JUST BELOW THE SURFACE: TOPMINNOW (FAMILY FUNDULIDAE) DIVERSITY IN NORTH CAROLINA

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The Family Fundulidae in North America is comprised of 40 extant species in 3 genera which are distributed from southern Canada to Baja California, throughout the Midwest and Great Plains, along the entire Gulf Coast from the Yucatan Peninsula to Key West, and up the East Coast to New Brunswick and Nova Scotia (Cashner et al. 2020). One species, the Whiteline Topminnow *Fundulus albolineatus*, endemic to Big Spring and its outflow Spring Creek in Huntsville, Alabama, was last captured in 1890 and is considered extinct.

Surprisingly, for such a small family of fishes, North Carolina is home to 11 scientifically described and one undescribed species (Table 1), occurring primarily within the eastern Coastal Plain and within the estuarine marshes along the Atlantic Coast (Menhinick 1991; Tracy et al. 2020a). Note: distributional maps for all species may be found in Tracy et al. 2020a or at: https://ncfishes.com/topminnow-family-fundulidae-diversity-in-north-carolina/. Often referred to as killifishes, top minnows, or mud minnows, each species has its own scientific (Latin) name, which actually means something (Table 2) along with an American Fisheries Society-accepted common name (Table 1, Page et al. 2013).

As previously stated, most species are found in the eastern part of the state, although one species, Speckled Killifish *F. rathbuni*, is found in the central Piedmont (Figure 1). [Note: see Figure 2, showing North Carolina's 100 counties, 21 river basins, and 4 physiographic regions (Mountains, Piedmont, Sand Hills, and Coastal Plain.]

The Lined Topminnow *F. lineolatus* is our most widely distributed species being found in 11 basins (Table 3; Figure 3). The Cape Fear basin contains the most species, seven; whereas the Catawba and Lumber basins each have only one species, Speckled Killifish and Lined Topminnow, respectively.

Table 1. Species of topminnows found in North Carolina. Common names enclosed within quotation marks ("") are scientifically undescribed species. Common names are those accepted by the American Fisheries Society.

Common Name	Scientific Name	Common Name	Scientific Name
Golden Topminnow	*Fundulus chrysotus*	Striped Killifish	*F. majalis*
Marsh Killifish	*F. confluentus*	Speckled Killifish	*F. rathbuni*
Banded Killifish	*F. diaphanus*	Waccamaw Killifish	*F. waccamensis*
Mummichog	*F. heteroclitus*	*Fundulus* sp. "Lake Phelps" Killifish	
Lined Topminnow	*F. lineolatus*	Bluefin Killifish	*Lucania goodei*
Spotfin Killifish	*F. luciae*	Rainwater Killifish	*L. parva*

There are no species of Fundulidae in North Carolina's river basins west of the Appalachian Mountains (Tracy et al. 2020a; Table 3) even though three other *Fundulus* species are found just across the border in Tennessee (i.e., Northern Studfish *F. catenatus*, Blackstripe Topminnow *F. notatus*, and Blackspotted Topminnow *F. olivaceus*) (Etnier and Starnes 1993). The absence of these topwater micropredators may be due to physiographic factors and ecological breaks (Tracy et al. 2020b). At the North Carolina–Tennessee state line, prior to the creation of mainstem impoundments on the Hiwassee, Little Tennessee, and Pigeon rivers, these rivers were high-gradient, through gorges, much like the Watauga and Nolichucky rivers of today. There are many other species found in eastern Tennessee, such as Chestnut Lamprey *Ichthyomyzon castaneus*, Stargazing Minnow *Phenacobius uranops*, Blue Sucker *Cycleptus elongatus*, Mountain Madtom *Noturus eleutherus*, Banded Sculpin *Cottus carolinae,* and Tennessee Snubnose Darter *Etheostoma simoterum*, whose distributions do not stray far from the state line into the Blue Ridge of North Carolina (Etnier and Starnes 1994; Tracy et al. 2020a).

Topminnows range in size from the two diminutive *Lucania* species at 50 mm to the 200-mm Striped Killifish *F. majalis*. Because of their abundance and ease by which they can be collected, they are often sold and used as bait fish along the Atlantic Coast. Most of our species inhabit a variety of coastal aquatic environments (Table 4) and have a wide-ranging tolerance to salinities. Speckled Killifish, Waccamaw Killifish *F. waccamensis*, and *Fundulus* sp. "Lake Phelps" Killifish are known to inhabit only freshwater environments.

The Waccamaw River basin is home to two of our three species found in only one river basin: Golden Topminnow *F. chrysotus,* and Waccamaw Killifish; the third species, Bluefin Killifish *Lucania goodei*, inhabits only the Cape Fear River basin. The Golden Topminnow is a recent, naturally occurring migrant from South Carolina; it did not occur in North Carolina until 2007 when it was first discovered in Marlowe Branch in Columbus County (Waccamaw River basin). The Bluefin Killifish is our state's only nonindigenous (nonnative or introduced) topminnow; it was first detected in the state in 1977 (Tracy et al. 2020a).

Based on the Speckled Killifish's indigenous distribution and occupied instream habitats in other river basins in North Carolina (Figure 1), it appears that the localities clustered in eastern Lincoln and western Mecklenburg counties in the Catawba River basin (Figure 1) possibly constitute an indigenous introduction because suitable habitats throughout the middle and lower reaches of this basin are unoccupied by this species (Tracy et al. 2020a). *Fundulus* sp. "Lake Phelps" Killifish or perhaps Banded Killifish *F. diaphanus* are also suspected of being introduced in Shearon Harris Lake in

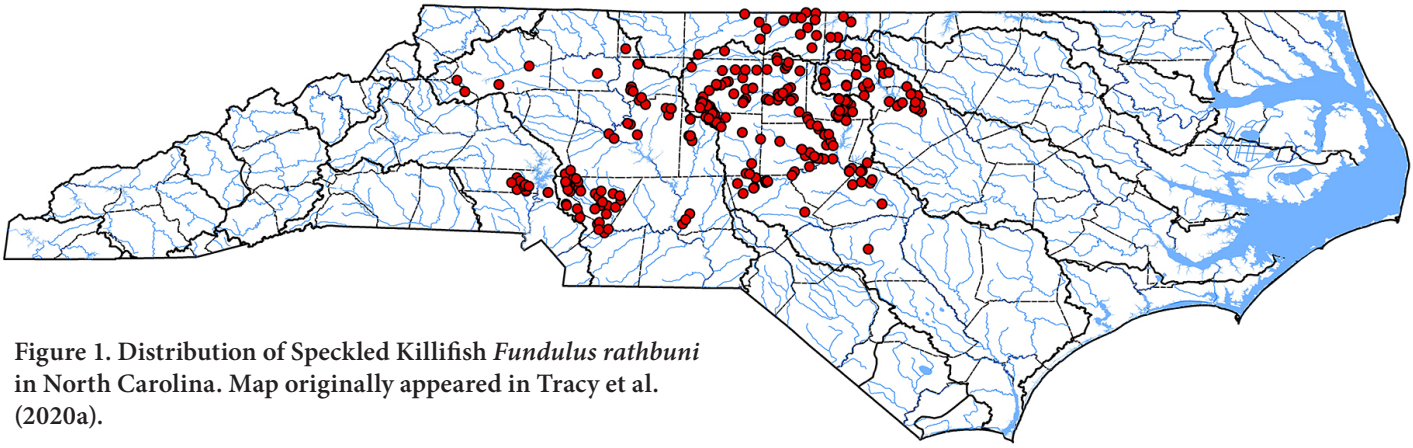

Figure 1. Distribution of Speckled Killifish *Fundulus rathbuni* in North Carolina. Map originally appeared in Tracy et al. (2020a).

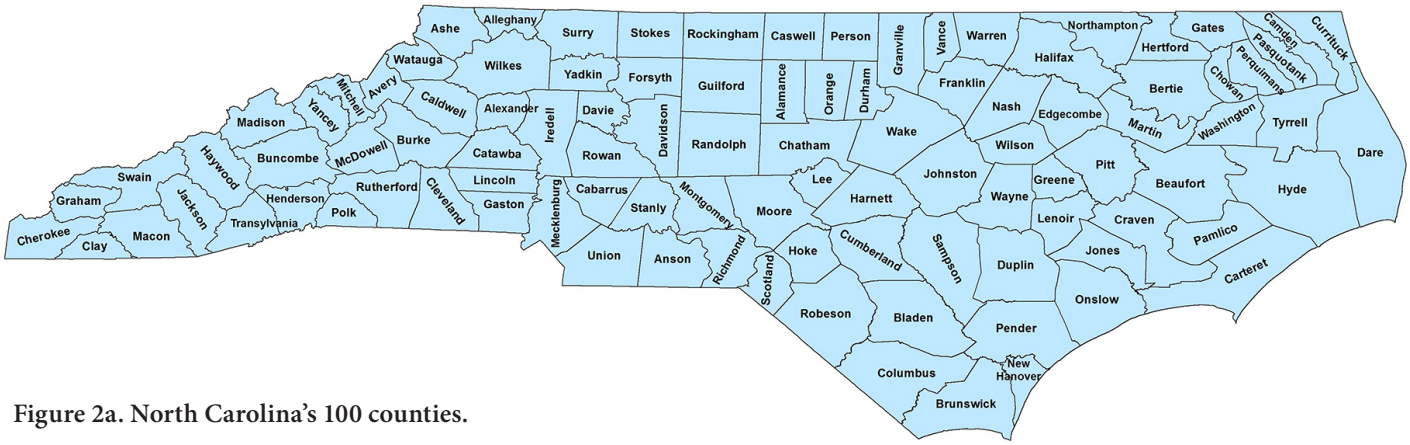

Figure 2a. North Carolina's 100 counties.

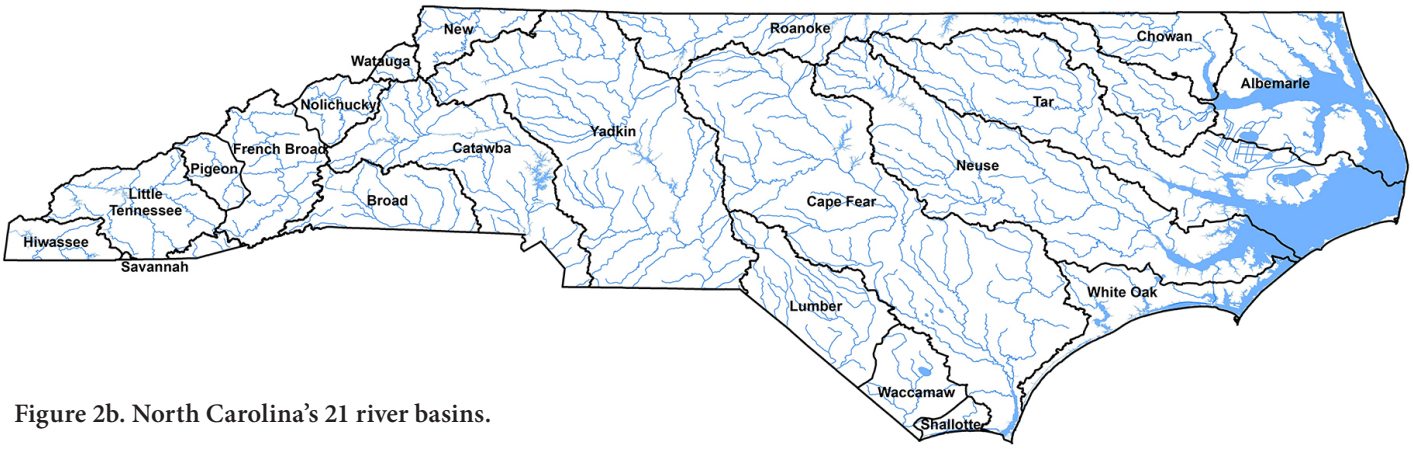

Figure 2b. North Carolina's 21 river basins.

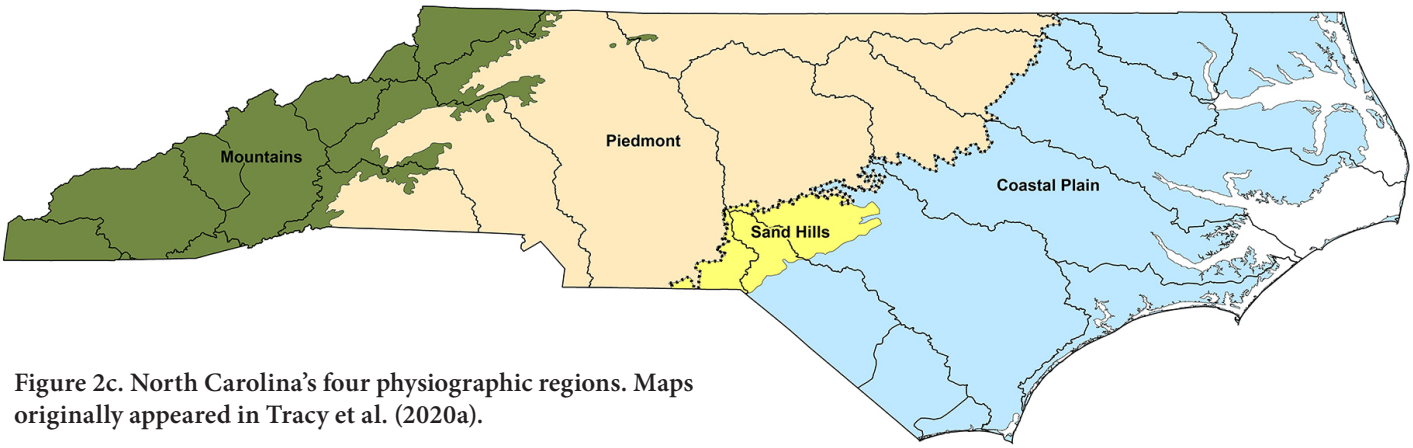

Figure 2c. North Carolina's four physiographic regions. Maps originally appeared in Tracy et al. (2020a).

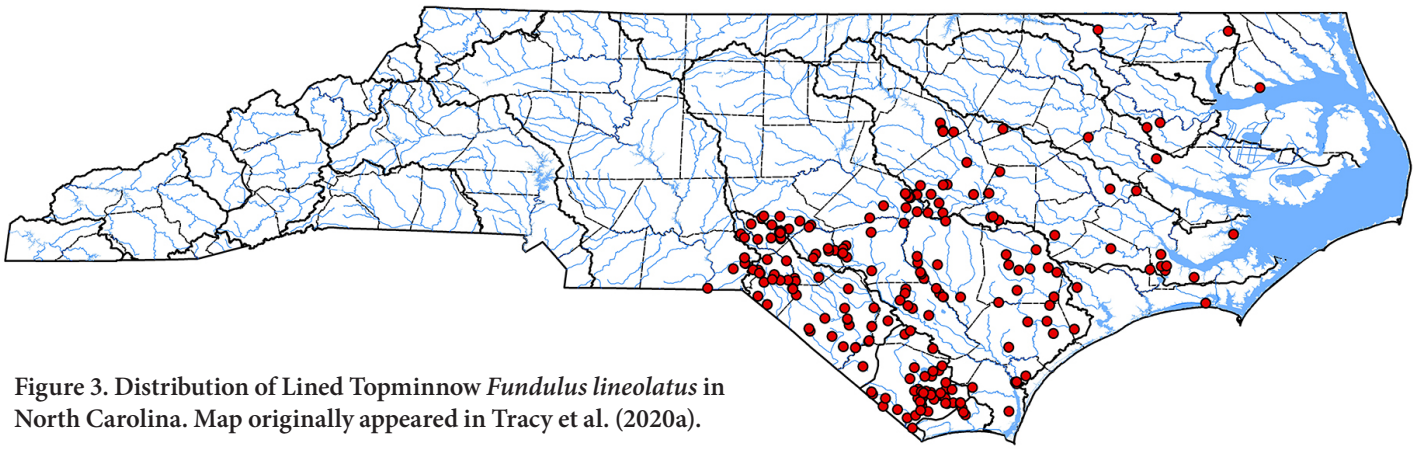

Figure 3. Distribution of Lined Topminnow *Fundulus lineolatus* in North Carolina. Map originally appeared in Tracy et al. (2020a).

southern Wake County, Cape Fear River basin (Tracy et al. 2020a). In 2020, Fritz Rohde collected Mummichog *F. heteroclitus* for the first time from the Waccamaw River basin (from Lake Waccamaw). It is unknown if this indigenous introduction represents a reproducing and persistent population (Tracy et al. 2020a).

Two species were scientifically described for the first time from North Carolina: Waccamaw Killifish described in 1946 from Lake Waccamaw in Columbus County (Hubbs and Raney 1946) and Speckled Killifish described in 1889 from several localities in the Haw River watershed (Cape Fear River basin) in Guilford County (Jordan 1889).

Because of their limited distributions and the anthropogenic impacts upon their habitats, three species are listed as imperiled in North Carolina: *Fundulus* sp. "Lake Phelps" Killifish, which is Significantly Rare; Waccamaw Killifish which is Special Concern; and Bluefin Killifish which is Special Concern (Krabbenhoft et al. 2009; NCAC 2017; NCNHP 2020; NCWRC 2017).

The identification of North Carolina's topminnows is relatively straight-forward. Key characteristics for their proper identification include the positioning of the dorsal fin relative to the snout and caudal fin; origin of the dorsal fin relative to the origin of the anal fin; color patterns; number of dorsal fin rays; number of gill rakers; and lateral scale count (please refer to the accompanying Identification Key to the Species of Topminnows (Family Fundulidae) in North Carolina). However, several species can co-occur within the same habitat at the same time, rendering field identifications a challenge.

If you have troubles with your identifications, just send us (https://ncfishes.com/contact/) an e-mail and include as many quality digital photographs as you can along with all the pertinent locality descriptors so that we will know from where the fish came.

Table 2. The meanings of the scientific names of topminnows (Family Fundulidae) found in North Carolina. Adapted from the ETYFish Project by Christopher Scharpf and Kenneth J. Lazara, accessed November 26, 2020, http://www.etyfish.org/.

***Fundulus* Lacepède 1803:** *fundus*, bottom; *–ulus*, a diminutive suffix, i.e., a "small burrower," referring to "mudfish," local name for *F. heteroclitus* in South Carolina, perhaps referring to their occurrence in muddy pools, creeks, and ditches, and/or to how they bury 15–20 cm into the mud during winter.

- ***F. chrysotus* (Günther 1866):** based on the manuscript name coined by physician-naturalist John E. Holbrook (1796–1871); scholars have offered two etymologies: gilded, referring to gold flecks on sides, and *chrysos*, gold and *otos*, ear, referring to gold iridescence on opercle (neither character mentioned by Günther, who remarked "it is impossible to know whether the specimens described are identical with those for which Holbrook intended this name.")
- ***F. confluentus* Goode & Bean 1879:** flowing together; allusion not explained, perhaps referring to confluence of salt and fresh water at type locality (Lake Monroe, Florida), which is 161 miles from the sea; Wildekamp (1996) says name refers to "partial interconnection of the cross-bars on the sides of the body" but provides no source for this explanation.
- ***F. diaphanus* (Lesueur 1817):** transparent, referring to its semi-translucent ("diaphanous") body (probably a male).
- ***F. heteroclitus* (Linnaeus 1766):** *heteros*, different; *clinus*, leaning or inclining, i.e., deviating, abnormal or different; allusion not explained, perhaps referring to Linnaeus' uncertainty ("Genus *nondun certam*") in placing it in the loach genus *Cobitis*, from which it clearly differs; Wildekamp (1996) states that name refers to "differences between the sexes," but sexual dimorphism is not included in Linnaeus' brief description (based on notes from South Carolina naturalist Andrew Garden, who sent Linnaeus right half-skins of two specimens, pressed in a botanical press, varnished, and glued to a sheet of herbarium paper).
- ***F. lineolatus* (Agassiz 1854):** lined, presumably referring to black stripes on sides of females (vertical bars on males).
- ***F. luciae* (Baird 1855):** in honor of Baird's daughter, Lucy Hunter Baird (1848–1913).
- ***F. majalis* (Walbaum 1792):** pertaining to May, based on "May-fish;" local name recorded by Schöpf (1788), who collected specimens from New York City's East River.
- ***F. rathbuni* Jordan & Meek 1889:** in honor of Richard Rathbun (1852–1918), Chief of the Division of Scientific Inquiry, US Fish Commission.
- ***F. waccamensis* Hubbs & Raney 1946:** *–ensis*, suffix denoting place: Lake Waccamaw, North Carolina, where it is endemic

***Lucania* Girard 1859:** a Native American word chosen presumably because Girard liked the sound of it.

- ***L. goodei* Jordan 1880:** in honor of ichthyologist George Brown Goode (1851–1896), who collected type.
- ***L. parva* (Baird & Girard 1855):** small, referring to its "diminutive size" (up to 6.2 cm TL).

Table 3. Species of topminnows found in North Carolina listed by river basin in which they occur.[1, 2] Common name enclosed within quotation marks ("") is a scientifically undescribed species. Table originally appeared in Tracy et al. (2020).

	Mountain								Piedmont							Coastal						
Scientific Name	HIW	LTN	SAV	PIG	FRB	NOL	WAT	NEW	BRD	CTB	YAD	CPF	NEU	TAR	ROA	CHO	ALB	WOK	SHL	WAC	LBR	Total No. of Basin Occurrences
Fundulus chrysotus																				I		1
Fundulus confluentus												I	I	I			I	I				5
Fundulus diaphanus												I	I	I	I	I	I					6
Fundulus heteroclitus												I	I	I		I	I	I	I	IB		8
Fundulus lineolatus											I	I	I	I	I	I	I	I	I	I	I	11
Fundulus rathbuni										IB	I	I	I		I							5
Fundulus waccamensis																				I		1
Fundulus sp. "Lake Phelps" Killifish																	I					1
Lucania goodei												NI										1
Lucania parva												I	I	I		I	I	I	I			7
Total Number of Species	0	0	0	0	0	0	0	0	0	1	2	7	6	5	3	4	6	4	3	4	1	
No. of Indigenous Species (= I + E)	0	0	0	0	0	0	0	0	0	0	2	6	6	5	3	4	6	4	3	3	1	
No. of Nonindigenous Species (IB + NI)	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	

[1] I = Indigenous (native), IB = Indigenous but not in this basin, NI = Nonindigenous (introduced).

[2] River basin abbreviations are: HIW = Hiwassee, LTN = Little Tennessee, SAV = Savannah, PIG = Pigeon, FRB = French Broad, NOL = Nolichucky, WAT = Watauga, NEW = New, BRD = Broad, CTB = Catawba, YAD = Yadkin, CPF = Cape Fear, NEU = Neuse, TAR = Tar, ROA = Roanoke, CHO = Chowan, ALB = Albemarle Sound, WOK = White Oak, SHL = Shallotte, WAC = Waccamaw, and LBR = Lumber.

Table 4. Physiographic regions and habitats in which to find North Carolina's topminnows. Adapted from Hardy (1980), Lee (1980), Shute et al. (1983), Rohde et al. (2009), and Kells and Carpenter (2011).

Species	Physiographic Region	Habitats
Golden Topminnow	Southeastern Coastal Plain	Open, sunlit, quiet, slow, shallow, warm, heavily vegetated marshes, swamps, lake shores, sloughs, drainage ditches, borrow pits, and creeks; also occurring in slightly to moderately saline waters
Marsh Killifish	Eastern Coastal Plain	Freshwater rivers and streams and brackish tidal streams, coastal bays, marshes, channels, and over seagrass flats
Banded Killifish	Primarily Northeastern Coastal Plain	Calm, slow, and clear rivers and creeks, but also occurring from small inland streams to wide tidal rivers with low salinity, usually over a bottom of open sand
Mummichog	Eastern Coastal Plain	Tidal marshes, creeks, and ditches over mud flats and in or near vegetation, but also often occurring in fresh water
Lined Topminnow	Sand Hills, Coastal Plain	Fresh water, soft-water, dystrophic, acidic, clear or tannin-stained quiet portions of streams, sloughs, drainage ditches, borrow pits, and ponds, especially near submerged or emergent vegetation
Spotfin Killifish	Southeastern Coastal Plain	Estuarine, typically in intertidal salt marshes
Striped Killifish	Eastern Coastal Plain	High salinity inlets, bays, estuaries, marshes, and along beaches
Speckled Killifish	Central Piedmont	Fresh water, common in pools and runs of streams, usually over mud or sand bottoms
Waccamaw Killifish	Coastal Plain – Lake Waccamaw	Fresh water, occurring in large schools in shallow water along sandy to muddy shorelines, often associated with submerged or emergent vegetation
Fundulus sp. "Lake Phelps" Killifish	Coastal Plain – Lake Phelps	Fresh water, occurring in large schools in shallow water along sandy to muddy shorelines, often associated with submerged or emergent vegetation
Bluefin Killifish	Wilmington, New Hanover County	Fresh water, only occurring in Burnt Mill Creek, an impoundment of the creek at Anne McCrary Park and the lake's outfall
Rainwater Killifish	Eastern Coastal Plain	Saltwater environments, but also occurring in some fresh water habitats; usually associated with dense vegetation

IDENTIFICATION KEY TO THE SPECIES OF TOPMINNOWS (FAMILY FUNDULIDAE) IN NORTH CAROLINA

(Please refer to NCFishes.com for distributional maps, pictures, and characteristics for all species)
(Identification key adapted from Menhinick (1991) and Rohde et al. (2009))

1a Dorsal fin origin closer to preopercle than to caudal fin base (Figure 4) 2

1b Dorsal fin origin closer to caudal fin base than to preopercle (Figure 4) 3

2a Lateral stripe black, extending from snout to caudal fin spot (Figure 5). Dorsal fin rays 8–11. Restricted to Burnt Mill Creek and an impoundment of the creek at Anne McCrary Park in Wilmington, New Hanover County . . . . . **Bluefin Killifish *Lucania goodei***

2b Lateral stripe inconspicuous; caudal fin spot absent (Figure 6). Dorsal fin rays 11 or 12. Not restricted as above . . . . **Rainwater Killifish *Lucania parva***

3a Dorsal fin rays 9 or fewer. Dorsal fin origin behind anal fin origin (Figure 7) 4

3b Dorsal fin rays 10 or more. Dorsal fin origin in front of anal fin origin (Figure 7) 6

Figure 4. Left: Dorsal fin closer to preopercle than to caudal fin base. Right: Dorsal fin closer to caudal fin base than to preopercle.

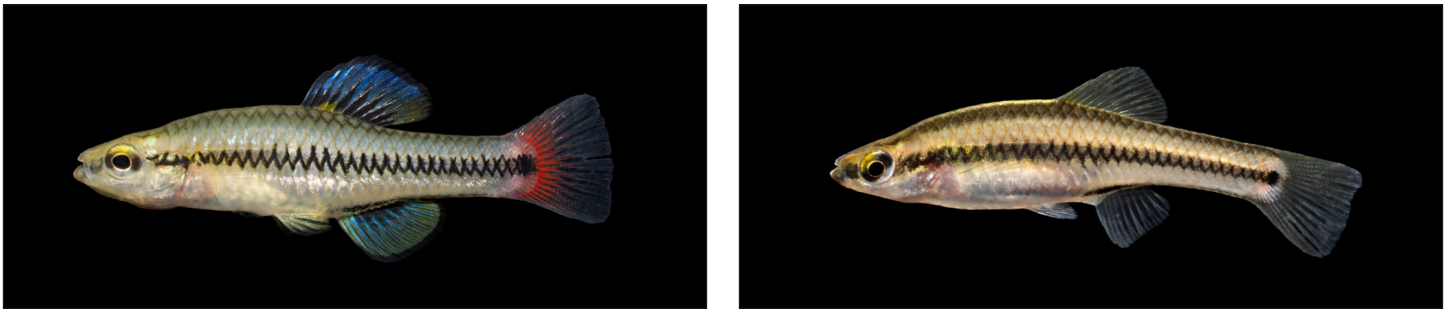

Figure 5. Bluefin Killifish. Left: Male. Right: Female.

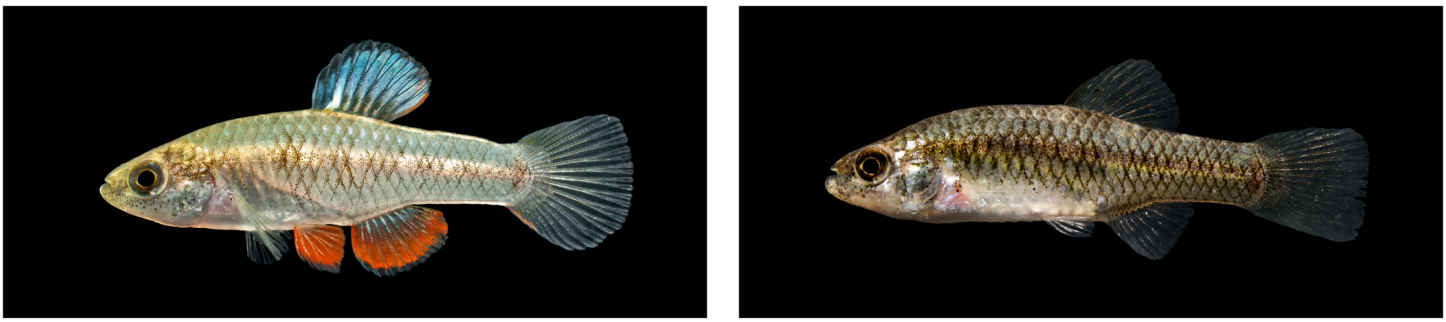

Figure 6. Rainwater Killifish. Left: Male. Right: Female.

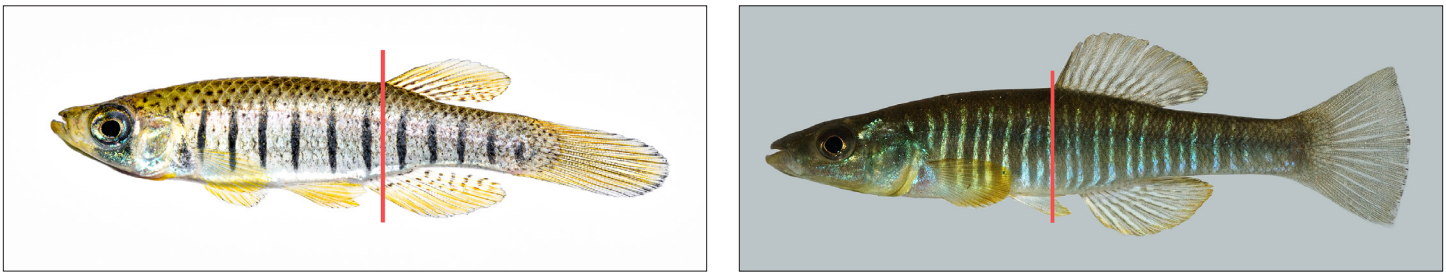

Figure 7. Red bars showing positioning of the dorsal fin relative to that of the anal fin. Left: Dorsal fin origin posterior to anal fin origin. Right: Dorsal fin origin anterior to anal fin origin.

4a Predorsal median stripe distinct and dark (Figure 8). Male with 10-13 dark bars on the side and a black spot on the dorsal fin (Figure 8). Female more or less plain gray with no spot on the dorsal fin . . . . . **Spotfin Killifish *Fundulus luciae***

4b Predorsal stripe light or absent. No black spot on the dorsal fin 5

5a Dark blotch below eye. Female with 6–8 narrow longitudinal black stripes; male with 9–13 narrow dark bars on the side (Figure 9) . . . . . **Lined Topminnow *Fundulus lineolatus***

5b No dark blotch below eye; many small golden or pearly (in females and juvenile) to red (in males) spots on the side (Figure 10). Male can develop 10–12 broad, wavy indistinct vertical bars on the side. Range currently restricted to the Waccamaw River basin . . . . **Golden Topminnow *Fundulus chrysotus***

6a Bars or distinct stripes present in one or both sexes. Dorsal fin origin usually in front of anal fin origin. Range confined to the Coastal Plain and Atlantic Coast 7

6b Sides of adults with no bars (Figure 11). Dorsal fin origin over or slightly behind anal fin origin. Female with irregular black spots on sides and head; males plain on sides, head spotted. Range generally restricted to the central Piedmont. . . . . **Speckled Killifish *Fundulus rathbuni***

Figure 8. Spotfin Killifish. Left: Male. Right: dorsal view with arrowing pointing to the very thin black predorsal stripe.

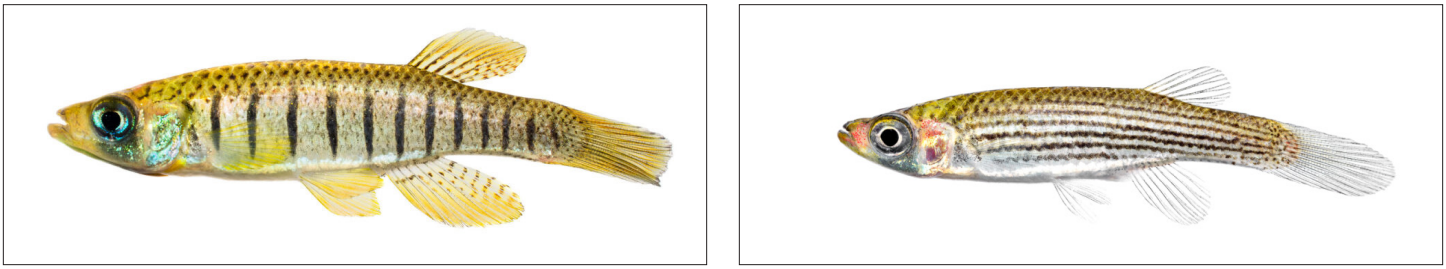

Figure 9. Lined Topminnow. Left: Male. Right: Female.

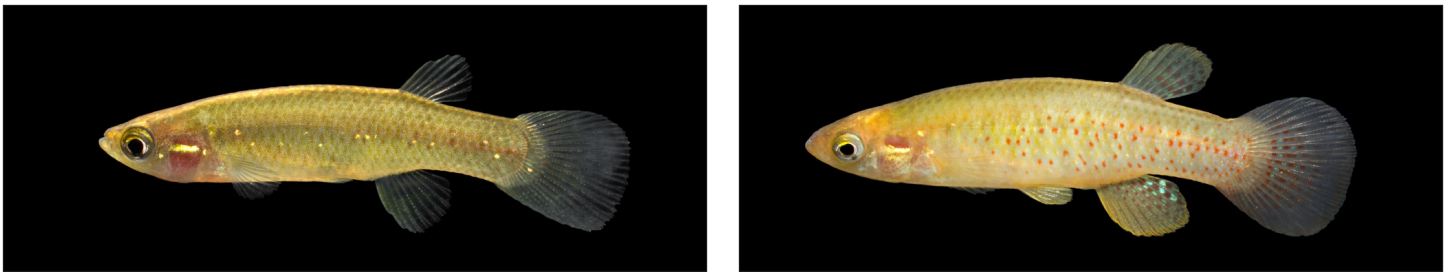

Figure 10. Golden Topminnow. Left: Female. Right: Male.

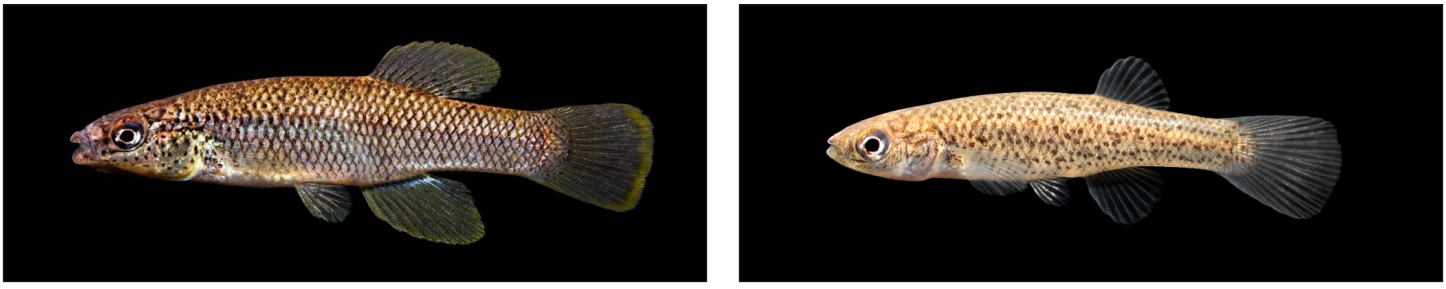

Figure 11. Speckled Killifish. Left: male. Right: Female.

7a Caudal fin truncate or emarginate. Dorsal fin with no black spot. Female with about 12–16 narrow dark bars; males with 15–20 dark bars, usually wider than light interspaces. Lateral scales 37–64. Gill rakers 4 or 5 8

7b Caudal fin rounded. Bars, if present, fewer than 15 (but up to 18 in female Marsh Killifish). One sex often with a black spot at the posterior of the dorsal fin. Lateral scales modally 30–36 (range 29–39). Gill rakers 5–10 10

8a Lateral scales modally 36–39 (range 34–46). Depth of caudal peduncle going 2.0–2.8 times in the length of the caudal peduncle (Figure 12) . . . . . **Banded Killifish *Fundulus diaphanus***

8b Lateral scales modally 52–58 (range 50–64). Depth of caudal peduncle going 2.8–3.5 times in length of caudal peduncle 9

9a Restricted to Lake Waccamaw and adjacent canals, Columbus County (Figure 13) . . . . . **Waccamaw Killifish *Fundulus waccamensis***

9b Restricted to Lake Phelps in Washington and Tyrell counties (Figure 14) . . . . . ***Fundulus* sp. "Lake Phelps" Killifish**

10a Snout long, eye width going about 1.5 times into the snout length. Dorsal fin rays 14 or 15. Female with horizontal black stripes; male with black bars on the side and a dark spot in the dorsal fin (Figure 15). Caudal fin slightly rounded . . . . . **Striped Killifish *Fundulus majalis***

10b Snout short, eye width going about one time into the snout length. Dorsal fin rays 10–12. Both sexes may have bars on the body. Caudal fin rounded . .11

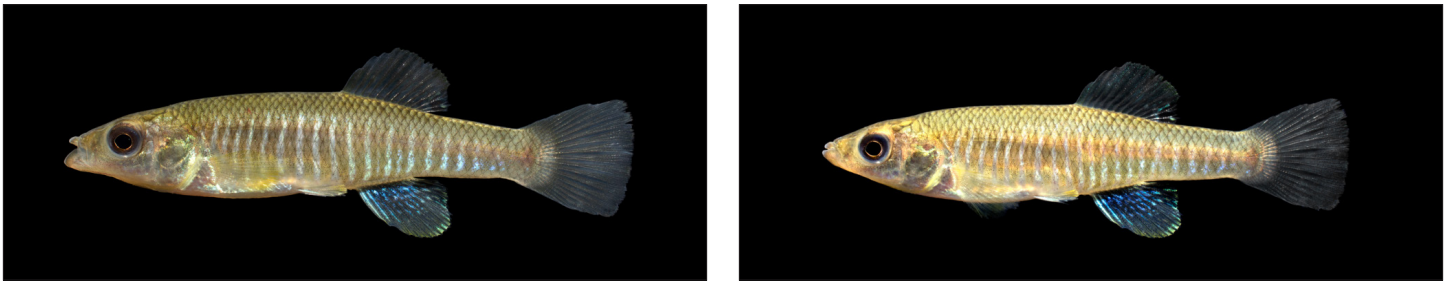

Figure 12. Male Banded Killifish

Figure 13. Waccamaw Killifish. Left: Juvenile or Female. Right: Male.

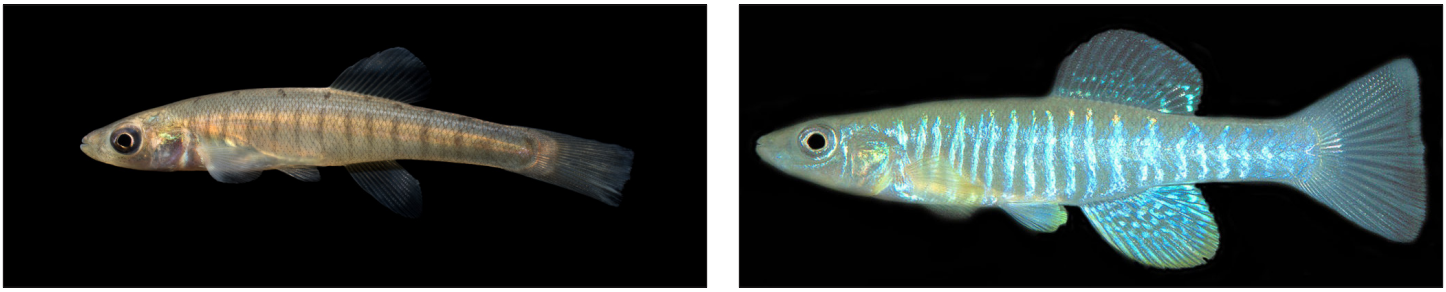

Figure 14. Fundulus sp. "Lake Phelps" Killifish. Left: Juvenile or Female. Right: Male.

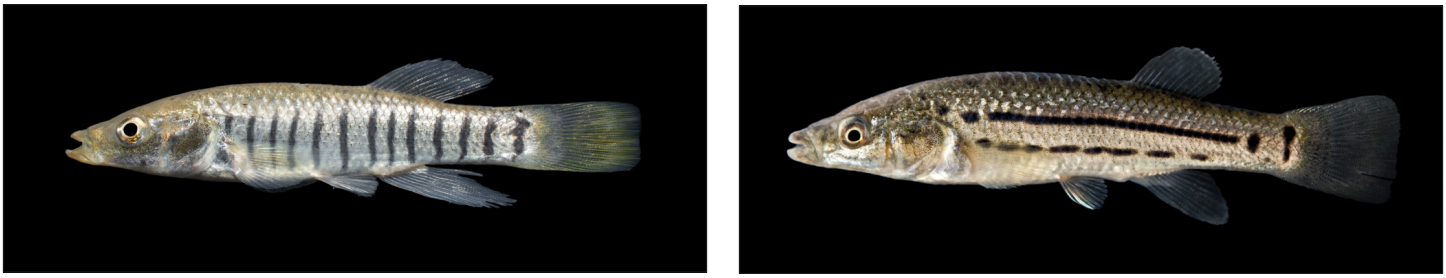

Figure 15. Striped Killifish. Left: Male. Right: Female.

11a Gill rakers 5. Females with normal genital pouch, black spot on the posterior part of the dorsal fin; 14 narrow black bars on sides, and poorly defined longitudinal rows of black dots on the dorsum (Figure 16). Males with about 18 gray bars about same width as spaces and with a gold spot anterior to the dorsal fin and black spots on the dorsum (Figure 16) . . . . . **Marsh Killifish *Fundulus confluentus***

11b Gill rakers 9 or 10. Females with long genital pouch that extends to near tip of anal fin; no black spot on the dorsal fin; plain dorsal, anal, and caudal fins (Figure 17). Males with about 14 narrow white bars that fade anteriorly, blotch sometimes present on last rays of dorsal fin, and with black spot anterior to the dorsal fin (Figure 17). Dorsal, anal, and caudal fins of males often dark with light spots and light margin (Figure 17) . . . . . **Mummichog *Fundulus heteroclitus***

Figure 16. Marsh Killifish. Top: Male. Middle: Female with arrow pointing to the black spot on the posterior part of the dorsal fin. Bottom: Male with gold spot anterior to the dorsal fin.

Figure 17. Mummichog. Top: Male. Middle: Juvenile female. Bottom: Arrow pointing to the black spot anterior to the dorsal fin.

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(Continued on page 28)

Figure 1. Repatriated Longhead Darter captured in late October 2021 from two Ohio River localities: left, from below the New Cumberland Dam in Ohio (photo by Cameron McCune); right, from below the Montgomery Dam in Pennsylvania (photo by Curt Wagner).

OSU Museum as OSUM 121115. A week later, on another sportfish survey conducted jointly between Ohio Division of Wildlife and Pennsylvania Fish and Boat Commission, they captured a second Longhead Darter below the Montgomery Dam on the Ohio River in Pennsylvania 8.3 miles upstream of the Ohio state line (Figure 1).

Despite these guys stealing my thunder and beating me to my predicted find, I still went out on the 9th of November 2021 to look for additional Longhead Darter. Using both boat electrofishing and benthic trawls, I sampled a few miles downstream of the New Cumberland Dam in several areas near Browns Island, but I was unable to repeat their finds. I do plan to make another effort next year (2022) to see if more individuals can be found in the upper Ohio River. Hopefully, the population continues to expand there in the future and, due to our reintroduction efforts, in the upper Muskingum River basin as well. The future of the species in Ohio looks bright.

(Topminnow Diversity in North Carolina, continued from page 26)

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