** Rainbow Smelt (landlocked)
4. Yellow Perch	**14**. ***Black Crappie***
5. White Sucker	**15.** Brook Trout
6. Chain Pickerel	**16.** ***Brown Trout***
7. ***Bluegill***	**17.** ***Rainbow Trout/Salmon***
8. ***Yellow Bullhead***	**18.** ***Rock Bass***
9. White Perch	**19.** Alewife (landlocked)
10. ***Smallmouth Bass***	**20.** Atlantic Salmon (landlocked)

Table 6. Most commonly encountered fishes – Northeastern United States

Wadeable Streams	**Lakes and Ponds**
1. Blacknose Dace	**1.** Pumpkinseed
2. White Sucker	**2.** Yellow perch
3. Longnose Dace	**3.** Golden Shiner
4. Brook Trout	**4.** Brown Bullhead
5. Common Shiner	**5.** ***Largemouth Bass***
6. Tessellated Darter	**6.** Chain Pickerel
7. Creek Chub	**7.** ***Bluegill***
8. ***Brown Trout***	**8.** White Sucker
9. Fallfish	**9.** ***Black Crappie***
10. Slimy Sculpin	**10.** American Eel

Lotic: MA, CT, VT, NJ (n=3,000) **Lentic:** ME, EMAP, CT, NJ (n=2,400)

A recent article in AFS *Fisheries* (Troia 2017) state-listed freshwater fish 'species of special concern' to improve public awareness of endemic fishes in the *United States* (based on the original *NatureServe* 2004 HUC8 watershed dataset). The range for endemic fish species (including species endemic to border states that also occur in *Mexico* or *Canada*) ranged from single species in *Wyoming* to 31 species in *Texas.* Northeastern U.S. states were not included, even though ***Arctic Char*** are now regionally endemic to *Maine* (extirpated from *Vermont* and *New Hampshire*) and commonly found to occur in *Canada* and *Alaska*. Table x. shows a subset of the dataset, inclusive of the six *New England states*. ***Brook Trout*** were designated as a 'heritage' fish species in *MA, NH, ME and VT*. ***American Shad*** and ***Striped Bass*** were chosen for both *CT* and *RI*, respectively, reflecting their coastal marine affinities. Interestingly, ***Fallfish*** were included as species of special concern in all six *New England states*, while ***Bridle Shiner*** was chosen in southern *New England* (*CT, RI, MA*). Aside from ***Arctic Char*** in *Maine,* singular species assignments included ***Banded Sunfish*** in *RI* and ***Slimy Sculpin*** in *VT*. Dual species assignments included ***Lake Trout*** (*NH, ME*), while ***Atlantic Salmon*** was chosen for the three northern *New England* states (*NH, ME, VT*).

Table 7. Officially designated state fishes – New England (Troia 2017).

'Heritage'	**CT**	**RI**	**MA**	**NH**	**ME**	**VT**
Fish Species	Yes	Yes	**No**	Yes	Yes	Yes
Brook Trout			**3**	**A**	**A**	**A**
Arctic Char					A	
American Shad	A					
Striped Bass		A				
Slimy Sculpin						1
Tessellated Darter	1					
Bridle Shiner	**2**	**1**	**2**			
Fallfish	**3**	**3**	**1**	**3**	**3**	**2**
Banded Sunfish		2				
Atlantic Salmon				**1**	**1**	**3**
Lake Trout				2	2	

APPENDIX B

Table 1. Western <u>non-native</u> (introduced) fishes of New England proper

22	Bowfin	*Amia calva*
36	Goldfish (European)	*Carassius auritus*
46	Common Carp (European)	*Cyprinus carpio*
47	Grass Carp (European)	*Ctenopharyngodon idella*
82	Emerald Shiner	*Notropis atherinoides*
106	Mimic Shiner	*Notropis volucellus*
112	Bluntnose Minnow	*Pimephales notatus*
120	Rudd (European)	*Scardinius erythropthalmus*
148	White Catfish/Bullhead	*Ameiurus catus*
150	Yellow Bullhead	*Ameiurus natalis*
154	Channel Catfish	*Ictalurus punctatus*
158	Tadpole Madtom	*Noturus gyrinus*
160	Margined Madtom	*Noturus insignis*
168	Northern Pike	*Esox lucius*
170	Muskellunge	*Esox masquinongy*
186	Rainbow Trout/Salmon	*Oncorhynchus mykiss*
190	Brown Trout (European)	*Salmo trutta*
234	Rock Bass	*Ambloplites rupestris*
244	Green Sunfish	*Lepomis cyanellus*
248	Bluegill (sunfish)	*Lepomis macrochirus*
249	Redear Sunfish (VT)	*Lepomis microlophus*
250	Smallmouth Bass	*Micropterus dolomieu*
252	Largemouth Bass	*Micropterus salmoides*
254	White Crappie	*Pomoxis annularis*
256	Black Crappie	*Pomoxis nigromaculatus*
296_	Walleye (- Perch)	*Sander vitreus*

Table 2. Western native fishes of Lake Champlain in Vermont and New York

4	Northern Brook Lamprey	*Ichthyomyzon fossor*
10	Silver Lamprey	*Ichthyomyzon unicuspis*
16	Lake Sturgeon	*Acipenser fulvescens*
20	Longnose Gar	*Lepisosteus osseus*
23	Mooneye	*Hiodon tergisus*
44	Spotfin Shiner	*Cyprinella spiloptera*
56	Brassy Minnow	*Hybognathus hankinsoni*
92	Blackchin Shiner	*Notropis heterodon*
102	Rosyface Shiner	*Notropis rubellus*
103	Sand Shiner	*Notropis stramineus*
126	Quillback	*Carpiodes cyprinus*
136	Silver Redhorse	*Moxostoma anisurum*
144	Shorthead Redhorse	*Moxostoma macrolepidotum*
146	Greater Redhorse	*Moxostoma valenciennesi*
156	Stonecat	*Noturus flavus*
180	Cisco (Lake Herring)	*Coregonus artedi*
212	Brook Silverside	*Labidesthes sicculus*
222	Mottled Sculpin	*Cottus bairdi*
251	Northern Sunfish	*Lepomis peltastes*
258	Eastern Sand Darter	*Ammocrypta pellucida*
268	Fantail Darter	*Etheostoma flabellare*
284	Logperch	*Percina caprodes*
286	Channel Darter	*Percina copelandi*
297	Sauger	*Sander canadensis*
298	Freshwater Drum	*Aplodinotus grunniens*

Table 3. Western fish native to New York Adirondacks, Appalachians and Great Lakes

6	Mountain Brook Lamprey	*Ichthyomyzon greeleyi*
8	Ohio Lamprey	*Ichthyomyzon bdellium*
34	Central Stoneroller	*Campostoma anomalum*
38	Redside Dace	*Clinostomus elongatus*
42	Satinfin Shiner	*Cyprinella analostana*
48	Streamline Chub	*Erimystax dissimilis*
50	Gravel Chub	*Erimystax x-punctatus*
52	Tonguetied Minnow	*Exoglossum laurae*
60	Striped Shiner	*Luxilus chrysocephalus*
64	Redfin Shiner	*Lythrurus umbratilis*
66	Silver Chub	*Macrhybopsis storeriana*
70	Hornyhead Chub	*Nocomis biguttatus*
72	River Chub	*Nocomis micropogon*
76	Bigeye Chub	*Notropis amblops*
78	Comely Shiner	*Notropis amoenus*
80	Pugnose Shiner	*Notropis anogenus*
86	Silverjaw Minnow	*Notropis buccatus*
88	Ironcolor Shiner	*Notropis chalybaeus*
90	Bigmouth Shiner	*Notropis dorsalis*
98	Silver Shiner	*Notropis photogenis*
100	Swallowtail Shiner	*Notropis procne*
131	Summer Sucker	*Catostomus utawana*
133	Lake Chubsucker	*Erimyzon sucetta*
134	Northern Hogsucker	*Hypentelium nigricans*
138	River Redhorse	*Moxostoma carinatum*
140	Black Redhorse	*Moxostoma duquesnei*
141	Smallmouth Redhorse	*Moxostoma breviceps*
142	Golden Redhorse	*Moxostoma erythrurum*

Table 3. (con't) Western fishes native to NY Adirondacks, Appalachians and Great Lakes

151	Black Bullhead	*Ameiurus melas*
162	Brindled Madtom	*Noturus miurus*
200	Pirate Perch	*Aphredoderus sayanus*
210	Western Mosquitofish (NYC)	*Gambusia affinis*
228	White Bass	*Morone chrysops*
249	Longear Sunfish	*Lepomis megalotis*
260	Greenside Darter	*Etheostoma blennoides*
262	Rainbow Darter	*Etheostoma caeruleum*
264	Bluebreast Darter	*Etheostoma camurum*
266	Iowa Darter	*Etheostoma exile*
272	Spotted Darter	*Etheostoma maculatum*
274	Johnny Darter	*Etheostoma nigrum*
278	Variegate Darter	*Etheostoma variatum*
280	Banded Darter	*Etheostoma zonale*
288	Gilt Darter	*Percina evides*
290	Longhead Darter	*Percina macrocephala*
292	Blackside Darter	*Percina maculata*
294	Shield Darter	*Percina peltata*

Table 4. Southeastern fishes native to New Jersey (EPA Region 2)
Absent from New England Freshwaters (New York +/-)

176	Eastern Mudminnow (+ NY)	*Umbra pygmaea*
208	Eastern Mosquitofish (- NY)	*Gambusia holbrooki*
232	Mud Sunfish (+ New York)	*Acantharchus pomotis*
236	Blackbanded Sunfish (- NY)	*Enneacanthus chaetodon*
238	Bluespotted Sunfish (N-N NY)	*Enneacanthus gloriosus*

FISH DISTRIBUTION MAPS: 1-56

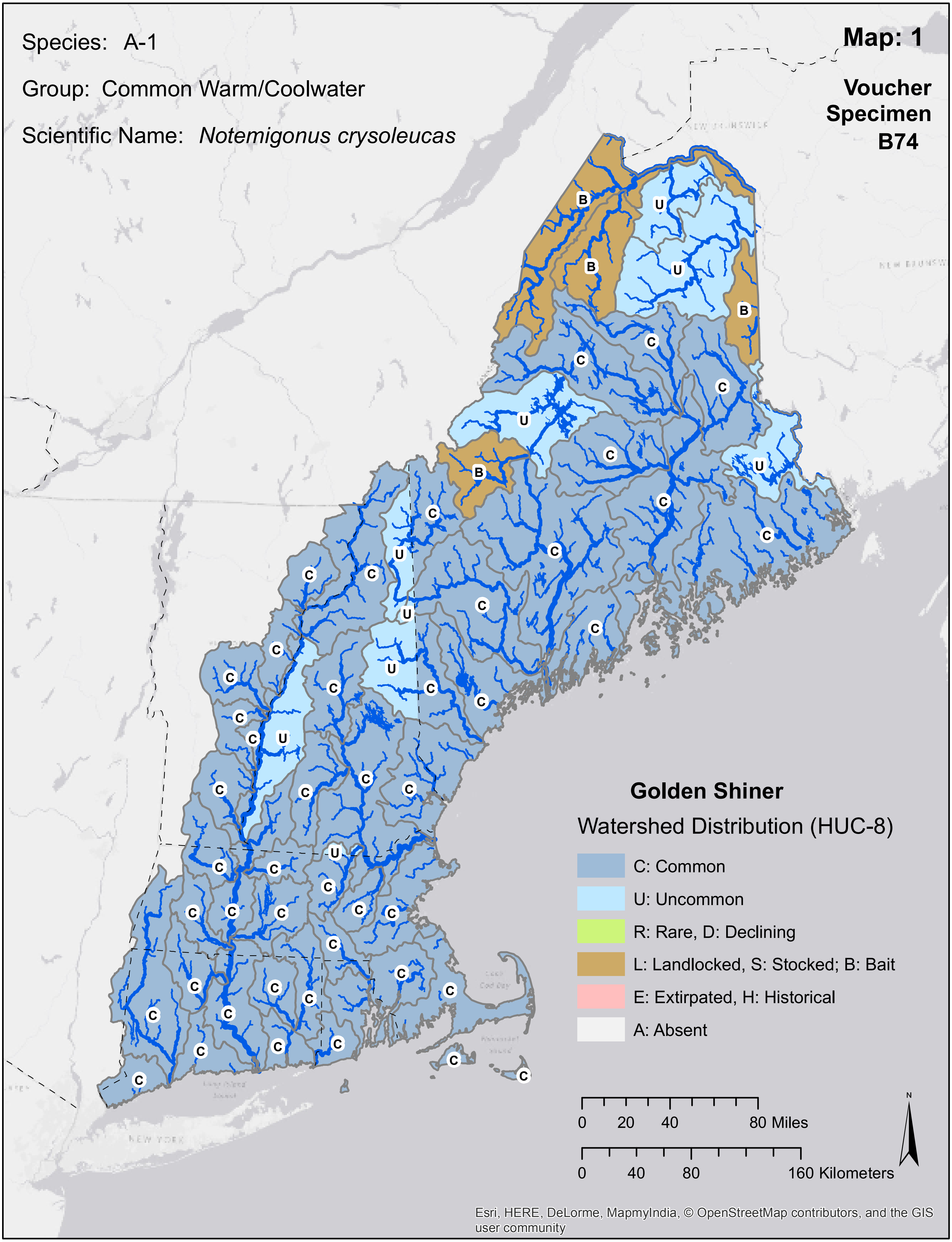
Species: A-1

Group: Common Warm/Coolwater

Scientific Name: *Notemigonus crysoleucas*

Map: 1

Voucher Specimen B74



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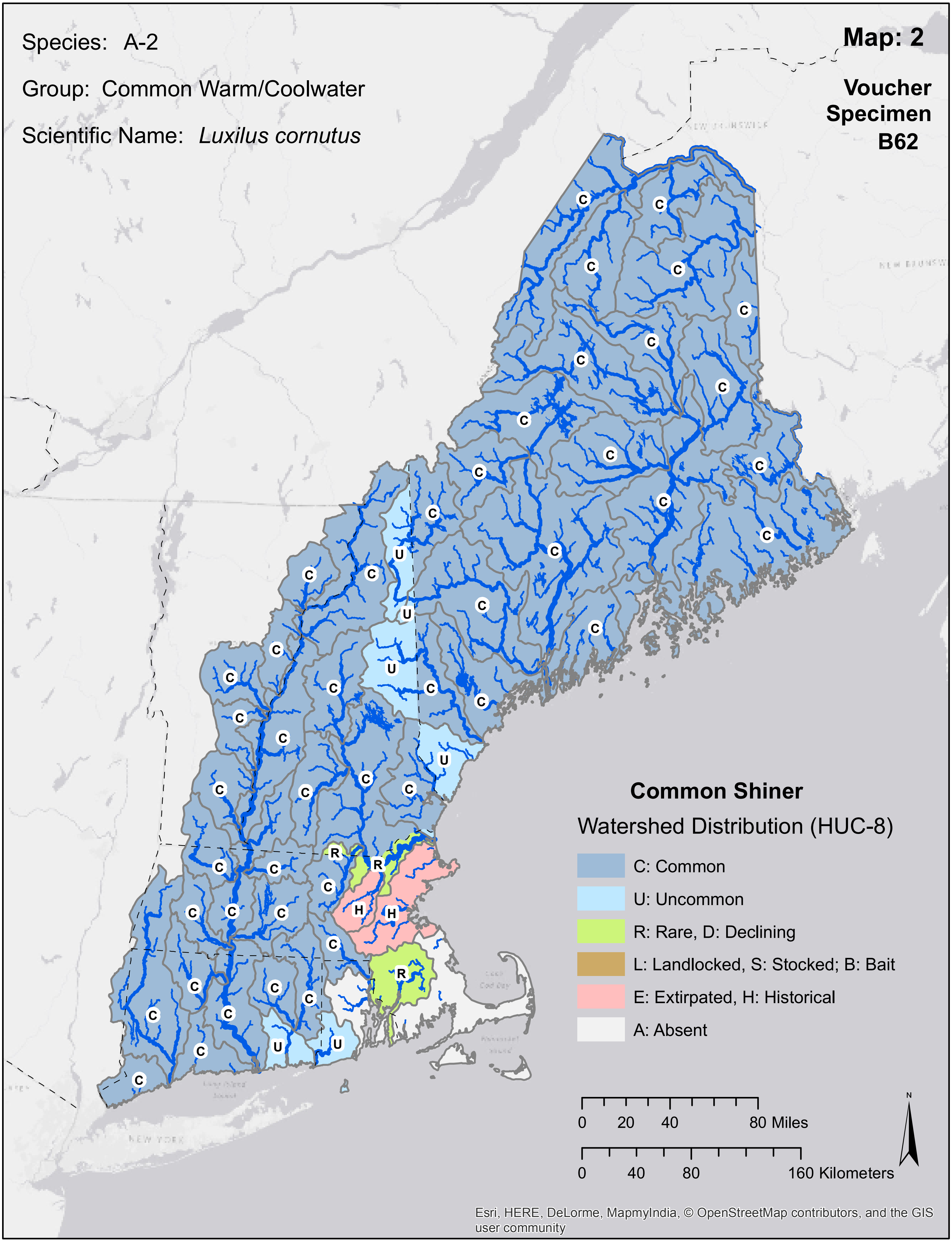
Species: A-2
Group: Common Warm/Coolwater
Scientific Name: *Luxilus cornutus*
Map: 2
Voucher Specimen B62
Common Shiner
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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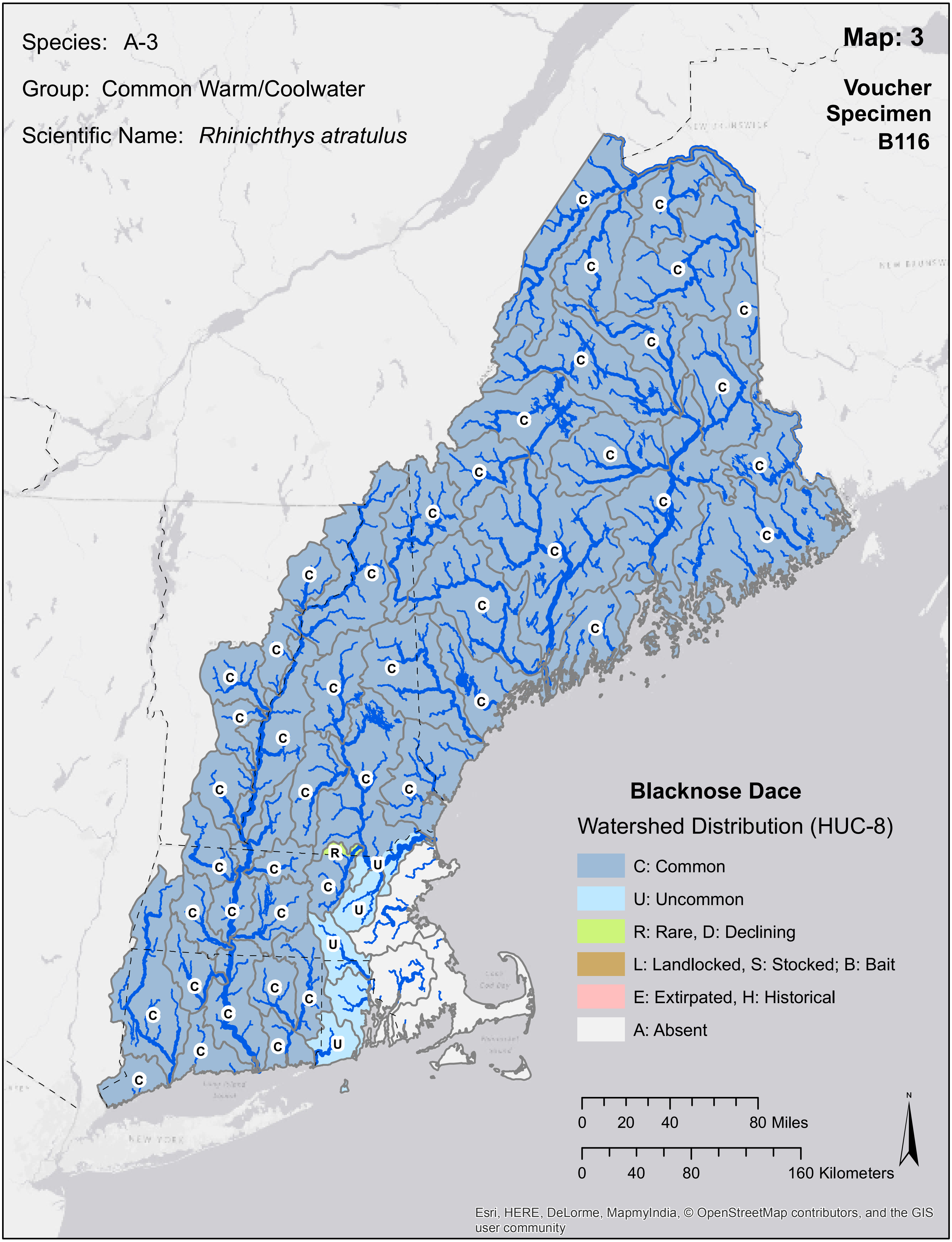
Species: A-3
Group: Common Warm/Coolwater
Scientific Name: *Rhinichthys atratulus*
Map: 3
Voucher Specimen B116
Blacknose Dace
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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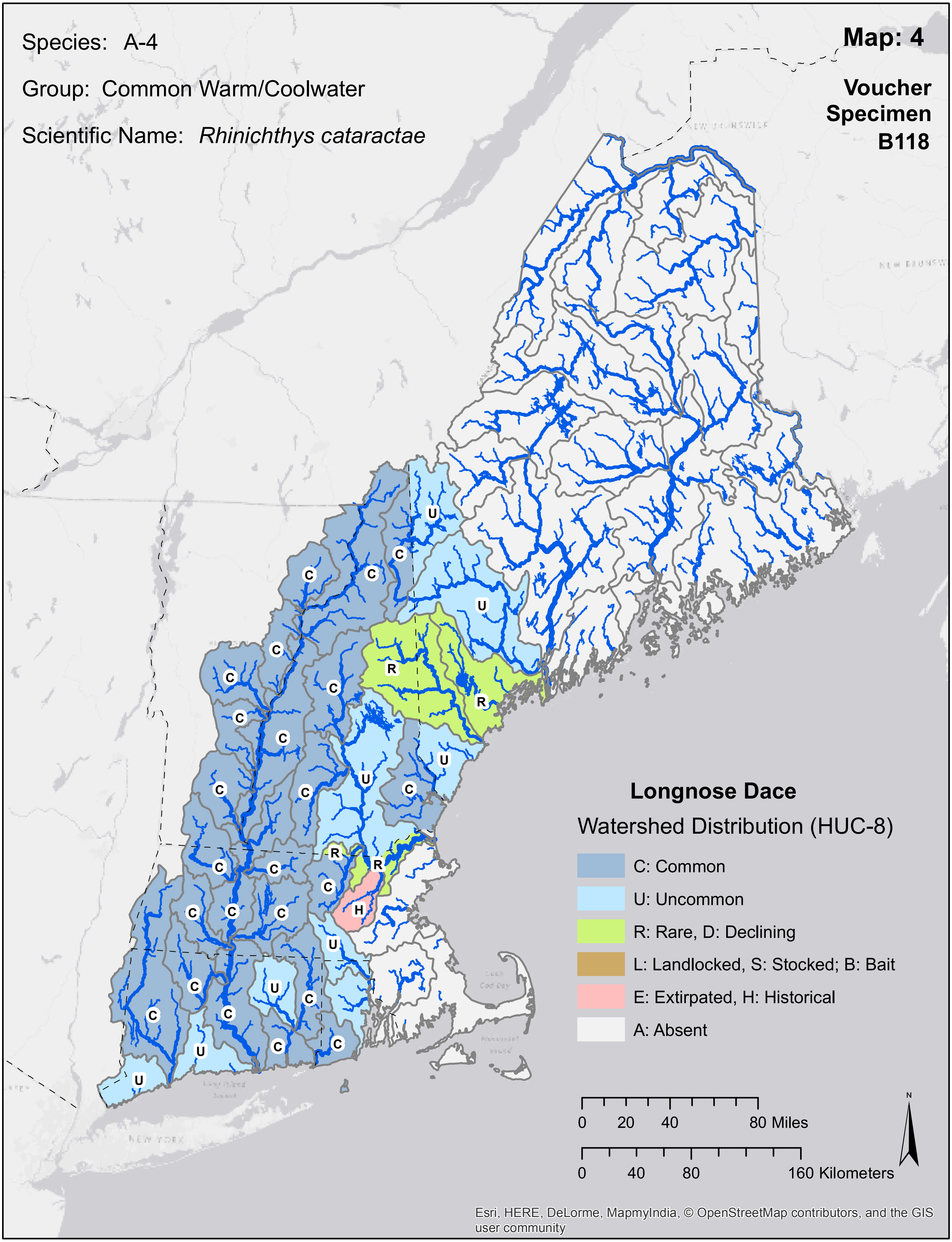
Species: A-4
Group: Common Warm/Coolwater
Scientific Name: *Rhinichthys cataractae*
Map: 4
Voucher Specimen B118
Longnose Dace
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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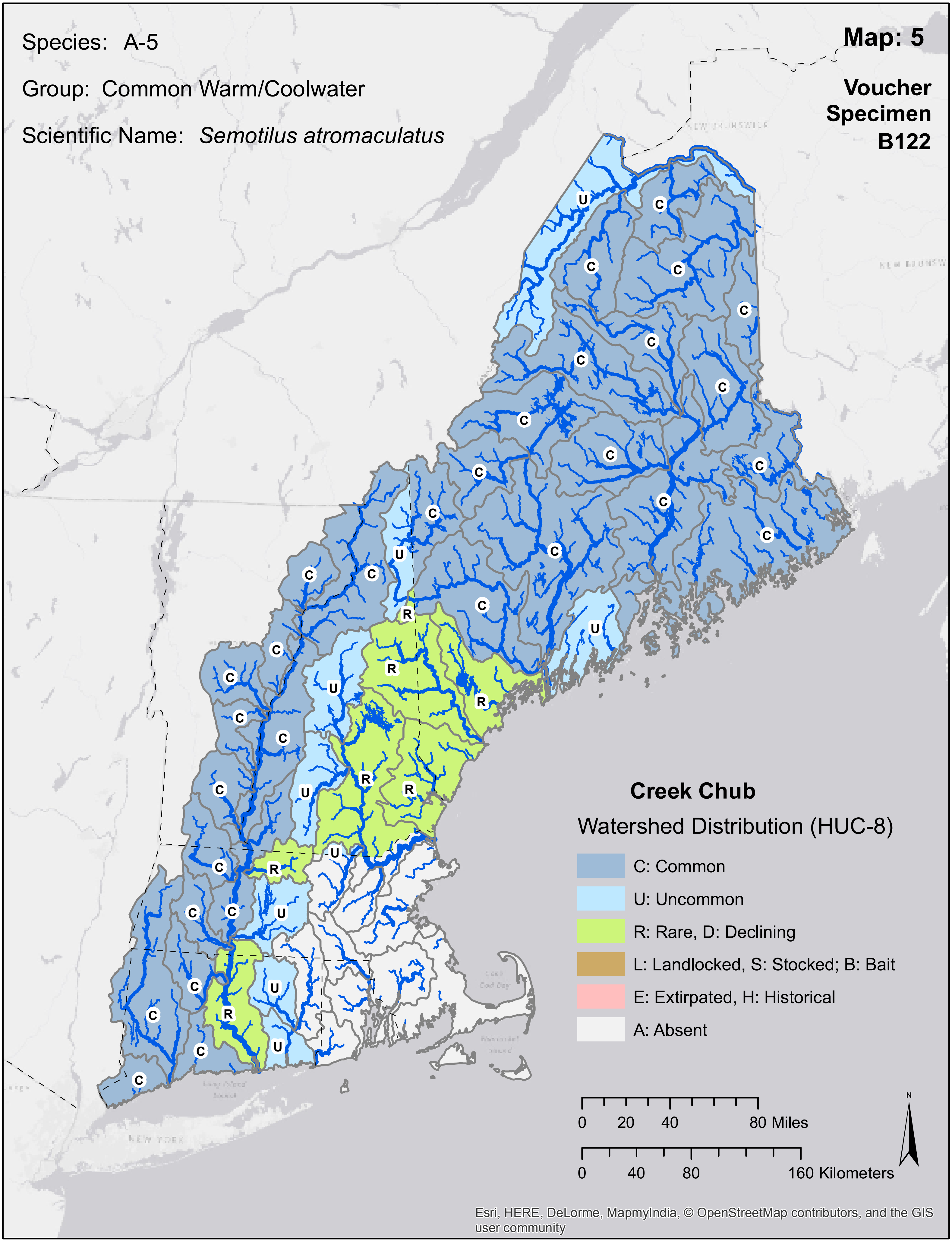
Species: A-5
Group: Common Warm/Coolwater
Scientific Name: *Semotilus atromaculatus*
Map: 5
Voucher Specimen B122
Creek Chub
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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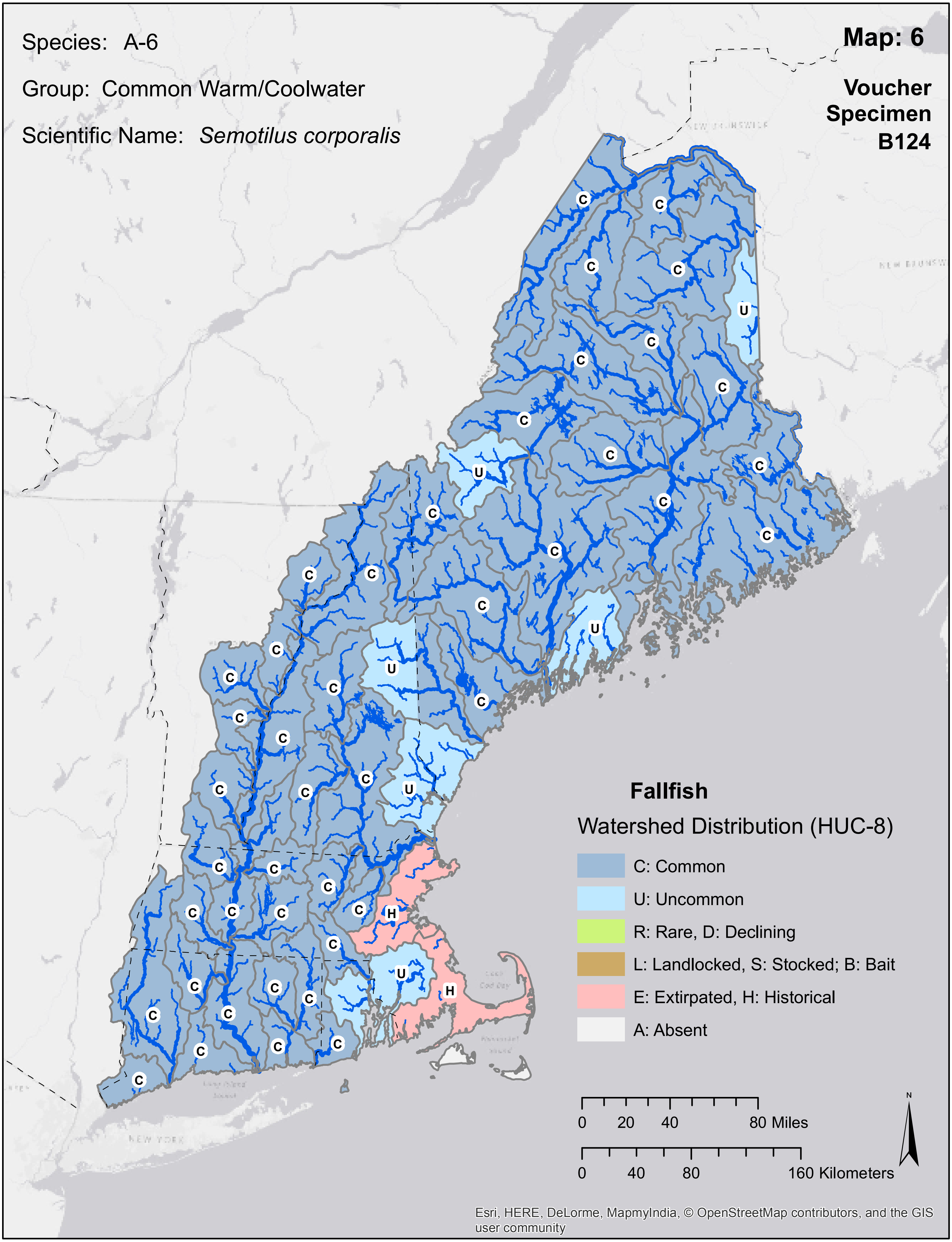
Species: A-6
Group: Common Warm/Coolwater
Scientific Name: *Semotilus corporalis*
Map: 6
Voucher Specimen B124
Fallfish
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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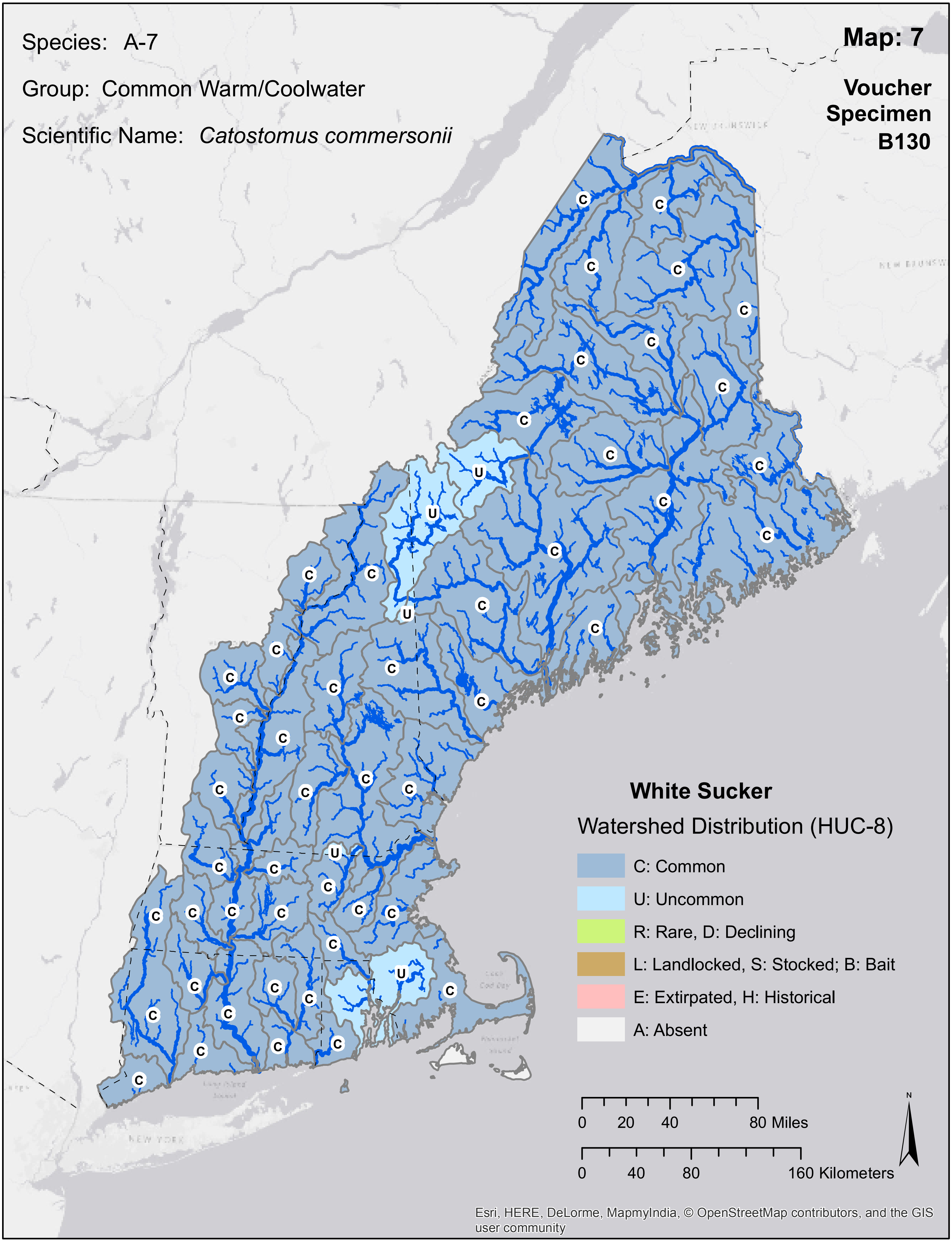
Species: A-7
Group: Common Warm/Coolwater
Scientific Name: *Catostomus commersonii*
Map: 7
Voucher Specimen B130
White Sucker
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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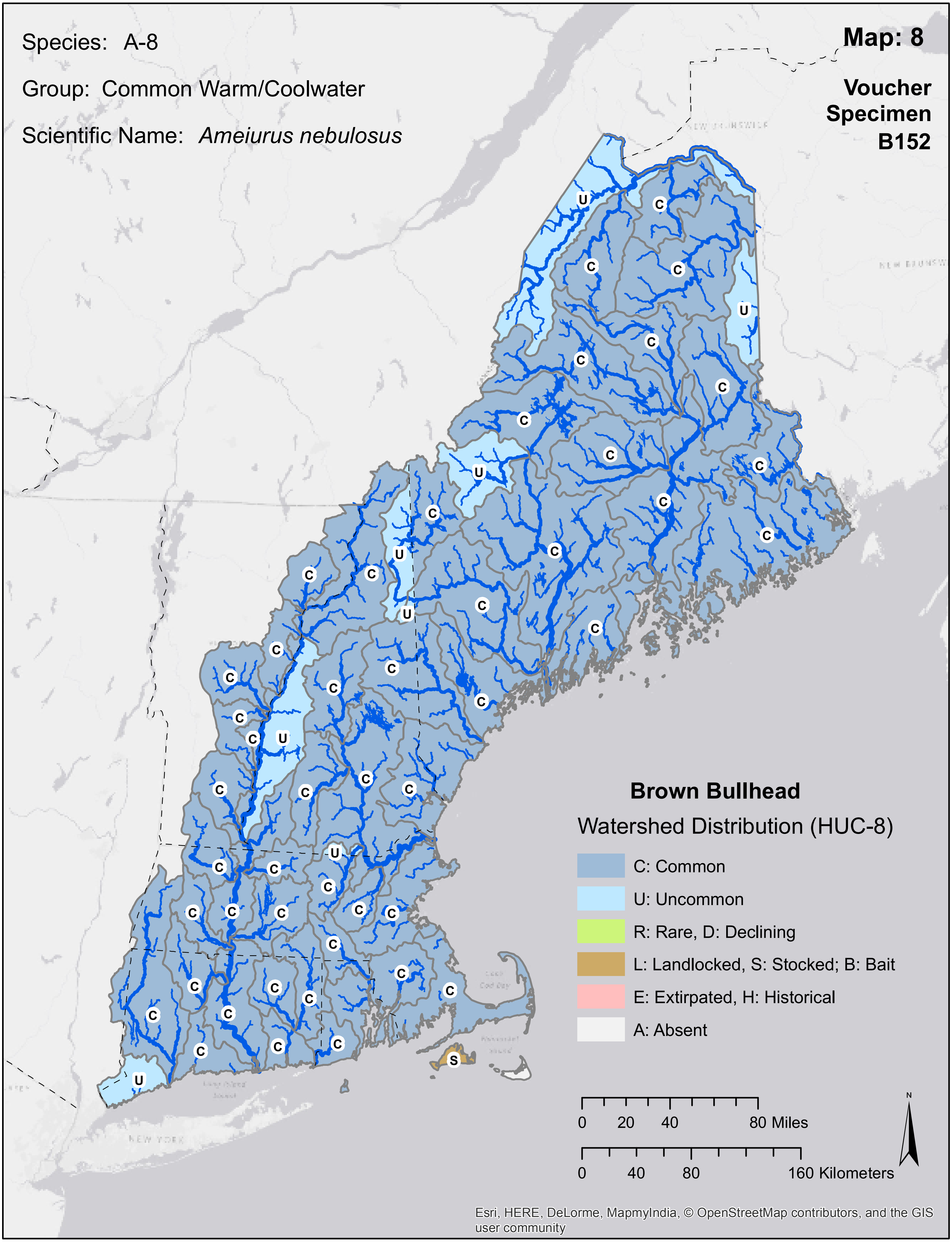

Species: A-8
Group: Common Warm/Coolwater
Scientific Name: *Ameiurus nebulosus*
Map: 8
Voucher Specimen B152
Brown Bullhead
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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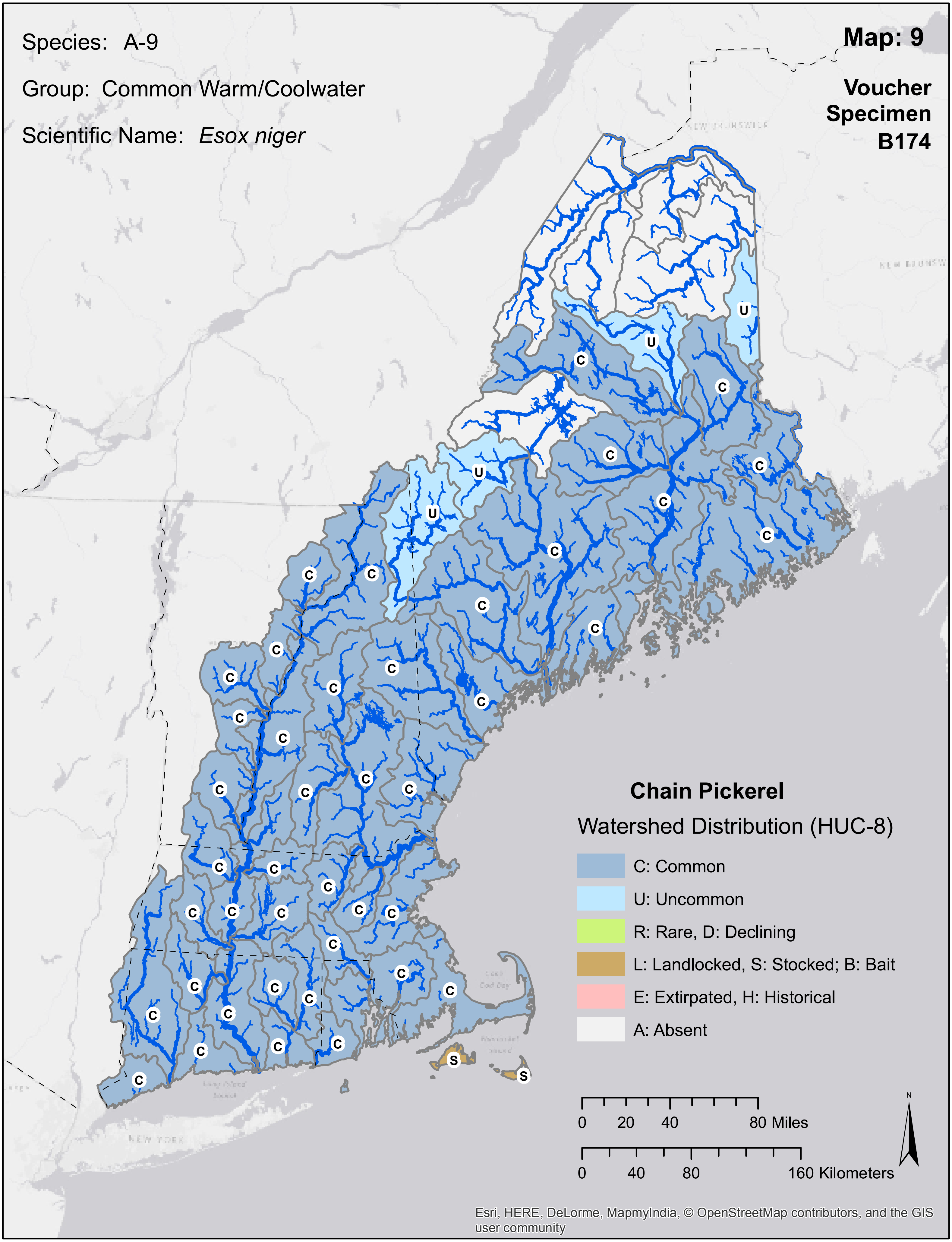
Species: A-9
Group: Common Warm/Coolwater
Scientific Name: *Esox niger*
Map: 9
Voucher Specimen B174
Chain Pickerel
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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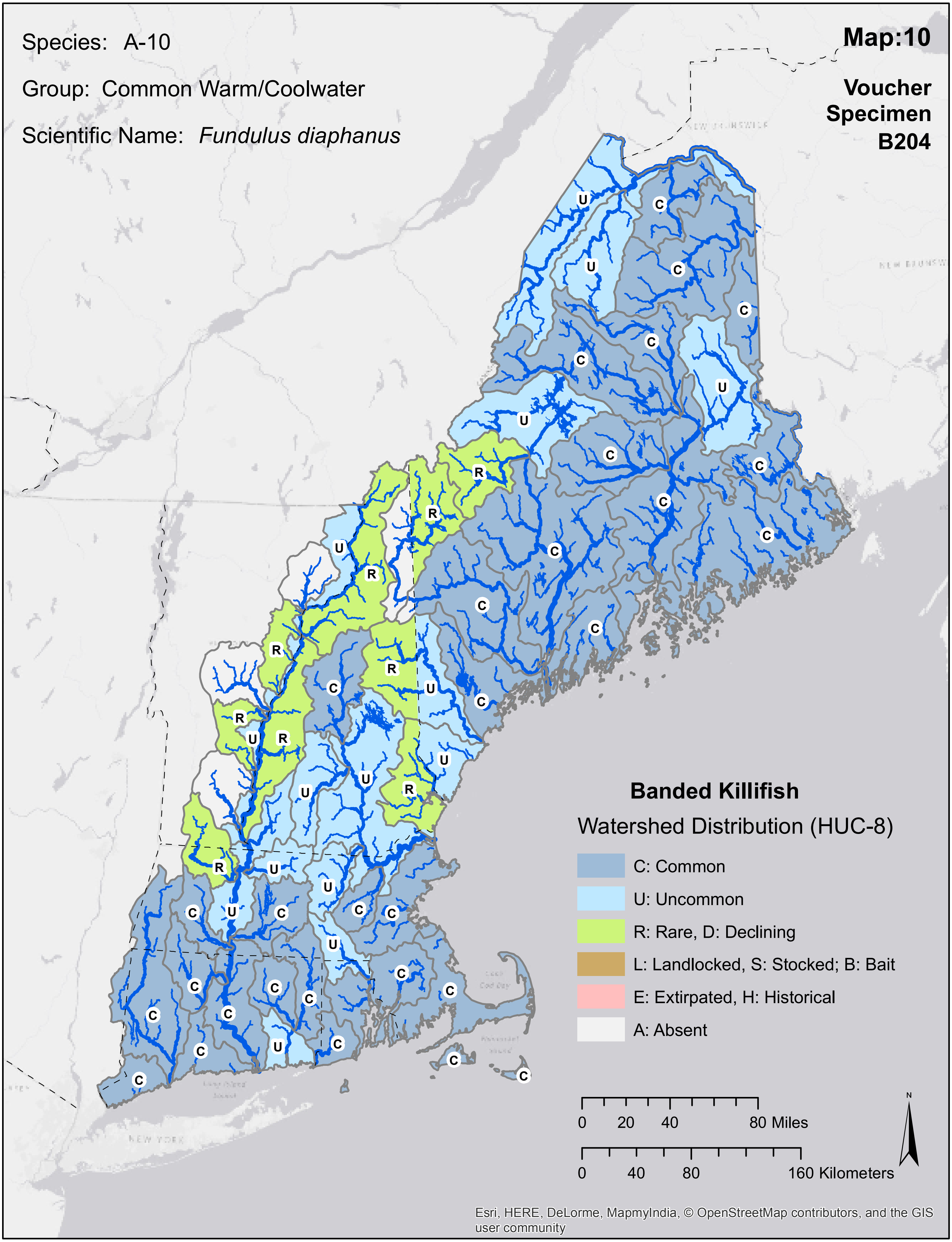
Species: A-10
Group: Common Warm/Coolwater
Scientific Name: *Fundulus diaphanus*
Map:10
Voucher Specimen B204
Banded Killifish
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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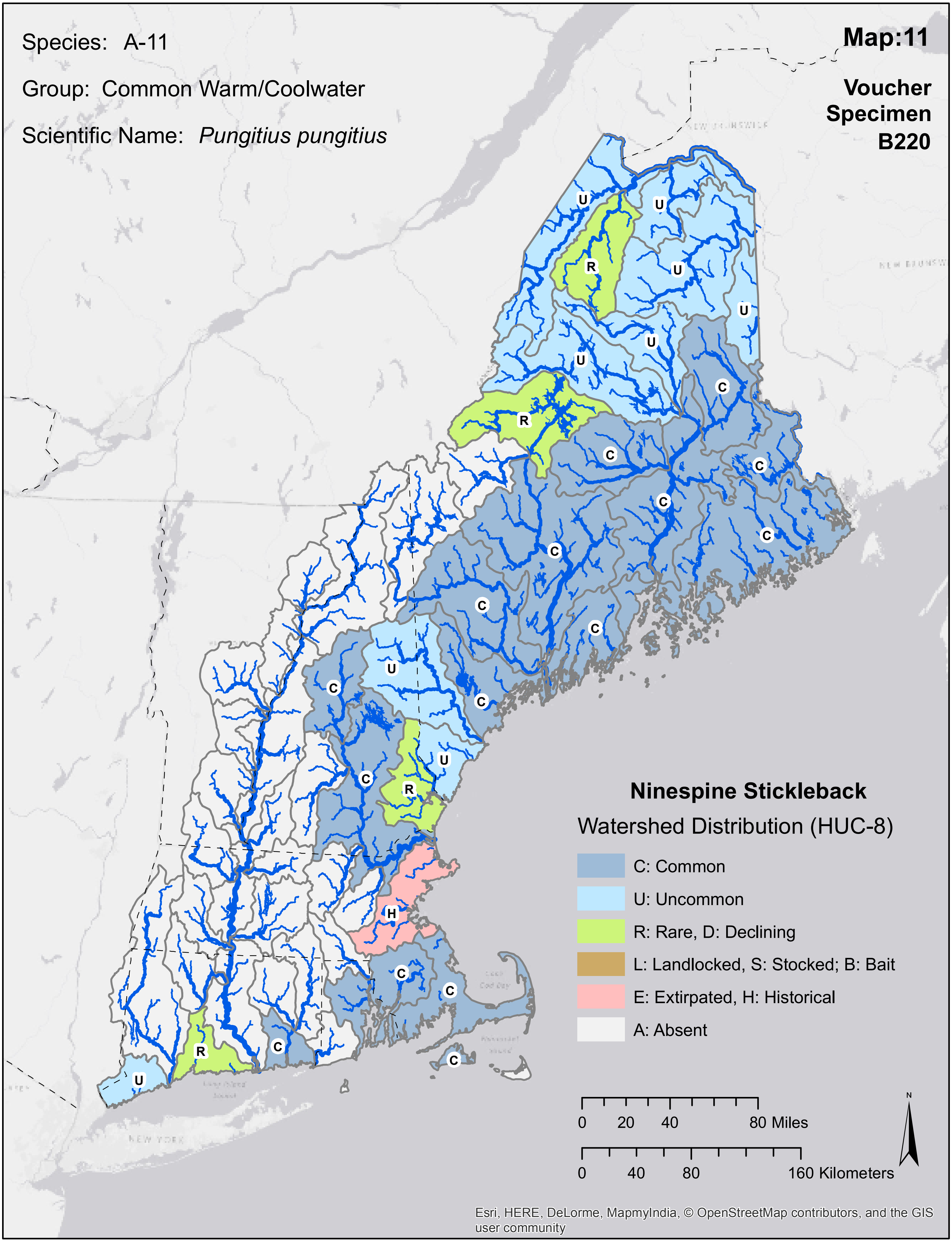
Species: A-11
Group: Common Warm/Coolwater
Scientific Name: *Pungitius pungitius*
Map:11
Voucher Specimen B220
Ninespine Stickleback
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
NEW YORK
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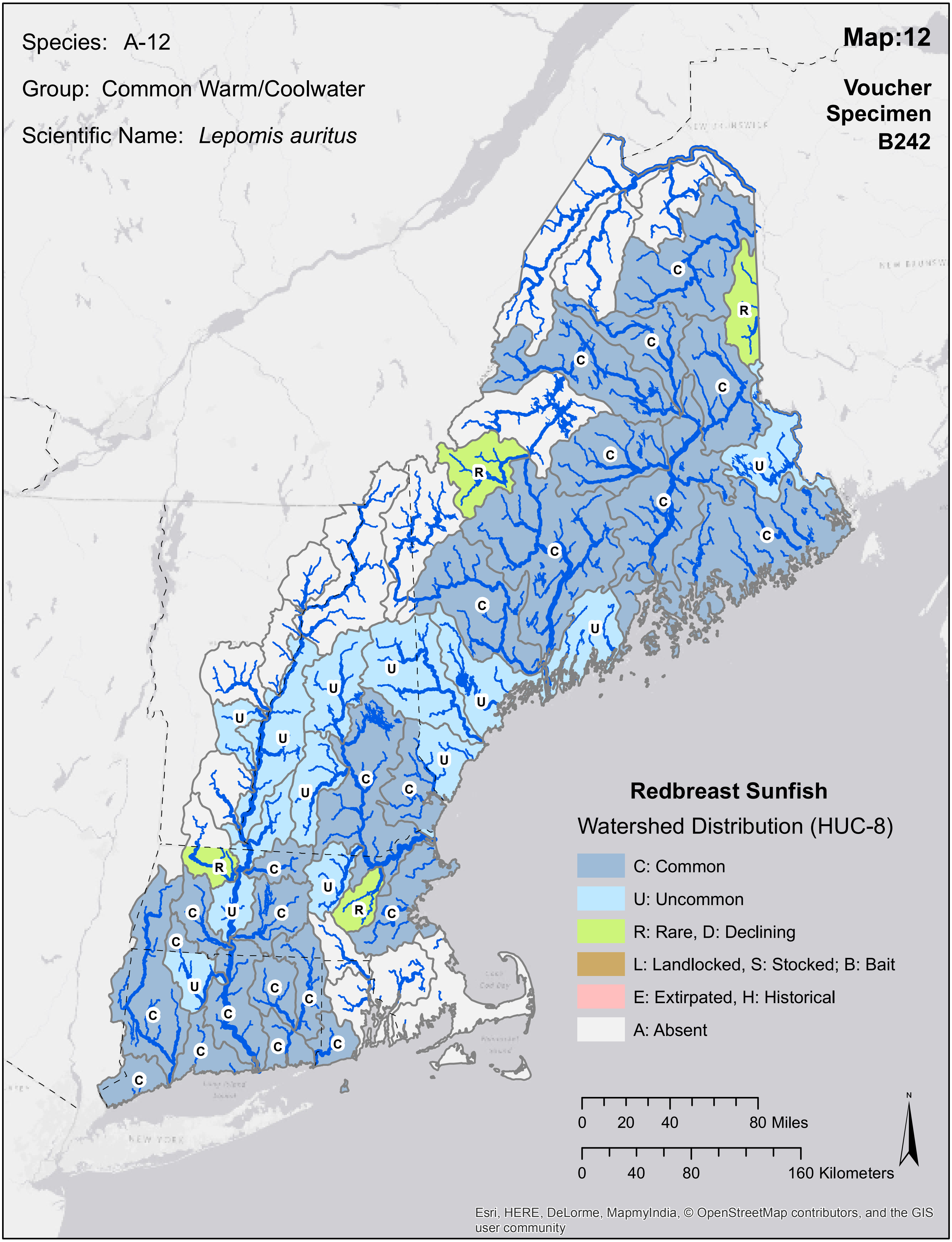
Species: A-12
Group: Common Warm/Coolwater
Scientific Name: *Lepomis auritus*
Map:12
Voucher Specimen B242
Redbreast Sunfish
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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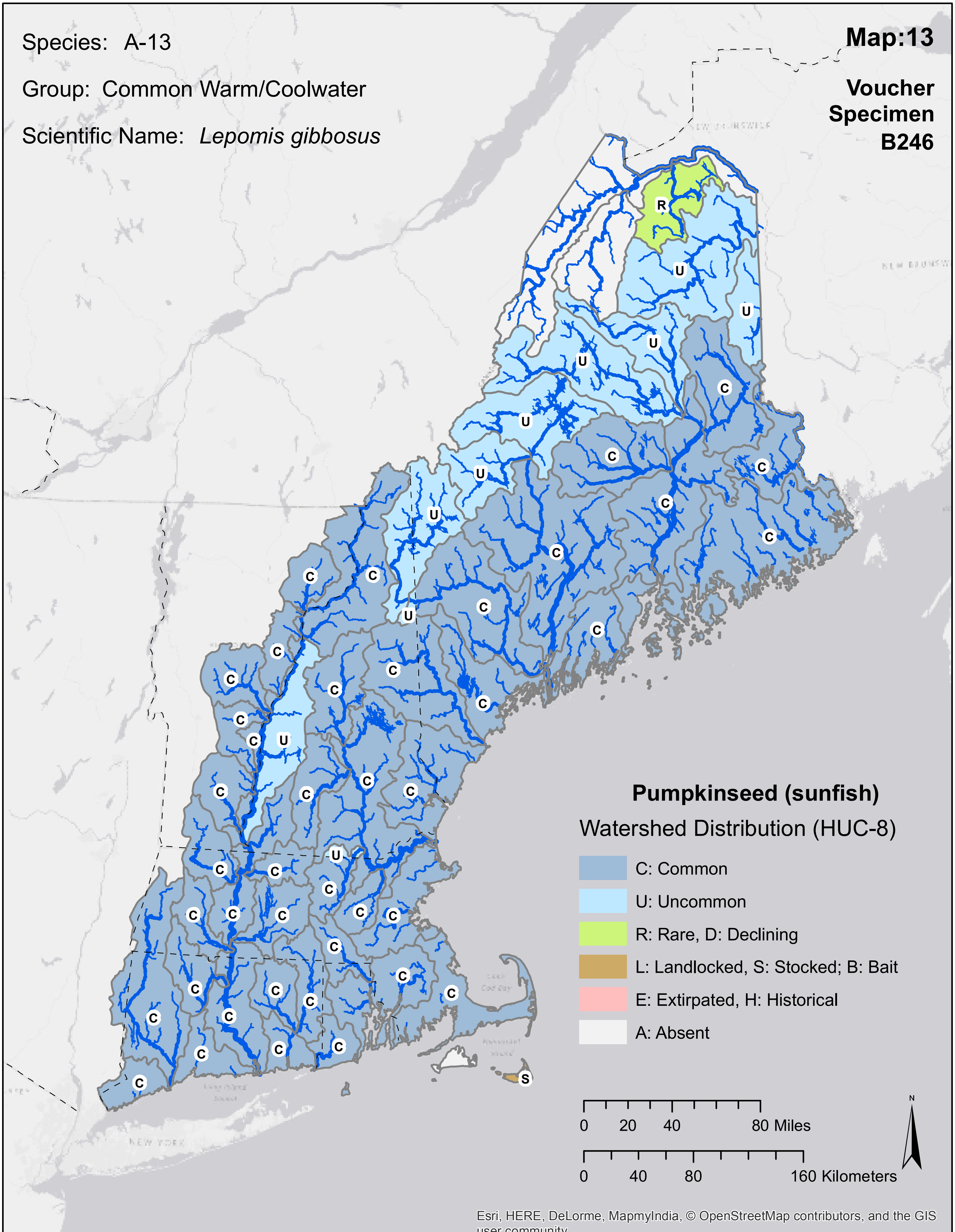
Species: A-13
Group: Common Warm/Coolwater
Scientific Name: *Lepomis gibbosus*
Map:13
Voucher Specimen B246
Pumpkinseed (sunfish)
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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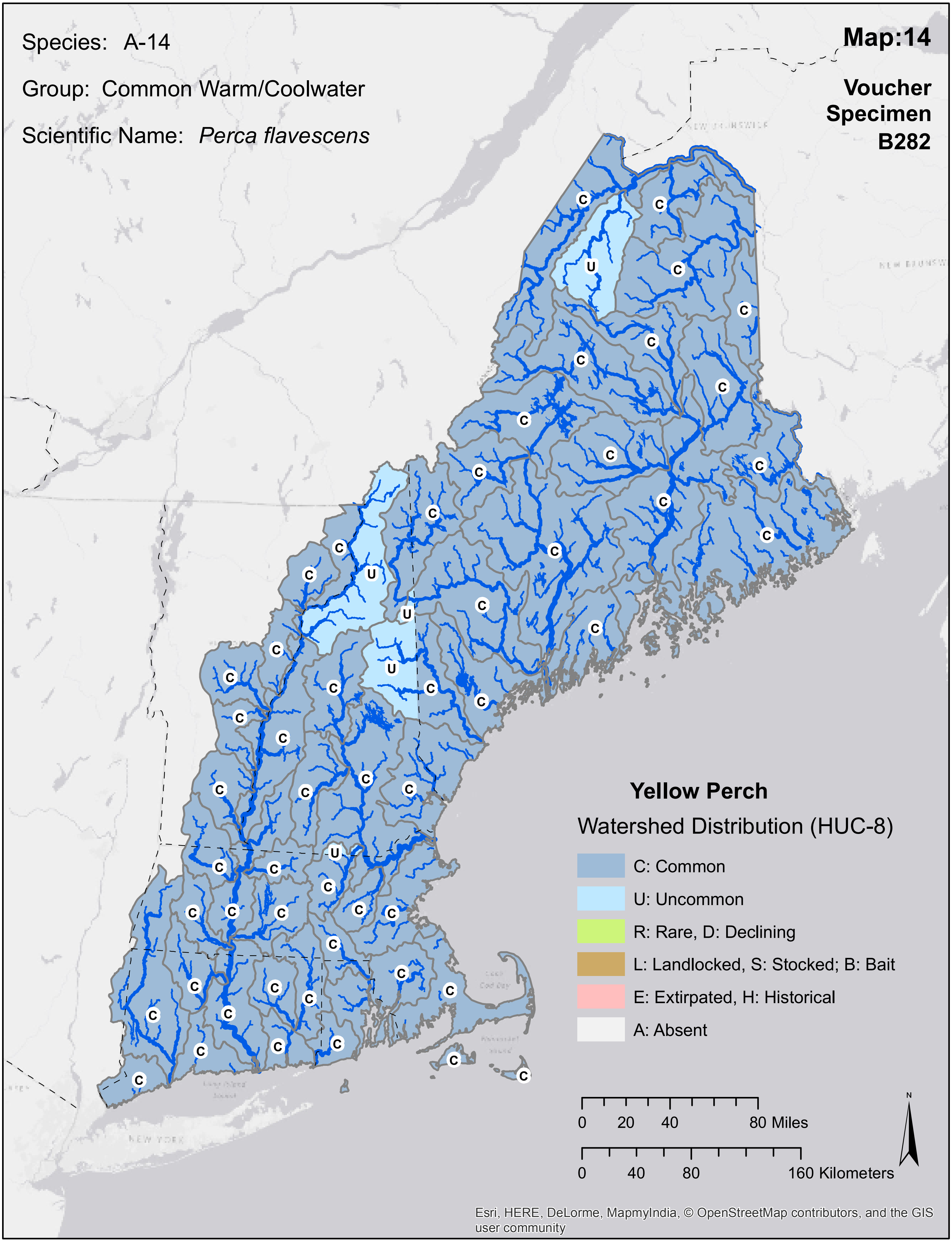
Species: A-14
Group: Common Warm/Coolwater
Scientific Name: *Perca flavescens*
Map:14
Voucher
Specimen
B282
Yellow Perch
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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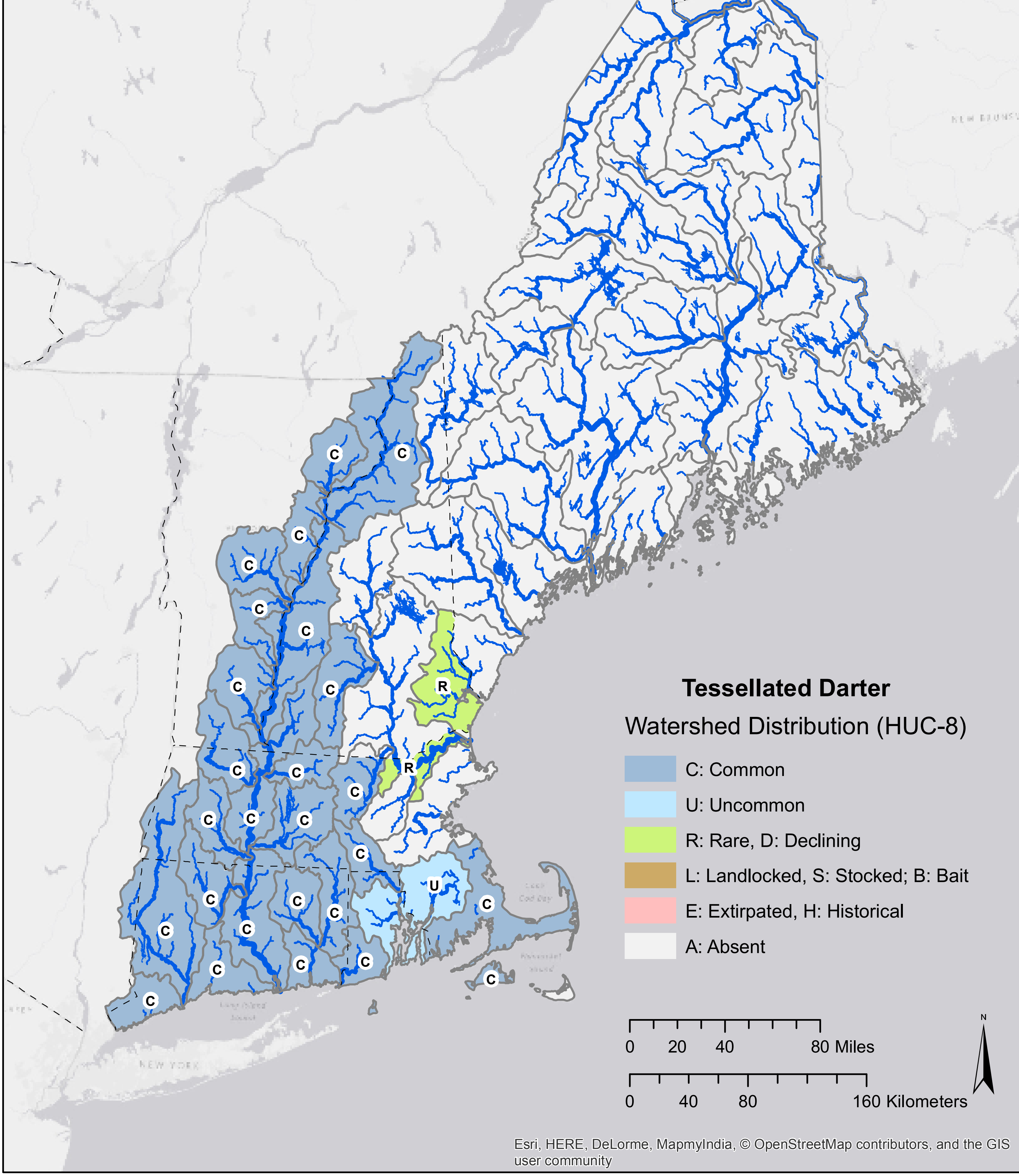
Species: A-15

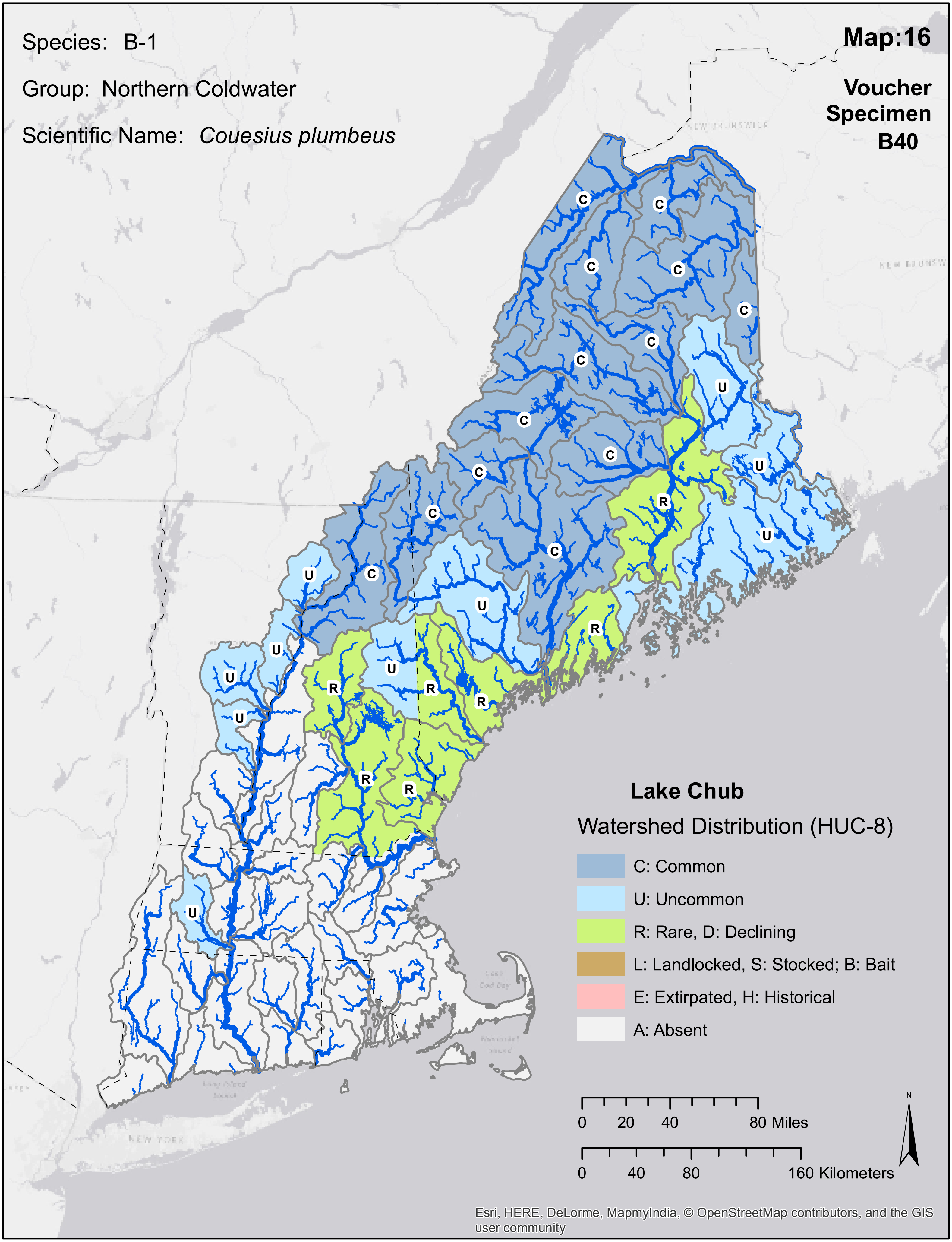
Group: Common Warm/Coolwater

Scientific Name: *Etheostoma olmstedi*

Map:15

Voucher Specimen B276




Species: B-1
Group: Northern Coldwater
Scientific Name: *Couesius plumbeus*
Map:16
Voucher Specimen B40
Lake Chub
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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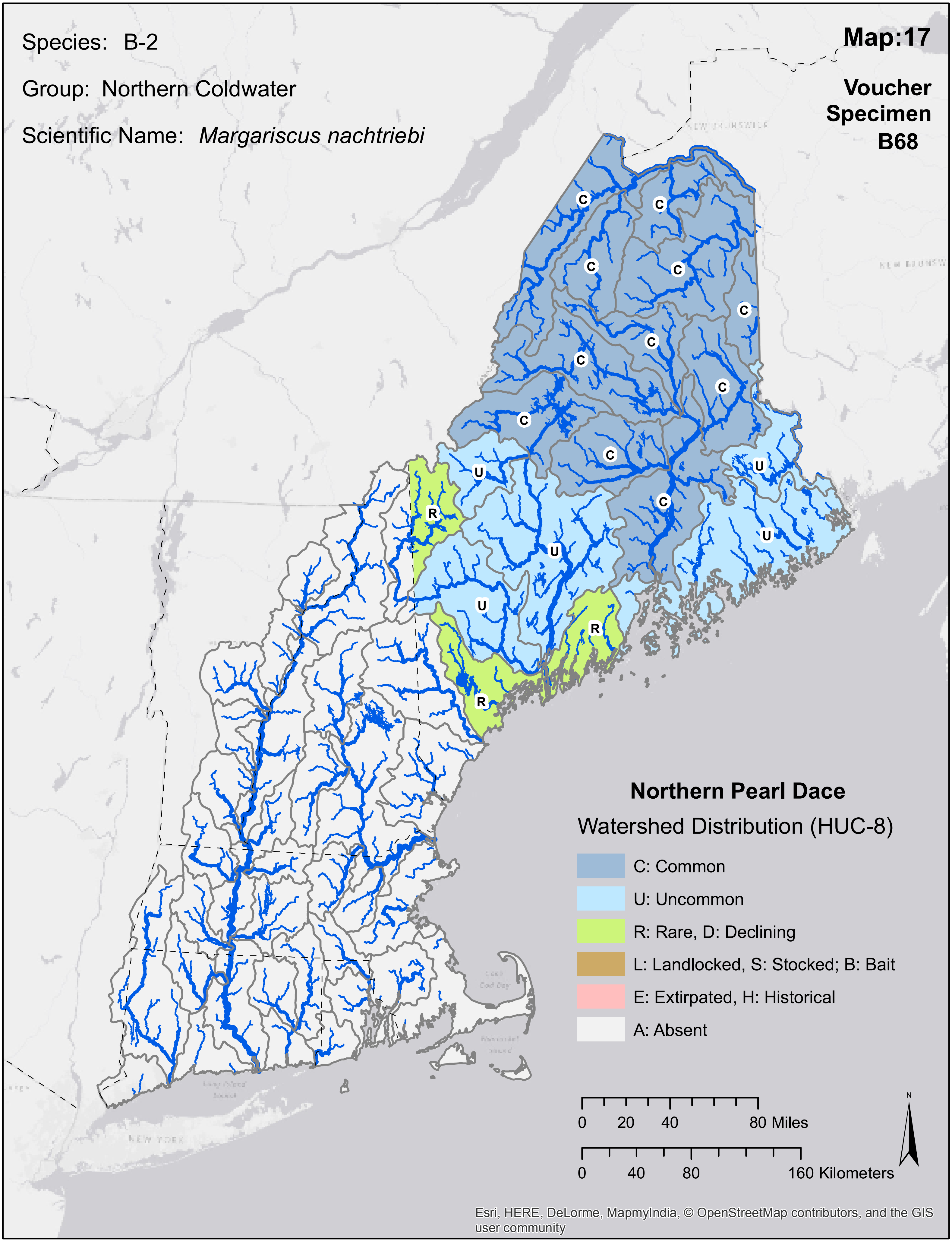
Species: B-2
Group: Northern Coldwater
Scientific Name: *Margariscus nachtriebi*
Map:17
Voucher Specimen B68
C
U
R
Northern Pearl Dace
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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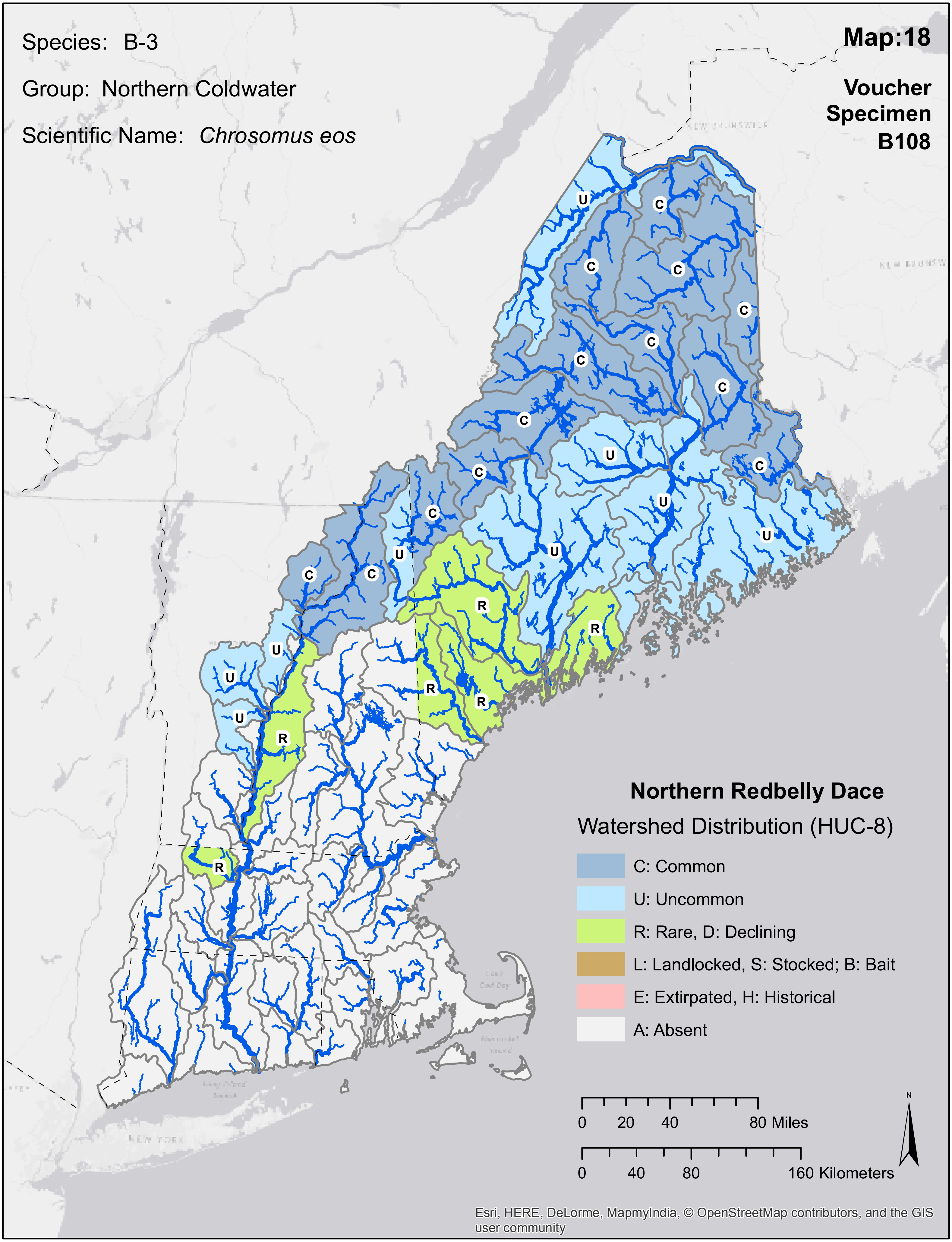
Species: B-3
Group: Northern Coldwater
Scientific Name: *Chrosomus eos*
Map:18
Voucher
Specimen
B108
Northern Redbelly Dace
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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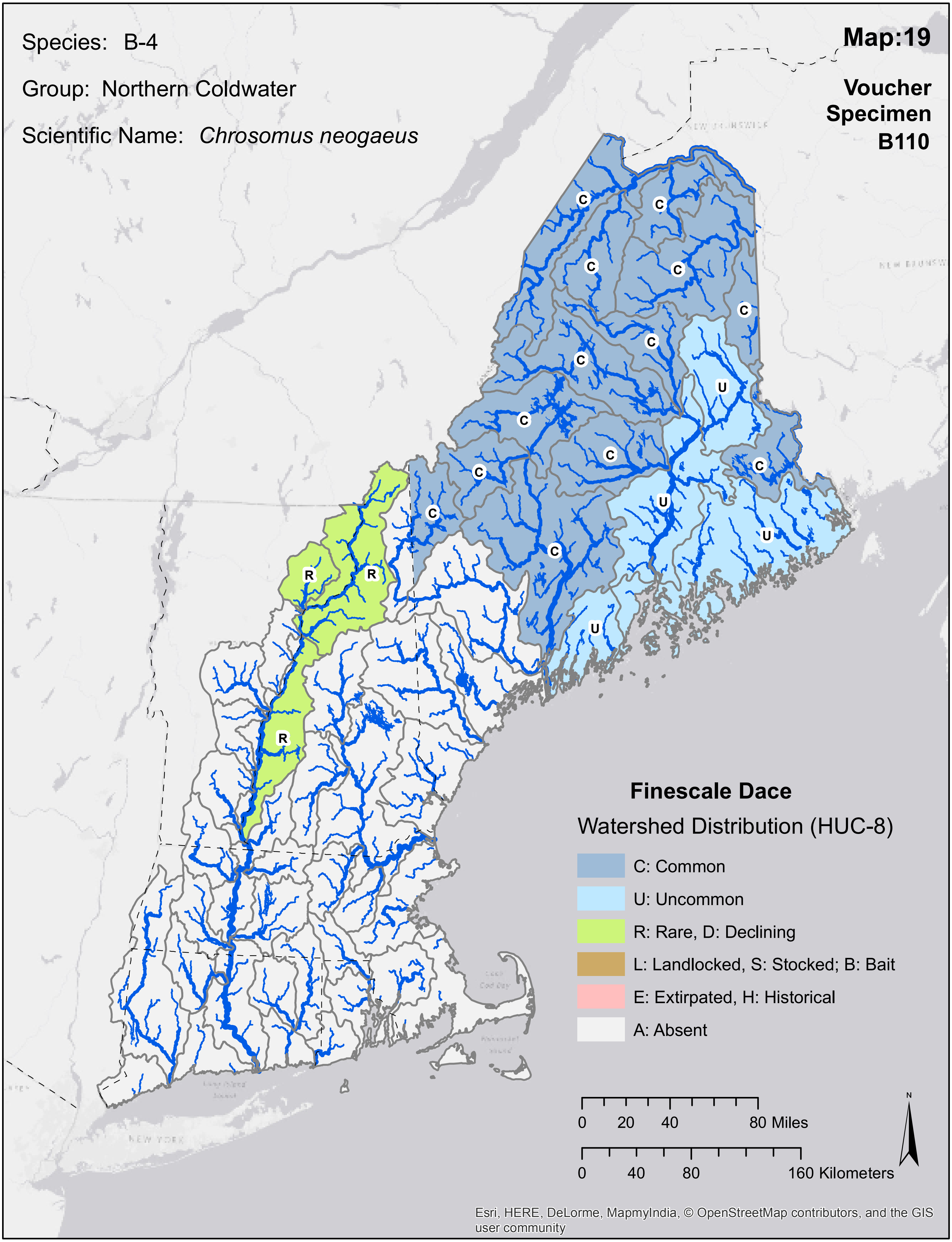
Species: B-4
Group: Northern Coldwater
Scientific Name: *Chrosomus neogaeus*
Map:19
Voucher
Specimen
B110
Finescale Dace
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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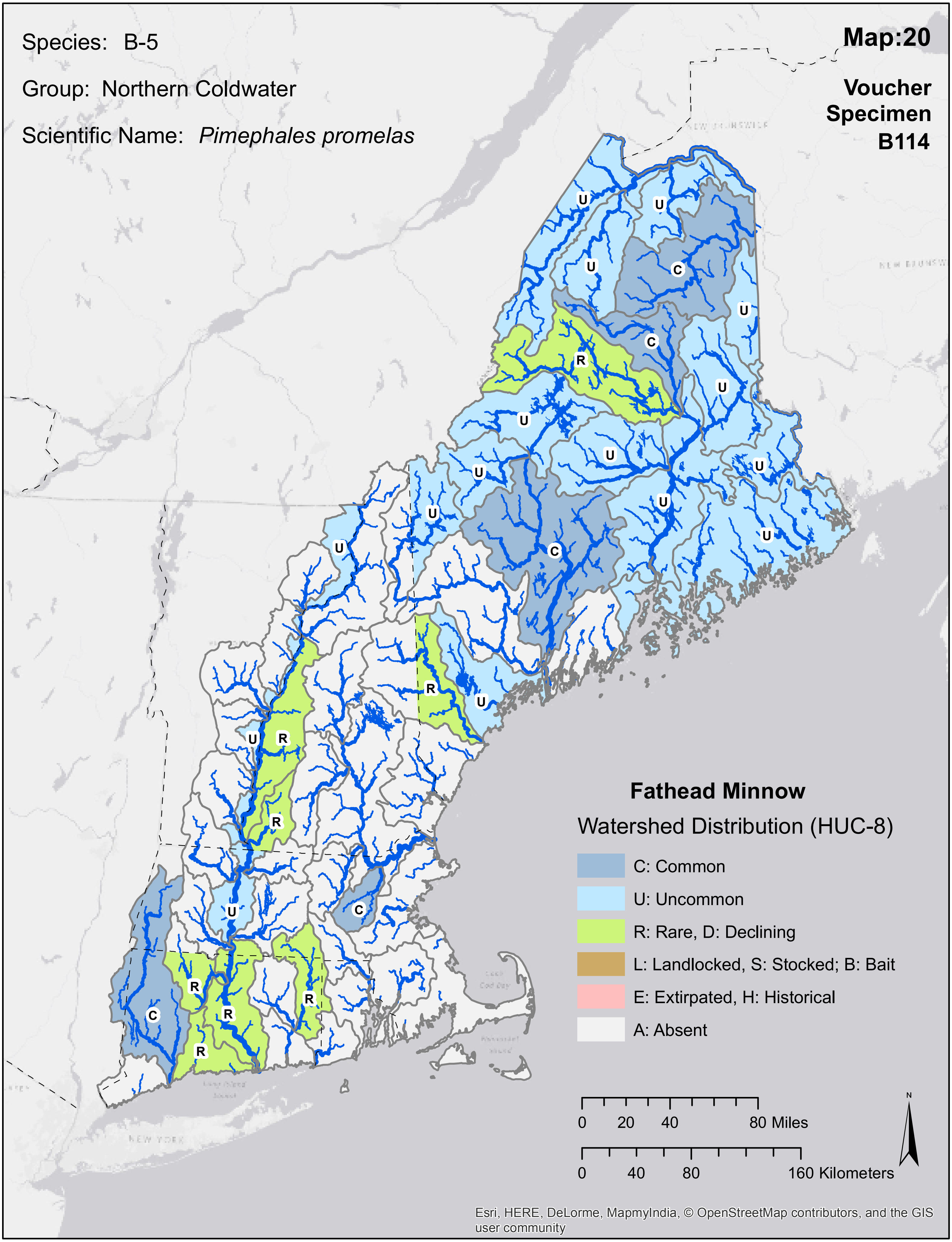
Species: B-5
Group: Northern Coldwater
Scientific Name: *Pimephales promelas*
Map:20
Voucher Specimen B114
Fathead Minnow
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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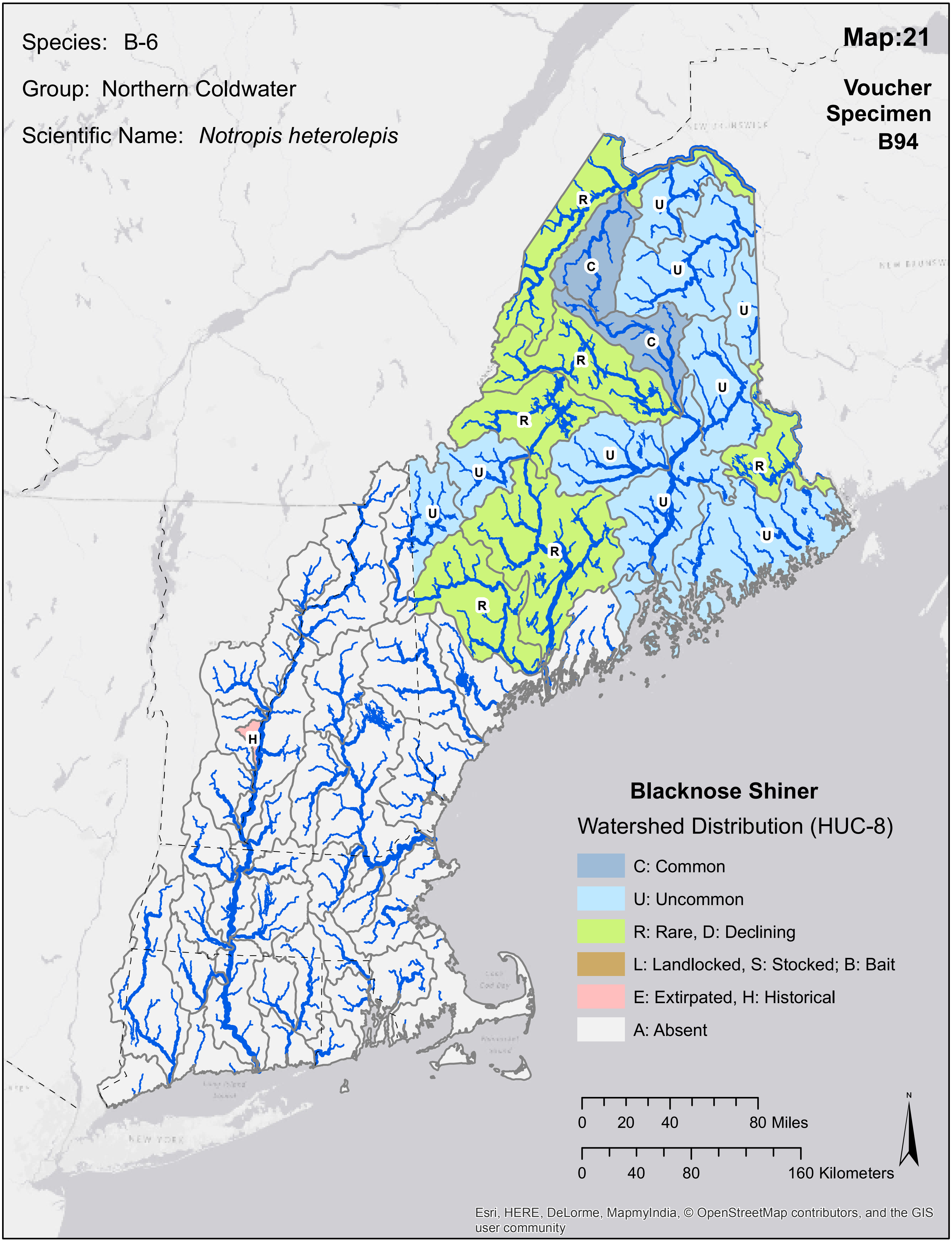
Species: B-6
Group: Northern Coldwater
Scientific Name: *Notropis heterolepis*
Map:21
Voucher Specimen B94
Blacknose Shiner
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
R
U
C
U
U
C
R
U
R
U
U
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U
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U
R
R
H
NEW BRUNSWICK
NEW YORK
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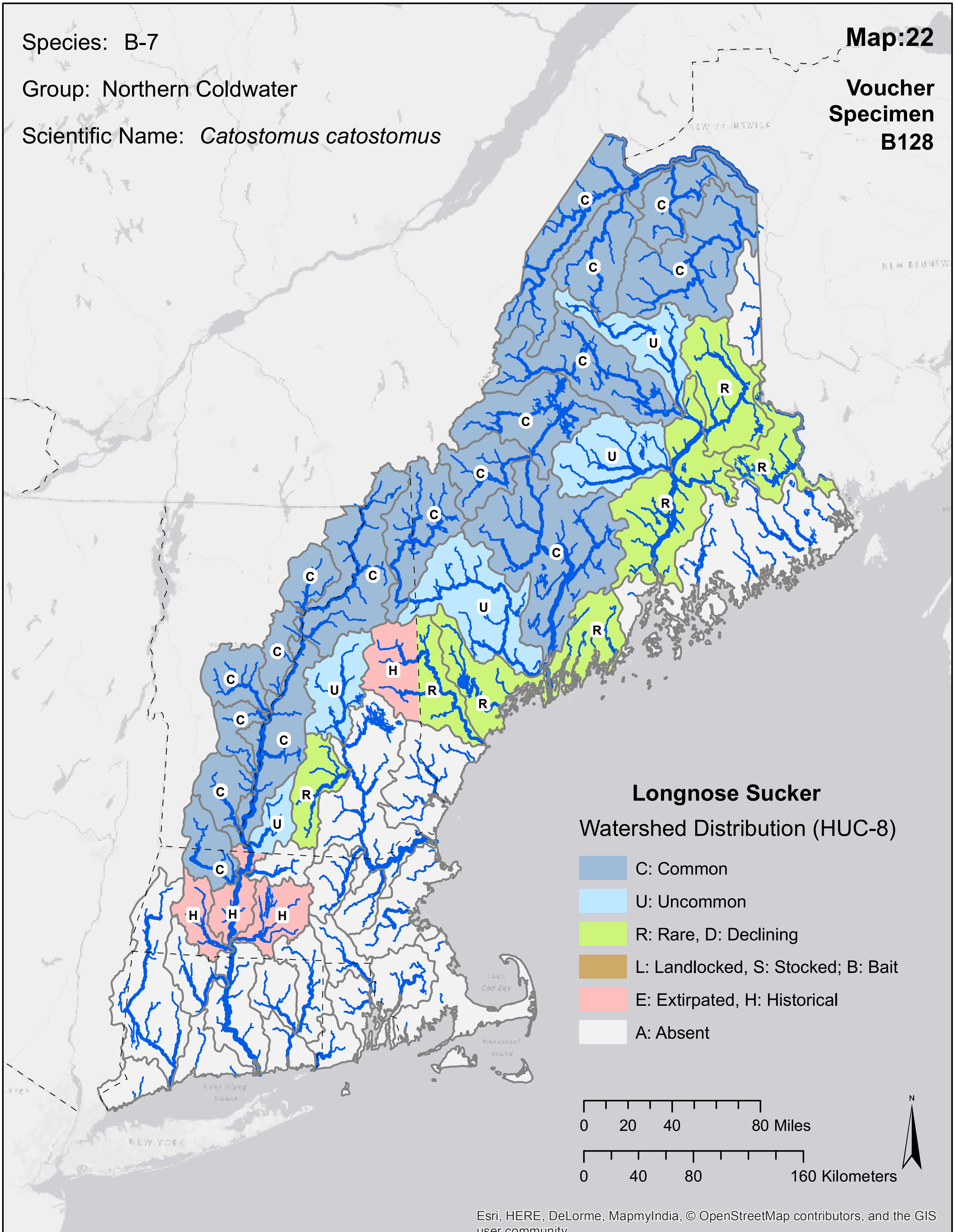
Species: B-7
Group: Northern Coldwater
Scientific Name: *Catostomus catostomus*
Map:22
Voucher Specimen B128
Longnose Sucker
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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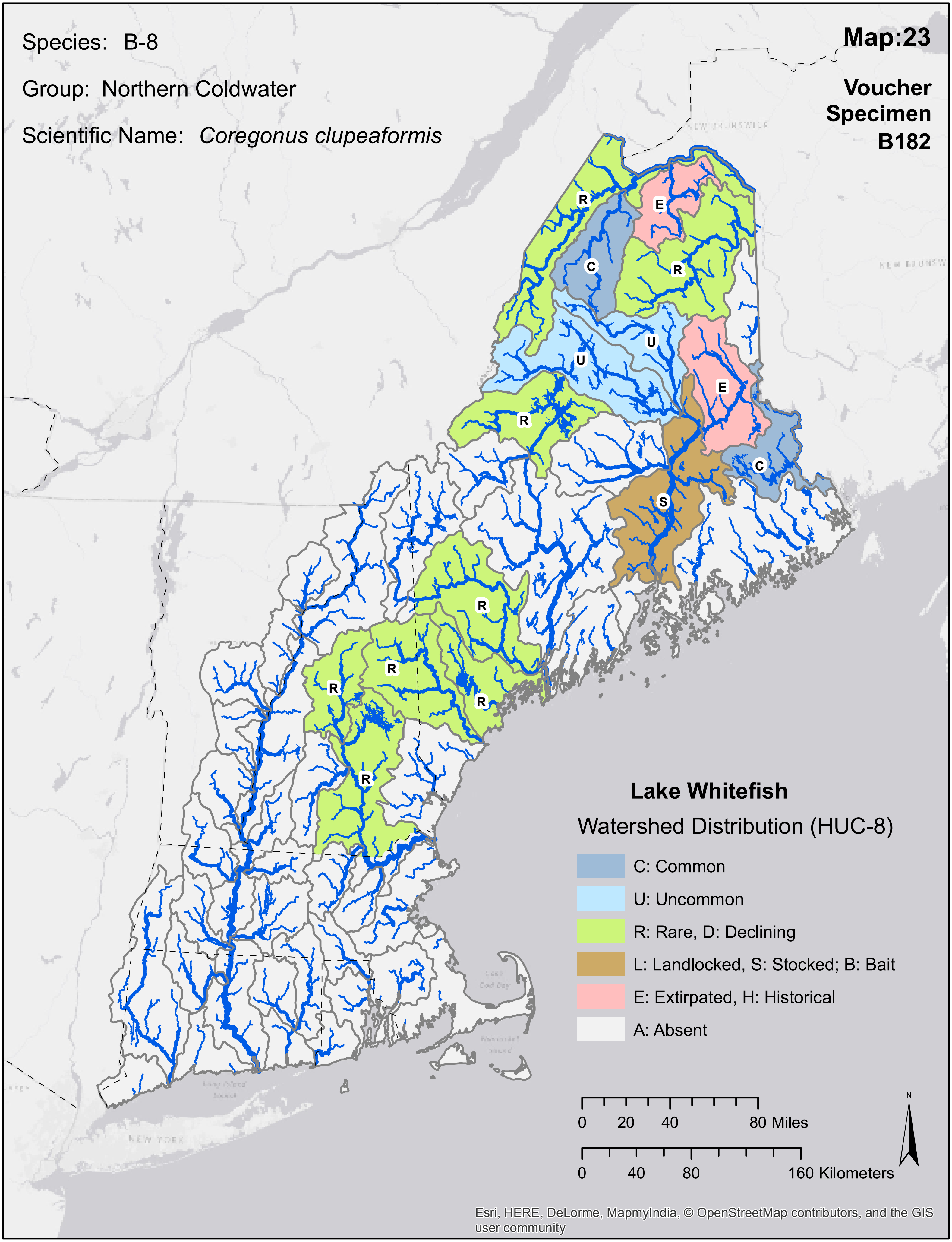
Species: B-8
Group: Northern Coldwater
Scientific Name: *Coregonus clupeaformis*
Map:23
Voucher Specimen B182
Lake Whitefish
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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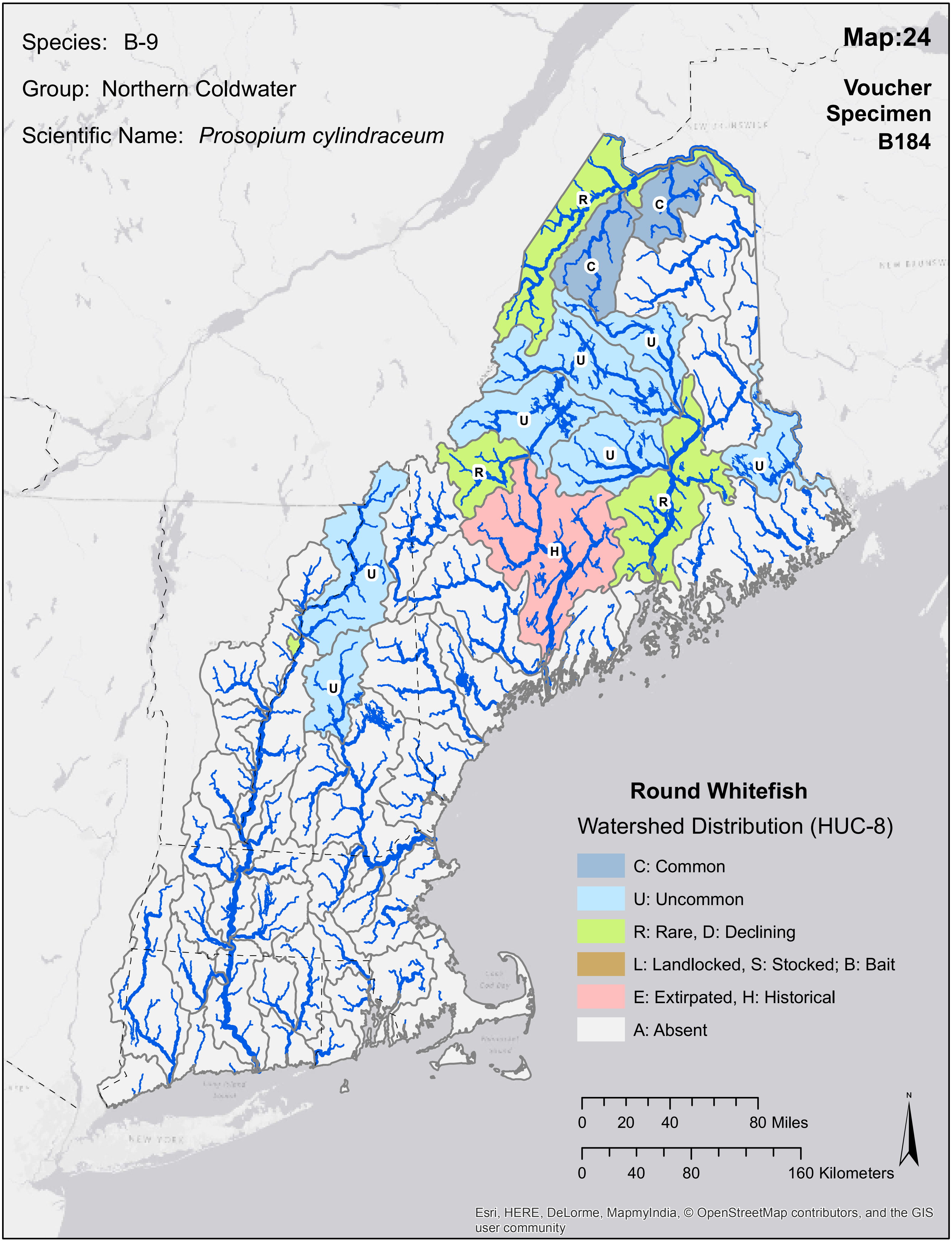
Species: B-9
Group: Northern Coldwater
Scientific Name: Prosopium cylindraceum
Map:24
Voucher Specimen B184
Round Whitefish
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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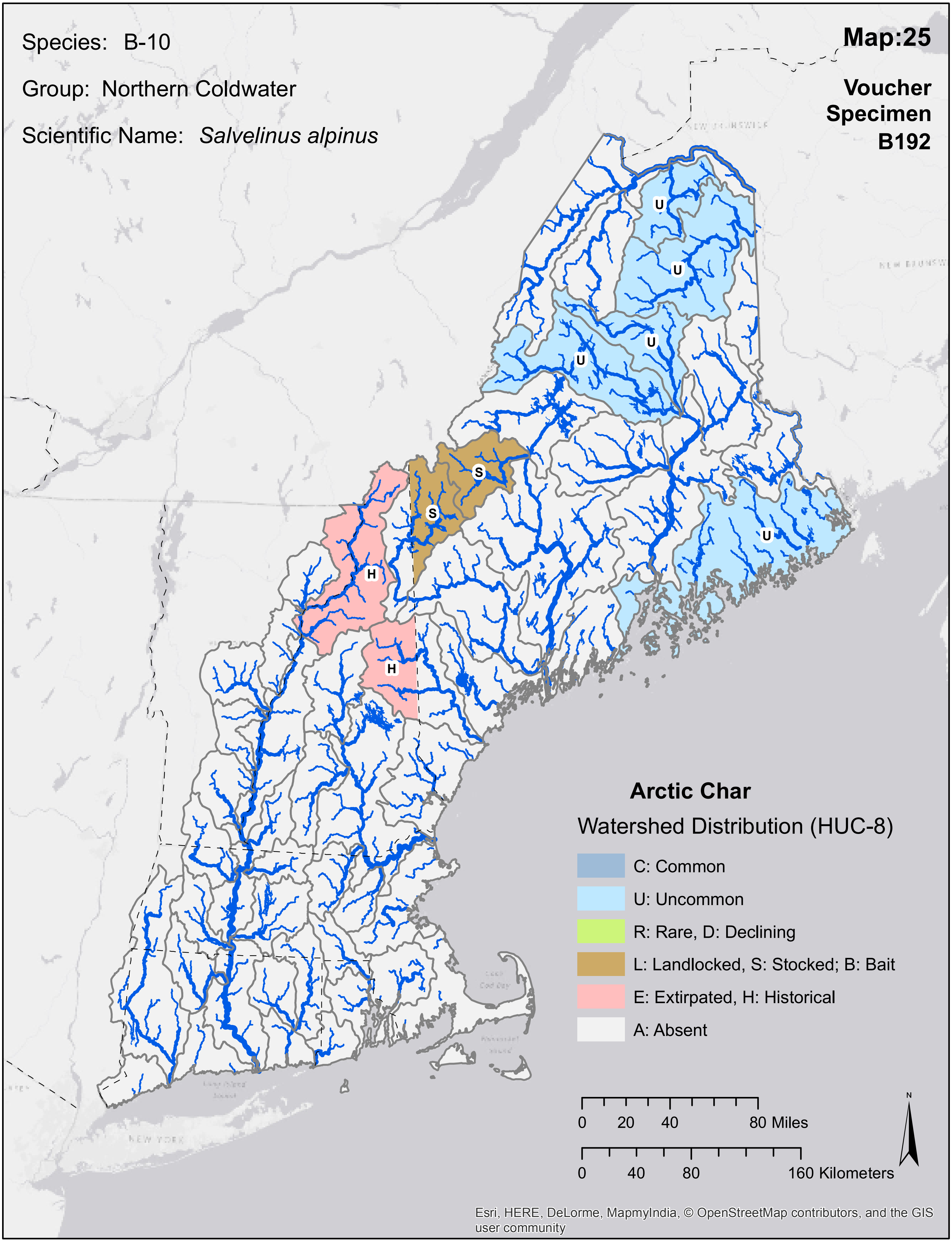
Species: B-10

Group: Northern Coldwater

Scientific Name: *Salvelinus alpinus*

Map:25

Voucher Specimen B192



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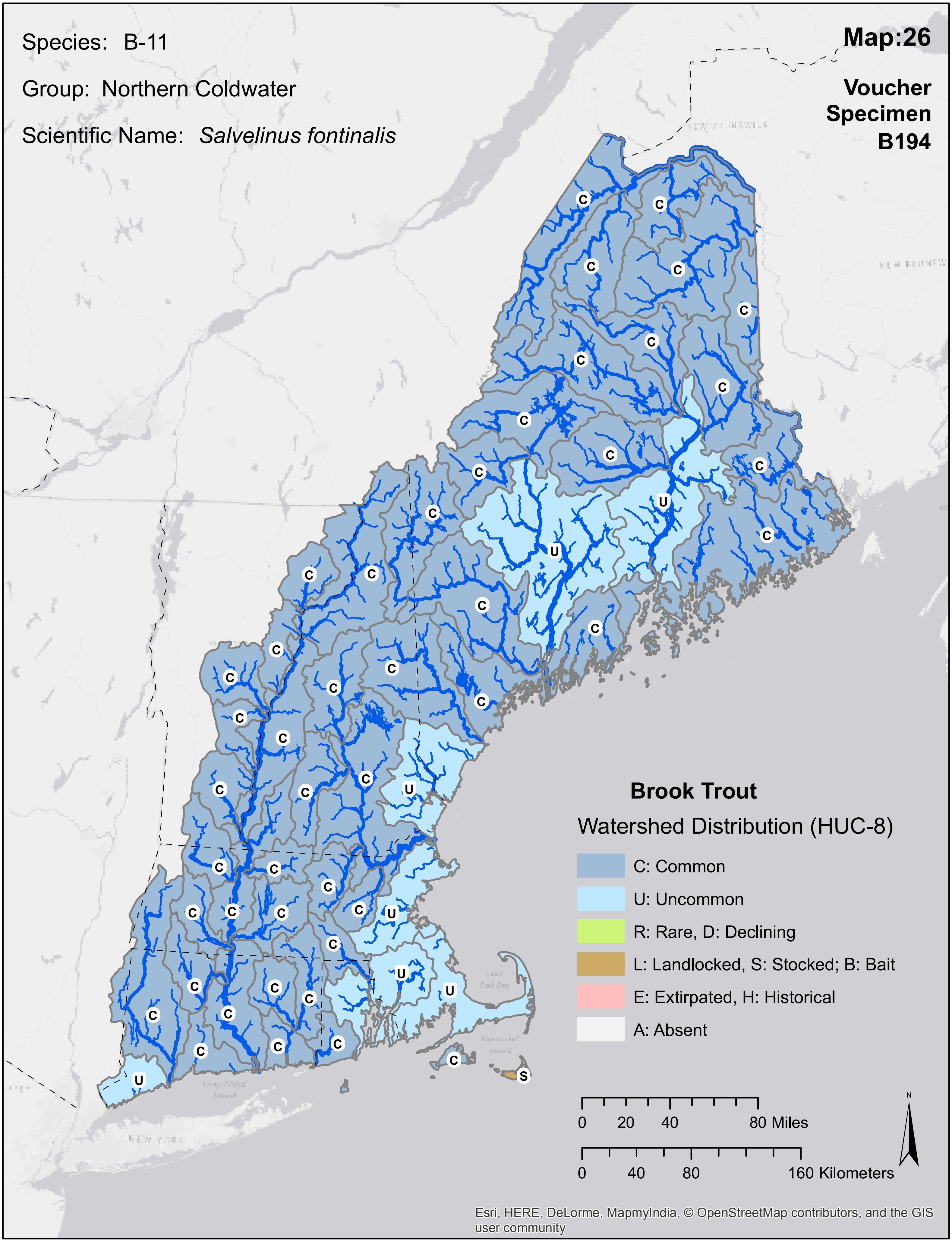

Species: B-11
Group: Northern Coldwater
Scientific Name: *Salvelinus fontinalis*
Map:26
Voucher Specimen B194
Brook Trout
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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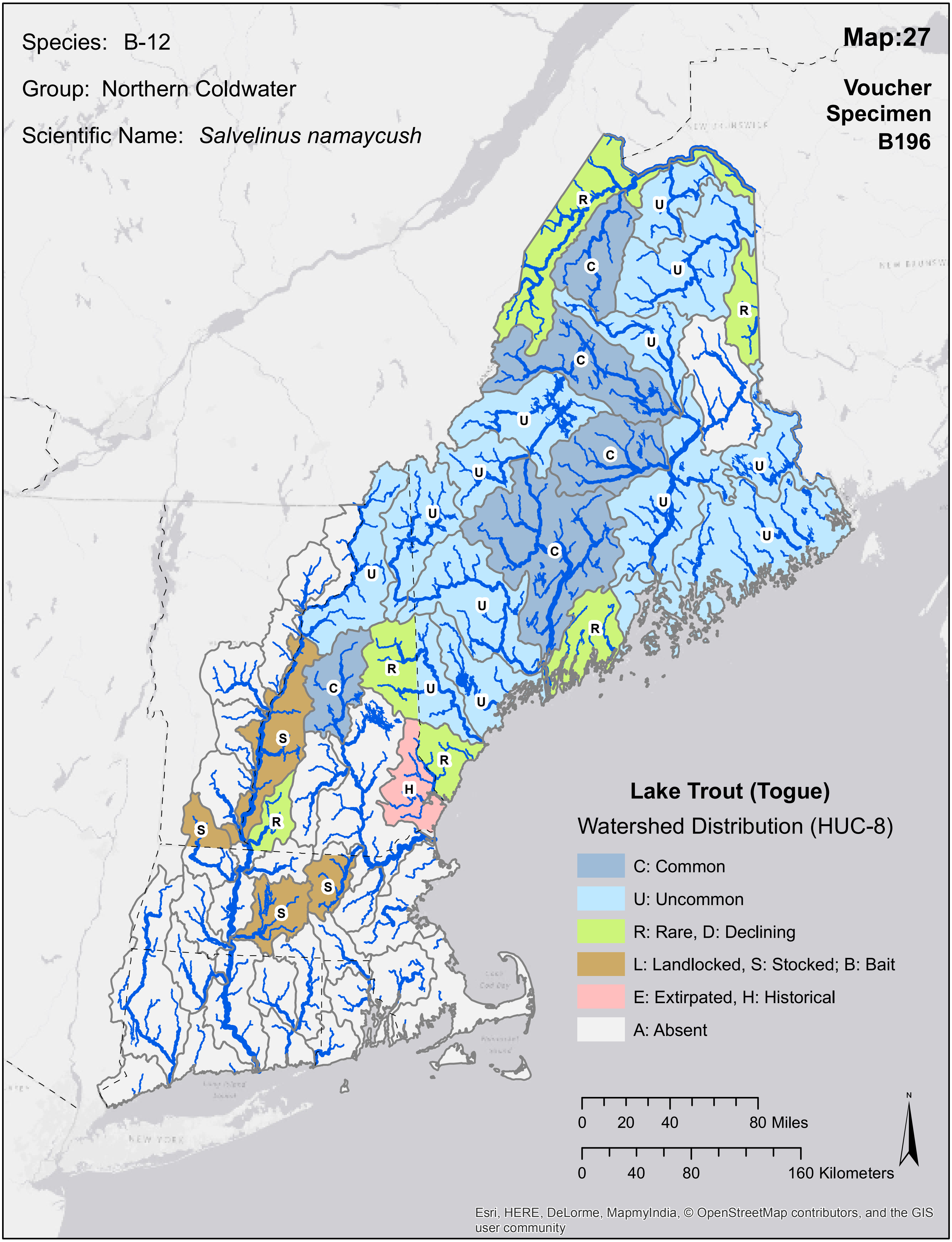
Species: B-12
Group: Northern Coldwater
Scientific Name: *Salvelinus namaycush*
Map:27
Voucher Specimen B196
Lake Trout (Togue)
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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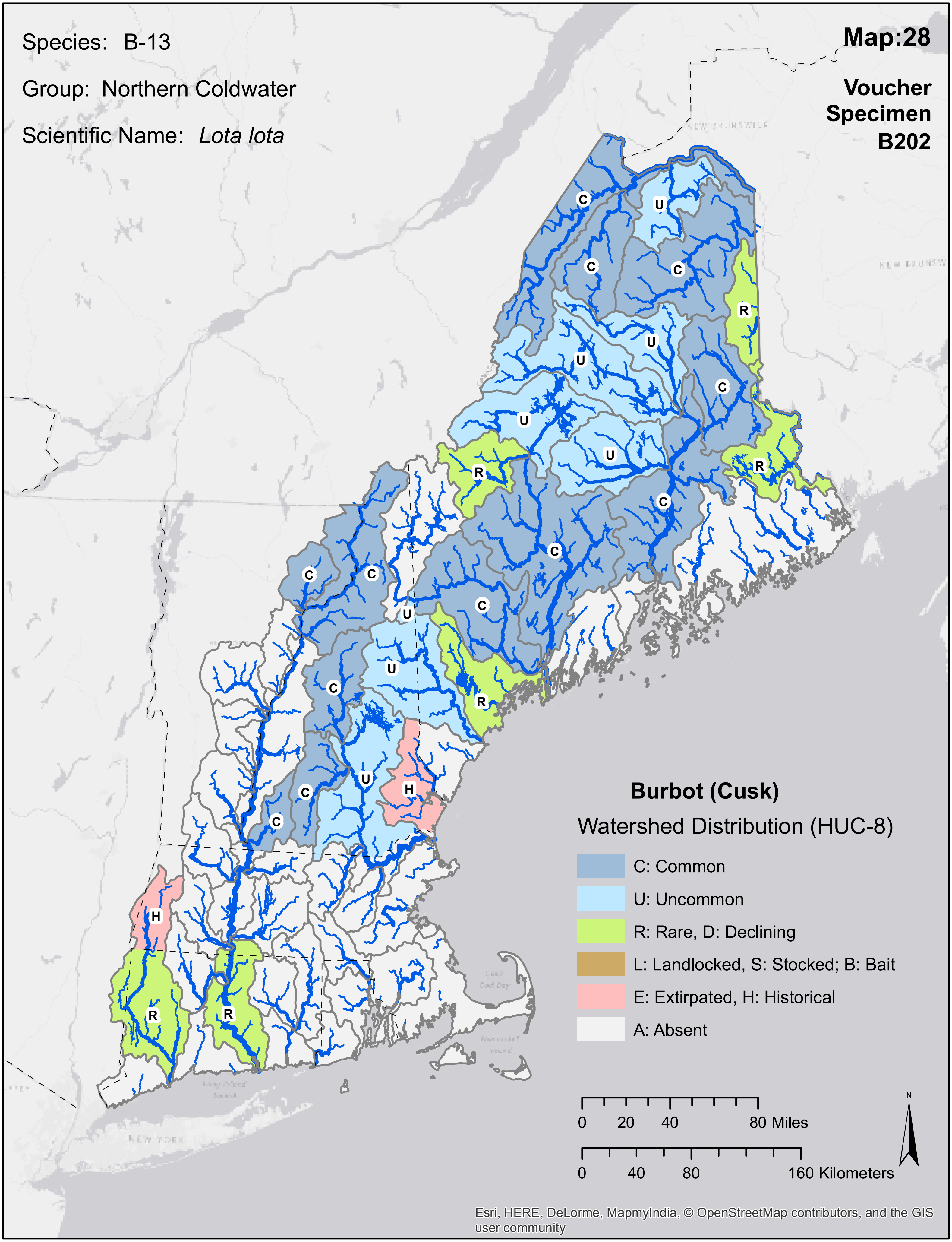
Species: B-13
Group: Northern Coldwater
Scientific Name: *Lota lota*
Map:28
Voucher Specimen B202
Burbot (Cusk)
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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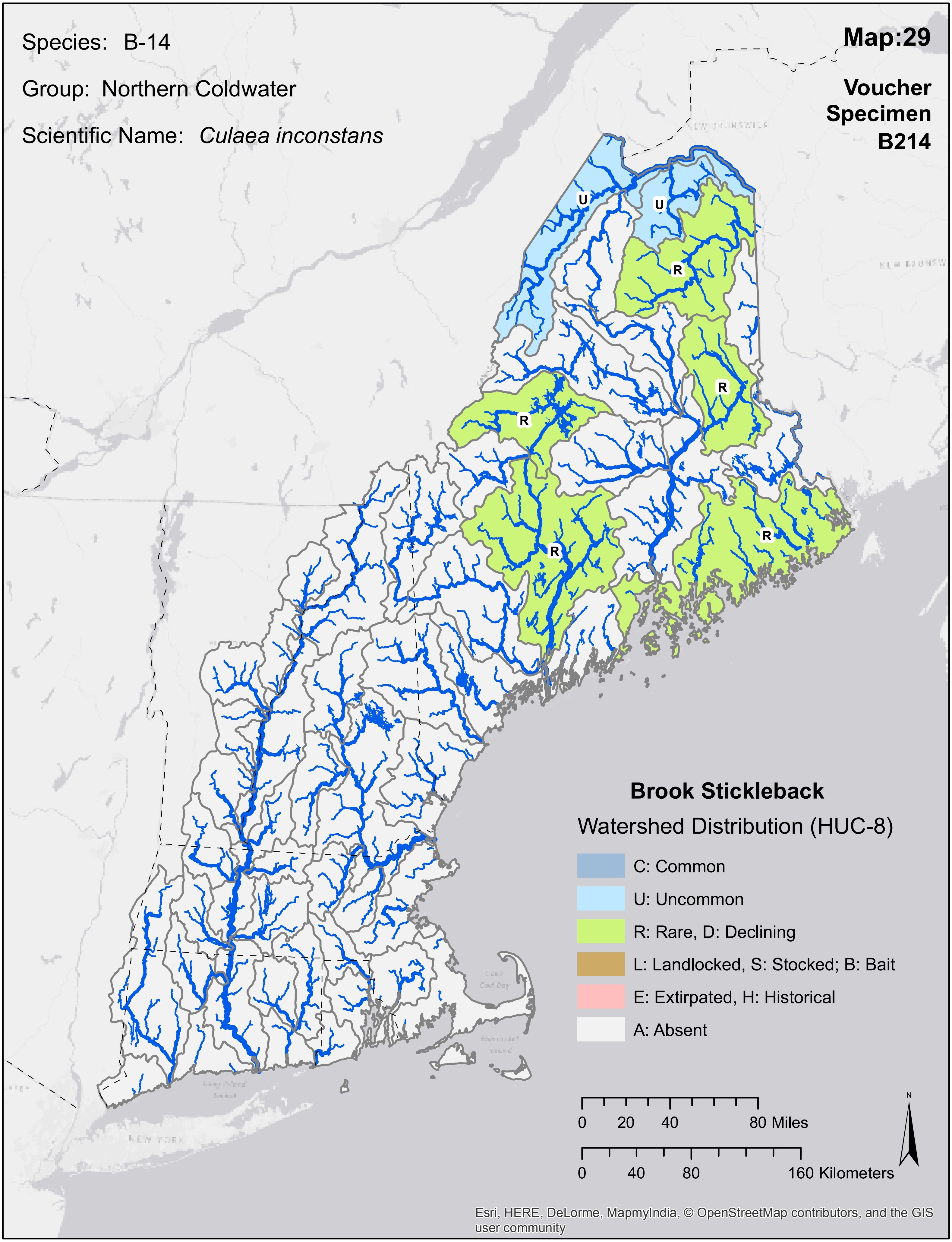
Species: B-14
Group: Northern Coldwater
Scientific Name: *Culaea inconstans*
Map:29
Voucher Specimen B214
U
U
R
R
R
R
R
Brook Stickleback
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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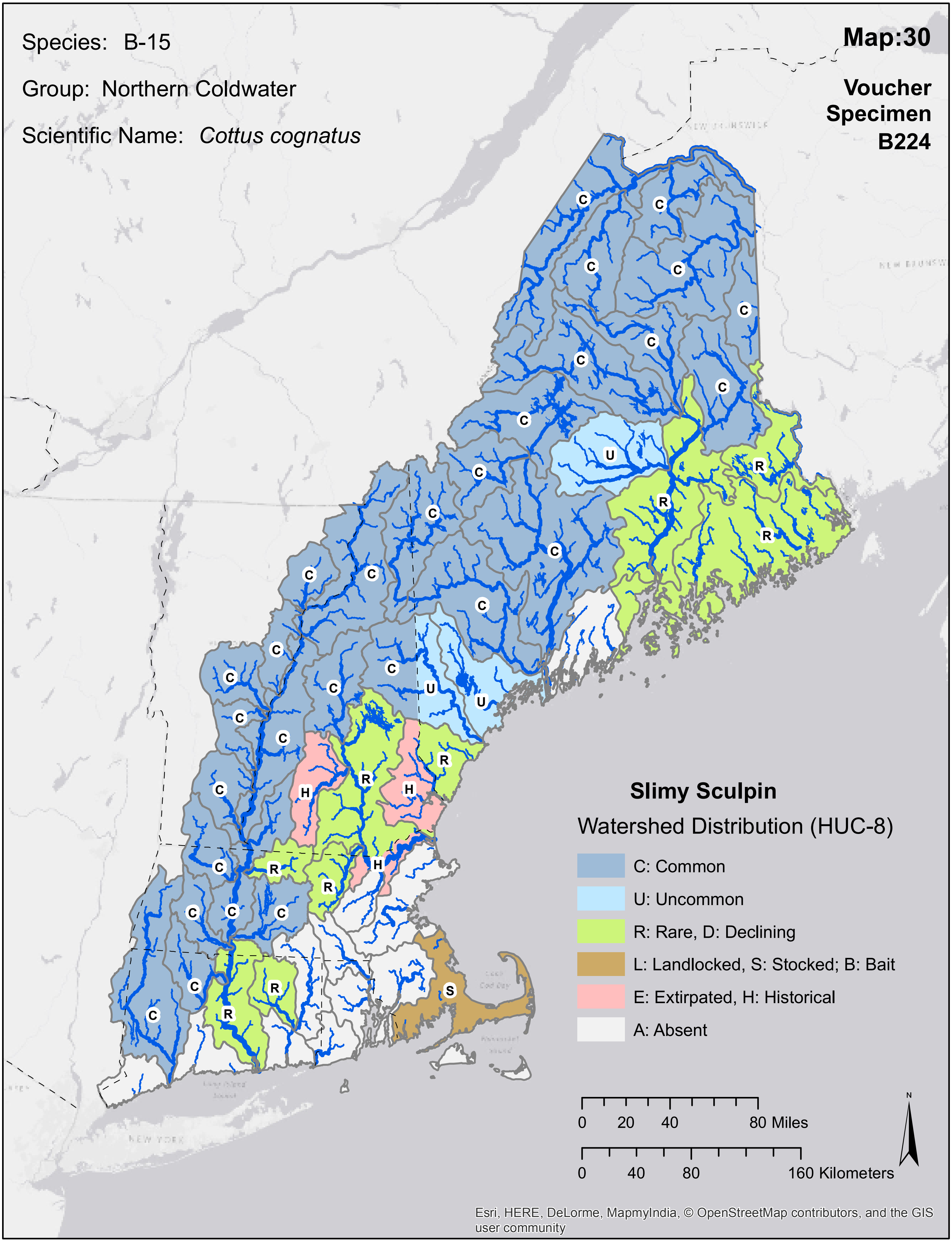
Species: B-15
Group: Northern Coldwater
Scientific Name: *Cottus cognatus*
Map:30
Voucher Specimen B224
Slimy Sculpin
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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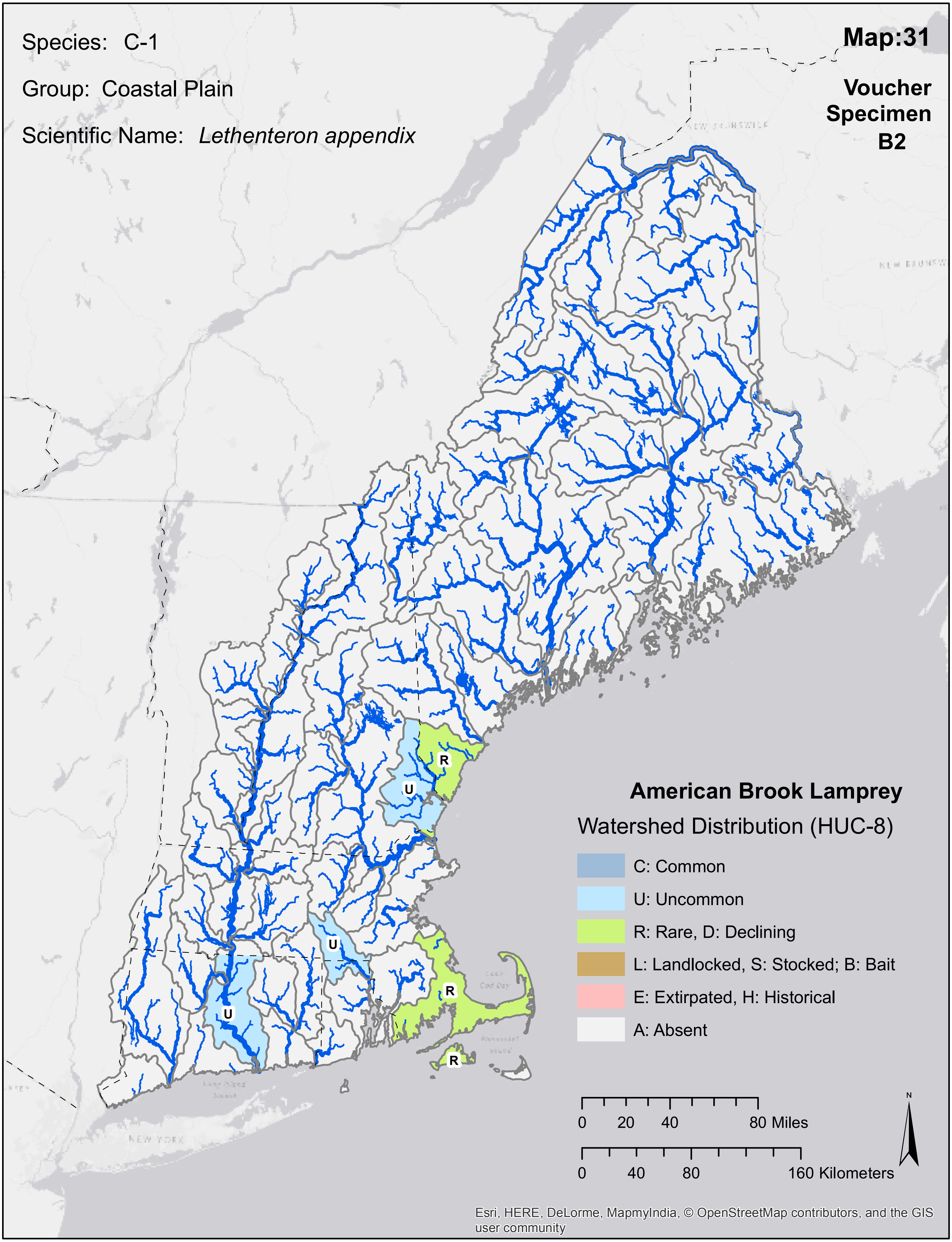
Species: C-1
Group: Coastal Plain
Scientific Name: *Lethenteron appendix*
Map:31
Voucher Specimen B2
American Brook Lamprey
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
U
U
U
R
R
R
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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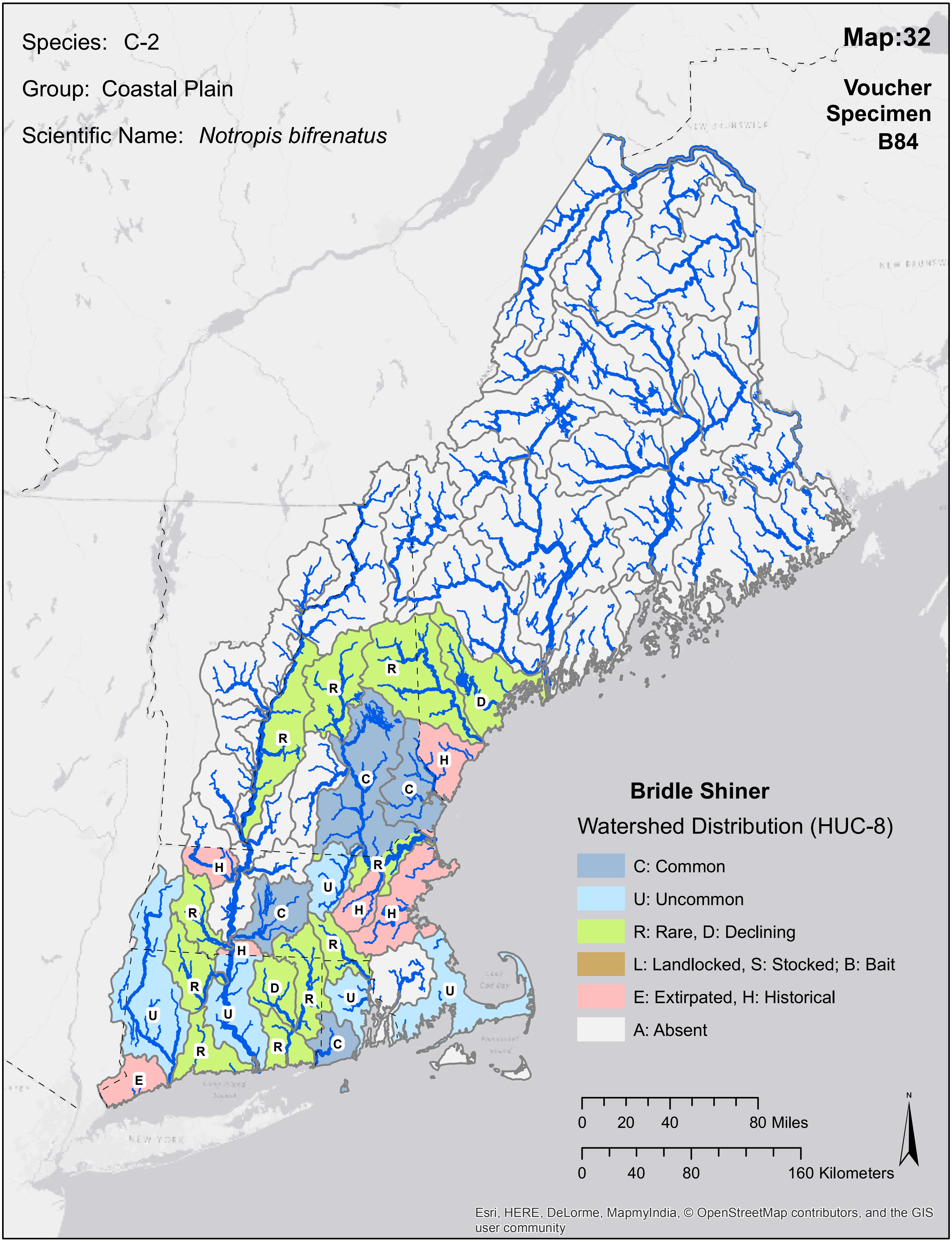
Species: C-2
Group: Coastal Plain
Scientific Name: *Notropis bifrenatus*
Map:32
Voucher Specimen B84
Bridle Shiner
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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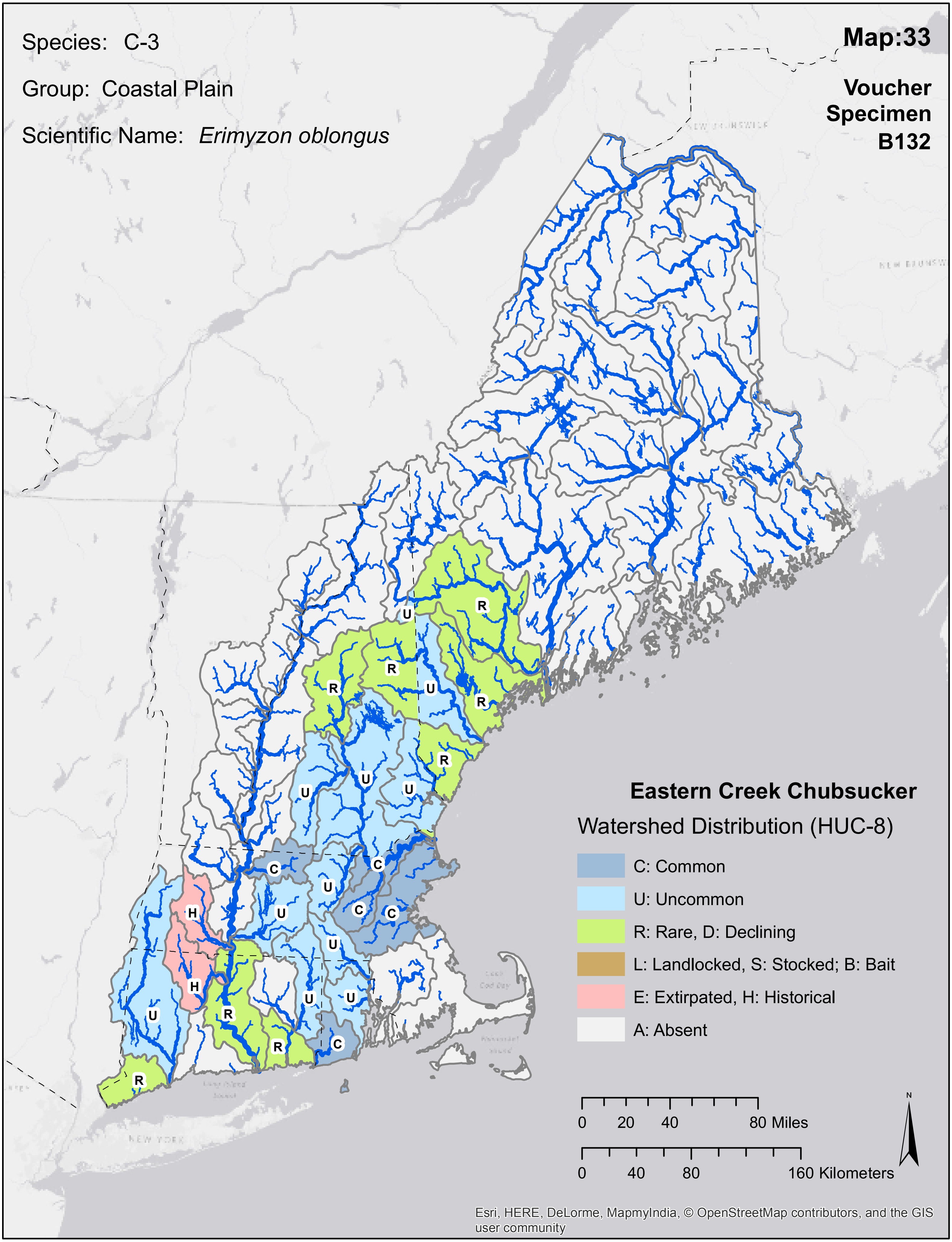

Species: C-3
Group: Coastal Plain
Scientific Name: *Erimyzon oblongus*
Map:33
Voucher Specimen B132
Eastern Creek Chubsucker
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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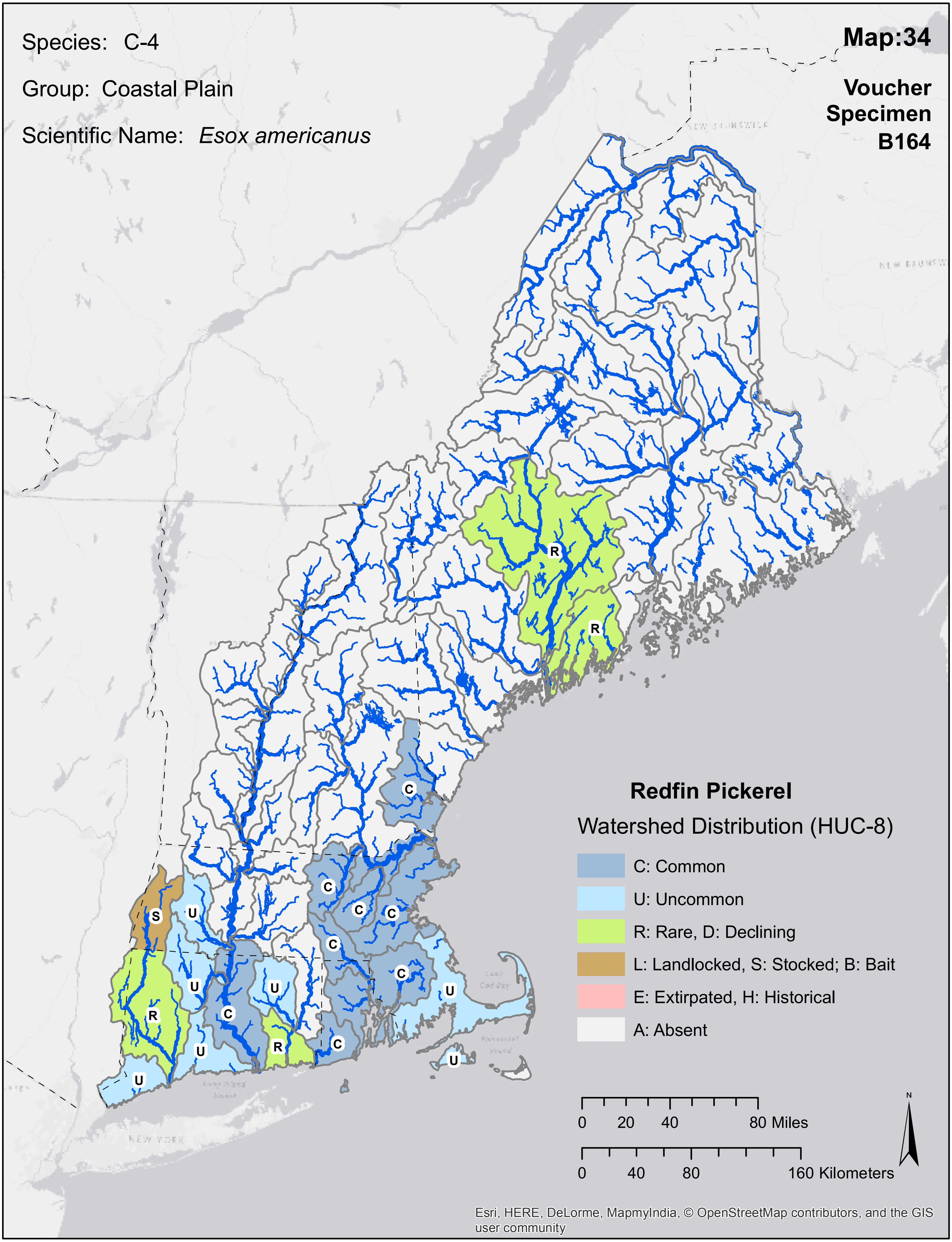
Species: C-4
Group: Coastal Plain
Scientific Name: *Esox americanus*
Map:34
Voucher Specimen B164
Redfin Pickerel
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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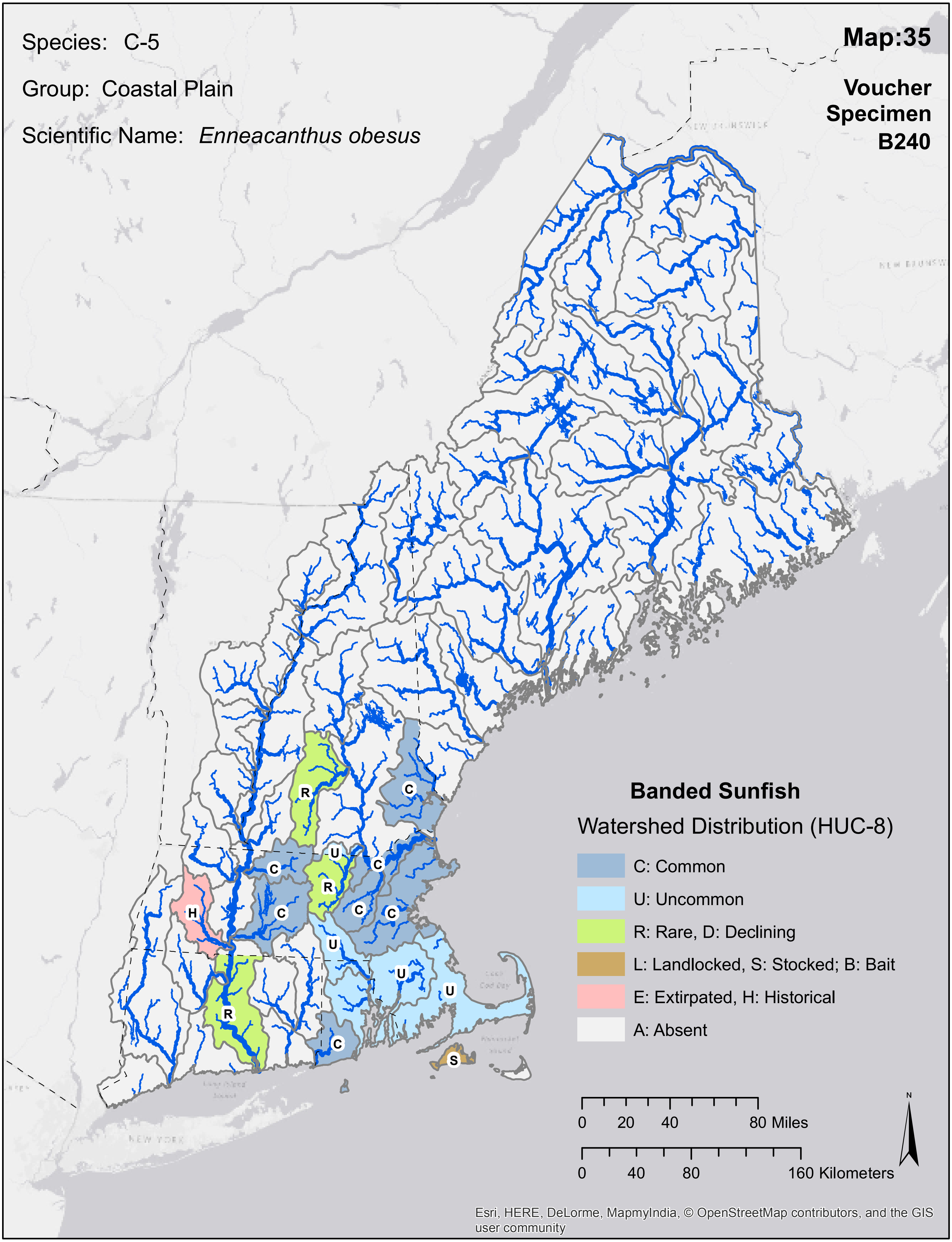
Species: C-5
Group: Coastal Plain
Scientific Name: *Enneacanthus obesus*
Map:35
Voucher Specimen B240
Banded Sunfish
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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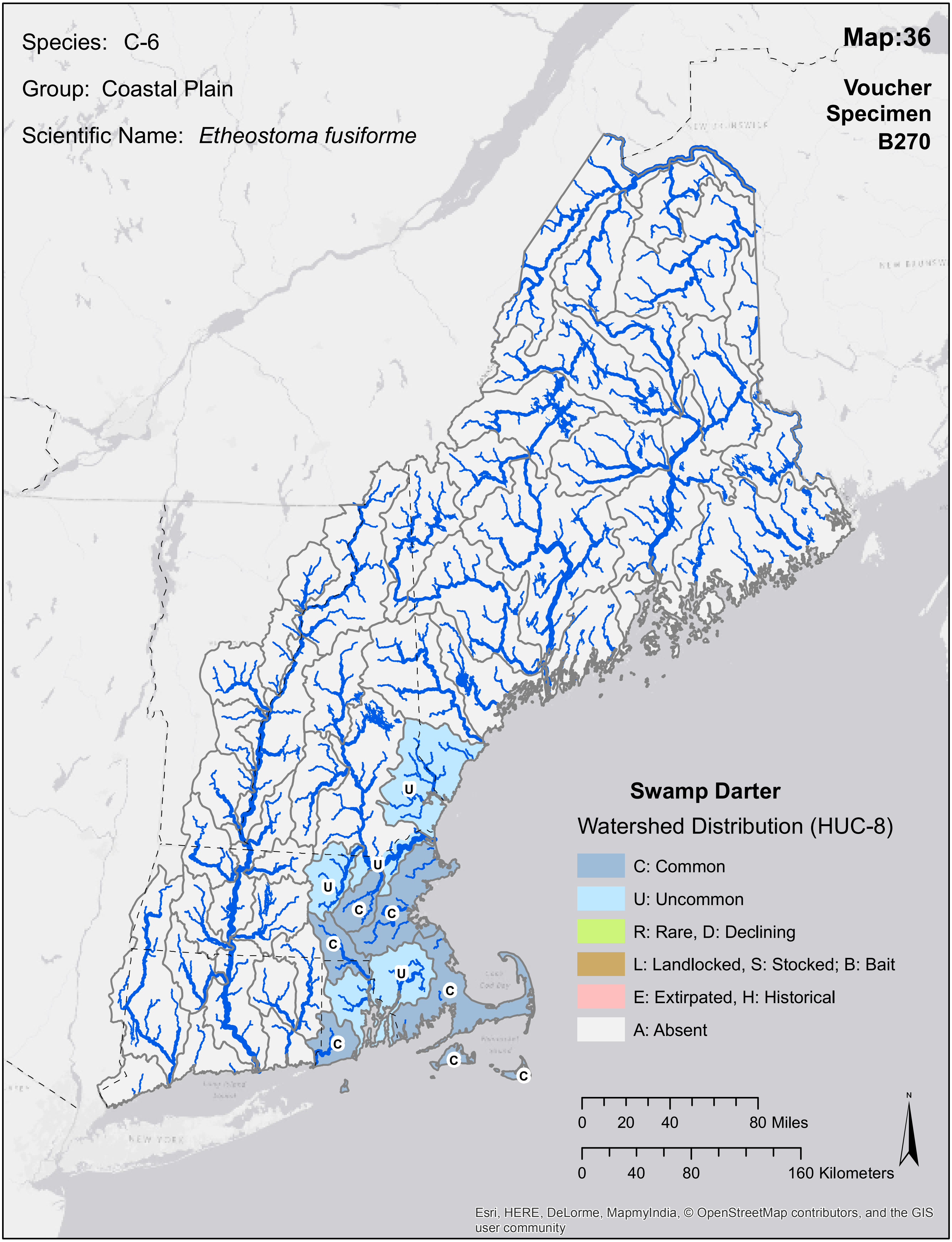
Species: C-6
Group: Coastal Plain
Scientific Name: *Etheostoma fusiforme*
Map:36
Voucher Specimen B270
Swamp Darter
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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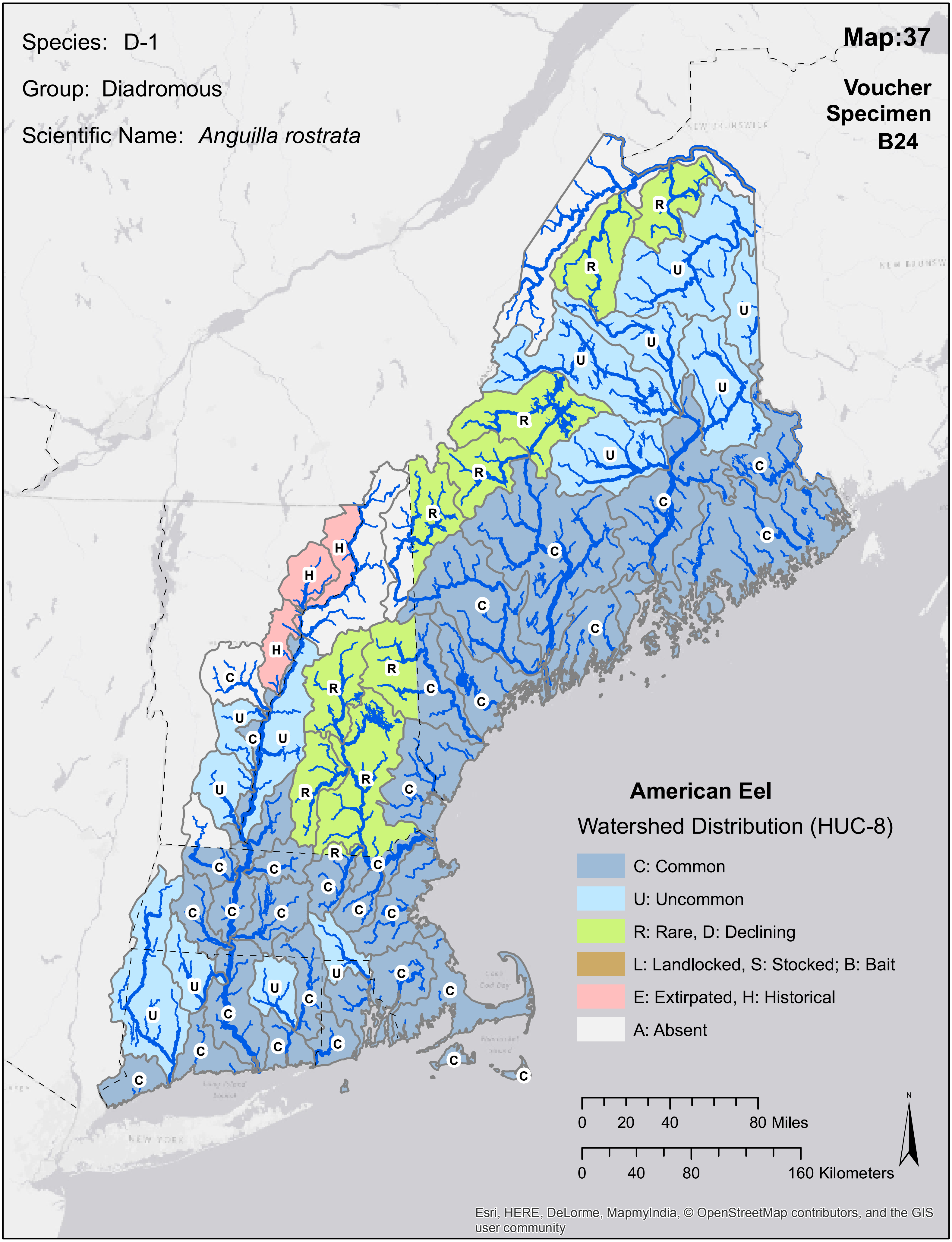
Species: D-1
Group: Diadromous
Scientific Name: *Anguilla rostrata*
Map:37
Voucher Specimen B24
American Eel
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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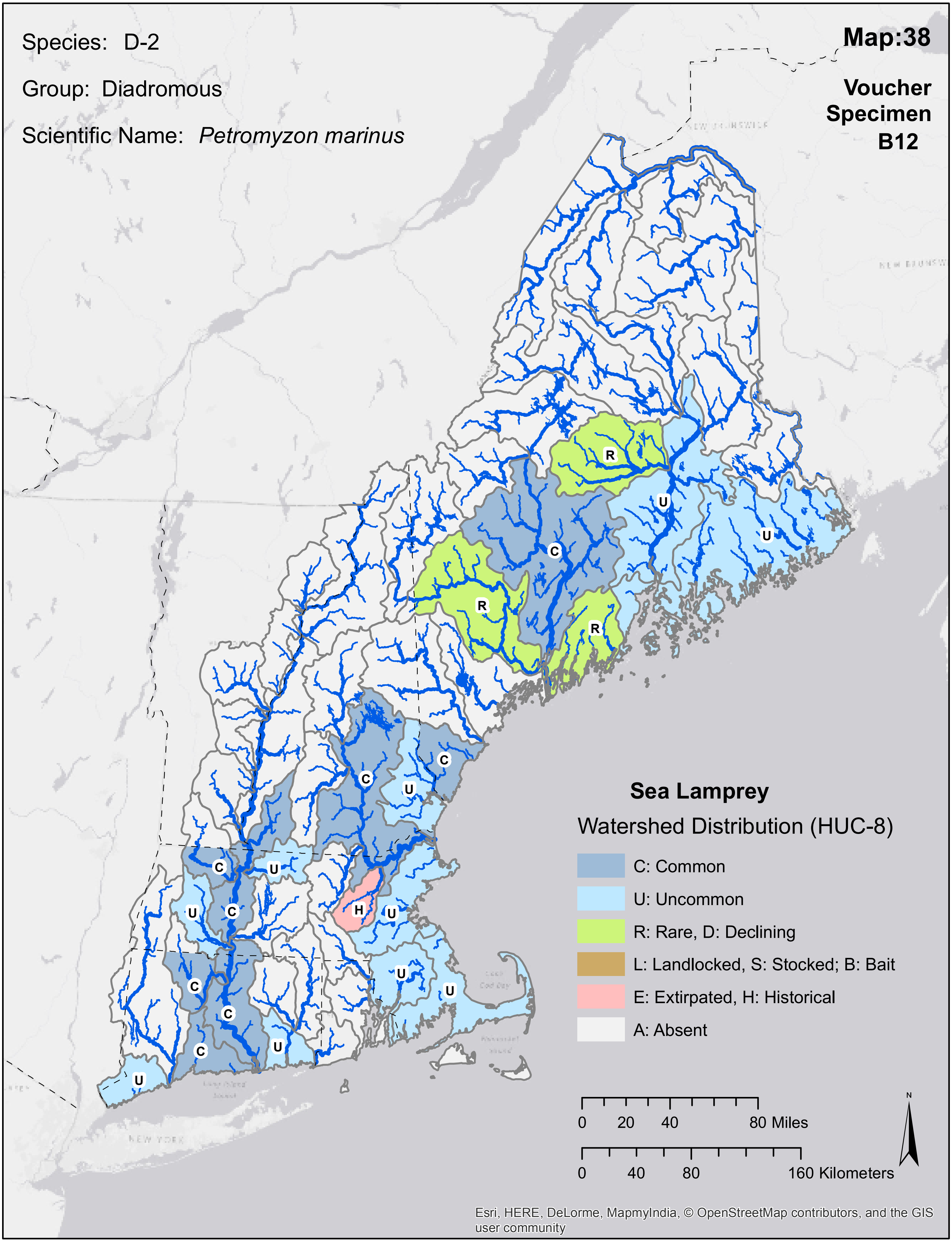
Species: D-2
Group: Diadromous
Scientific Name: *Petromyzon marinus*
Map:38
Voucher Specimen B12
Sea Lamprey
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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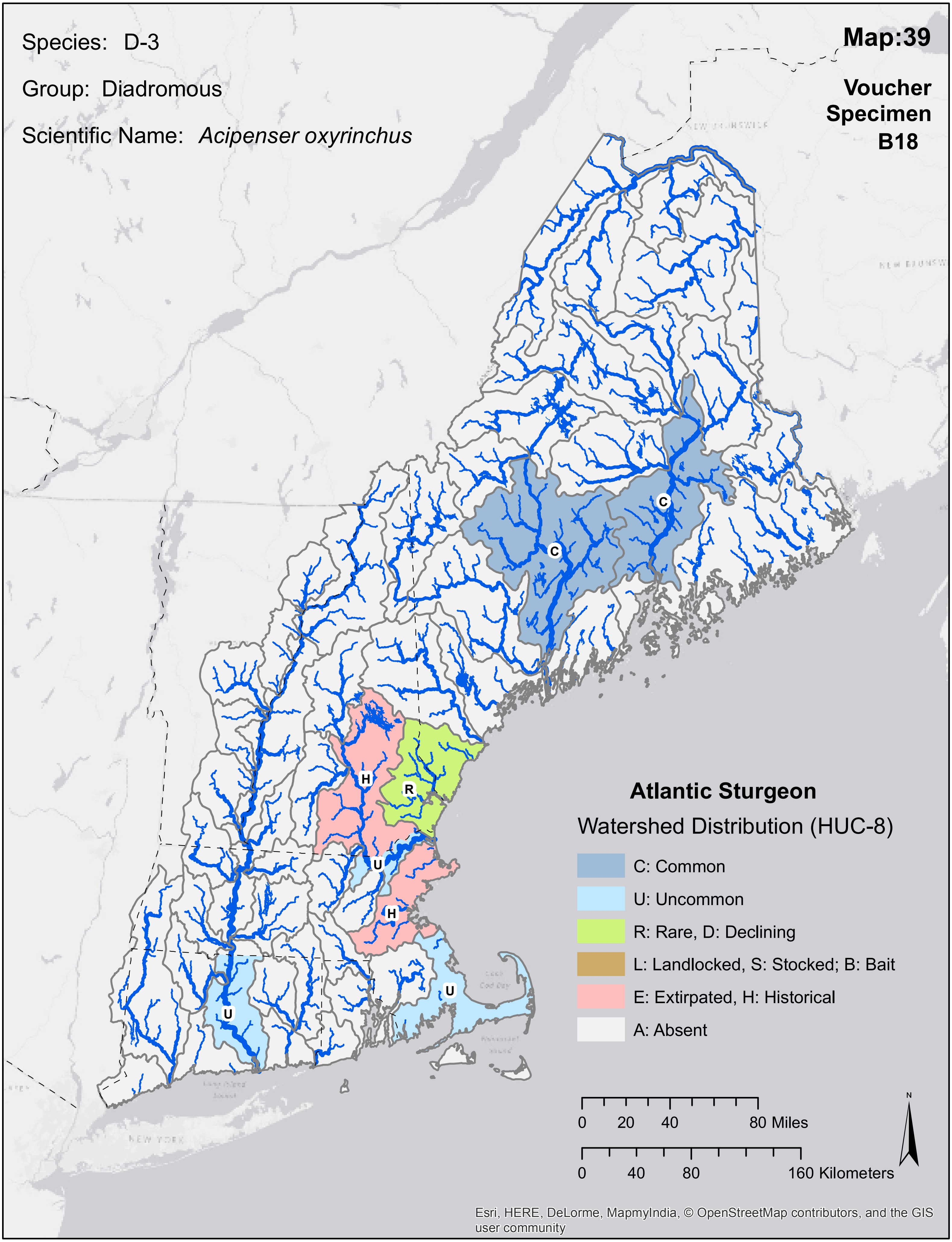
Species: D-3
Group: Diadromous
Scientific Name: *Acipenser oxyrinchus*
Map:39
Voucher
Specimen
B18
C
C
H
R
U
H
U
U
Atlantic Sturgeon
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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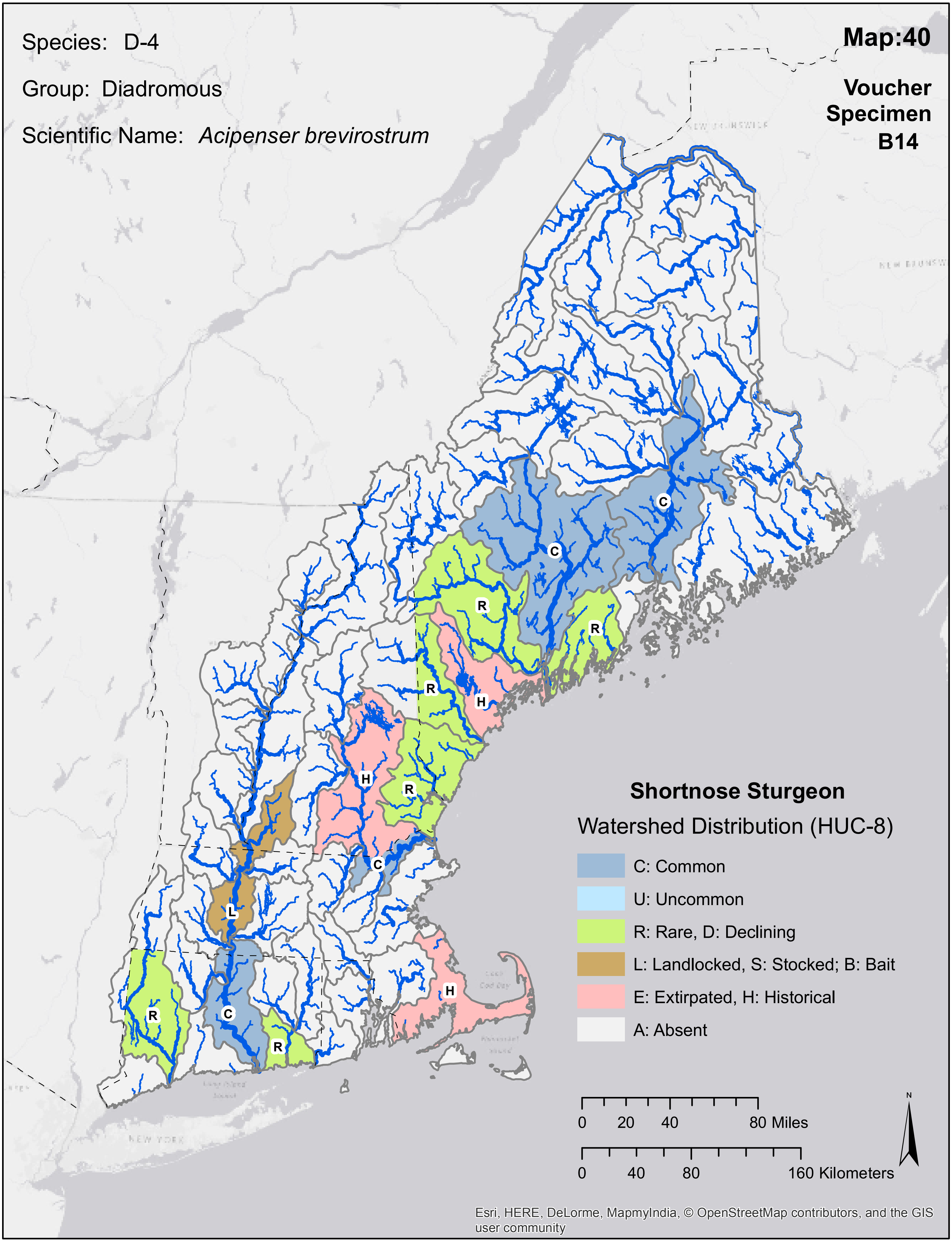

Species: D-4
Group: Diadromous
Scientific Name: *Acipenser brevirostrum*
Map:40
Voucher Specimen B14
Shortnose Sturgeon
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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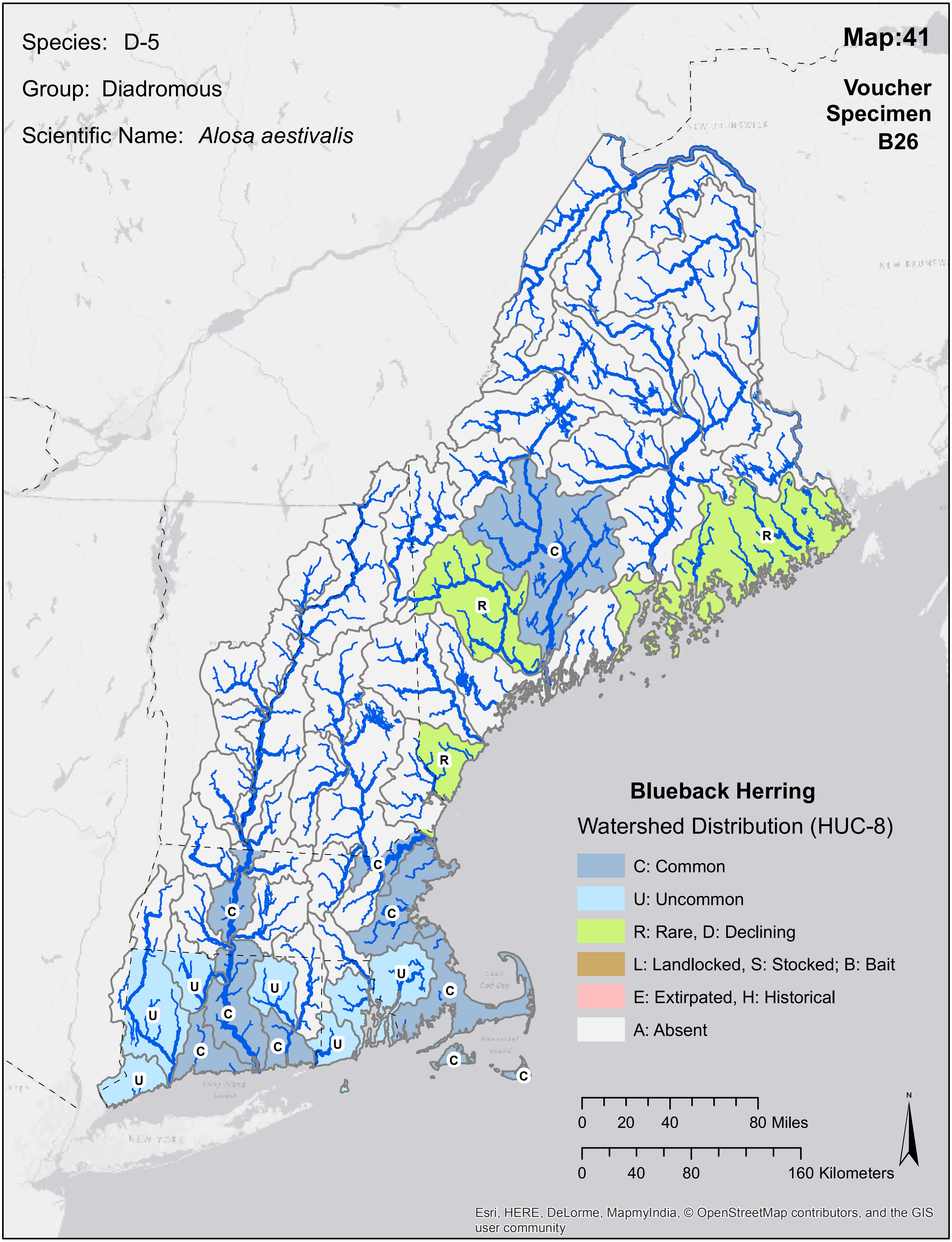

Species: D-5
Group: Diadromous
Scientific Name: *Alosa aestivalis*
Map:41
Voucher Specimen B26
Blueback Herring
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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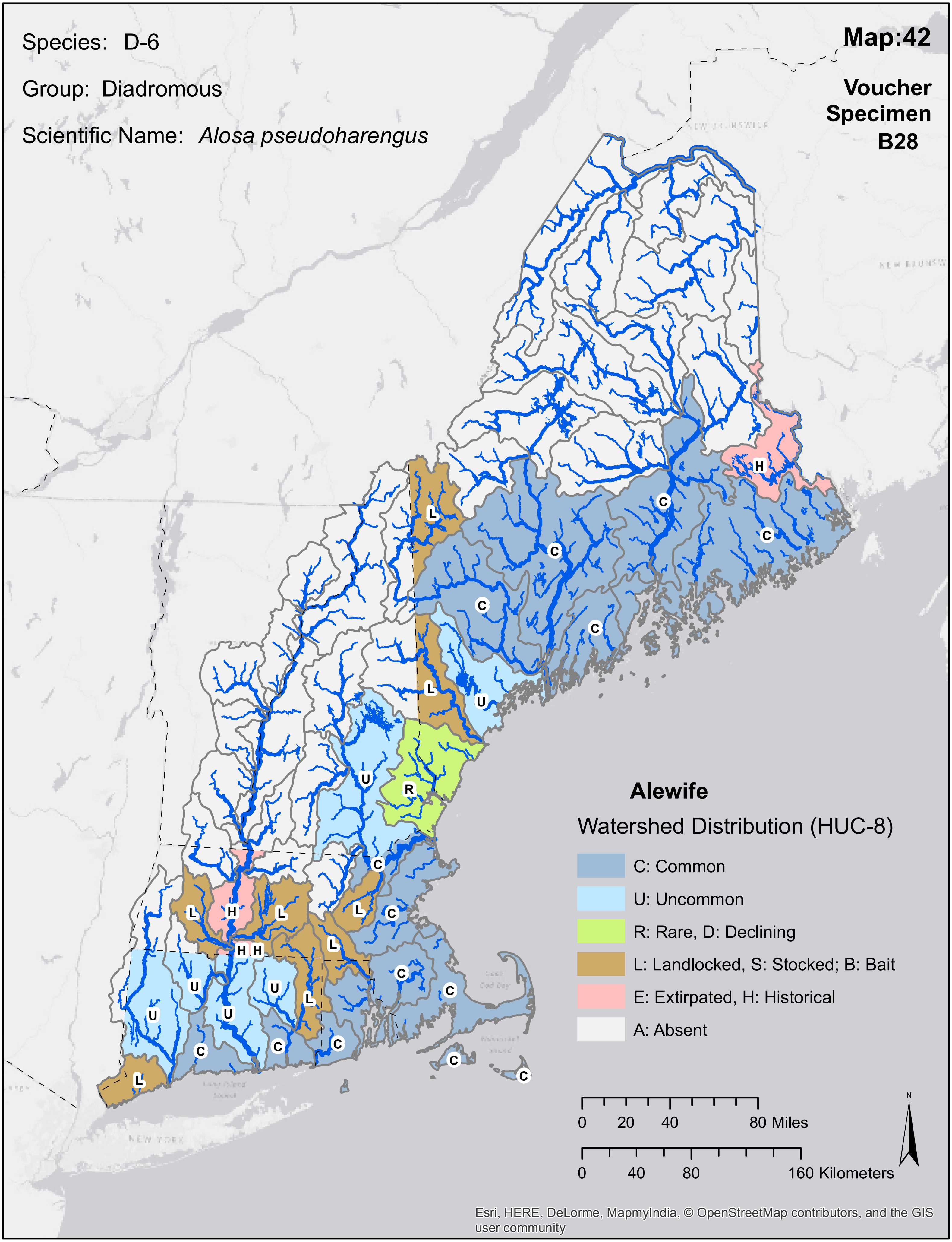
Species: D-6
Group: Diadromous
Scientific Name: *Alosa pseudoharengus*
Map:42
Voucher Specimen B28
Alewife
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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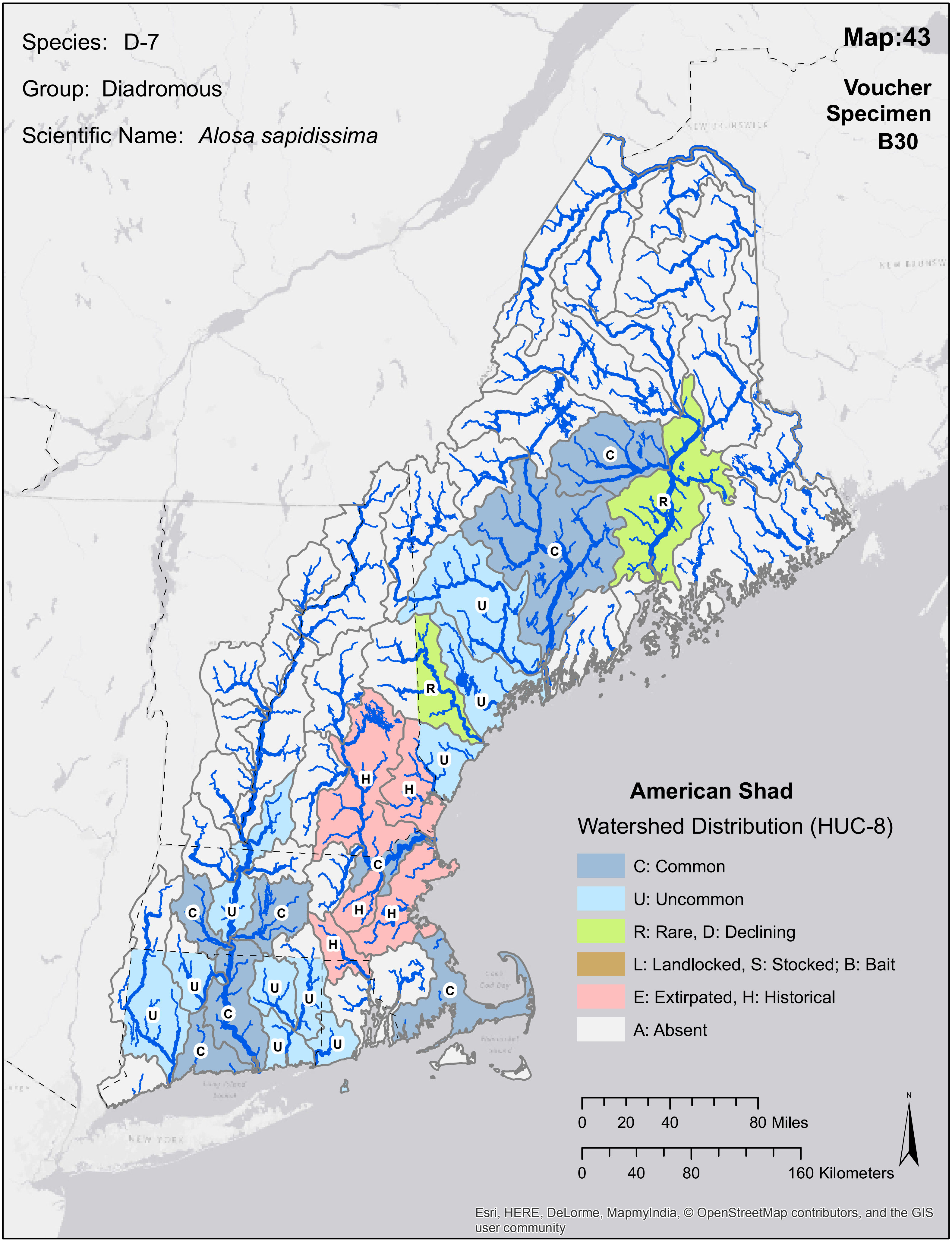
Species: D-7
Group: Diadromous
Scientific Name: *Alosa sapidissima*
Map:43
Voucher Specimen B30
American Shad
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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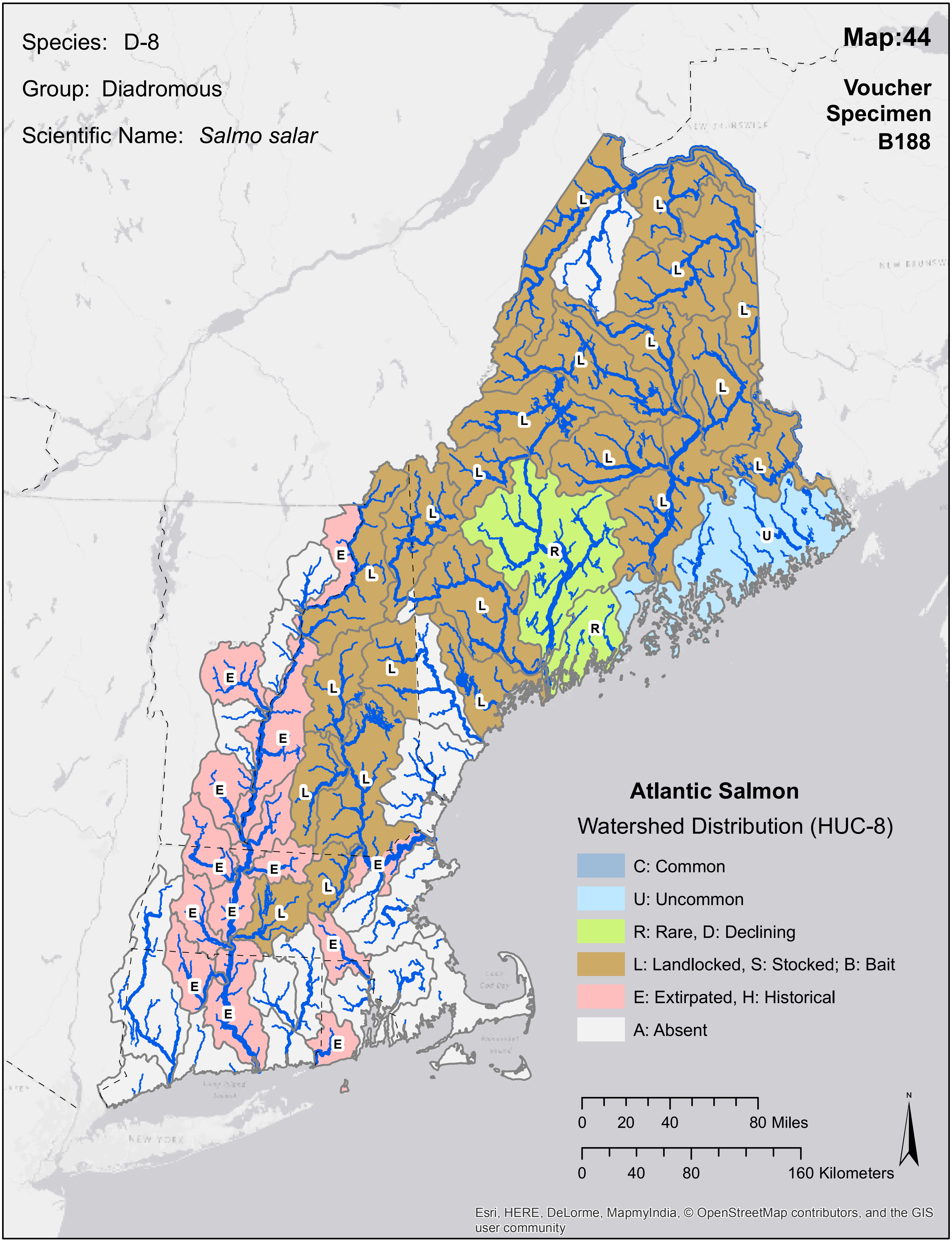
Species: D-8
Group: Diadromous
Scientific Name: *Salmo salar*
Map:44
Voucher Specimen B188
Atlantic Salmon
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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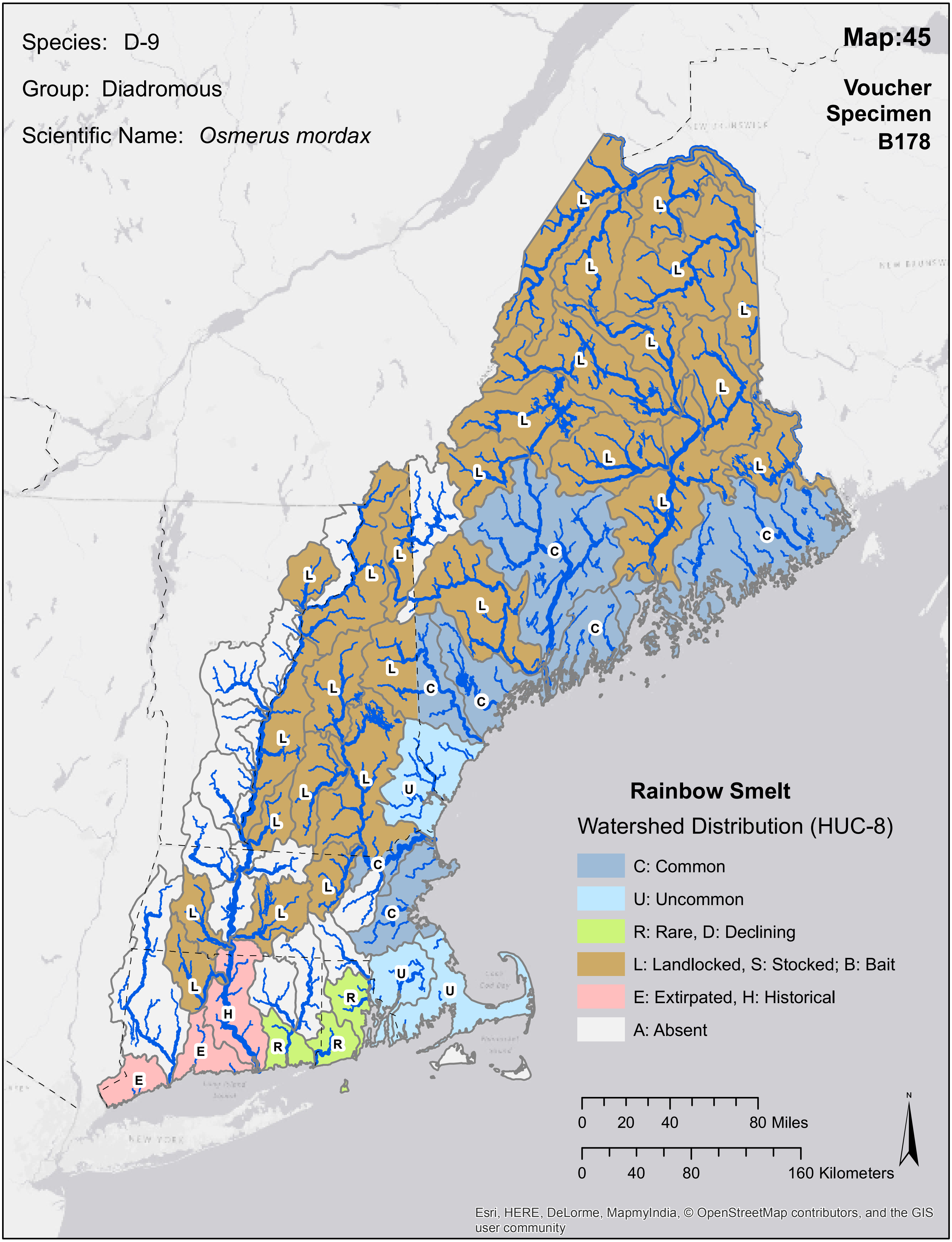

Species: D-9
Group: Diadromous
Scientific Name: *Osmerus mordax*
Map:45
Voucher Specimen B178
Rainbow Smelt
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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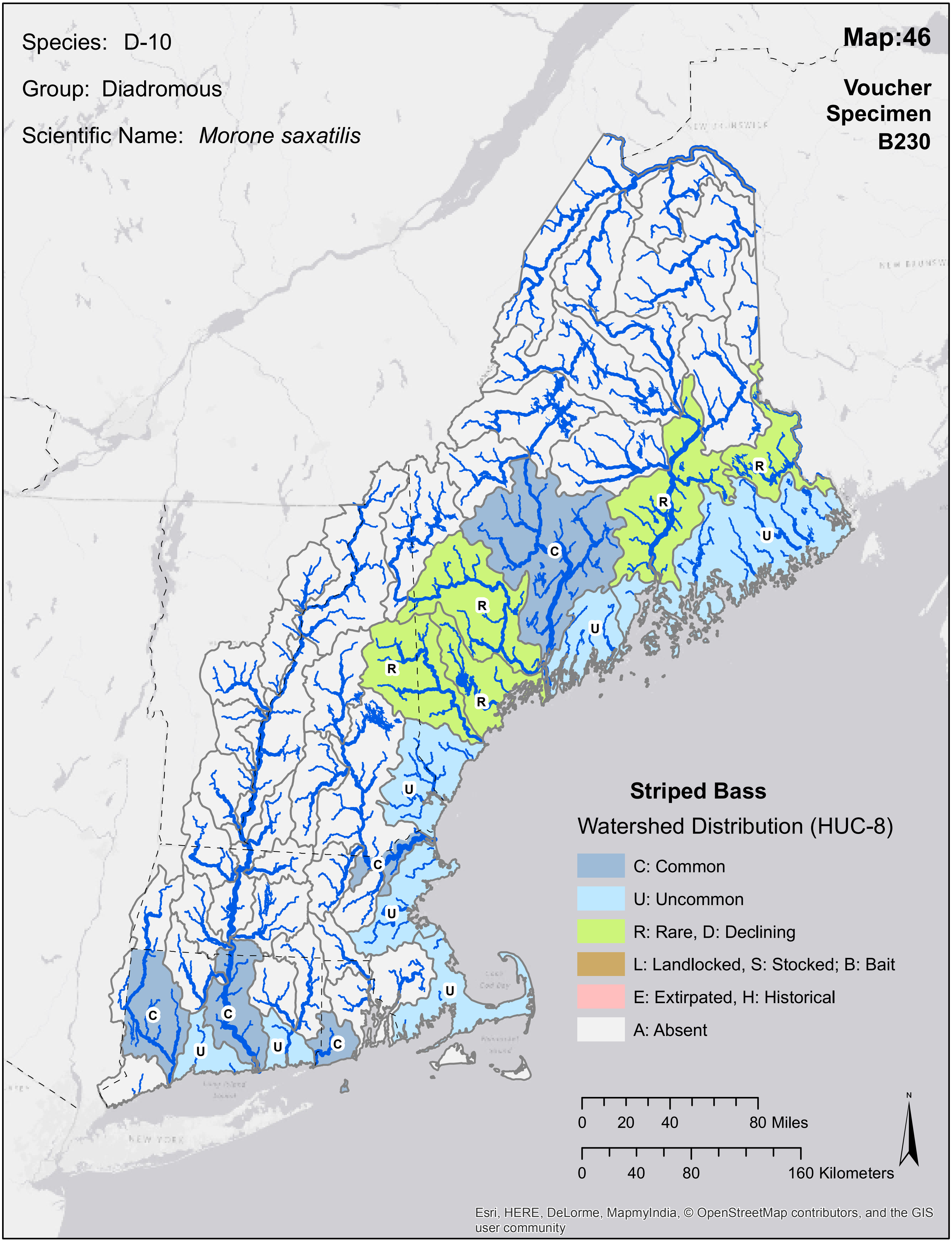
Species: D-10
Group: Diadromous
Scientific Name: *Morone saxatilis*
Map:46
Voucher Specimen B230
Striped Bass
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
C
U
R
0 20 40 80 Miles
0 40 80 160 Kilometers
N
NEW BRUNSWICK
NEW YORK
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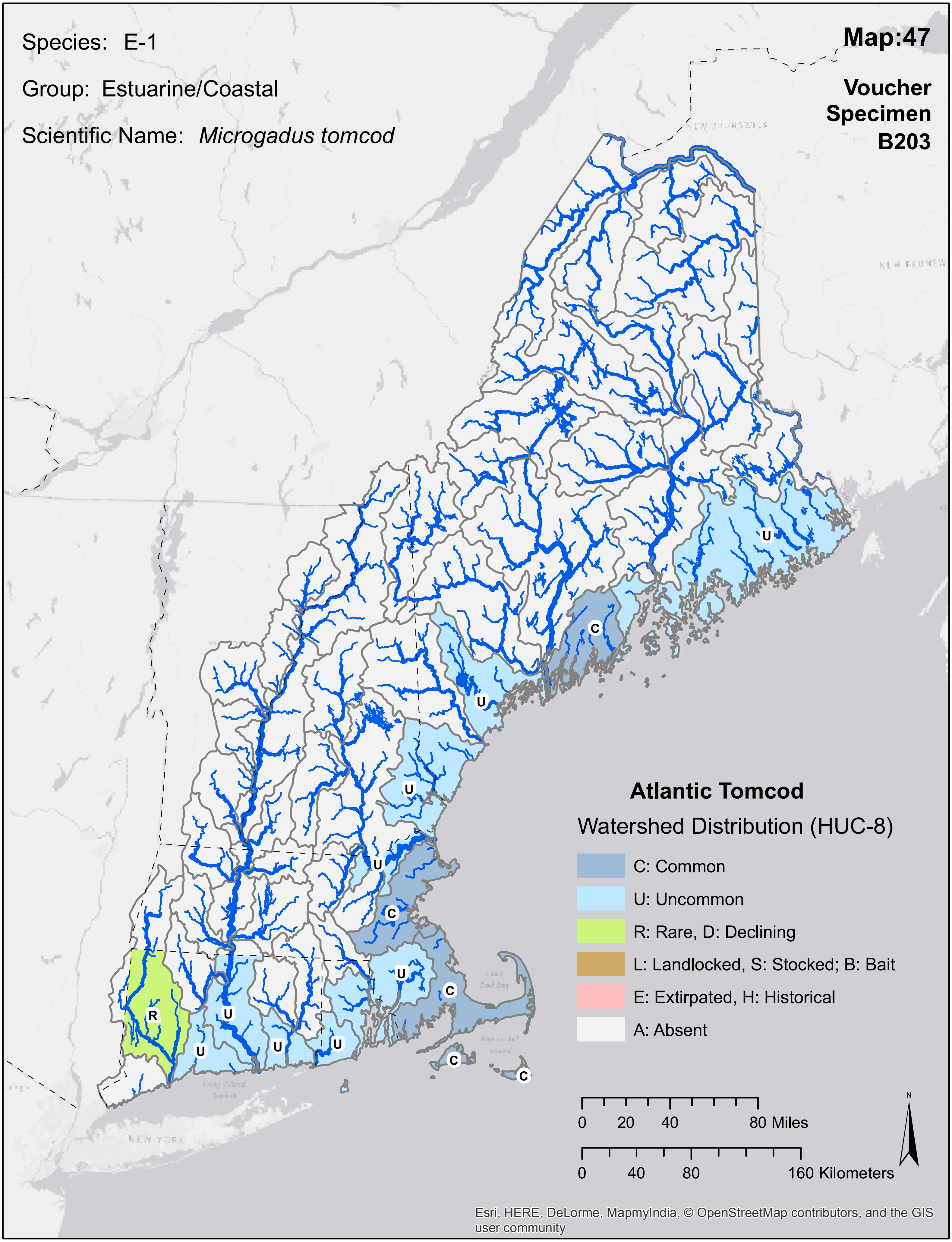
Species: E-1
Group: Estuarine/Coastal
Scientific Name: *Microgadus tomcod*
Map:47
Voucher Specimen B203
Atlantic Tomcod
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
NEW YORK
NEW BRUNSWICK
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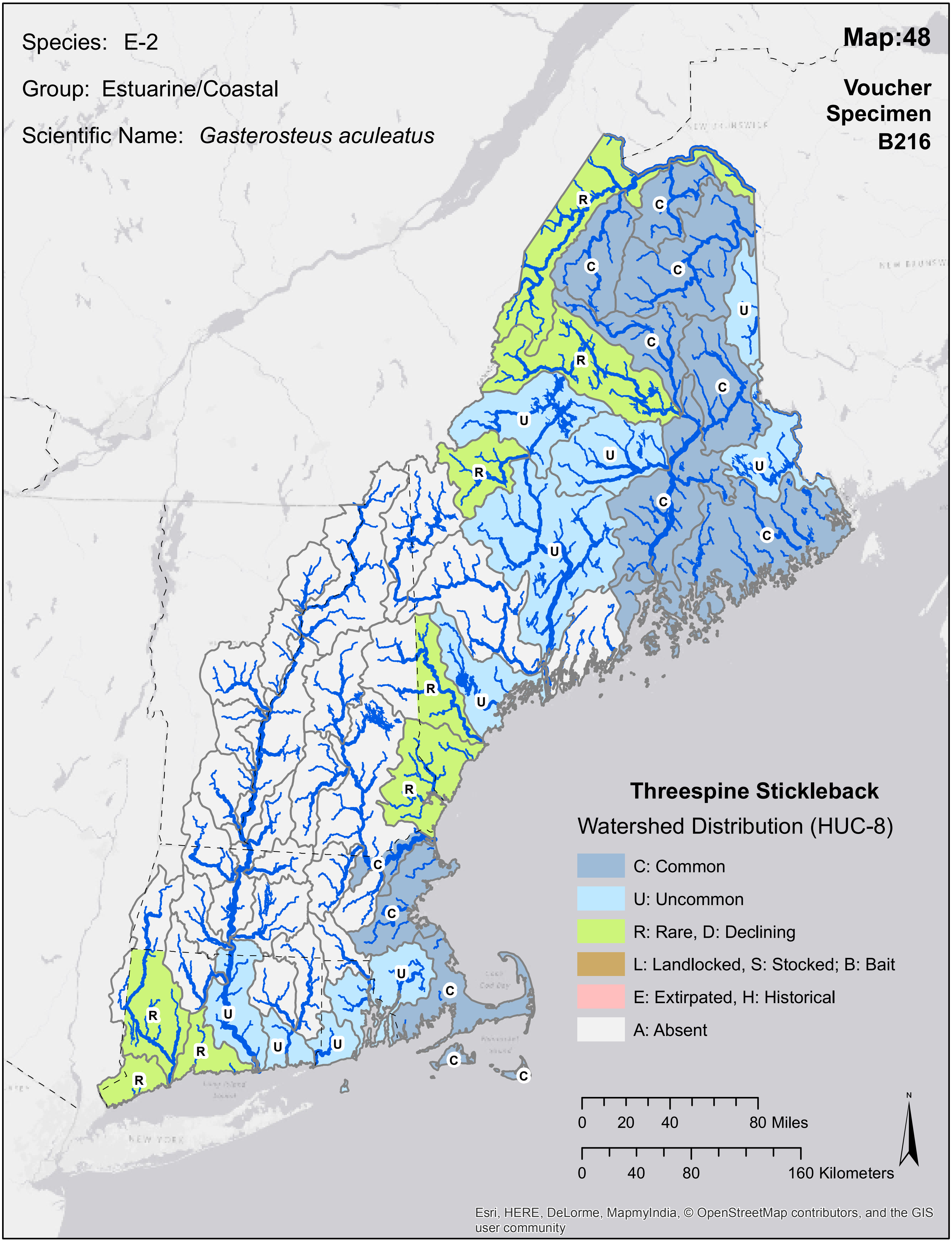
Species: E-2
Group: Estuarine/Coastal
Scientific Name: *Gasterosteus aculeatus*
Map:48
Voucher Specimen B216
Threespine Stickleback
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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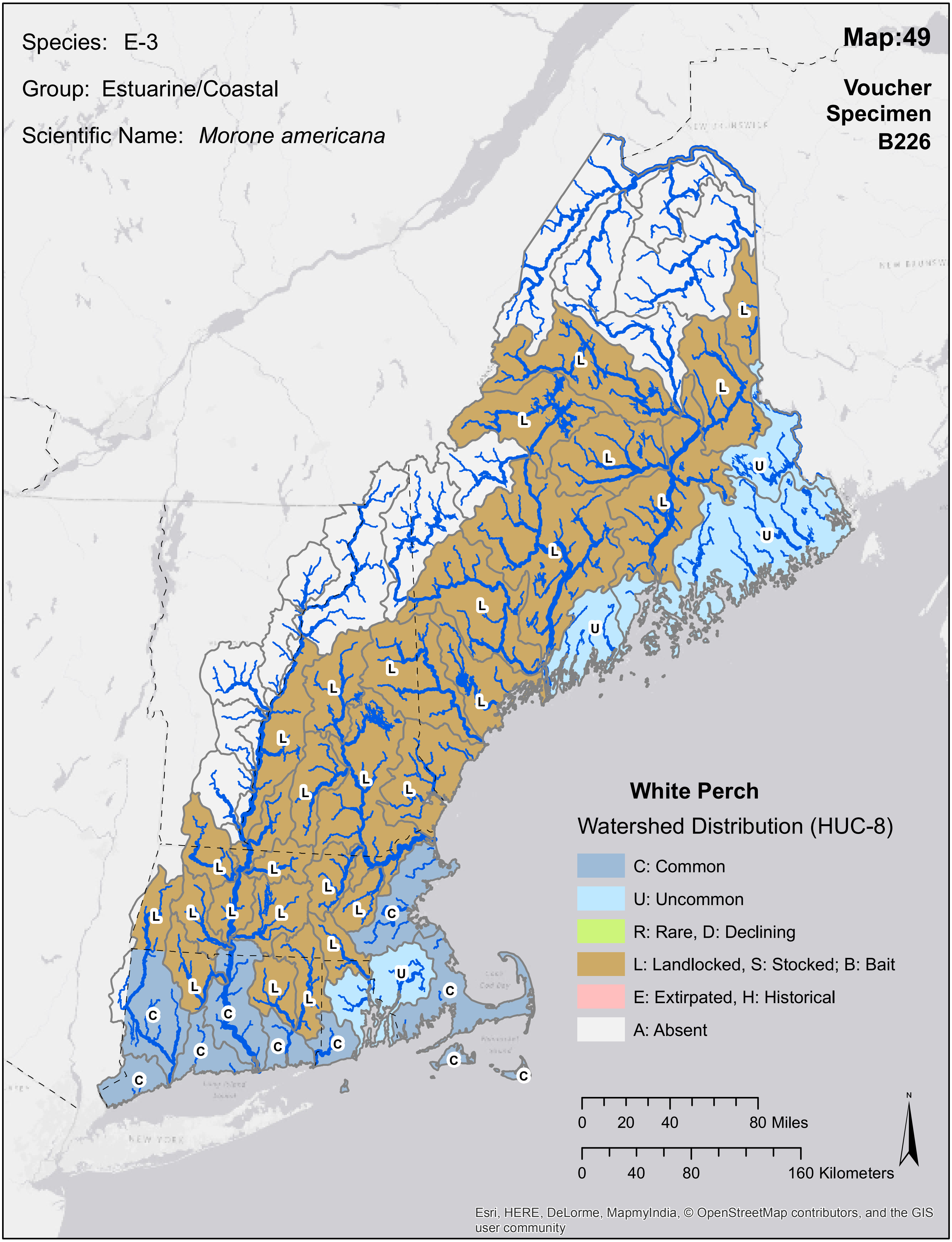

Species: E-3
Group: Estuarine/Coastal
Scientific Name: *Morone americana*
Map:49
Voucher Specimen B226
White Perch
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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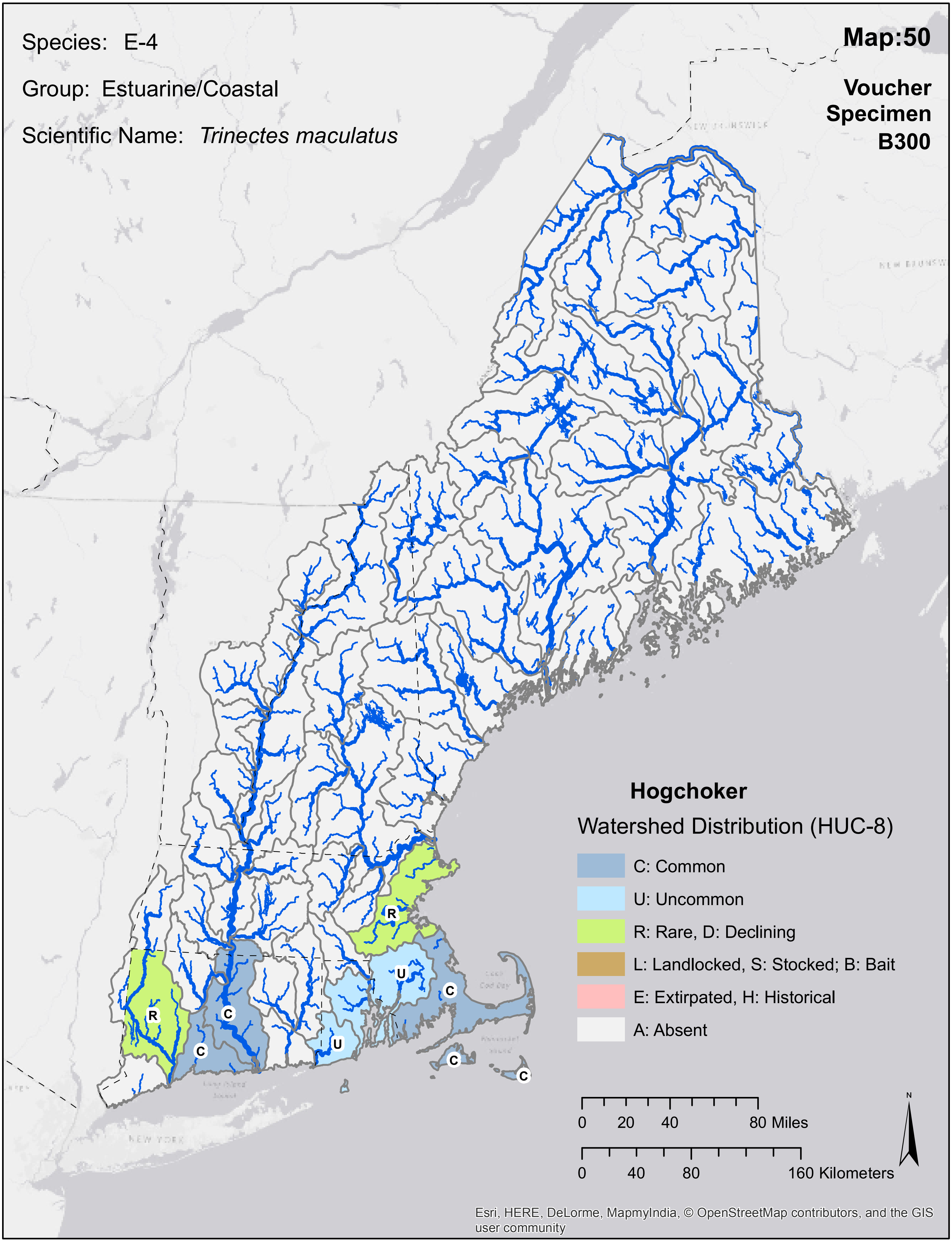
Species: E-4
Group: Estuarine/Coastal
Scientific Name: *Trinectes maculatus*
Map:50
Voucher
Specimen
B300
Hogchoker
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
R
R
C
C
C
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NEW YORK
0 20 40 80 Miles
0 40 80 160 Kilometers
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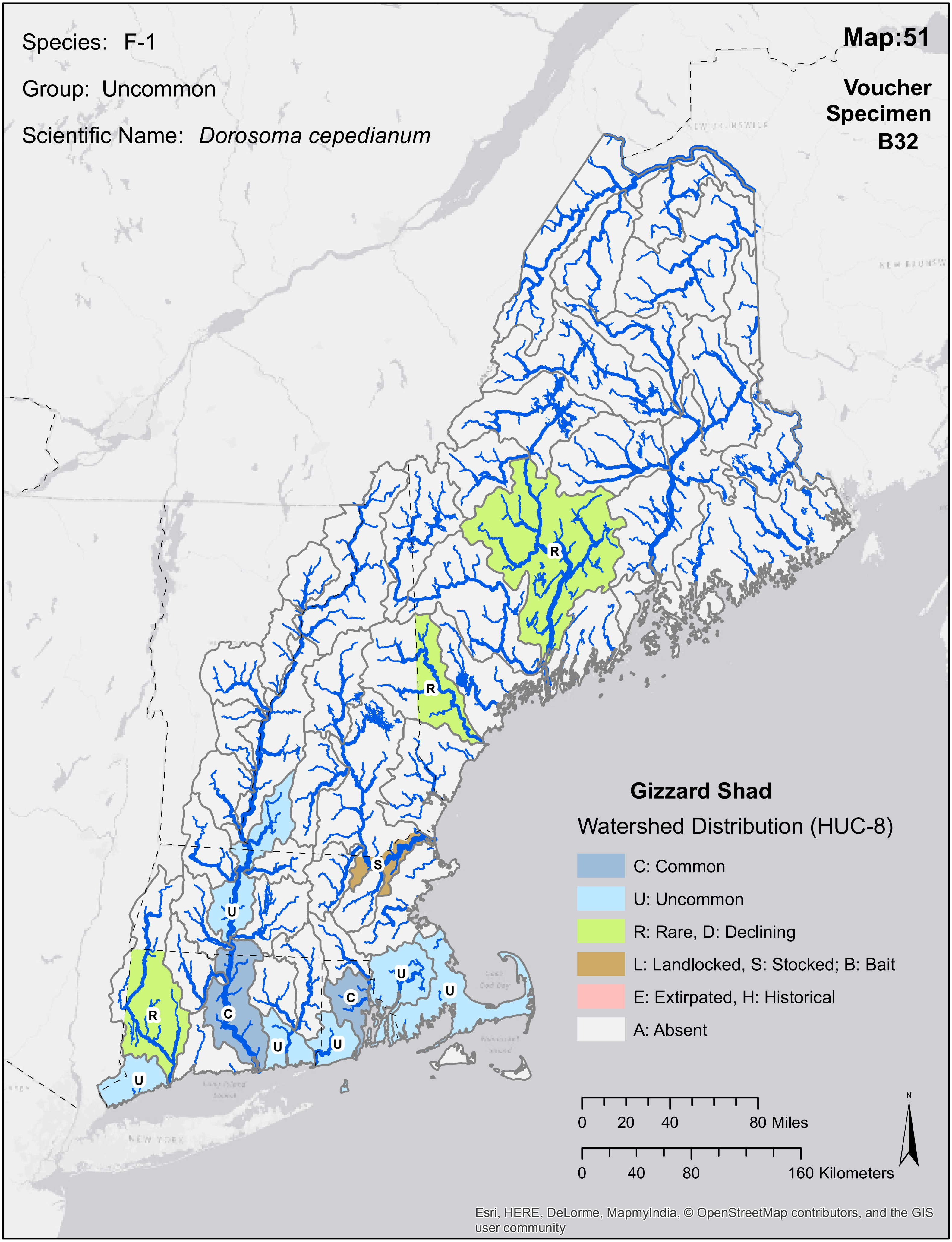
Species: F-1
Group: Uncommon
Scientific Name: *Dorosoma cepedianum*
Map:51
Voucher
Specimen
B32
R
R
S
U
C
C
U
U
U
U
R
U
Gizzard Shad
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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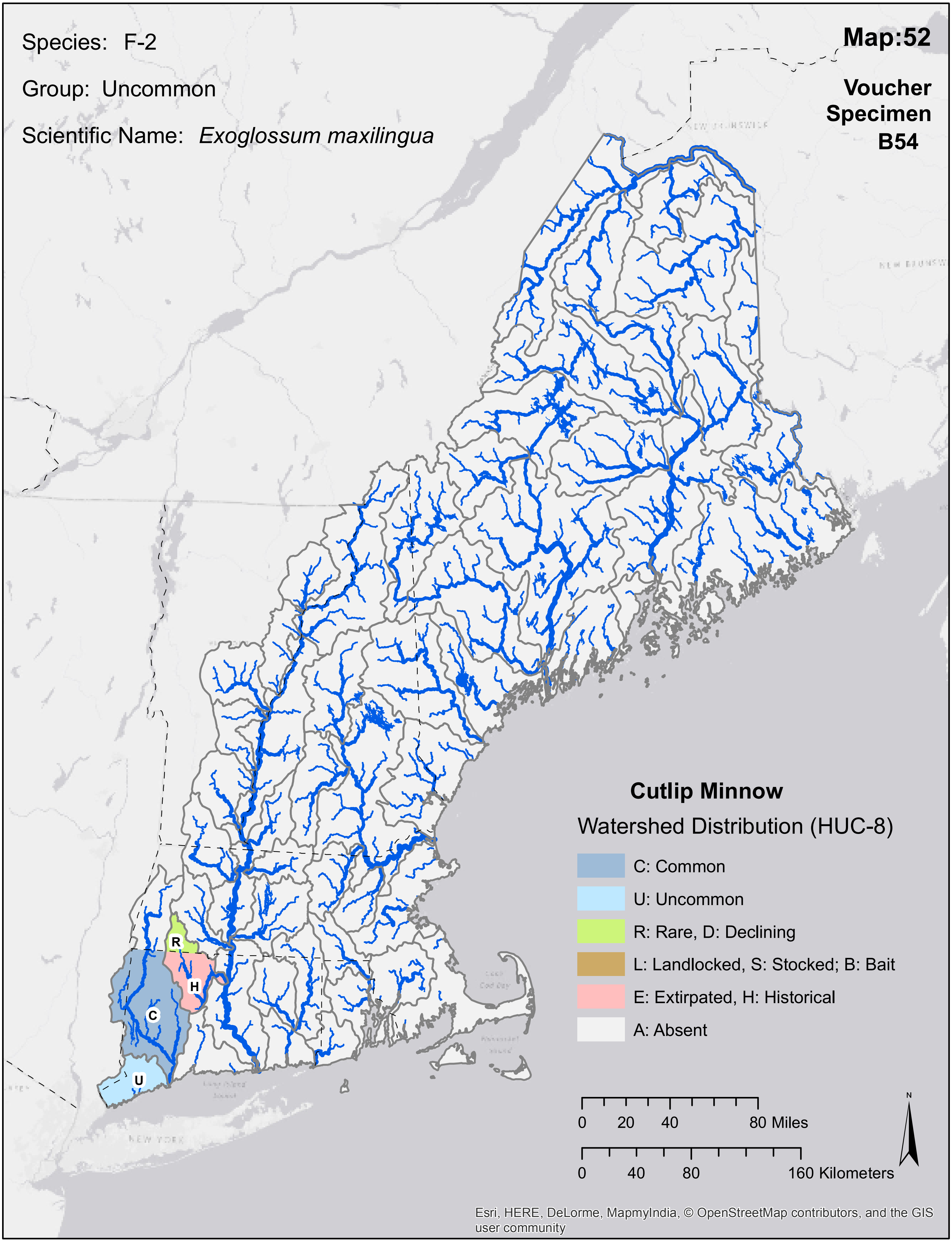

Species: F-2
Group: Uncommon
Scientific Name: Exoglossum maxilingua
Map:52
Voucher Specimen B54
Cutlip Minnow
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
R
H
C
U
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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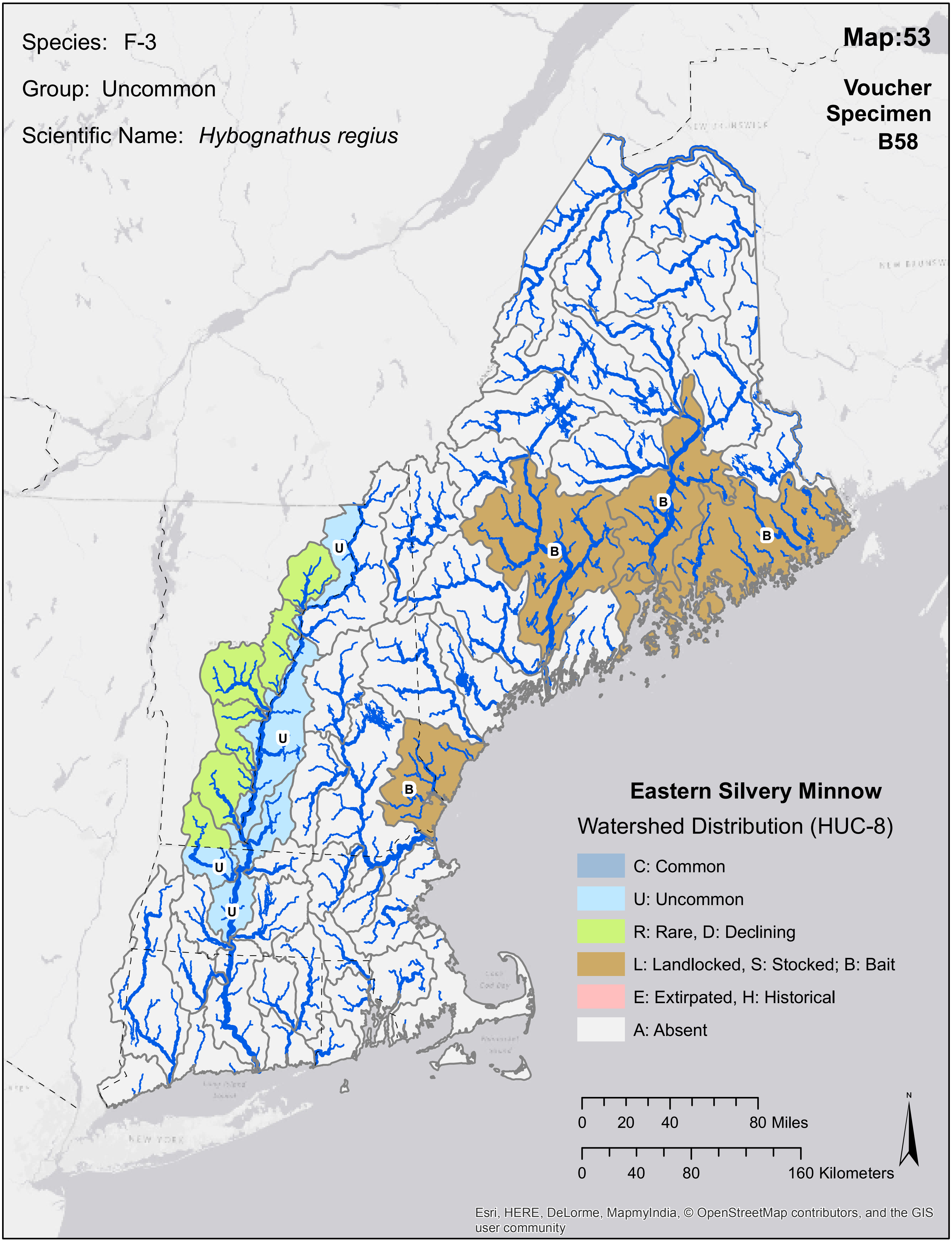
Species: F-3
Group: Uncommon
Scientific Name: Hybognathus regius
Map:53
Voucher Specimen B58
Eastern Silvery Minnow
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
U
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U
U
B
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B
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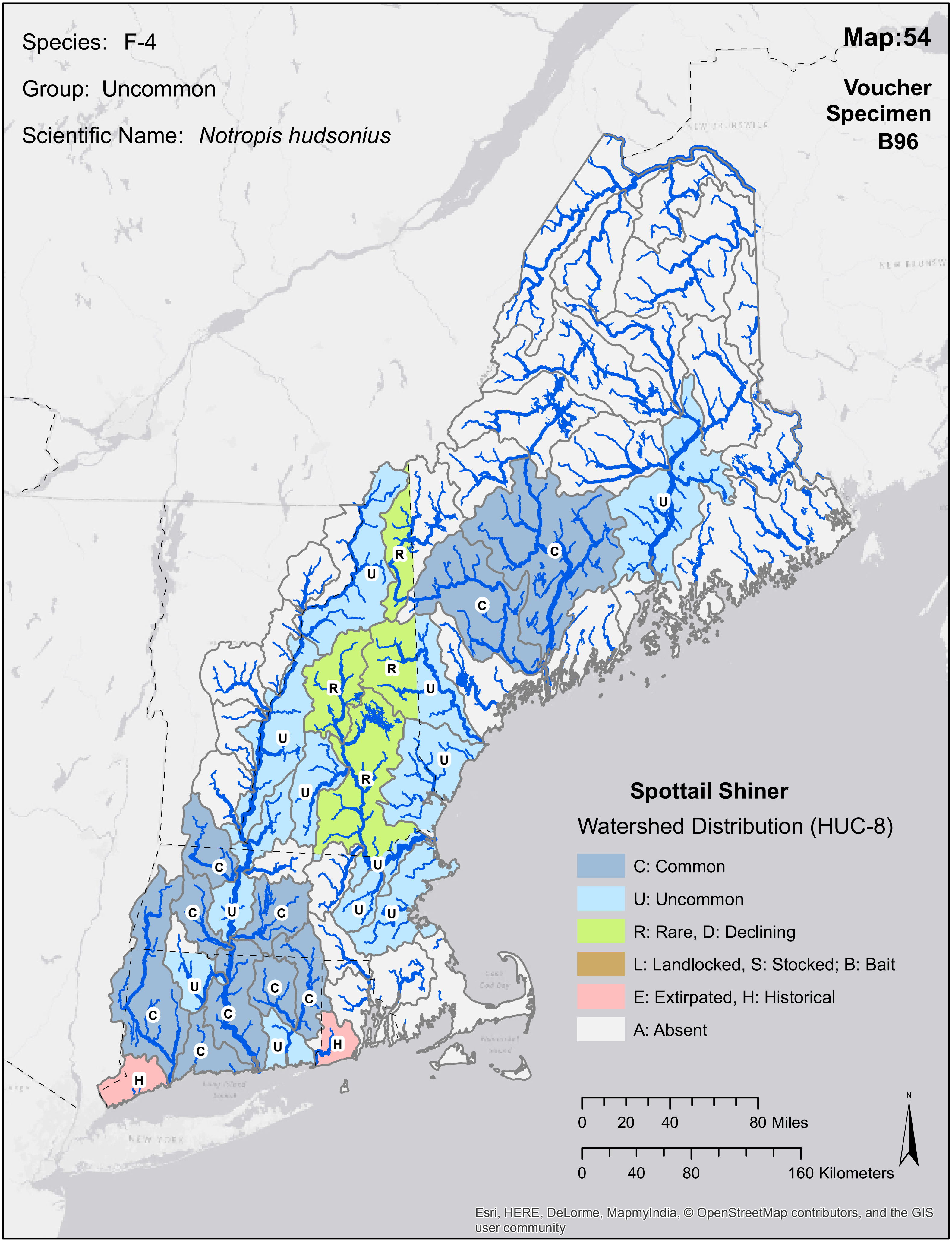
Species: F-4
Group: Uncommon
Scientific Name: *Notropis hudsonius*
Map:54
Voucher Specimen B96
Spottail Shiner
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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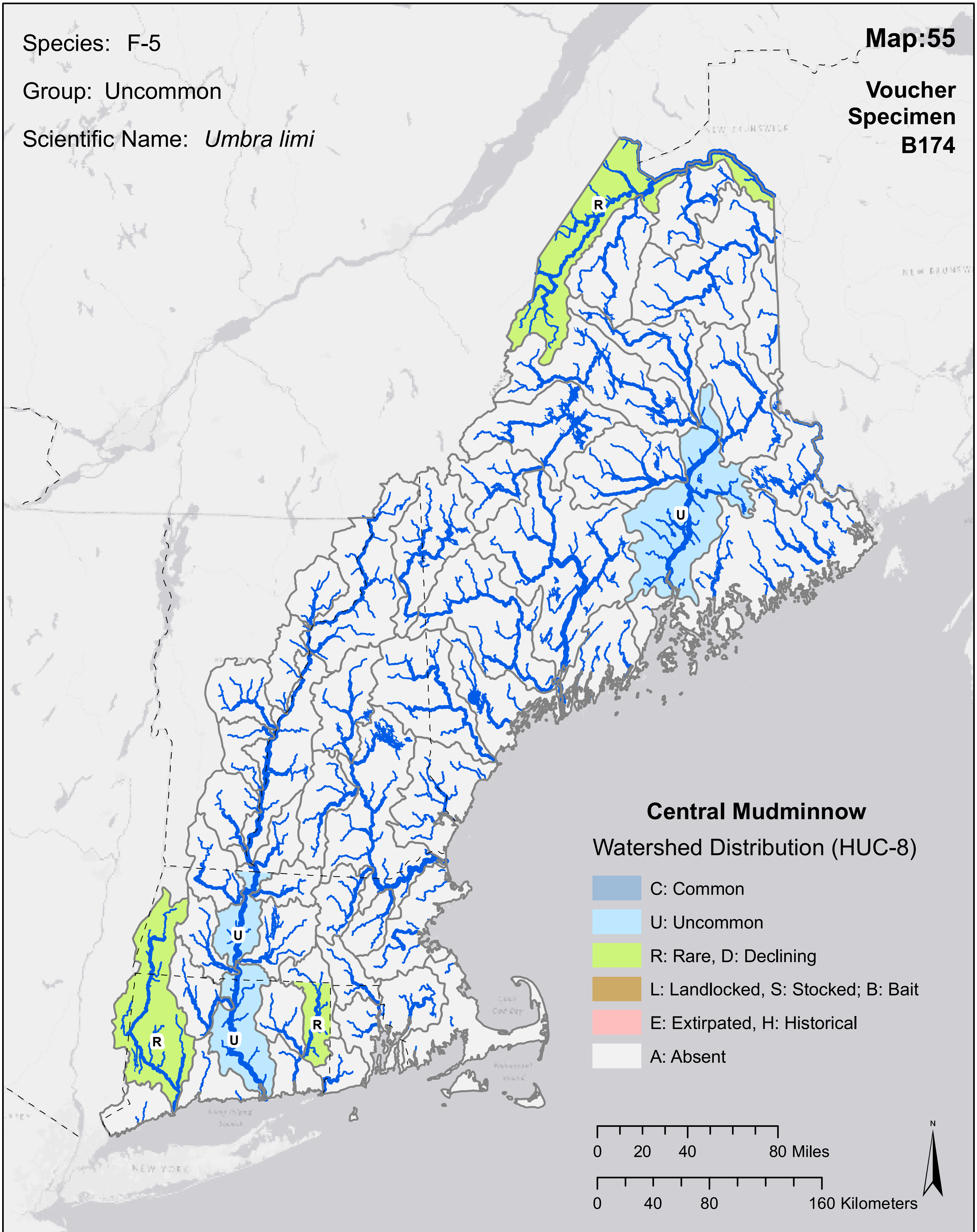
Species: F-5

Group: Uncommon

Scientific Name: *Umbra limi*

Map:55

Voucher Specimen B174



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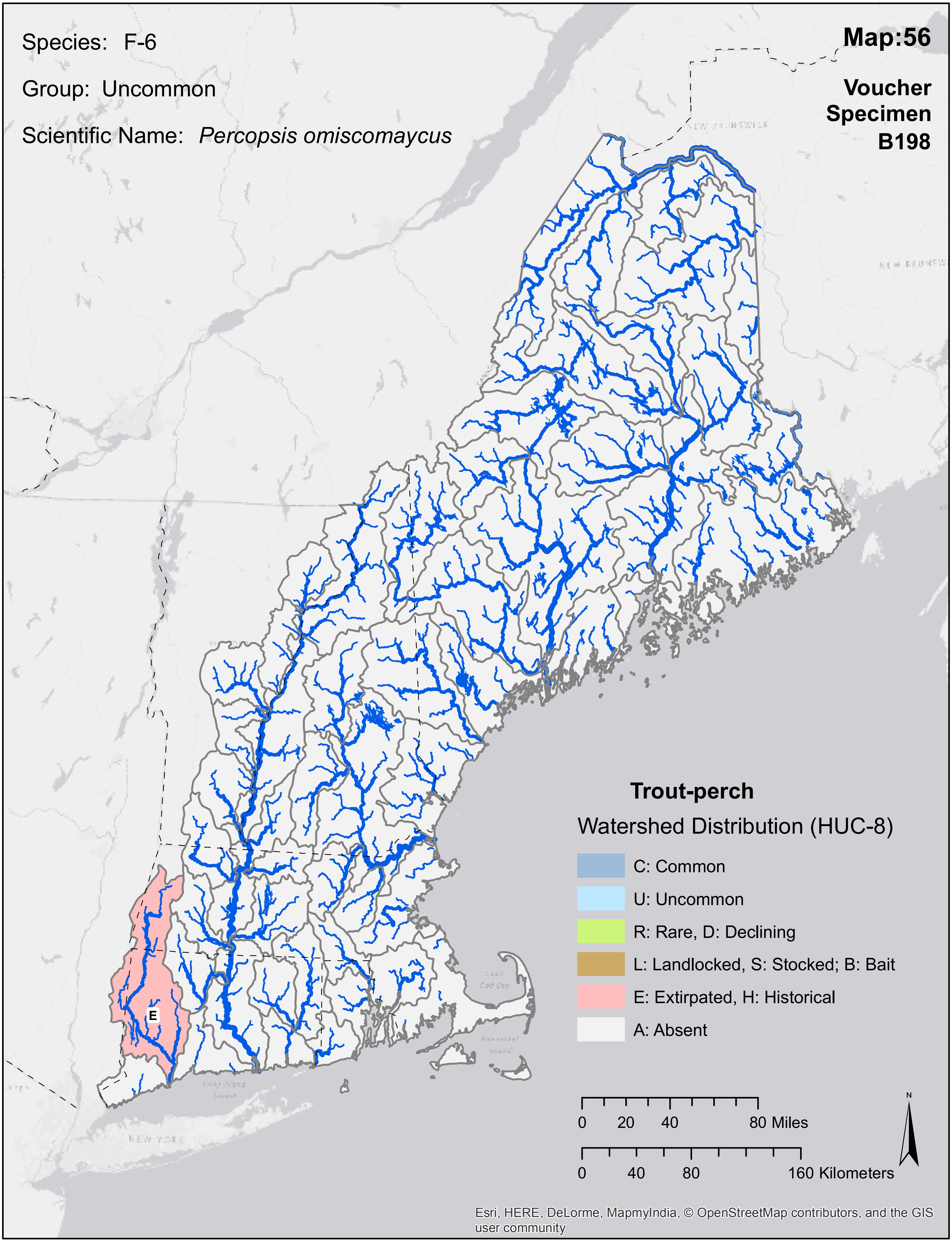
Species: F-6
Group: Uncommon
Scientific Name: *Percopsis omiscomaycus*
Map:56
Voucher Specimen B198
Trout-perch
Watershed Distribution (HUC-8)
C: Common
U: Uncommon
R: Rare, D: Declining
L: Landlocked, S: Stocked; B: Bait
E: Extirpated, H: Historical
A: Absent
E
0 20 40 80 Miles
0 40 80 160 Kilometers
N
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