GEORGIA DOT RESEARCH PROJECT 18-06

FINAL REPORT

REVIEW OF SPECIAL PROVISIONS AND OTHER CONDITIONS PLACED ON GDOT PROJECTS FOR IMPERILED SPECIES PROTECTION

VOLUME IV

Georgia Department of Transportation

OFFICE OF PERFORMANCE-BASED MANAGEMENT AND RESEARCH

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Georgia has numerous protected freshwater species, which means that the Georgia Department of Transportation (GDOT) must frequently consult with federal and state agencies to identify measures to avoid, minimize and mitigate impacts to imperiled aquatic organisms. Some of these measures, such as restrictions on in-water work during the reproductive season, impose substantial costs on GDOT projects, but their efficacy has not been thoroughly evaluated. The current system also provides limited flexibility. The research team have developed a system for assessing the impact of road construction projects on imperiled freshwater species that accounts for project characteristics, site characteristics, and species sensitivity. Called the "Total Effect Score" (TES), it is based on a comprehensive assessment of the tolerances and traits of 111 freshwater species and a thorough review of the literature on the efficacy of construction and post-construction BMPs. It employs a risk-based system to assess construction-phase effects and post-construction effects over a 50-year time horizon, making it possible to identify tradeoffs among alternative management practices. Additionally, the research team developed a template for a programmatic agreement (PA) that uses the TES as the basis for a streamlined system for evaluating projects. The PA is intended to cover both informal and formal consultation under a single system, which should reduce consultation time and increase predictability. To support the adoption of the PA, the research team conducted a biological assessment of all species. Adoption of the PA and the TES system should provide substantial cost savings for GDOT while improving outcomes for federally and state protected freshwater species.

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GDOT Research Project 18-06

Final Report

REVIEW OF SPECIAL PROVISIONS AND OTHER CONDITIONS PLACED ON GDOT PROJECTS FOR IMPERILED AQUATIC SPECIES PROTECTION
VOLUME IV

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Contract with
Georgia Department of Transportation

In cooperation with
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January 2021

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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HOLIDAY DARTER

Species

Holiday Darter, *Etheostoma brevirostrum*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999r): The holiday darter is a small species reaching 58 mm (2.3 in) total length and characterized by an extremely blunt snout and brilliant green and red-orange coloration in breeding males. The sides are marked with 8-10 dark blotches, becoming green bars interspersed with red on breeding males. There are eight dorsal saddles, and the first dorsal fin has a red window anteriorly (not evident in specimen show at bottom of account). In breeding males, the dorsal fins have blue marginal bands and broad red submarginal bands. Males also have a red band on the blue-green anal fin. A dark bar extends below each eye. The holiday darter is a complex of several cryptic species that are currently under investigation. All remarks in this account are pertinent to these new species, but the distribution will undoubtedly change to reflect the existence of several isolated and spatially restricted species deserving protection.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999r): Holiday darters are found in small- to medium-sized streams with relatively steep gradient. They often inhabit clean water with moderate to swift currents but can be found in slower pools and along stream margins where the substrate is composed of gravel, cobble and sand. They often occur in depths of approximately 30 cm (11.8 in). Their diet consists of aquatic invertebrates.

Spawning occurs in the Etowah from April-May at 10-17C. Breeding males follow or chase females in runs and pools adjacent to riffles. Females look for suitable spawning sites on vertical faces of large cobble, bedrock, or other clean and stable substrate, such as large pieces of wood. Once she has found a suitable spot, the female pecks at the spawning location with her mouth, possibly to further clean the area before the egg is attached. The female then positions her body vertically over the substrate and the male mounts her. A single egg is released at each spawn. The egg is given no further acknowledgement by the pair, though the same cobble or substrate may be used repeatedly.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999r): The holiday darter is endemic to the upper Coosa River system of Georgia, Alabama, and southeastern Tennessee. The holiday darter, as currently described, actually represents a species complex made up of as many as five genetically and morphologically distinct forms that merit description as new species. In Alabama, one form of the holiday darter is known from the type locality in Shoal Creek and the Choccolocco Creek systems in Calhoun and Cleburne Counties. In Georgia four different forms of the holiday darter occur. These are in the upper portion of the Conasauga system, the upper Coosawattee system, and the upper Etowah River system. In the Etowah system, two forms occur: one in the upper Etowah River and its direct tributaries, and the other in Amicalola Creek and its tributaries.

Holiday darters can be locally abundant where they occur in the Etowah and Conasauga River systems. Less is known about the status of the Coosawattee population. Cryptic diversity within this species conservatively requires that each of the four forms that occur within Georgia be independently evaluated by managers until further work formally establishing unique species can be completed.

Conservation

The holiday darter currently has a global conservation status ranking of G2, a Georgia state conservation status ranking of S1, and it is currently under no federal protections.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999r): As with the Cherokee darter, potential threats to the holiday darter are habitat loss due to excess silt and sediment runoff, reduced water quality and stream impoundment. The holiday darter is a montane species, and poor riparian management practices, including inadequate implementation of Forestry Best Management Practices (BMPs), pose a significant threat to the species. Sedimentation may also result from failure to control erosion from construction sites and bridge crossings. Holiday darters require clean cobble or other stable substrate for spawning, thus excess sediment could inhibit spawning success. Stream degradation results from increased stormwater runoff from developing urban and industrial areas.

Conserving populations of the holiday darter species complex depends on maintaining or improving habitat quality in streams: eliminating sediment runoff from land disturbing activities, such as roadway and housing construction and logging activities, maintaining forested buffers along stream banks, eliminating inputs of contaminants such as fertilizers and pesticides, and maintaining natural patterns of stream flow. Watershed clearing and urban development can lead to unnaturally flashy stormwater runoff that alters temperature regimes, scours stream channels, and reduces groundwater recharge resulting in lower baseflow conditions. Infiltrating and slowly releasing stormwater runoff from developed areas is an important element in protecting stream habitats for fishes and other aquatic organisms. The holiday darter and other fishes that similarly depend on riffle habitats and clean spawning substrate are especially vulnerable to streamflow depletion because habitats with swift currents that flush fine sediment are diminished at low flows. Impounding streams should be a last resort for developing water supplies in areas where the holiday darter species complex occurs.

Effects of Construction Activities on Holiday Darters

Sediment

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) classified sedimentation as a primary stressor to the holiday darter. Sedimentation is also considered a primary stressor to some other members of the subgenus *Ulocentra/Adonia,* such as *E. chermocki, E. scotti* and *E. tallapoosae* (Hartup 2005, FWS 2019; Hubbell and Banford 2019). Using occupancy models, Anderson et al. (2012) found that this species is sensitive to even small losses of upstream forest cover. Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species, including the closely related *E. scotti*, decreased with increasing turbidity and bedded sediments. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of several closely related species, categorizing three as moderate (*E. duryi, E. flavum, E. ramseyi*) and one as intolerant (*E. coosae*).

As a benthic invertivore, the holiday darter is likely indirectly and adversely affected by sediment via a reduction of macroinvertebrate abundance. Because the holiday darter attaches its eggs to the sides of large cobble/bedrock or wood and may clean the surface beforehand, the eggs are likely less vulnerable to the potential adverse effects of a sedimentation event. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration, common among darters (Seehausen et al. 1997; Burkhead and Jelks 2001).

Based on the work by Anderson et al., the research team categorizes the overall sediment sensitivity of the holiday darter as intolerant (1).

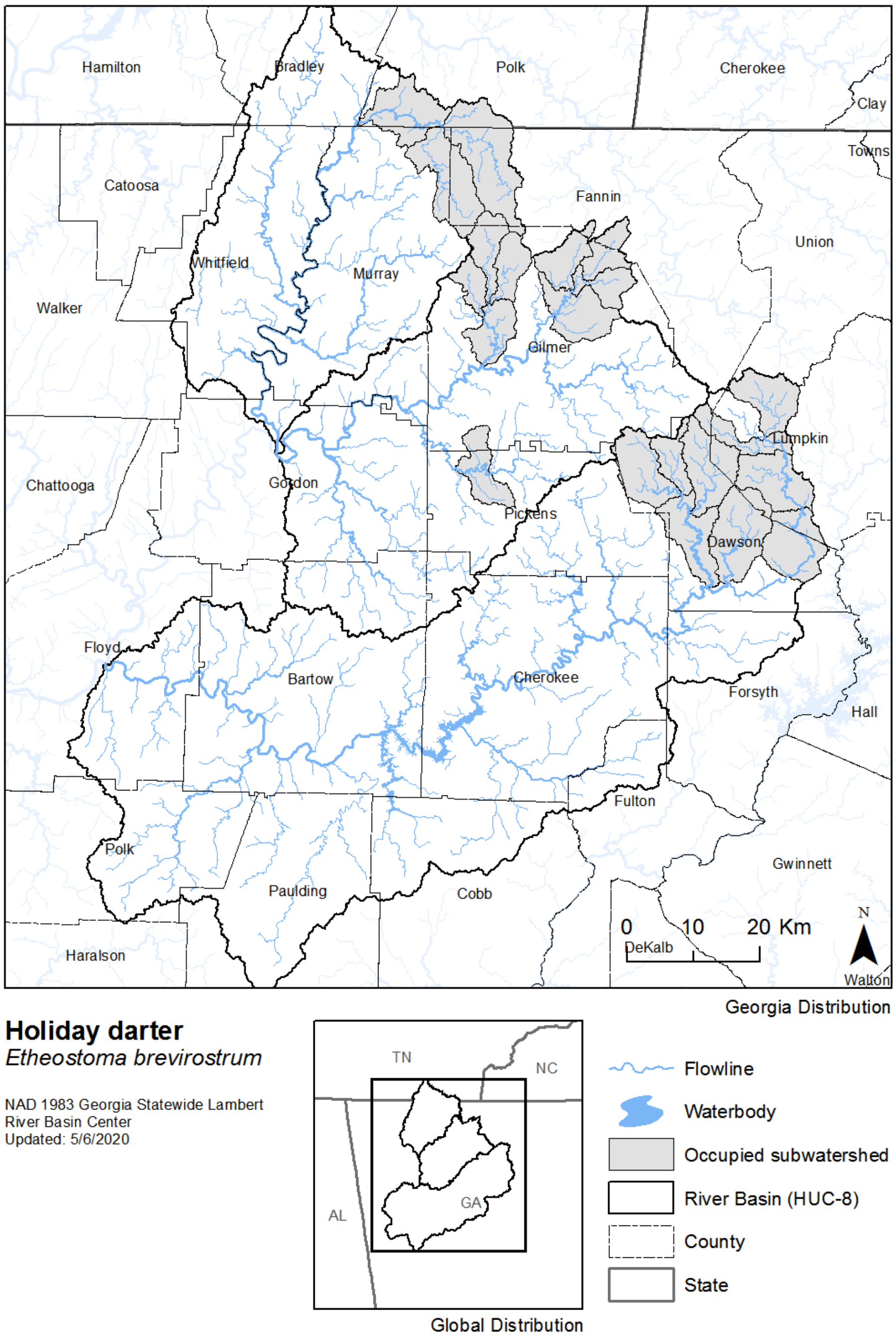
Pollutants

In an analysis conducted in support of the Etowah Habitat Conservation Plan, Wenger and Freeman (2007) classified pollutants from impervious surfaces as a primary stressor to the holiday darter. Pollutants are also considered a primary stressor to some other members of the subgenus *Ulocentra/Adonia,* such as *E. chermocki* and *E. scotti* (Hartup 2005; Wenger and Freeman 2007; FWS 2019). Wenger and Freeman (2008) found that abundance of *E. scotti* decreased with increasing imperviousness, although Wenger et al. (2008) found no relationship between imperviousness and occurrence. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of several closely related species, categorizing all four as moderate (*E. coosae, E. duryi, E. flavum, E. ramseyi*).

The holiday darter is a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. Because it attaches its eggs to the sides of large cobble/bedrock or wood, those eggs are less likely to come into direct contact with sediment-bound pollutants during development.

Reflecting a mixture of evidence on life history traits and related species, the overall pollutant sensitivity of the holiday darter is categorized as somewhat intolerant (3).

Figure 1. Map. Range map for the holiday darter.



LAKE STURGEON

Species

Lake Sturgeon, *Acipenser fulvescens*

Description

Lake sturgeon are large (males average ~115cm; females average ~140cm) and long-lived (up to 150 years) with an elongate body, five rows of bony plates (i.e. scutes), a spiracle, a highly protrusible mouth without teeth, and a heterocercal tail (Mettee et al. 1996, USFWS 2018c). Their snout is pointed, though not as pronounced as some similar species, and they have four barbels suspended from the snout (Mettee et al. 1996). Mettee et al. (1996) provide specific diagnostic characters: "Body stout; dorsal plates 9 to 17, averaging 13; lateral plates 29 to 42, averaging 35. Postdorsal and preanal shields in single row. Dorsal rays 35 to 40; anal rays 25 to 30; caudal fin without an elongate filament. Width of mouth about two-thirds interorbital distance. Gill rakers 25 to 40, averaging 33, short and blunt."

Life History

Reproduced from the U.S. Fish and Wildlife Service recent 90-day finding on the petition to list the species under the ESA (USFWS 2018c): Males typically reach sexual maturity about 14-16 years of age and about 45 inches in length and females at 2-26 years of age and about 55 inches in length, depending on the region.

Lake sturgeon is a periodic spawner, with males spawning every other year or one to three years while females may spawn once every four to six year. Some lake sturgeon are known to make long spring migrations, exceeding 300 miles to spawn while others make shorter, more localized migrations. Lake sturgeon spawn in clear rivers below natural falls, rapids, tailraces below dams if migration is blocked, or other areas where current is swift with coarse gravel, cobble, boulder and sand substrates. In lakes, rocky shoals and shorelines may be utilized for spawning habitat. Spawning usually occurs from April through June depending on the region and is dependent on water temperature and flows. Spawning lake sturgeon congregate in groups in shallow water where multiple spawning events occur over a period of hours until the female expends all her eggs. Females have a high fecundity and may produce 50,000-885,000 eggs, depositing eggs in batches over multiple spawning events.

The early life stages of lake sturgeon are very sensitive and vulnerable to anthropogenic factors. Eggs are adhesive and are deposited in rocky areas where water current keeps the eggs oxygenated and free of silt. Sturgeon spawn at temperatures ranging from 8℃ and 21℃, with eggs hatching within 5-8 days before hatch. Larvae tend to hide in rocky crevices during the day and drift in the upper 1.3 feet of the water column at night to suitable nursery habitat. Lake sturgeon yolk-sac larvae typically drift down river from approximately 7-16 miles, but can drift down river upwards of 38 miles. Larvae and young lake sturgeon feed on minute crustaceans until 7-8 inches length. Their diet shifts as larger juveniles and adult lake sturgeon prey on benthic organisms such as crayfish, mollusks, leeches, insect larvae like midges and small fish including round goby and sculpin.

Numbers, Reproduction, Distribution

The expansive range of the lake sturgeon extends throughout most of the Mississippi River, Great Lakes, St. Lawrence River, and Hudson Bay drainages; including 19 states and Canadian provinces (Bruch et al. 2016). Relative to historic estimates, the species' abundance is now extremely low, but the current trend in abundance appears to be positive (Bruch et al. 2016).

A disjunct population of the lake sturgeon occurred in the upper Coosa River system within Georgia, but the last report of an individual was in 1980 with the species later considered extirpated (Freeman et al. 2005). Using Wisconsin brood stock, the Georgia Dept. of Natural Resources began a lake sturgeon stocking program in 2002 and have since released more than 300,000 fingerlings into the Etowah, Coosawattee, and Oostanaula Rivers (GADNR 2020). A mark-recapture study from 2004 to 2007 estimated total abundance of juveniles in 2006 at 789 individuals (Bezold and Peterson 2008). Adult males have been observed attempting to spawn in the larger tributaries of the Coosa River basin, but gravid females have not yet been reported (GADNR 2020). An estimate of the population in the Upper Coosa basin is not available, but abundance is expected to increase as the stocking program continues.

Conservation

The lake sturgeon has a global conservation ranking status of G3G4 and a Georgia state conservation ranking status of S3. In 2018 the species was petitioned for listing under the ESA and the U.S. Fish and Wildlife Service is currently conducting a review to determine if listing is warranted.

In a study examining anthropogenic stressors to lake sturgeon, Haxton and Findlay (2009) cited the presence and operation of dams as the primary threat to the species. Specifically, the presence and operation of dams results in fragmentation of populations and habitat, altered flow regimes, degraded or lost habitat, and mortality due to entrainment of individuals (Bruch et al. 2016). Other substantial threats to the species across its range include: pollutants from municipal, commercial, agricultural, and industrial sources; lampricides; sedimentation of habitat; excessive recreational harvest; invasive species; and climate change (Bruch et al. 2016, CBD 2018).

Effects of Construction Activities

Sediment

The research team knows of no lab or field studies investigating the effects of sediment on the lake sturgeon or its closely related species.

Sedimentation of habitat may reduce diversity and abundance of lake sturgeon prey, but this effect is likely moderated by the variety of its prey (i.e. a generalist and opportunist feeder) and by its use of olfaction and electroreception for foraging. As a species that relies on coarse spawning substrate, with a preference for cobble/boulder, lake sturgeon reproduction may be sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. However, this effect is likely reduced by its selection of spawning habitat in areas of swift current, which flushes away fine sediments.

The sediment sensitivity of the lake sturgeon is categorized as moderate (2).

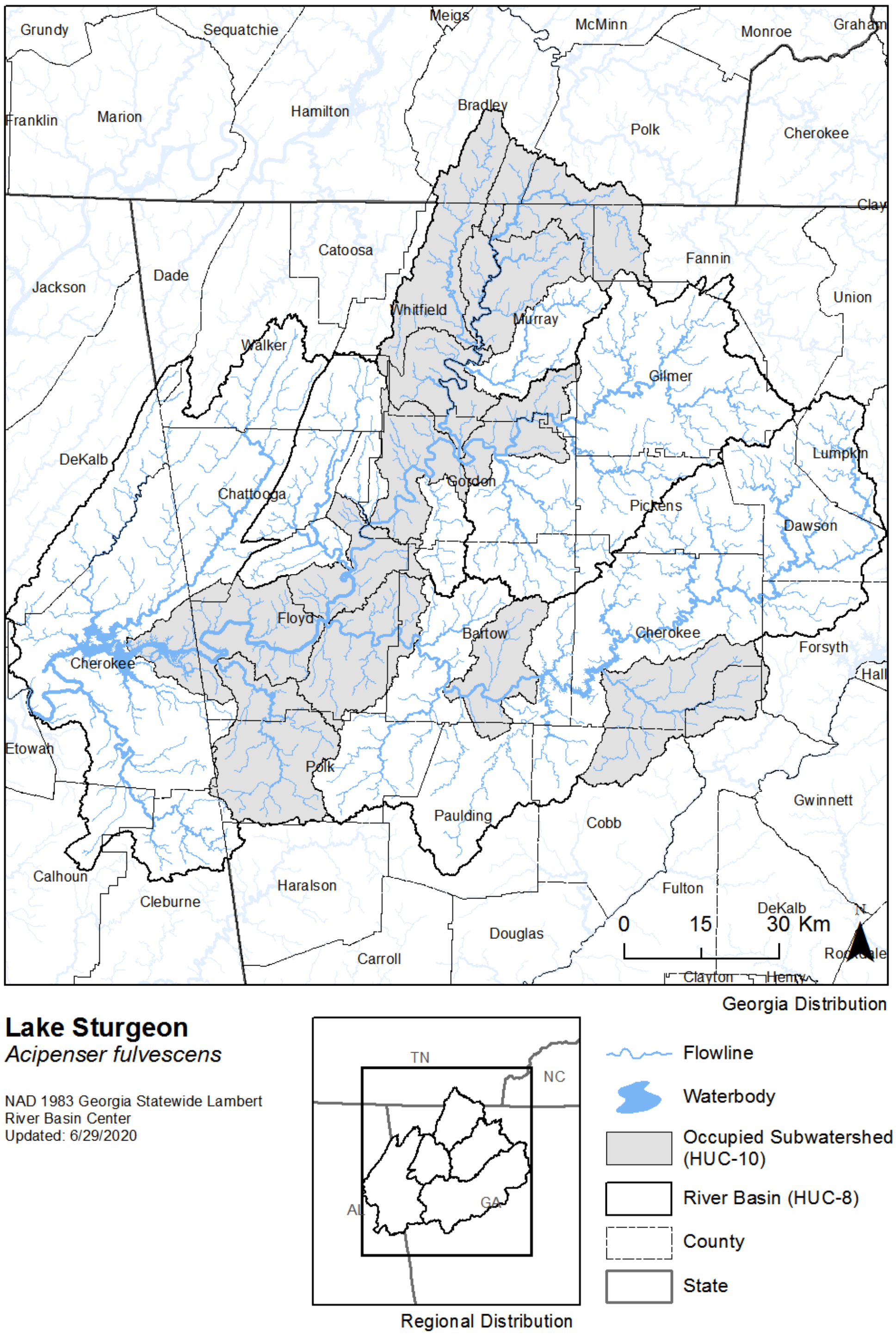
Pollutants

In an assessment of early life stage contaminant sensitivity of 17 fishes, Dwyer et al. (2005) found that the two tested sturgeon species, *A. oxyrinchus oxyrinchus* and the sister-species *A. brevirostrum*, were overall most sensitive to acute exposures of the five compounds (i.e. fungicide, detergent, molluscicide, and insecticides). In a study examining the toxicity of forest industry effluents, Bennett and Farrell (1998) concluded that early life stages of the congener *A. transmontanus* were more sensitive to most of the tested compounds than many other tested fish species.

As a benthic generalist feeder, the lake sturgeon is likely to accumulate pollutants both from prey organisms (that have direct contact with sediments) and from incidental ingestion of sediment. As a long-lived species (up to 150 years) with relatively high body fat, it is likely to accumulate a greater body burden of pollutants over its lifetime, which may reduce growth and reproduction. Because the lake sturgeon spawns in areas with coarse substrate, developing embryos are less likely exposed to sediment-bound pollutants.

Based on the comparative toxicological work by Dwyer et al. on related species, the pollutant sensitivity of the lake sturgeon is categorized as very intolerant (2).

Figure 2. Map. Range map for the lake sturgeon.



LINED CHUB

Species

Lined Chub, *Hybopsis lineapunctata*

Description

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008b):

The lined chub has a prominent snout overhanging an inferior mouth (a mouth that opens on the underside of the head). Adults reach about 85 mm (3⅜ inch) in total length. It *often* has a pair of maxillary barbels in the corner of the mouth that may be difficult to see without magnification. Its dark lateral stripe ends in a distinct caudal spot and is bordered above by a pale white area that is most discernible on the rear half of the body. The upper half of the body is yellow to golden and the belly is silvery-white. There are no reported differences in coloration between females and males.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008b): Very little is known about the life history of the lined chub. Spawning occurs minimally between May and June, but examination of gonads suggests that it may start as early as March. The lined chub is usually found in pools in small and medium-sized streams and near the shoreline in sections of rivers with moderate current. It is commonly collected over sandy substrates. The lined chub is an opportunistic invertivore. Both terrestrial (e.g., spiders, beetles, true bugs) and aquatic (e.g., midges, mayflies, caddisflies) invertebrates have been documented in gut content studies

While the spawning mode of the lined chub is unknown, Frimpong and Angermeier (2013) classify the closely related Hybopis amblops as a lithophilic spawner which utilizes gravel substrates to lay eggs. Spawning in Hybopsis spp. most likely involves releasing demersal eggs into the water column on gravel or cobble substrates and leaving eggs to sink to the bottom (Tarver and Stallsmith, 2019).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008b): The lined chub is endemic to both the Coosa and Tallapoosa river systems (Alabama River drainage) within the states of Alabama, Georgia, and Tennessee. Most of the Coosa River system records in Georgia are from the Ridge and Valley physiographic province.

Analysis of collection records in the upper Coosa River system suggests that many populations of the lined chub have already been lost. Remaining populations are limited in number and isolated by long distances. Based upon trends in Georgia, the lined chub is considered to be vulnerable to imperilment. There are many recent records of the lined chub within the upper Tallapoosa River system, where this species is apparently stable. However, many ichthyologists have recognized differences between the populations in the Tallapoosa and Coosa Rivers, elevating the importance of protecting populations in the Coosa system.

The lined chub is extirpated from areas in the upper Coosa River system in Georgia (Boschung and Mayden 2004). Despite uncertainty over general trends in the past 10 years, it is likely that lined chub numbers are relatively stable or slowly declining (NatureServe 2020).

Conservation

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008b): The current global conservation ranking status of the lined chub is G3/G4. The state conservation ranking status is S2. They are not under US federal protection. This species is protected as Rare in the state of Georgia.

Conserving populations of the lined chub will require general watershed-level conservation and restoration practices. Incentive programs to help farmers implement best-management practices could improve instream habitat by decreasing sediment, nutrient, and chemical runoff and increasing riparian forest cover. Conservation groups should work cooperatively with developers and local governments to minimize the impacts from new home construction and commercial development. Additional water withdrawals and impoundments should be minimized by promoting water conservation practices and augmenting existing water storage whenever possible.

Effects of Construction Activities

Sediment

In a study that looked at six streams in the Tallapoosa river basin, Alabama, the lined chub was not detected in any of the four agriculture dominated watersheds, but was detected in two watersheds where the pre-dominant land use was forestry/silviculture (Saalfeld et al. 2012). The authors identified sedimentation from agricultural activities as the primary driver behind lower relative abundance of invertivores and lithophilic spawners (such as the lined chub) compared to omnivorous and generalist species.

Since the lined chub is an opportunistic invertivore preying on both aquatic and terrestrial macroinvertebrates, it is likely to be indirectly and adversely affected by sedimentation via a reduction in abundance of the aquatic portion of their prey base. As a likely gravel/cobble spawner, lined chub reproduction is likely sensitive to sediments because of the need for clean substrate both initially and for the duration of embryonic development.
Based on the effects documented by Saalfeld et al. (2012), the sediment sensitivity of the lined chub is categorized as intolerant (1).

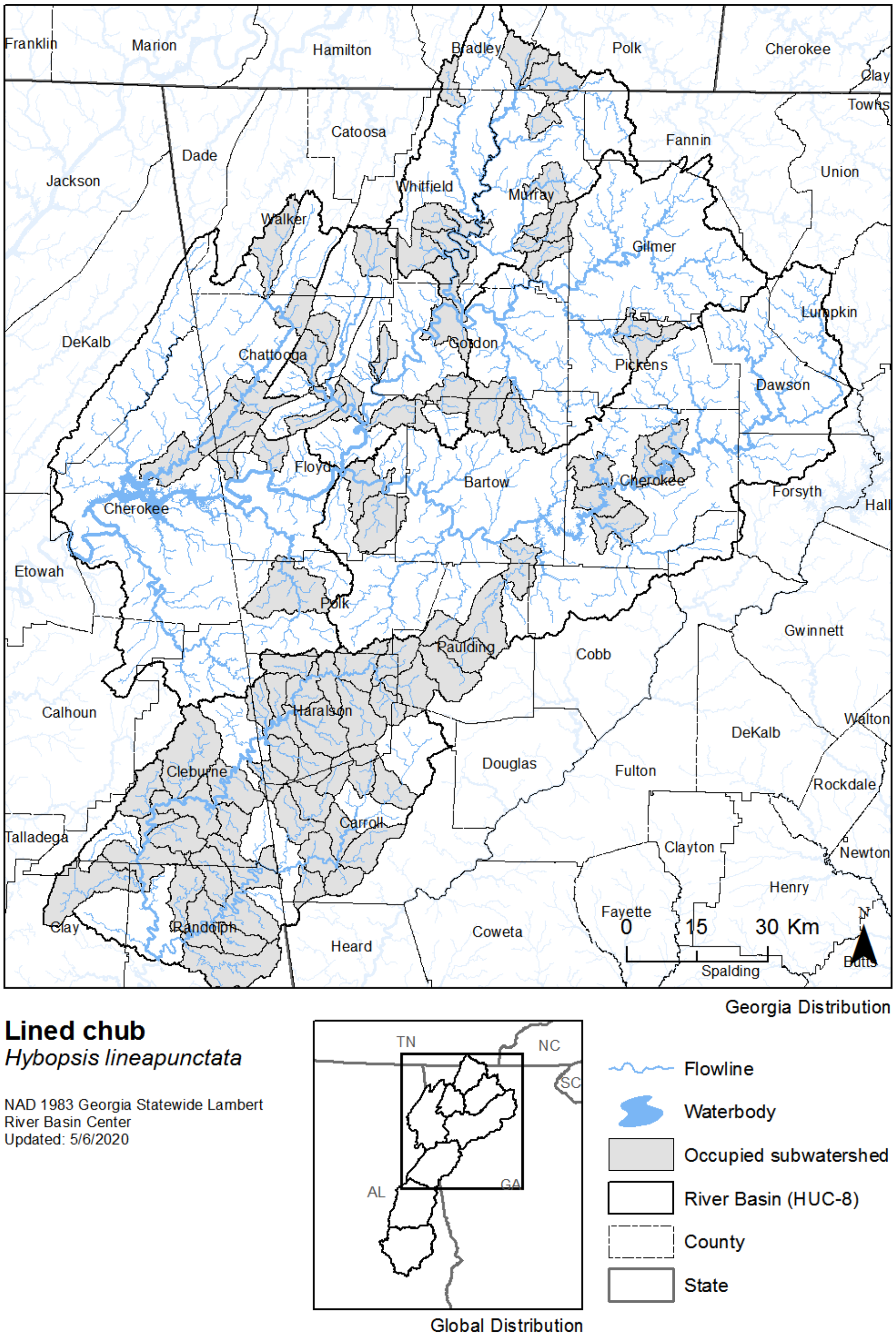
Pollutants

While the research team knows of no laboratory or field investigations that directly tested the sediment sensitivity of the lined chub, some work has been done on a closely related species. the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant) was converted, which yielded a classification of moderate for *H. amblops*.

Because the lined chub likely uses coarse substrate free of fine sediments, its embryos are unlikely to come into direct contact with sediment-associated pollutants. Since the lined chub is an opportunistic invertivore, it may experience higher exposure to pollutants bio-magnified through lower trophic levels.

Based on the limited and mixed information relating to life history traits, the lined chub pollutant sensitivity is categorized as moderate (4).

Figure 3. Map. Range map for the lined chub.



LIPSTICK DARTER

Species

Lipstick Darter, *Etheostoma chuckwachatte*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The lipstick darter is a small laterally compressed fish reaching a maximum length of about 60 mm standard length (2.4 in), with 8-9 square blotches on its back and 5-6 indistinct vertical bars located posteriorly along the sides. Adult males are distinguished by red-orange lips, large red-orange spots along the sides, and orange and blue-green coloration on the anal fin. On breeding males, the first dorsal fin is dusky and edged in orange, and the second dorsal fin has orange submarginal and blue marginal bands. The sides of females are brown and mottled and may be marked with faint vertical bars. Females may also have a thin red marginal band on the first dorsal fin and faint turquoise coloration on the breast.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Lipstick darters inhabit riffles with swift currents in larger streams and rivers, where they commonly forage in and around gravel and cobble substrata. They feed on aquatic larvae picked from riverweed and rock surfaces. At low or moderate flow conditions, lipstick darters occur most abundantly in shallow riffles 12-36 cm deep (5-14 in), with fast currents (>36 cm/s) and cover provided by riverweed, cobbles or rock ledges. Their laterally compressed shape allows this small darter to maneuver and forage among rocks and crevices even in very swift currents.

Their diet consists of aquatic insect larvae picked from riverweed and rock surfaces.
Lipstick darters spawn in riffles from April through June. Small young of year have also been collected in late summer, which suggests that the spawning season may extend later in the year than reported above. They bury their eggs in sand and small gravel between riffle cobbles. Young of year first appear in June. Length-frequency data indicate a lifespan of 2-3 years.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): The lipstick darter is endemic to the Tallapoosa River system above the Fall Line in Alabama and Georgia. Although the species commonly occurs in the main channel of the Tallapoosa River and its larger tributaries, the lipstick darter has not been found in the Little Tallapoosa River system. As a result, the species has a relatively restricted distribution in Georgia where it is limited to the upper portion of the Tallapoosa River main channel and a few tributary streams.
A recent study documented 25 (30% of surveyed sites) collections of the lipstick darter between 1991 and 2002 in the Georgia portion of the Tallapoosa River system, with most collections being from the mainstem Tallapoosa River and larger tributary streams. This same study found

no evidence for decline when comparing 22 sites that were sampled with similar methods in 1990 and 2002.

The total adult population size of the lipstick darter is unknown, but it is regarded as common (Page and Burr 2011). The short-term trend of the species population shows a decline of less than 30% to relatively stable, and a long-term trend shows a decline of 30 to 50% (NatureServe 2019). Sampling of 22 sites in Georgia between 1990 and 2002 produced no evidence of decline (Freeman et al. 2004).

Conservation

The lipstick dater has a current global conservation status ranking of G3, a Georgia state ranking of S2, and it is not currently under any federal protections. Little information on population status for this species has been reported, but it appears to be stable within its limited range (NatureServe 2019). This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Impoundments, particularly Harris Reservoir in Alabama, eliminate or alter the flow regime of approximately 40% of the lipstick darter's native range. Populations persist upstream and downstream of Harris Reservoir and in larger tributary streams. Construction of additional impoundments on the Tallapoosa River upstream from Harris Dam would further fragment populations in the main channel of the upper Tallapoosa River and would likely isolate populations in newly cut off tributaries. The occurrence of lipstick darters is positively associated with forest cover, suggesting vulnerability to future land use change associated with the westward expansion of metropolitan Atlanta. Finally, this species is vulnerable to impacts from sedimentation associated with land clearing and failure to follow best management practices. Excessive sediment deposition in riffles reduces habitat quality by filling in the spaces where lipstick darters forage, spawn, and find refuge during high flows.

Conserving species unique to the Tallapoosa River system, such as the lipstick darter, depends on maintaining and improving flowing-water habitats and water quality in the river and its tributaries. It is essential to eliminate sediment runoff from land-disturbing activities such as roadway and housing construction as well as inputs of contaminants such as fertilizers and pesticides. Forested buffers should be maintained or restored along the banks of the river and the smaller tributary streams that feed the river. Maintaining natural streamflow patterns by preventing excessive water withdrawal or unnaturally flashy runoff (such as from urban stormwater runoff) is also an essential element of protecting riverine habitat quality in the free-flowing and unregulated portions of the Tallapoosa River system. The lipstick darter and other fishes that similarly depend on riffle and run habitats are especially vulnerable to prolonged streamflow depletion, because habitats with swift currents are diminished at low flows.

Effects of Construction Activities

Sediment

There are no studies investigating the effects of sediment on the lipstick darter, but some data are available on its closely related species in the subgenus *Nothonotus*. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of two closely related species (*E. acuticeps, E. jordani*) as moderate. Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species including two closely related species (*E. etowahae, E. jordani*), decreased with increasing turbidity and bedded sediments.

As a benthic invertivore, the lipstick darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that spawns in a combination of sand and gravel, lipstick darter reproduction is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration common among darters (Seehausen et al. 1997; Burkhead and Jelks 2001).

Based on the sensitivity of its spawning habitat, the overall sediment sensitivity of the lipstick darter is categorized as intolerant (1).

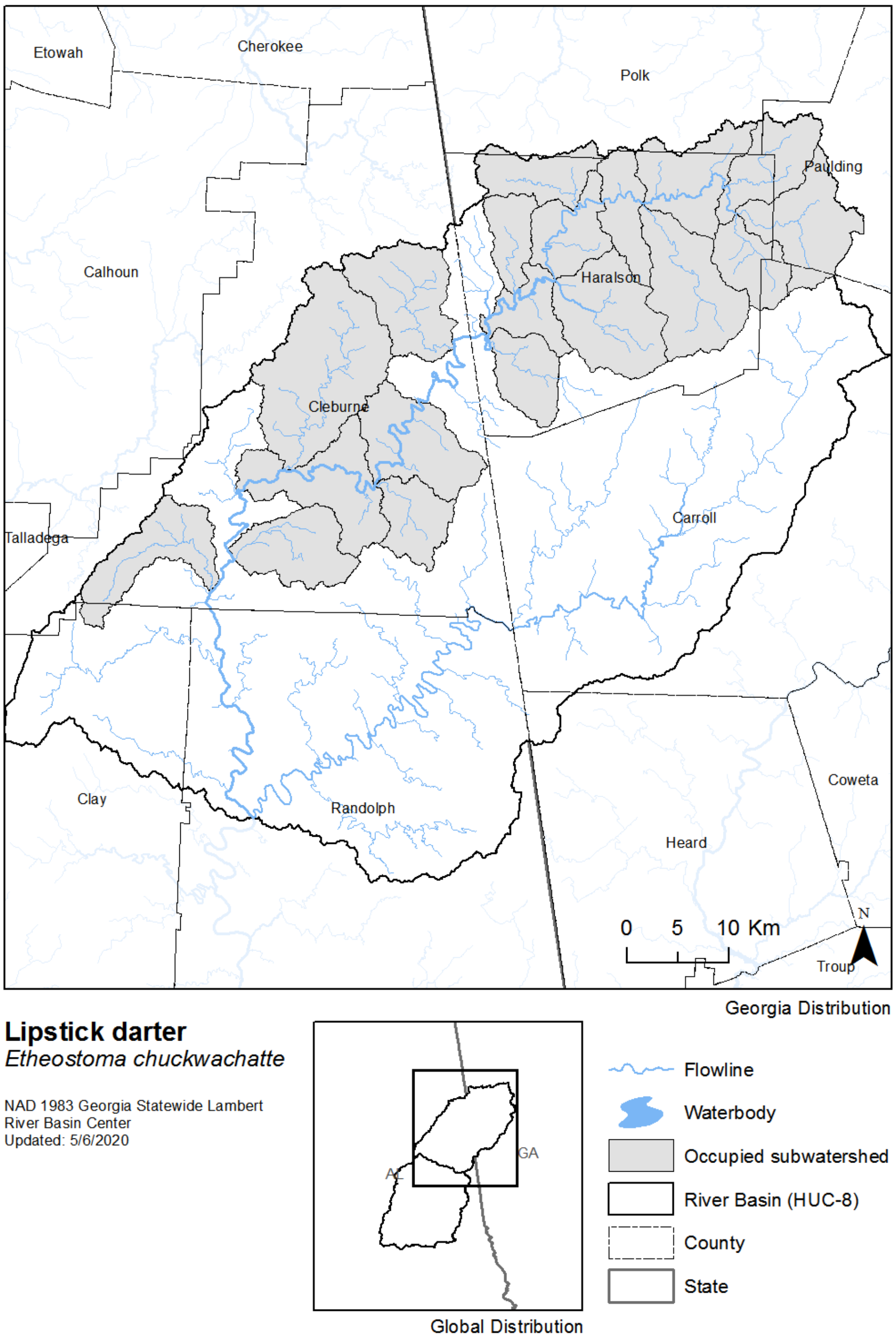
Pollutants

There are no studies investigating the effects of pollutants on the lipstick darter, but some data are available on its closely related species in the subgenus *Nothonotus*. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of two closely related species (*E. acuticeps, E. jordani*) as moderate. Onorato et al. (2000) found that relative abundance of *E. jordani* declined in response to urbanization of the Upper Cahaba watershed. Wenger et al. (2008) modeled the occurrence of the closely related *E. etowahae* and found it to be highly sensitive to watershed imperviousness.

The lipstick darter is a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. As a species that spawns in a combination of sand and gravel, greenfin darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Because its life history traits suggest a degree of sensitivity, the overall pollutant sensitivity of the lipstick darter is categorized as somewhat intolerant (3).

Figure 4. Map. Range map for the lipstick darter.



MOUNTAIN MADTOM

Species

Mountain Madtom, *Noturus eleutherus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): This species is a small, slender catfish attaining a maximum total length of around 85 mm (3.3 in). It is usually mottled dorsally with a wide pale margin on the adipose fin, which is fused to the body as in other madtoms but nearly free from the caudal fin. Fins and sides are mottled brownish-yellow, and three light-brown dorsal saddles may be present. The pectoral spines are slightly curved and have small anterior serrae (teeth) and large, sharp, posterior serrae.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

This species inhabits large creeks to medium-sized rivers and is found in greatest numbers at gravel shoals. It is not known from impoundments.

Their diet consists of larvae of aquatic insects such as mayflies, caddisflies, and stoneflies. Feeding occurs primarily at night.

Spawning occurs in June and July, and egg clutches are deposited in cavities underneath flat rocks in gravel and cobble bottomed pools. The eggs are then guarded by males. The mountain madtom lives about 4 years and may be sexually mature after 1 year.

In a study on the fishes in rivers of eastern Tennessee, Starnes and Starnes (1985) reported observing a mountain madtom nest on clean-swept fine gravel under a rock of diameter ~20cm. They suggest that mountain madtom is one of the few species in the genus *Noturus* whose preferred primary habitat is fast-flowing riffle. Their study also found peak abundances of mountain madtom were associated with "clean-swept, gravel-rubble riffles" with heavy Podostemum growth.

Number, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

East of the Mississippi River, the mountain madtom's range includes the Ohio, Cumberland, and Tennessee drainages. West of the Mississippi, it can be found in Missouri, Arkansas, and Oklahoma. In Georgia, this species is only known from South Chickamauga Creek in Catoosa County.

The entire range of the mountain madtom in Georgia is restricted to the main channel of South Chickamauga Creek, a large direct tributary to the Tennessee River that originates in Catoosa and Walker counties and flows northward into Hamilton County, Tennessee. There have only been two specimens of the mountain madtom captured in the Georgia section of South Chickamauga Creek since 1980, but in 2006 a single specimen was captured approximately 12 miles downstream of the Georgia/Tennessee border.

Mountain madtoms exhibit relatively low fecundity, a high degree of parental care, and a lifespan of around 4-5 years (Starnes and Starnes 1985).

Conservation

The mountain madtom currently has a global conservation ranking status of G4 and a Georgia state conservation ranking status of S1. It is currently under no federal protections. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):
Degraded habitat and water quality in the South Chickamauga Creek watershed are the primary threats to the mountain madtom. Stream degradation results from failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas. Fishes such as the mountain madtom that depend upon clean gravel and cobble substrates are eliminated from habitats destroyed by excessive sedimentation.

Conserving populations of the mountain madtom depends on maintaining habitat quality in South Chickamauga Creek and its tributaries, and ultimately on improving habitat and water quality in degraded streams. It is essential to control sediment from land-disturbance activities, such as roadway and housing construction, and to minimize the input of contaminants such as fertilizers and pesticides from agricultural fields and residential properties. Vegetated buffers should be maintained or restored along the banks of all streams in the South Chickamauga Creek system. Protecting water quality in this ecologically valuable stream system also depends on maintaining natural patterns of streamflow by preventing excessive water withdrawal and by controlling stormwater runoff from urban and suburban areas.

Effects of Construction Activities

Sediment

Based on expert opinion, Jester et al. (1992) classified the mountain madtom as intolerant (on a four-point scale) to degradation of habitat, as opposed to degradation of water quality. However, in more recent quantitative work, Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of mountain madtom as moderate. Sedimentation was identified as a primary stressor for the closely related N. munitus and other imperiled species of the Etowah River by Wenger and Freeman (2007).

As a species that requires clean coarse substrate for spawning, the mountain madtom is likely sensitive to sedimentation by degradation of spawning habitat; however, because males guard embryos, they may also maintain nests free of additional sedimentation. Because aquatic insects form a large part of its diet, the mountain madtom is likely to be indirectly and adversely affected by sediment via a reduction of macroinvertebrate diversity and abundance.

Although sensitivity classifications to date have been inconsistent, there is sufficient evidence to categorize the sediment sensitivity of the mountain madtom as intolerant (1).

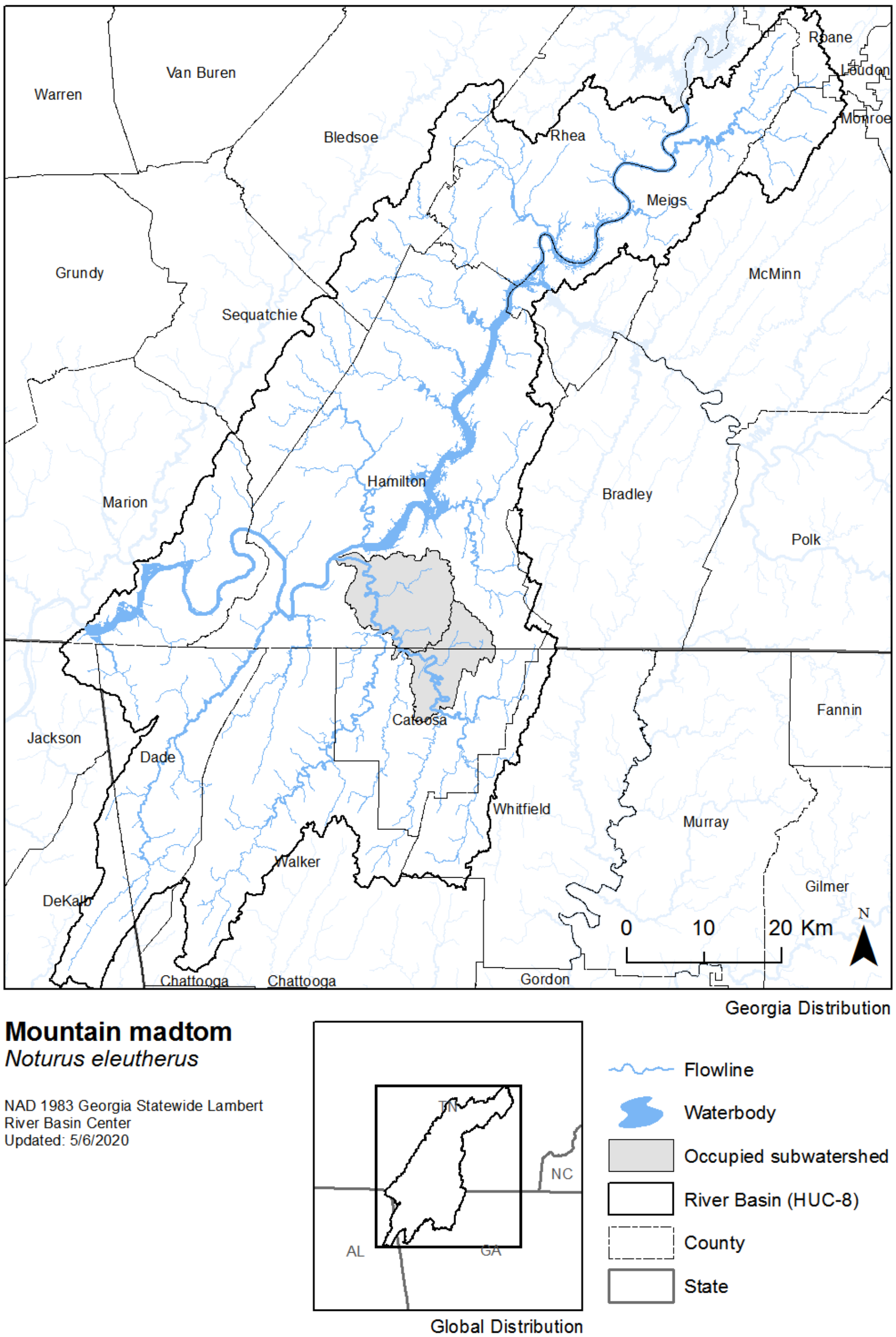
Pollutants

Based on expert opinion, Jester et al. (1992) classified the mountain madtom as intolerant (the least tolerant on a four-point scale) to degradation of water quality, as opposed to degradation of habitat. Stormwater from impervious surfaces was identified as a primary stressor for the closely related *Noturus sp. cf. munitus* (Coosa madtom) and other imperiled species of the Etowah River by Wenger and Freeman (2007). In a study examining the legacy effects of lead and zinc mining activities on freshwater biota in the Spring River system (Kansas, Oklahoma, Missouri), reduced densities of the closely related *N. placidus* were explained by elevated ion concentrations (Wildhaber et al. 2000). The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of moderate for *N. miurus*.

As a benthic invertivore, the mountain madtom is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey come into direct contact with sediment-bound pollutants. Because they spawn in coarse substrate, incubating embryos are unlikely to come into direct contact with pollutants associated with fine sediments.

Based on the work of Jester et al., the pollutant sensitivity of the mountain madtom is categorized as very intolerant (2).

Figure 5. Map. Range map for the mountain madtom.



MUSCADINE DARTER

Species

Muscadine Darter, *Percina smithvanizi*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

A slender darter reaching up to 75 mm (3 in) in total length, the muscadine darter is marked with 8-11 black, rounded blotches on the sides that merge into a lateral stripe and an off-center black blotch at the base of the caudal fin. The upper sides and dorsum are pale brown with irregular darker brown markings, contrasting with the pale venter. The brown to black lateral stripe continues as a stripe through each eye and onto the snout. The first dorsal fin is narrowly edged in black and has a black basal band. The lateral line is complete, but pored scales typically do not extend onto the caudal fin. Gill membranes are narrowly joined or separate.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The muscadine darter inhabits larger streams such as the mainstem Tallapoosa and Little Tallapoosa Rivers, as well as smaller tributary streams (e.g., Walker Creek, Beach Creek, etc.). Preferred habitats within these streams include riffle and flowing pool areas, in moderate to swift currents over sand, gravel and cobble substrates.

Their diet consists of aquatic invertebrates.

Aging by scales indicates a life span of two to three years, with reproduction beginning at age 1. Unlike many darters that forage almost exclusively on benthic prey, these darters forage on the stream bottom and also hover above the bottom, capturing animals drifting in the current.

Muscadine darter spawning occurs between late March and July, when water temperatures range 12-15 °C (54-59 °F; Freeman et al. 1999). However, other reproductive characteristics are unknown for muscadine darters. Their spawning habitat may be similar to that of P. kusha, the most closely related species, which is thought to spawn in sandy areas and to bury eggs (Williams et al. 2007).

Number, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The muscadine darter occurs in the Tallapoosa River system above the Fall Line in Alabama and Georgia and occupies both mainstem and tributary streams.

Although the global range of the muscadine darter is restricted to the Tallapoosa River system upstream of the Fall Line, it is relatively widespread within this range. A recent study documented 33 (40% of surveyed sites) and 11 (55% of surveyed sites) collections between 1991 and 2002 in the Georgia portion of the Tallapoosa and Little Tallapoosa systems, respectively.

The muscadine darter is common in undisturbed portions of the Tallapoosa River above the fall line, but it is not found in disturbed streams or reservoirs in its historic range (Williams et al. 2007).

Conservation

The muscadine darter currently has a global conservation ranking status of G3, a Georgia state conservation ranking status of S3, and it is currently under no federal protection. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

A recent study found that the occurrence of muscadine darters is strongly and positively associated with the percentage of forest cover in the watershed, suggesting vulnerability to future land use change associated with the expansion of metropolitan Atlanta.

Conserving populations of the muscadine darter depends on maintaining and improving stream habitat quality by eliminating sediment runoff from land-disturbing activities (such as roadway and housing construction), maintaining and restoring forested buffers along stream banks, eliminating inputs of contaminants (such as fertilizers and pesticides), and maintaining natural patterns of stream flow. Watershed clearing and urban development can lead to unnaturally flashy stormwater runoff, which scours stream channels and results in lower baseflows. For these reasons, promoting natural infiltration of stormwater runoff from developed areas is an important element in protecting stream habitats for fishes and other aquatic organisms. Impounding streams should be a last resort for developing water supplies.

Effects of Construction Activities

Sediment

There are no studies investigating the effects of sediment on the muscadine darter, but some work has been done to evaluate its closely related species within the subgenus Hadropterus. Wenger and Freeman (2007) identified sedimentation as a primary stressor to *P. kusha* and other imperiled species of the Etowah River. Walters et al. (2003) found that relative richness and relative abundance of two closely related species, *P. kusha* and *P. palmaris,* decreased as turbidity and bedded sediments increased. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of two closely related species, categorizing both as moderate (*P. nigrofasciata, P. sciera*).

As a benthic invertivore, the muscadine darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance; however, because it is known to feed on insects from drift, this effect should be reduced. As a species that likely spawns in sand, muscadine darter reproduction is likely not sensitive to the initial presence of fine sediment, but still sensitive to smothering of eggs/larvae by subsequent sedimentation events.

Because of the mix of trait-based evidence, the overall sediment sensitivity of the muscadine darter is categorized as moderate (2).

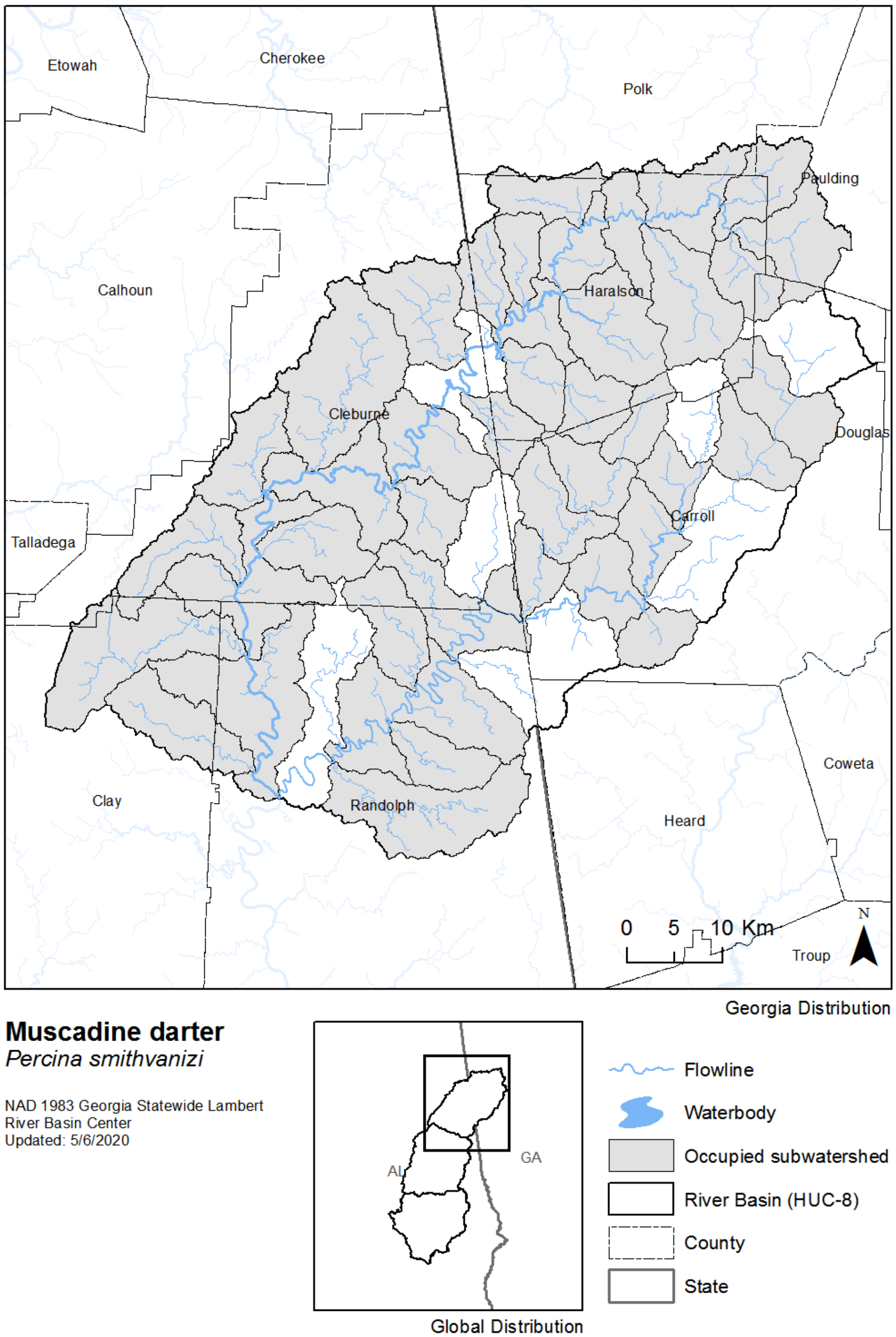
Pollutants

There are no studies investigating the effects of construction- or roadway-derived pollutants on the muscadine darter, and evidence on closely related species within the subgenus Hadropterus is mixed. Wenger and Freeman (2007) identified stormwater pollutants as a primary stressor to *P. kusha* and other imperiled species of the Etowah River. Kollaus et al. (2015) found a significant decrease in *P. apristis* abundance following urbanization of the surrounding watershed. Schweizer and Matlack (2005) found *P. nigrofasciata* to be 'excluded' from streams heavily influenced by urbanization and sedimentation, relative to a nearby undisturbed stream. In contrast, Johnston and Maceina (2009) found that relative abundance of *P. nigrofasciata* increased as urbanization of the Little Uchee creek increased from 8-13%. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of two closely related species, categorizing both as moderate (*P. nigrofasciata, P. sciera*).

Because the muscadine darter feeds on invertebrates both in drift and in the benthos, it may be indirectly affected by the effects of pollutants on its prey base. As a species that may spawn in sand, muscadine darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Based on little direct information but traits that suggest a degree of sensitivity, the overall pollutant sensitivity of the muscadine darter is categorized as somewhat intolerant (3).

Figure 6. Map. Range map for the muscadine darter.



NORTHERN STUDFISH

Species

Northern Studfish, *Fundulus catenatus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

Northern studfish generally has silvery to brown body coloration, with scattered horizontal brown dash marks forming lines on the sides. Fins lack coloration and the mouth is upturned. Breeding males are extremely colorful, having bright blue coloration along the sides with horizontal red lines. These males develop orange spots and lime-gold coloration on the head. Anal and caudal fins have yellow-orange margins, and all fins except for the caudal have tubercles on the fin rays. The northern studfish is one of the largest killifishes, with total body length that may reach up to 180 mm (7 in.).

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

Northern studfish are usually located along the edges of small to medium-sized streams with minimal to moderate current velocity, often occurring in sluggish margins and pools. Juveniles feed mostly at the water surface, preying on fallen organisms and emergent aquatic insects. Adults eat a variety of organisms mostly from the substrate at the bottom including snails, fingernail clams, aquatic insect larvae and even crayfish. Main feeding times are in the morning and late afternoon. Larger adults will school in groups of about 30 and feed together. Topminnows and studfish (*Fundulus* spp.) that occur in streams are often found along sluggish margins and are well adapted to swimming just below the water surface. The northern studfish is aggressive, and males are territorial during the breeding season, which occurs from April through July. Preferred spawning habitat is calm water over shallow gravel patches with eggs being laid on gravel; there is one report of spawning in the saucer-shaped nest of a male sunfish. This species may live for 5 years or longer.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

The northern studfish occurs west of the Mississippi River in the lower Ohio River basin and streams draining the Ozark and Ouachita mountains, and east of the Mississippi in the Tennessee, Cumberland, and Green river drainages. Isolated populations occur in Indiana and Mississippi. Georgia populations occur in South Chickamauga Creek watershed (Tennessee River drainage), primarily in the Lookout and West Chickamauga Creek systems.

The northern studfish has only been documented from two small watersheds (HUC 10s) in northwest Georgia. It has been observed at several sites within both of these watersheds during the last 10 years.

The northern studfish is common in most of its range. Exact trends in population are unknown but the total population is presumed to be very large. Despite uncertainty over general trends in the past 10 years, it is likely that northern studfish numbers are relatively stable across its range (NatureServe 2020).

Conservation

The global conservation ranking status of the northern studfish is G5 and the Georgia state conservation ranking status is S2. It is currently under no US federal protections. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

The northern studfish has a very small range within Georgia, making it vulnerable to extirpation from the state. Stream degradation results from failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas. Fishes like the northern studfish that depend upon clean gravel substrates on which to lay their eggs are especially vulnerable to impacts of excessive sedimentation, as these spawning sites will fill in with silt and sediment.

Conserving populations of the northern studfish and other rare fishes in the Chickamauga Creek system depends on maintaining habitat quality in the creek and its tributaries, and ultimately on improving habitat and water quality in degraded streams. It is essential to eliminate sediment runoff from land-disturbing activities (such as roadway and housing construction) and inputs of contaminants (such as fertilizers and pesticides). Forested buffers should be maintained along the banks of rivers and all of their tributaries. In addition, there are many technical assistance and cost-sharing program that can help farmers implement best management practices, such as restricting cattle access to streams. Maintaining natural streamflow patterns by preventing excessive water withdrawal or unnaturally flashy runoff (such as from urban storm water runoff) also is an essential element of protecting riverine habitat quality.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the northern studfish tolerance to suspended sediment as moderate; they also evaluated the suspended sediment tolerance of the closely related *F. stellifer* as intolerant. In the Osage River Basin, Missouri, the northern studfish was detected only in 4% of the sampled range and only in streams whose beds contained 1-4% fine sediments (Turner and Rabeni 2009).

As a species that spawns over gravel, northern studfish reproduction is likely sensitive to the degradation of spawning habitat by the initial presence of fine sediments as well as the direct smothering of eggs/larvae by subsequent sedimentation events. As an invertivore, the northern studfish is likely indirectly affected by suspended and bedded sediments via a reduction of macroinvertebrate abundance.

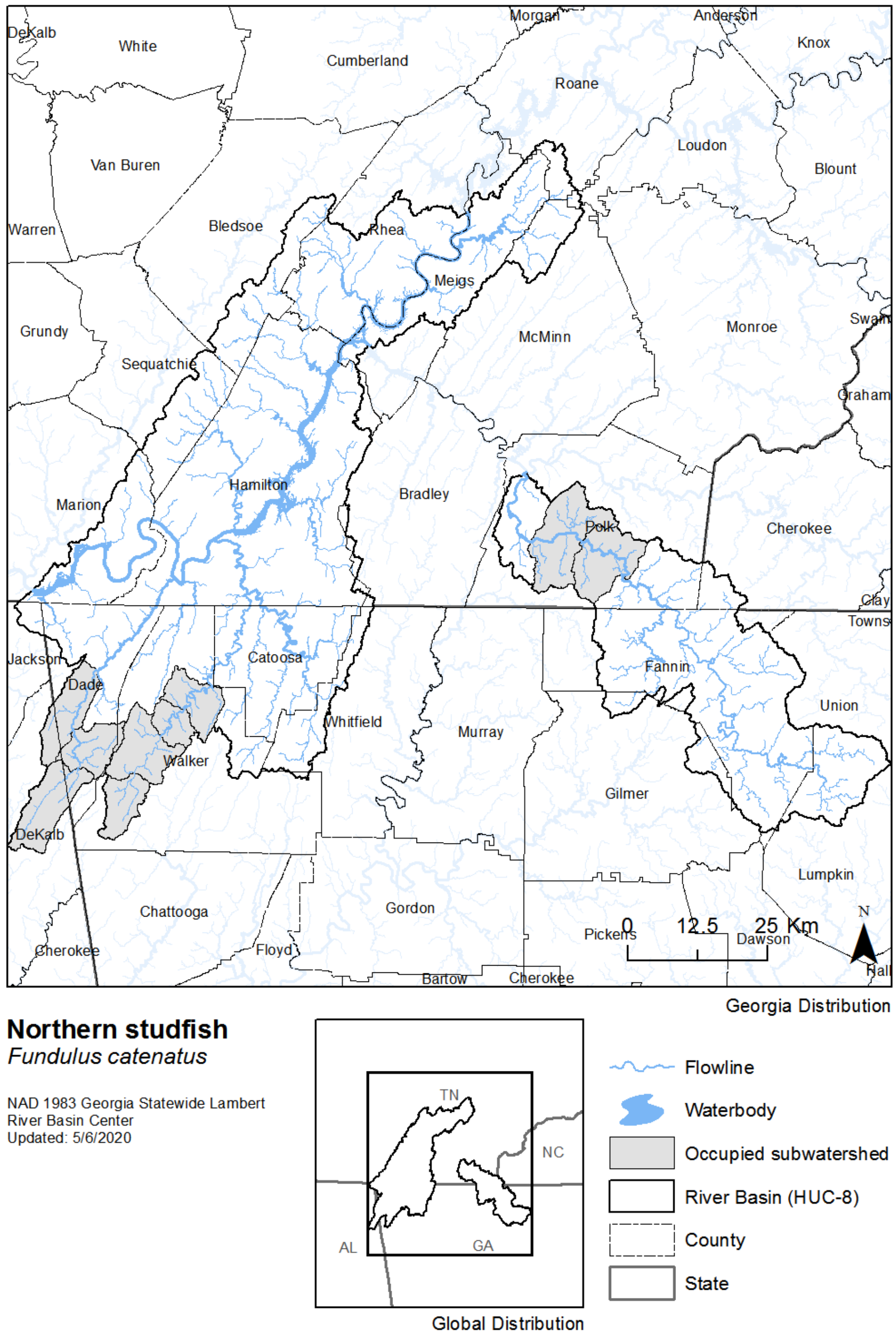
Based on the findings of Turner and Rabeni, the research team follows Meador and Carlisle in categorizing the sediment sensitivity of the northern studfish as intolerant (1).

Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the tolerance of the northern studfish to specific conductivity as moderate; they also classified the closely related *F. stellifer* as moderate.

As an invertivore, the northern studfish is likely to be indirectly affected by pollutants that biomagnify from its prey base. Incubating embryos may come into contact with sediment-associated pollutants; however, because of the low surface area of their preferred spawning gravels to which pollutants may bind, the exposure to those pollutants is likely low. therefore, per Meador and Carlisle, the northern studfish pollutant sensitivity is categorized as moderate (4).

Figure 7. Map. Range map for the Northern studfish.



OHIO LAMPREY

Species

Ohio Lamprey, *Ichthyomyzon bdellium*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman and Albanese 1999b):

Lampreys are elongated, cylindrical, primitive fishes that lack true jaws, paired fins, and anal fins. Larval lampreys or ammocoetes differ trenchantly from adults: they lack functional eyes, have a hood of loose skin around the mouth as opposed to a round sucking disc (i.e., the oral disc), and are passive filter-feeders on detritus, micro-organisms, and algae.

Transformation from the larval to adult stage differs among species. Some species transform into parasitic adults that feed on host fishes for an extended period before spawning, while non-parasitic species transform directly into a non-feeding and reproductive adult. The Ohio lamprey is a parasitic species that reaches about 305 mm (12 in) in total length. The single dorsal fin may be slightly to deeply notched but is never divided. Ohio lampreys are gray to olive in color dorsally, light ventrally, and have sensory pores that are marked by small dark spots. The number of muscle bands (myomeres) between the last gill pore and the cloaca ranges 55-62 (usually 56-

58). The teeth are well developed on the posterior field of the oral disc. The width of the oral disc is wider than the body and divides into total length about 14-16 times.

Life History

Larval Ohio lampreys live in soft, silty substrates rich in organic materials (Barnes et al. 1993, Freeman and Albanese 1999b). They filter feed on bacteria, detritus, decaying algae, and protozoans. After four years they undergo metamorphosis to the parasitic adult stage, characterized by the development of an oral disc and teeth to be used in attachment to and feeding on the skin, blood and fluids of host fish. When not attached to fish, adult Ohio lampreys are found around rocks or other cover in small upland rivers and streams. Adults will feed on a wide range of host fishes for almost two years, before making a short spawning migration into small tributaries. Spawning occurs in late spring or early summer in riffles with gravel/cobble substrate over a pit-like nest (Barnes et al. 1993, Freeman and Albanese 1999b).

Numbers, Reproduction, Distribution

The range of the Ohio lamprey extends throughout the Ohio River Basin from Georgia and Alabama to New York. Within Georgia, it has only been reported from fewer than 10 collections, all of them in the Chickamauga Creek watershed. Population size and trends, short- or long-term, are unknown (Freeman and Albanese 1999b).

Conservation

The global conservation ranking of the Ohio lamprey is G3/G4, its Georgia state conservation ranking is S1, and it is not under US federal protection. This species is protected as Rare in the state of Georgia.

Because of their habitat requirements and life history characteristics, Ohio lampreys are vulnerable to a number of anthropogenic impacts to their habitat (Freeman and Albanese 1999b). They require clean coarse substrate for spawning, so are susceptible to land-use changes that may result in increased sediment inputs. They make limited spawning migrations, so are susceptible to stream alterations that block passage of adults. They are also susceptible to pollutants from nearby urbanized areas (metals and hydrocarbons) and agricultural lands (nutrients and herbicides/pesticides) (Freeman and Albanese 1999b, Maitland et al. 2015).

Freeman and Albanese (1999b) recommend that conservation actions should aim to improve spawning habitat and overall water quality. This may be done by reducing sediment inputs from agricultural and construction activities, by restoration of riparian buffers, and by management of industrial or stormwater runoff to reduce pollutant inputs (Freeman and Albanese 1999b).

Effects of Construction Activities

Sediment

Maitland et al. (2015) identified siltation of habitat as a primary threat to the Ohio lamprey. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the Ohio lamprey tolerance to suspended sediment as moderate. They also evaluated the suspended sediment tolerance of some closely related species (Lang et al. 2009; Potter et al. 2015), categorizing all five as moderate (*I. greeleyi, I. castaneus, I. gagei, I. unicuspis, I. fossor*).

The prey base of the Ohio lamprey (bacteria, detritus, decaying algae, protozoans) is unlikely to be affected by sedimentation. However, as a species that requires clean gravel/cobble for spawning, Ohio lamprey reproduction is likely sensitive to sedimentation by both degradation of habitat and direct smothering of developing embryos. As a semelparous species, Ohio lamprey reproduction may be less resilient to the adverse effects of a sedimentation event.
Based on the high sensitivity of its spawning habitat, the overall sediment sensitivity of the Ohio lamprey is categorized as intolerant (1).

Pollutants

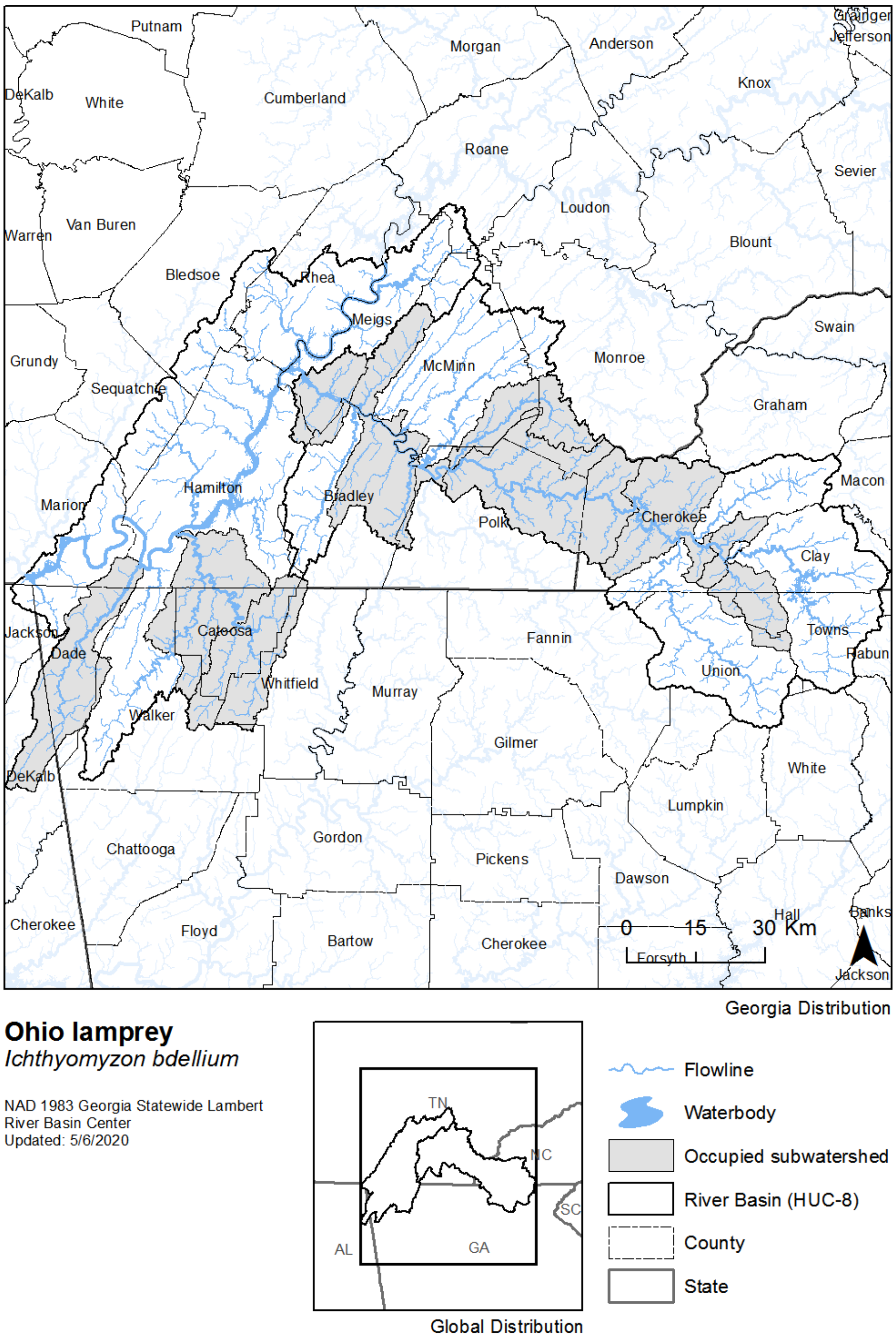
Maitland et al. (2015) identified pollutants as a primary threat to the Ohio lamprey, although Meador and Carlisle (2007; Meador unpublished data 2020) categorized the Ohio lamprey tolerance to conductivity as moderate. Meador and Carlisle also evaluated the conductivity tolerance of some closely related species, categorizing two as tolerant (*I. unicuspis, I. fossor*), one as moderate (*I. castaneus*), and two as intolerant (*I. greeleyi, I. gagei*). Relative to a nearby undisturbed stream, Schweizer and Matlack (2005) found the closely related *I. gagei* to be 'excluded' from streams partially and heavily influenced by urbanization (though the authors focused on the sedimentation effects of urbanization rather than pollutants).

Because Ohio lamprey use gravel/cobble substrate for spawning, incubating embryos are unlikely to come into direct contact with fine sediments that are often associated with pollutants.

Larval Ohio lamprey likely carry a lower body burden of pollutants since they feed at a low trophic level, but adult parasitic lamprey may experience higher dietary exposure to pollutants.

Because the available evidence is mixed, the pollutant sensitivity of the Ohio lamprey is categorized as moderate (4).

Figure 8. Map. Range map for the Ohio lamprey.



OLIVE DARTER

Species

Olive Darter, *Percina squamata*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

The olive darter is a large olive-colored darter that reaches a maximum total length in excess of 13 cm (5.1 in) and is characterized by an exceptionally pointed snout. Young fish are marked with dark blotches along the sides and on the dorsum, but these marking become less distinct with age. All ages have a small, distinct spot at the base of the caudal fin. The only noticeable bright color on this darter is an orange band in the first dorsal fin. Their sharply pointed snout and overall drab coloration of this species makes it difficult to confuse with any co-occurring darter species.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

Because its typical swift-water habitat makes sampling and underwater observations difficult, there is very little known about the life history and behavior of the olive darter. Reproductive condition of adults and the timing of young-of-year recruitment indicate a May-July spawning season. Length frequency histograms from a Tennessee population include four different size groups, suggesting a lifespan of at least four years. Growth is relatively rapid, with young of year exceeding 50 mm during their first year.

The olive darter inhabits deep, swift, rocky habitats of high elevation rivers, where the fish forages in very fast current around boulders.

Their diet consists of benthic aquatic insects, including caddisflies and mayflies.

Spawning behavior and spawning habitat of the olive darter are unknown, but its reproductive biology may be similar to that of the closely related slenderhead darter (*P. phoxocephala*), which is known to spawn in swift gravel riffles (Page 1983, Etnier and Starnes 1993).

Number, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

The olive darter is restricted to the upper-most portions of the Tennessee River and Cumberland River systems in Tennessee, Kentucky, North Carolina, and Georgia. In Georgia, this species is only known from the Toccoa and Little Tennessee River systems. Almost all of Georgia's records are from the mainstem Toccoa River upstream of Lake Blue Ridge, but there a few records known from the lower reaches of larger tributary streams (e.g., Coopers Creek). The olive darter is known from the Little Tennessee River in North Carolina and was collected in Betty's Creek (GA) during 2011.

Twenty-nine randomly selected sites, located upstream and downstream of Lake Blue Ridge on the mainstem Toccoa River, were surveyed by snorkeling during summer 2008. Twenty percent of these sites, along with all olive darter historic sites within Coopers Creek and Wilscot Creek, were also surveyed by electrofishing in 2011. A single olive darter was observed in Betty's Creek during this sampling. While this species may be very difficult to collect and observe, the results of this survey suggest that the olive darter is very rare and vulnerable to extirpation from Georgia.

An estimate of the total adult population size of the olive darter is unavailable, but is presumably at least several thousand individuals (NatureServe 2020). The distribution and abundance are likely still declining, but the rate of decline over the past ten years is uncertain (NatureServe 2020).

Conservation

The current global conservation ranking status of the olive darter is G3, a Georgia state conservation ranking status of S1, and it is not under any US federal protections. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

The olive darter depends on good water quality and fast-water habitats in upland streams. Impoundments have reduced available habitat for the olive darter and remaining free-flowing mountain streams are vulnerable to degradation by excessive inputs of silt and sediment. Stream degradation results from failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas. Increasing development of houses utilizing poor construction and riparian management practices poses a significant threat to the olive darter in the Toccoa River system. In addition, hemlock wooly adelgid is a significant threat to riparian zone habitats in this region.

Conserving populations of the olive darter will require maintaining and improving habitat quality in the Toccoa River by eliminating sediment runoff from land-disturbing activities such as roadway and housing construction, maintaining forested buffers along stream banks, eliminating inputs of contaminants such as fertilizers and pesticides, and maintaining natural patterns of streamflow. There are many opportunities to enhance and widen riparian zone habitats by *planting native trees and shrubs* along creeks and streams. The Georgia Forestry Commission provides information on treatment options for hemlock wooly adelgid. Finally, ongoing monitoring efforts should be continued for this species.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of the olive darter as intolerant. Meador and Carlisle also evaluated the tolerance of two closely related species, categorizing one as tolerant (*P. phoxocephala*) and one as intolerant (*P. oxyrhynchus*).

As a benthic invertivore, the olive darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that may spawns over gravel in riffles, olive darter reproduction is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae.

Therefore, per Meador and Carlisle. the overall sediment sensitivity of the olive darter is categorized as intolerant (1).

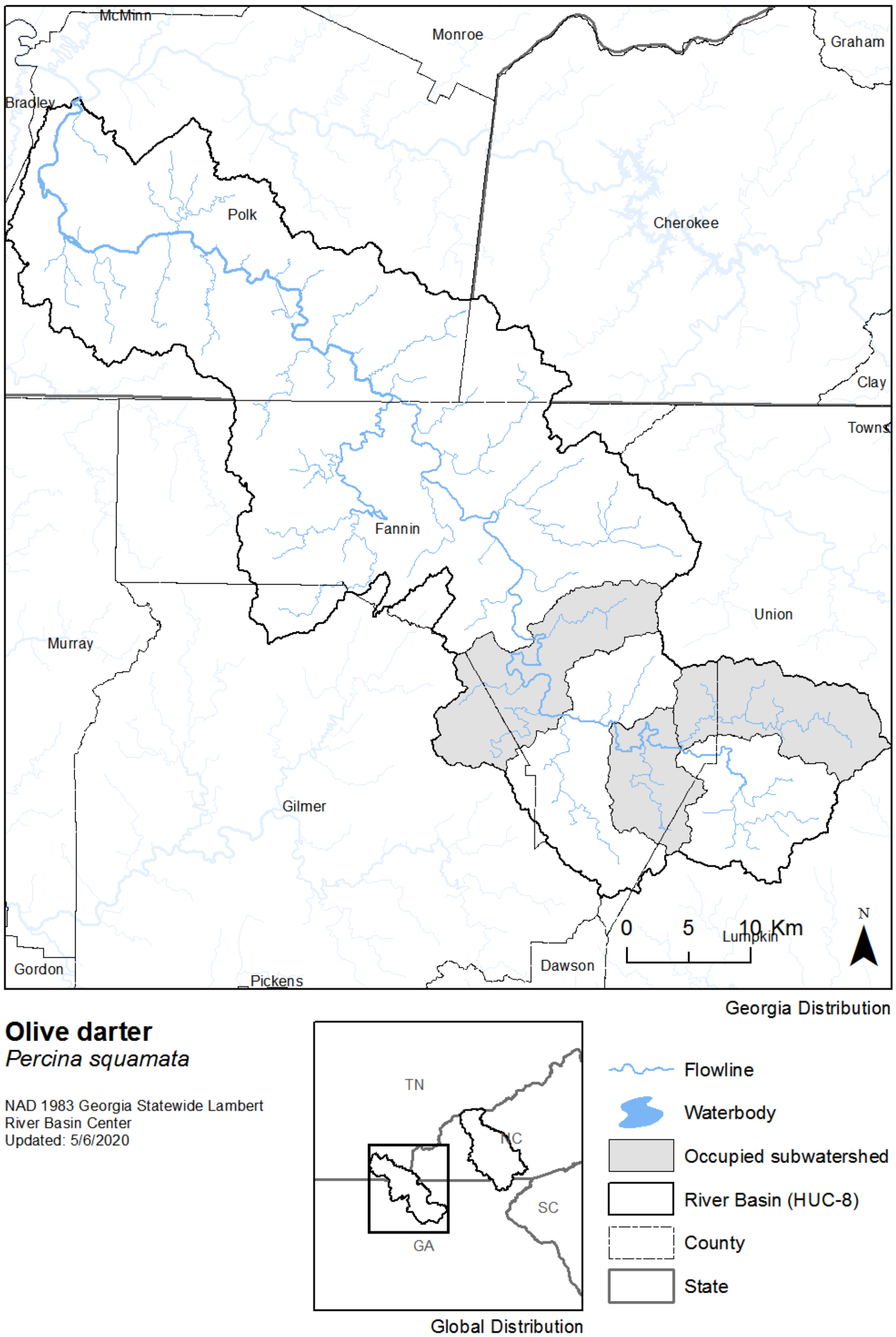
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) classified the specific conductivity tolerance of the olive darter as intolerant. Meador and Carlisle also evaluated the tolerance of two closely related species, categorizing one as tolerant (*P. phoxocephala*) and one as intolerant (*P. oxyrhynchus*).

The olive darter is a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. As a species that may spawn in gravel, olive darter eggs/larvae may be exposed to roadway pollutants that are bound to bedded sediments, although these particles have fewer associated pollutants due to their lower surface area per volume.

Based on the previous classification by Meador and Carlisle as well as the traits-based evidence, the pollutant sensitivity of the olive darter is categorized as very intolerant (2).

Figure 9. Map. Range map for the olive darter.



POPEYE SHINER

Species

Popeye Shiner, *Notropis ariommus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999d):

The popeye shiner is silver with very large eyes, a slightly pointed snout, and a large terminal mouth. The eyes are more than 1.5 times the length of the snout. There have 9 anal rays (8-10), a 2-4-4-2 pharyngeal tooth count formula, and a dorsal fin that is positioned directly over the beginning (i.e., the origin) of the pelvic fins. In breeding males, the rays of the dorsal and caudal fins are distinctly outlined in black. The popeye shiner is a medium-sized minnow attaining a maximum total length of approximately 90 mm (3.5 in).

Life History

Little is known about the biology of this species. In Tennessee, the occurrence of tubercles in males suggested a spawning season from early April through late June (Etnier and Starnes 1993).

While the spawning mode of the popeye shiner is unknown, the closely related N. telescopus is considered a broadcast spawner (Holmes et al. 2010) and the popeye shiner may be the same. Stomach contents of specimens examined by Etnier and Starnes (1993) contained a variety of adult and larval insects, including terrestrial prey. The large eye is indicative of sight feeding behavior (Freeman et al. 1999d). Popeye shiners occur in clear warmwater streams of moderate size (i.e., large streams and small rivers), often in flowing pools and in association with small gravel, moderate depths and currents (Etnier and Starnes 1993, Freeman et al. 1999d).

Number, Reproduction, Distribution

The popeye shiner occurs patchily throughout the Ohio River Basin. It is generally considered rare and has apparently been extirpated from many locations (Etnier and Starnes 1993). The species has not been detected in Georgia in recent years: it is known from one collection in Lookout Creek (1959) and from several collections in the South Chickamauga Creek system, although the last confirmed record from this location was in 1993 (Freeman et al. 1999d). Total adult population size is unknown, but distribution and abundance may be slowly declining (NatureServe 2020).

Conservation

Popeye shiners have a global conservation ranking status of G3, a Georgia state conservation ranking status of S1, and are currently not under federal protection. This species is listed as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999d): Conservation of populations of popeye shiners in Georgia will depend upon maintaining habitat quality in the South Chickamauga Creek system. Streams in this area of Georgia are very susceptible to modification. The West Chickamauga Creek system is currently extremely silted due to poor land-use practices and has lost several species of fishes. It is essential to eliminate sediment runoff from land-disturbing activities (such as roadway and housing construction) and inputs of contaminants (such as fertilizers and pesticides). Forested buffers should be maintained and restored along the banks of the mainstem and the smaller tributary streams. Maintaining natural streamflow patterns by preventing excessive water withdrawal or unnaturally flashy runoff (such as from urban storm water runoff) is another essential element of protecting stream habitat quality. The popeye shiner and other fishes that similarly depend on clean gravel habitats and moderate currents are especially vulnerable to streamflow depletion, because habitats with swift currents are diminished at low flows.

Effects of Construction Activities

Sediment

Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described the popeye shiner as "highly sensitive" to sedimentation. However, using more recent quantitative data from a wider geographic area, Meador and Carlisle (2007; Meador unpublished data 2020) categorized the popeye shiner's tolerance to suspended sediment as moderate. They also categorized the suspended sediment tolerance of the closely related *N. telescopus* as moderate.

As insectivorous sight feeders, popeye shiners are likely adversely affected by sedimentation and turbidity via impaired foraging ability, resulting from a reduction of visual acuity, and reduced abundance of the aquatic portion of their prey base (See Section XX). Assuming the popeye shiner is a broadcast spawner as mentioned above, its reproduction is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae.

Although the evidence is mixed, the disappearance of the species from Chickamauga Creek suggests sensitivity, therefore the popeye shiner is categorized as intolerant (1).

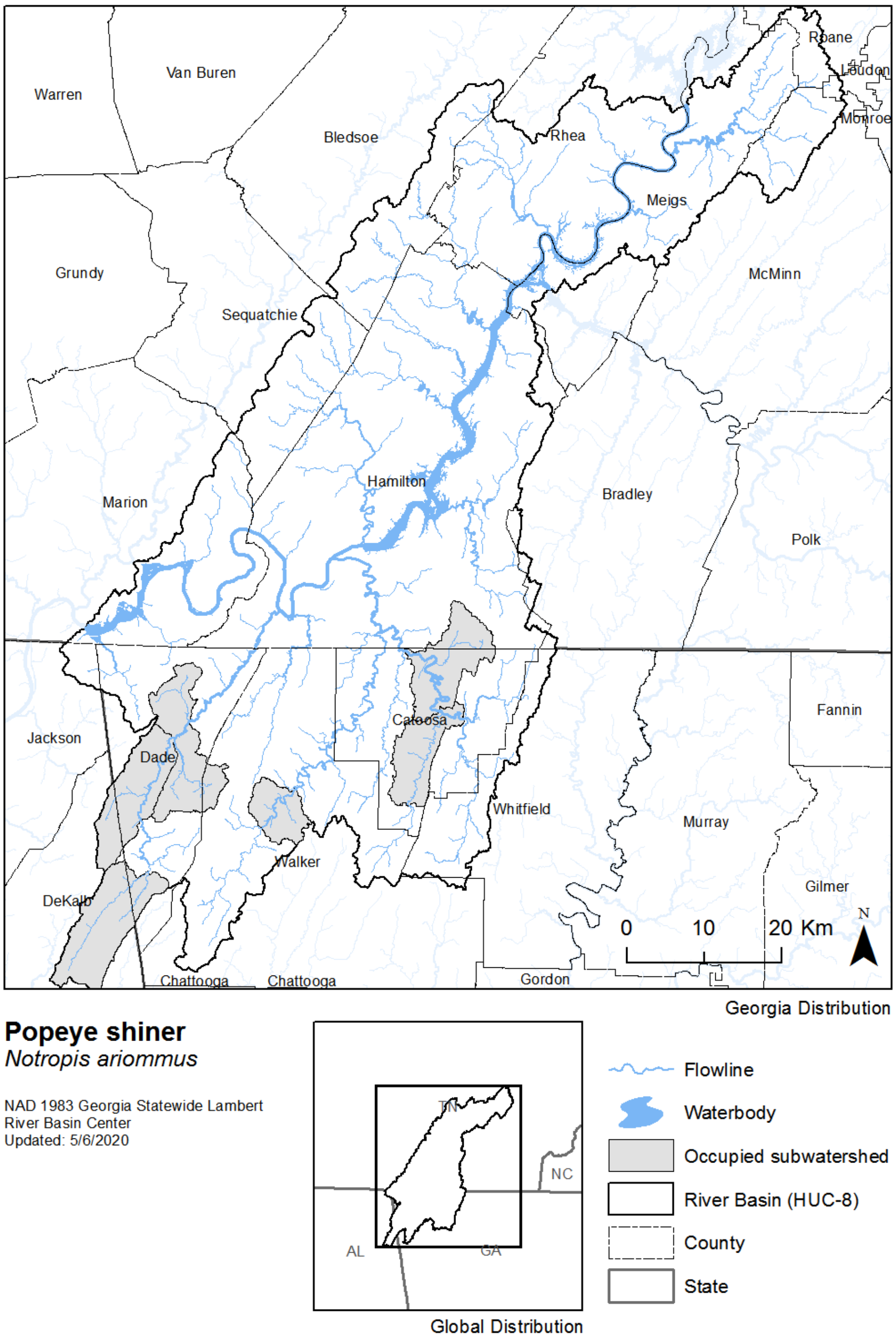
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the popeye shiner tolerance to conductivity as moderate. They also categorized the specific conductivity tolerance of the closely related N. telescopus as moderate. The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of intolerant for the closely related N. telescopus. Following a period of urbanization (1958 to 1990) of the Tuckahoe Creek (Virginia) watershed, the closely related N. rubellus was not collected from previously occupied sites (Weaver Garman 1994). Relative abundance of the congener N. amplamala decreased as urbanization of the Little Uchee creek increased from 8-13% (Johnston and Maceina 2009). In contrast, the closely related

N. stilbius increased in occurrence and relative abundance in the upper Cahaba River (Alabama) following a long period associated with increasing urbanization of the watershed (Onorato et al. 2000).

The balance of evidence suggests intermediate sensitivity, therefore the popeye shiner is categorized as somewhat intolerant (3).

Figure 10. Map. Range map for the popeye shiner.



ROBUST REDHORSE

Species

Robust Redhorse, *Moxostoma robustum*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999b):

The robust redhorse is a large, heavy-bodied sucker that attains total lengths greater than 70 cm (28 in) and weights up to 8 kg (17.6 lbs). Like the river redhorse, a related species, the robust redhorse has large molar-like pharyngeal teeth, which are a specialization for crushing hard-bodied prey such as native mussels. The robust redhorse is bronze on the back and sides, with scattered mid-lateral dark blotches. Adults have a broad faint lateral stripe that varies in intensity, and nuptial males have a dark intense stripe extending along lower sides to the snout tip. The lips are plicate (divided into longitudinal sections) with the posterior margin of the lower lip relatively straight except for a few central plicae that extend noticeably beyond the margin; this character is best developed in large adults. Juveniles will have intense red in the caudal fin and often in other fins as well, and this red coloration becomes less intense in adults. Adult males develop large prominent tubercles on the snout, head, anal, and caudal fins during the spawning season.

Life History

Adult robust redhorse habitat is characterized by large woody debris in runs and pools of moderate to swift current that's generally deeper and close to shore, such as the outer bends of rivers (Freeman et al. 1999b, Grabowski and Isely 2006, Fisk et al. 2014). The diet of robust redhorse is comprised primarily of invertebrates such as freshwater bivalves (native and otherwise), snails, insects, and crayfish (Freeman et al. 1999b). Adults may live up to 25 years (Freeman et al. 1999b).

Spawning activities by robust redhorse have been observed from April to early June (18-20°C water temp) over in shoals and mid-channel bars with gravel substrate (Freeman et al. 1999b, Grabowski and Isely 2007). To spawn, the adult female shakes vigorously while resting on the gravel substrate and flanked on either side by males. This act effectively cleans the incubating substrate of some amount of fine sediments. Larval robust redhorse use the gravel as cover during development. Robust redhorse have been shown to make long (>100km) seasonal migrations between adult and spawning habitats (Grabowski and Isely 2006).

Numbers, Reproduction, Distribution

Robust redhorse once occurred along southern Atlantic rivers from Georgia (Altamaha and Savannah drainages) to the Pee Dee River in North Carolina (Freeman et al. 1999b). Three evolutionary significant units (ESUs) exist: the Altamaha, Savannah, and Pee Dee. Current

Georgia populations are known in the Ocmulgee and Oconee rivers (Altamaha ESU), and the Savannah River (below the New Savannah Bluff Lock and Dam) (Freeman et al. 2003; Marcinek 2020 pers. comm.). Populations are also known from the Santee and Pee Dee rivers in the Carolinas. Robust redhorse have been stocked, and their populations persist, in the Broad River of Georgia (GADNR pers comm; Straight and Freeman 2003). Spawning activities have been recently documented in the Broad, Ocmulgee, and Savannah rivers. (Marcinek 2020 pers. comm.). Robust Redhorse from the Altamaha ESU were also stocked in the Ogeechee River in Georgia, but recruitment has never been documented and stocked individuals have not been collected since 2014.

Conservation

The robust redhorse currently has a global conservation ranking status of G1 and a Georgia state conservation ranking of S1. This species is protected as Endangered in the state of Georgia and is a candidate for listing under the ESA with an expected review in 2025. A number of reasons have been cited in support of these conservation rankings: the current limited range of the species, large reductions in population abundance of each ESU due to anthropogenic activities (e.g. overfishing, loss/degradation of habitat, extensive damming of rivers and resultant altered flows), and invasive predatory species (Freeman et al. 1999b).

The presence and effects of large dams are considered a primary stressor to robust redhorse populations (Freeman et al. 1999b). Specific effects include the restriction of access to much of their historic range as well as the alteration of temperature and flow regimes. Historic and current chronic stressors include degradation of habitat by hydropower production, water withdrawal, and poor agricultural practices that often result in sedimentation of gravel substrate. The introduction of multiple predatory catfishes (blue catfish, flathead catfish) is also considered a threat to young of the year and juveniles. Because of the small number and sizes of existing populations, the species is vulnerable to unforeseen events such as chemical spills from nearby highway transportation activities and industrial activities such as mining for kaolin clay (Freeman et al. 1999b).

Effects of Construction Activities

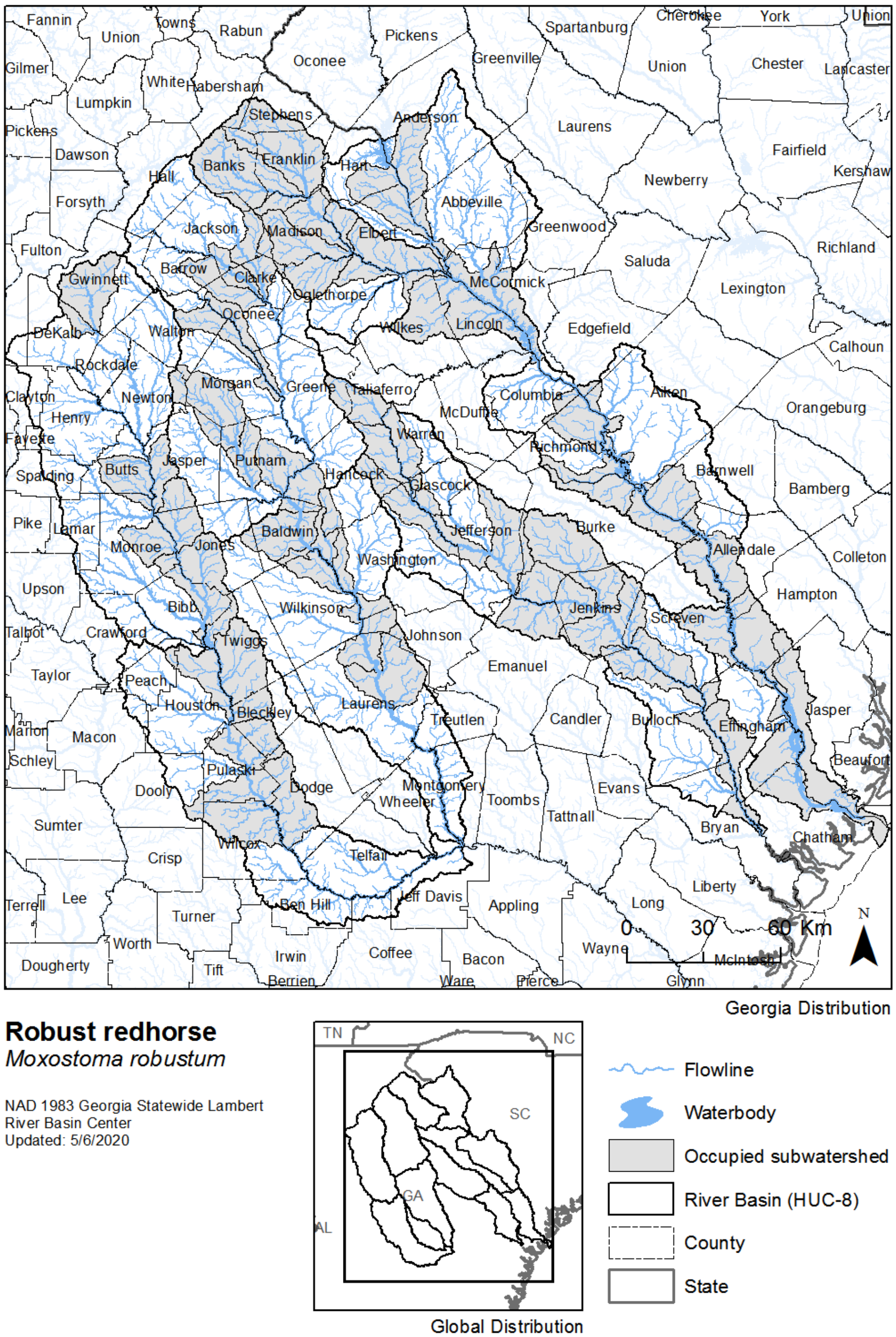
Sediment

Dodd (2016) identified degradation of suitable habitat (i.e. gravel) for adult and early life stages as a primary threat to the species. Fisk et al. (2014) modeled habitat suitability for the robust redhorse and through sensitivity analysis found that depth and substrate (i.e. gravel) were the limiting factors within the assessed reach. This finding supports the previous results of Grabowski and Isely (2006) who reported consistent association of adult robust redhorse with gravel substrate and woody debris, both of which aspects of habitat would be degraded by inputs of sedimentation. In a 2-year laboratory study, Jennings et al. (2010) found that increasing levels of fine sediment reduced survival of robust redhorse eggs and larvae. A clear threshold of adverse effect on survival was reached at approximately 15% fine substrate, with zero survival in the highest treatment groups (75% fine sediment) and an estimated 8% survival rate when fines sediments were more than 25% of substrate. The act of spawning by robust redhorse (shaking and burying eggs in gravel) clears some fine sediment from surrounding gravel; however, it is unclear to what degree this reduces the known adverse effects of fine sediments (Jennings et al. 2010). As a benthic invertivore, robust redhorse may also be indirectly and adversely affected by the reduction of diversity and abundance of macroinvertebrates that may result from elevated sediment inputs. Because of its spawning sensitivity, the robust redhorse sediment sensitivity is categorized as intolerant (1).

Pollutants

Dodd (2016) identified pollutants as a concern for robust redhorse populations and Lasier et al. (2004) cited sediment-associated metals from point-source effluents and from urban areas as a likely stressor to robust redhorse early life stages and reproduction. Penland et al. (2018) investigated food web dynamics of a suite of metals, PAHs, and other compounds. They detected PCBs in robust redhorse eggs and found the concentrations to be comparable to levels detected in muscle tissues of other fishes. Effects of pollutants on robust redhorse are generally unclear (Fisk et al. 2014), but Lasier et al. (2001) investigated robust redhorse early life stage sensitivity to a number of metals and found that while toxicity of specific compounds varied, overall sensitivity was comparable to many other fishes. Therefore,the robust redhorse pollutant sensitivity is categorized as somewhat intolerant (3).

Figure 11. Map. Range map for the robust redhorse.



ROCK DARTER

Species

Rock Darter, *Etheostoma rupestre*

Description

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008a): The rock darter has a small, sub-terminal mouth, and a blunt (down-curved instead of pointed) snout that is connected to the upper jaw by a fleshy bridge of tissue (the frenum). It reaches about 84 mm (3⅜ inches) in total length. Its large pectoral fins and six, square-shaped dorsal saddles are prominent when viewed from above. There are 6-9 markings on the sides that can be represented as either blotches or vertical bars. Dark markings are usually evident before and below the eye and on the base of the pectoral fin. Breeding males have green in all fins, as blotches along the sides, and on the underside of the head.

Life History

The rock darter is a benthic species found in swift riffles among coarse gravel substrates of medium to large streams (Kuehne and Barbour, 1983; Joachim, Guill, and Heins 2003). It is often found in association with riverweed (*Podostemum ceratophyllum*) (Albanese 2008a). The diet of the rock darter is unknown, but it likely consists of aquatic insects and other invertebrates (Albanese 2008).

A life span of at least three years is suggested by length-frequency data (Albanese 2008a). While breeding is known to occur between late March and May (Albanese 2008a), spawning mode and preferred spawning substrate of the rock darter are unknown. Such information from closely related species would be useful to estimate these life history characters. However, the most closely related species are members of the *E. blennioides* complex, with a variety of spawning substrates having been reported: vegetation, boulders, and sandy areas in riffles (Etnier and Starnes 1993).

Numbers, reproduction, distribution

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008a): The rock darter is endemic to the Mobile Basin in Mississippi, Alabama, Georgia, and a small portion of Tennessee. Most Georgia records are from the mainstem of the Conasauga and Etowah Rivers, but the rock darter is also known from the Coosawattee and Oostanaula River systems. The largest populations of this species in Georgia occur in the Etowah and Conasauga mainstems. Some of the headwater streams in these systems occur on public lands.

Conservation

The rock darter has a global conservation status ranking of G4, a Georgia state conservation status ranking of S2, and it is currently under no federal protections. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Albanese 2008a): Non-point pollution associated with agriculture and residential development are primary threats in the Conasauga system. The Etowah population is threatened by urbanization and water supply development.

Conserving populations of the rock darter will require a watershed-level focus. Incentive programs to help farmers implement best-management practices could improve instream habitat by decreasing sediment, nutrient, and chemical runoff and increasing riparian forest cover. Conservation groups should work cooperatively with developers and local governments to minimize the impacts from new home construction and commercial development. Additional water withdrawals and impoundments should be minimized by promoting water conservation practices and augmenting existing water storage whenever possible.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the rock darter tolerance to suspended sediment as moderate. They also evaluated the suspended sediment tolerance of some closely related species in the subgenus *Neoethostoma*, categorizing six as moderate (*E. blennioides, E. blennius, E. inscriptum, E. lynceum, E. swannanoa, E. zonale*) and one as tolerant (*E. thalassinum*). Several closely related species (*E. blennioides, E. maculatum, E. zonale*) have been characterized as sensitive to the adverse effects of sedimentation (Larsen et al. 1986; Miltner et al. 2004; Sullivan et al. 2004; Osier 2005). Sutherland, Meyer, and Gardiner (2002) found that relative abundance of gravel-spawners declined, including the closely related *E. blennioides*, as turbidity and suspended/bedded sediments increased. Schweizer and Matlack (2005) found *E. lynceum* to be dominant in a relatively undisturbed stream and 'excluded' from a nearby stream heavily affected by sedimentation. Crumby et al. (1990) failed to collect *E. zonale* individuals from any sites where it had previously been found, following a period with high levels of sedimentation. In contrast, Ross et al. (2001) found that density of *E. lynceum* did not change significantly over a time period associated with increasing sedimentation. In the same vein, Scott (2006) classified *E. zonale* as a 'cosmopolitan' species and less sensitive to anthropogenic disturbance than co-occurring "highland endemic" species.

The spawning guild of the rock darter is unknown. As a probable benthic invertivore, the rock darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration.

Without knowledge of the rock darter's spawning mode, and with mixed information from related species, estimating sediment sensitivity is challenging, but per Meador and Carlisle, the overall sediment sensitivity of the rock darter is categorized as moderate (2).

Pollutants

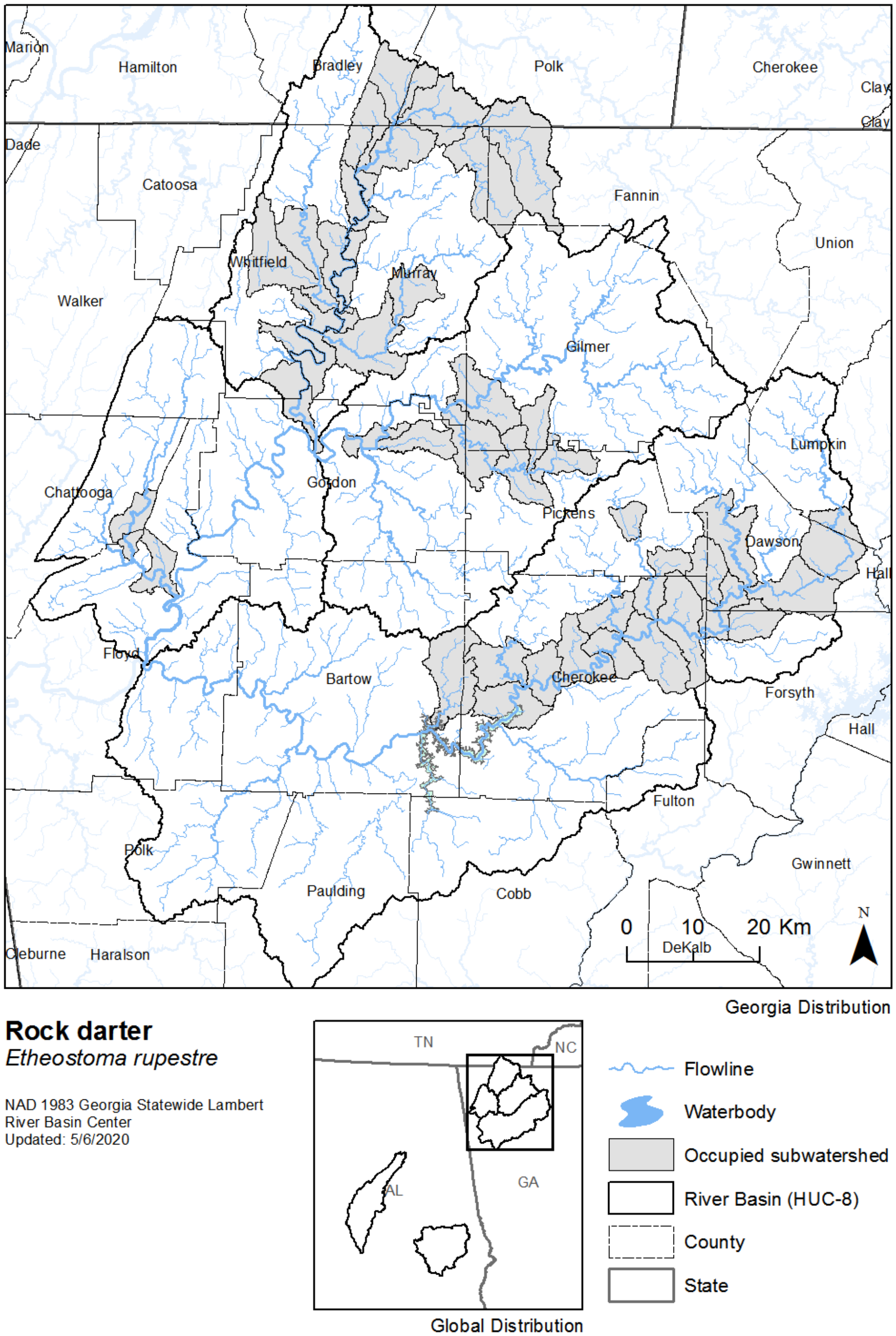
Meador and Carlisle (2007; Meador unpublished data 2020) categorized the rock darter tolerance to specific conductivity as moderate. They also evaluated the suspended sediment tolerance of some closely related species in the subgenus *Neoethostoma*, categorizing four as moderate (*E. blennioides, E. blennius, E. thalassinum, E. zonale*) and three as intolerant (*E. inscriptum, E. lynceum, E. swannanoa*).

The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of tolerant for both *E. blennioides* and *E. zonale*. Schweizer and Matlack (2005) found *E. lynceum* to be dominant in a relatively undisturbed stream and 'excluded' from a nearby stream within a heavily urbanized watershed. In contrast, Dye and Benton (2001) found that *E. blennioides* was collected at 6 of 10 mercury-contaminated sites in the North Fork Holston River, suggesting it is relatively tolerant of mercury.

The rock darter is likely a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants.

Based on the work by Meador and Carlisle and the mixed sensitivities of related species, per Meador and Carlisle, the overall pollutant sensitivity of the rock darter is categorized as somewhat intolerant (3).

Figure 12. Map. Range map for the rock darter.



SANDBAR SHINER

Species

Sandbar Shiner, *Notropis scepticus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999z):

The sandbar shiner is a medium-sized minnow attaining lengths up to 90 mm (3.5 in). It has silvery sides and an olive dorsum, lacking any chromatic coloration in the fins. The back scales are darkly outlined and the lateral-line pores are stitched with black pigment. A prominent feature of the sandbar shiner is its large eyes, which are wider than the length of the snout. This species also has a large terminal mouth with black pigment on its lips. There are usually 10-11 anal fin rays and the pharyngeal tooth count formula is typically 2-4-4-2.

Life History

Life history information on the sandbar shiner comes primarily from a study in South Carolina, in which all males and most females were found to mature at age two and no fish exceeded a lifespan of three years (Harrell and Cloutman 1978). Spawning in this location occurred from late May to early July at water temperatures from 18-24°C (64-75°F). The spawning guild of the sandbar shiner is not known. However, spottail shiners (*Notropis hudsonius*), which is a fairly close relative in multiple genetic analyses (Stout 2017; Schönhuth et al. 2018), spawn in aggregations, with eggs subsequently adhering to sand or gravel (Rohde et al. 2009).

Sandbar shiners are primarily insectivorous; major components of the diets of South Carolina individuals were terrestrial and aquatic insects, with plant material and algae apparently being important only in winter months. Their large eyes and association with clear streams suggest a possible reliance on sight for feeding. (Harrell and Cloutman 1978; Chittick et al 2001). Sandbar shiners typically inhabit clear, medium-and large-sized streams (i.e., 2 to 30 m in width). They are most often found in flowing pools and runs over sandy substrate adjacent to riffles, and are generally absent in small headwaters streams and impoundments. They frequently form school-like aggregations. (Harrell and Cloutman 1978).

Number, Reproduction, Distribution

The sandbar shiner occurs in Atlantic Slope drainages from the Cape Fear River in North Carolina to the Savannah River in Georgia. It is primarily found within the Piedmont but its range extends slightly into both the Coastal Plain and Blue Ridge physiographic provinces. In Georgia, it is known from tributaries of the Savannah River, including the Broad River and Little River, as well as the mainstem Savannah River, Chattooga River, and Beaverdam Creek (Freeman et al. 1999z).

Conservation

The sandbar shiner has a current global conservation status ranking of G4 and a Georgia state ranking of S2. It is currently under no federal protections. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 2008):

The sandbar shiner occurs in clear streams with high water quality. One study concludes that the sandbar shiner is primarily a sight feeder, based upon the species' large eyes and the prey items the fish consumes. The sandbar shiner is threatened by stream degradation resulting from poor land-use practices in forestry and agriculture, as well as failure to control soil erosion from construction sites and bridge crossings. Increased stormwater run-off from developing urban and industrial areas further threatens the sandbar shiner where populations still exist. The central portion of its range, especially in the Carolinas, is an area of intense current growth and historical widespread textile development.

Conserving populations of the sandbar shiner in Georgia depends on maintaining habitat and water quality in streams of the middle Savannah River drainage. These streams are highly susceptible to impacts from various land-disturbing activities. It is essential to eliminate sediment runoff (from activities such as roadway and housing construction), inputs of contaminants (such as fertilizers and pesticides), and chronic discharges of industrial effluent and sewage while maintaining forested buffers along stream banks and natural streamflow patterns.

Watershed clearing and urban development can lead to unnaturally flashy stormwater runoff, which scours stream channels and results in lower baseflows.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the sandbar shiner's tolerance to suspended sediment as moderate. More generally, relative intolerance of the species to disturbance has been inferred from its characteristic occurrences in streams of high water quality (Harrell and Cloutman 1978).

As insectivorous sight feeders, sandbar shiners could potentially suffer sublethal effects of sedimentation on their foraging ability as a result of impaired visual acuity and reduced abundance of the aquatic portion of their prey base. Assuming that the sandbar shiner spawns over sand or gravel like the spottail shiner, its reproduction is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae
Based on its previous classification by Meador and Carlisle on balance with a degree of sensitivity of its likely spawning habitat, the overall sediment sensitivity of the sandbar shiner is categorized as moderate (2).

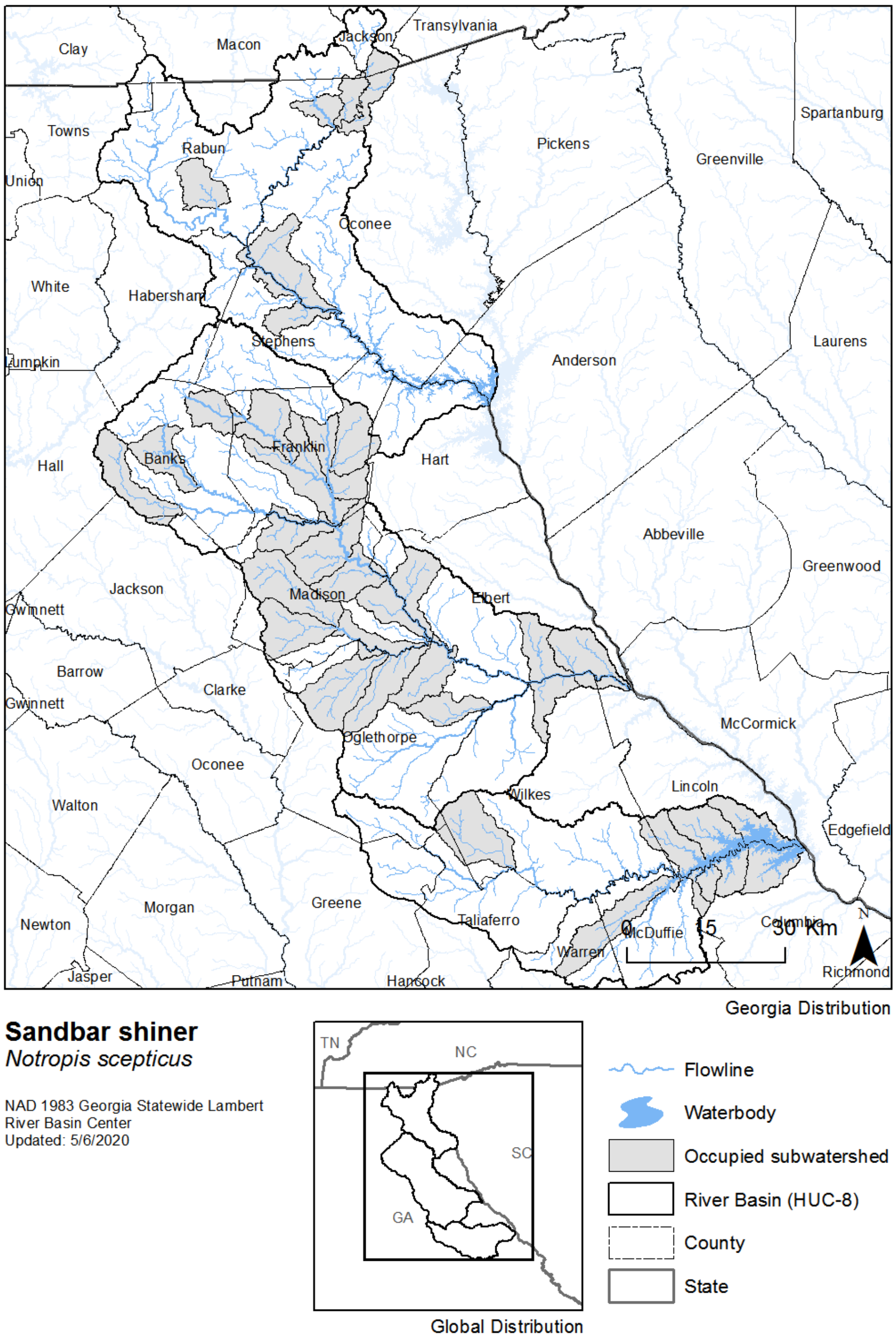
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the sandbar shiner's tolerance to conductivity as intolerant. In an assessment of the effects of headwater urbanization on fish communities in the piedmont of South Carolina, sandbar shiners were only found at rural sites and not at urban sites (Lewis et al. 2007).

As an insectivore that likely feeds at the water surface and also forages on plants/algae, the sandbar shiner feeds at a low trophic level and its dietary exposure to roadway-associated pollutants is likely to be relatively low. As a species that likely spawns over a combination of sand and gravel, sandbar shiner eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments.

Based on its reported absence from urban areas and its previous tolerance classification, the overall pollutant sensitivity of the sandbar shiner is categorized as very intolerant (2).

Figure 13. Map. Range map for the sandbar shiner.



SILVER SHINER

Species

Silver Shiner, *Notropis photogenis*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The silver shiner is a slender, laterally compressed fish that reaches lengths approaching 150 mm total length (5.9 in). It is characterized by two black crescents between the nostrils, a large terminal mouth on a long snout, large eyes, and a dorsal fin origin behind the pelvic fin origin. There are 10-11 anal fin rays and a pharyngeal tooth count formula of 2-4-4-2. The back is a light olive color, the sides are bright silver with blue reflective stripes, and the lips are black.

Life History

In the Flint River in north Alabama, silver shiners begin breeding from February to April, with females releasing eggs during broadcast spawning events (Stallsmith 2015; Hodgskins et al. 2016). Spawning in Tennessee and Virginia is thought to occur from late April to mid-June based on tuberculate males, whose presence in smaller streams during these months suggests possible upstream spawning movement (Etnier and Starnes 1993; Freeman et al. 1999). In Ohio, fishes reach sexual maturity in the second or third summer of life (Trautman 1981); maximum age is thought to be about 3 years (Freeman et al. 1999).

Silver shiners feed mainly on terrestrial insects based on gut content analyses (Burress et al. 2016) but are also known to feed on aquatic insects and other macroinvertebrates. Etnier and Starnes (1993) indicate that silver shiners are surface-oriented feeders who have been observed jumping to feed on flying insects. Silver shiners occur in large creeks to small rivers, preferring flowing pools with clear water, moderate to swift currents, and firm substrate (Etnier and Starnes 1993).

Number, Reproduction, Distribution

The silver shiner occurs widely throughout the Ohio River and Lake Erie drainages, but in Georgia is known only from a tributary of the Little Tennessee River, Betty Creek, in Rabun County. It has also been collected in a North Carolina portion of Brasstown Creek, which originates in Georgia. This species is represented by a large number of subpopulations at numerous locations, though these subpopulations appear to be severely fragmented and continue to see a decline in mature individuals (IUCN Redlist 2019). The Silver Shiner has recently been collected in the Little Tennessee River system. There are also recent records in Brasstown Creek in North Carolina, suggesting that the species may still occur in the Georgia portion of Brasstown Creek. There is a potential record from South Chickamauga Creek downstream of Graysville Dam which needs further verification (B. Albanese 2020 pers. comm.).

Conservation

The silver shiner has a global conservation status ranking of G5, a Georgia state conservation ranking of S1, and it is under no US federal protections. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The silver shiner is imperiled in Georgia because of its limited distribution. It is associated with relatively silt-free bottoms, which suggests vulnerability to sedimentation. Threats to the existence of the silver shiner in Georgia include impacts from poor land use practices as a result of farming, roadbuilding, and increasing urbanization. Much of the riparian buffer along streams has been impacted or eliminated in the more developed region of Rabun County. This allows for an increase in sunlight, which can result in changing water temperatures, and allows sediment and excess nutrients to reach the stream more quickly. Hydrologic alteration as a result of increased areas with paving and other impervious surfaces is also a threat.

Conservation of the silver shiner and other stream fishes in the Little Tennessee River system depends upon maintaining and improving habitat quality. It is essential to minimize sediment runoff from land-disturbing activities (such as roadway and housing construction), inputs of contaminants (such as fertilizers and pesticides), and chronic discharges of industrial effluent and sewage. Existing stream buffers should be maintained and there are many opportunities to enhance and widen riparian zone habitats along creeks and streams.

Effects of Construction Activities

Sediment

Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described the silver shiner as "highly sensitive" to sedimentation. The silver shiner may now be extirpated from the Big Sandy River in Virginia (Jenkins and Burkhead 1994), possibly as a result of siltation of habitat from mining and agricultural activities, as suggested by Buckwalter et al. (2018). D'Ambrosio et al. (2009) conducted a multivariate analysis evaluating fish abundances and environmental conditions and found a strong relationship between silver shiner and substrate size/quality. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the silver shiner's tolerance to suspended sediment as moderate.

As a pelagophilic broadcast spawner, sedimentation may lead to degradation of spawning habitat or smothering of developing embryos. As insectivorous sight feeders, silver shiners may suffer sublethal effects of sedimentation on their foraging ability as a result of impaired visual acuity and reduced abundance of prey. Its reliance on terrestrial prey, however, may mitigate the adverse effects of sediment on its overall prey base.
Because D'Ambrosio found a strong relationship between its abundance and substrate size/quality, the sediment sensitivity of the silver shiner is categorized as intolerant (1).

Pollutants

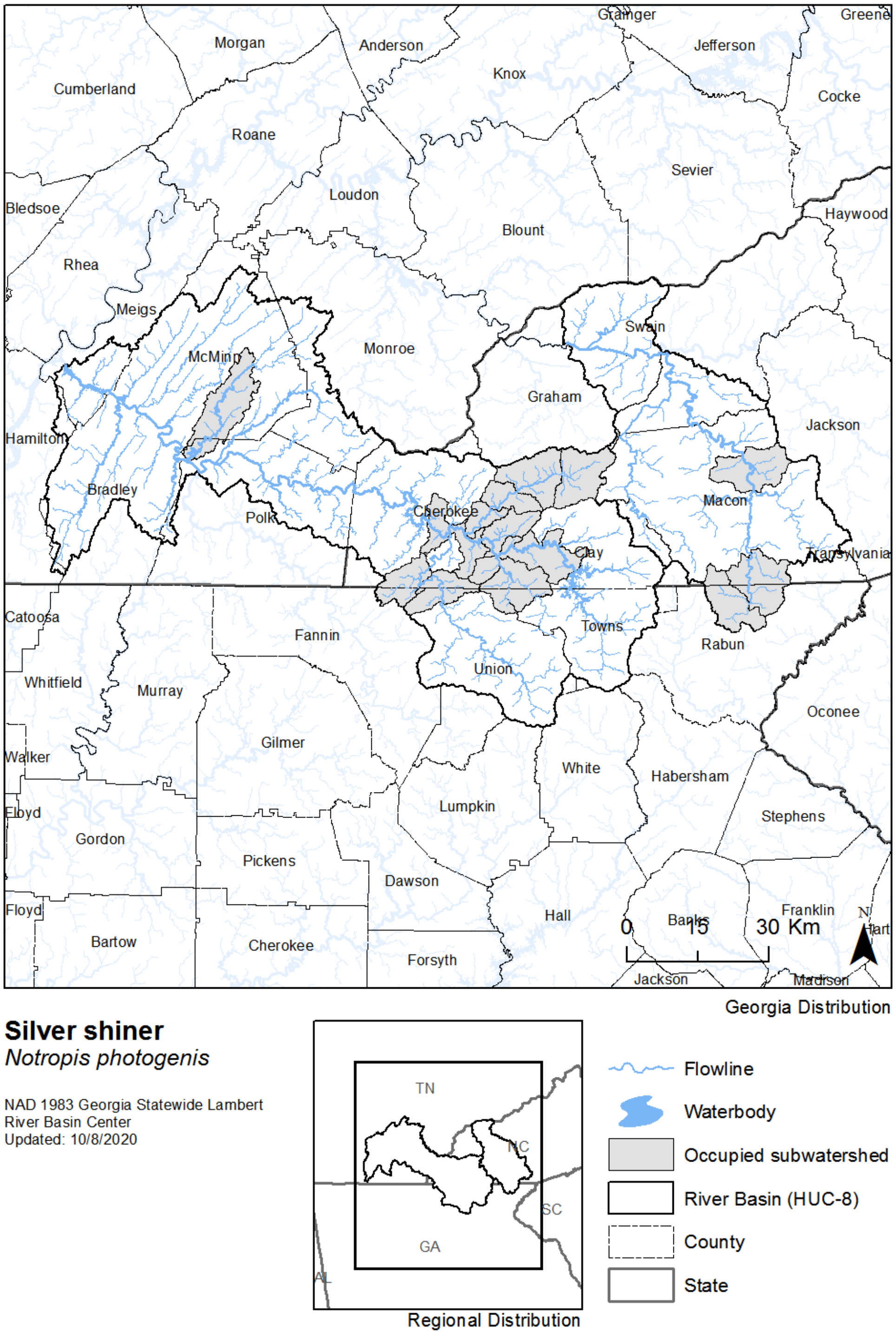
Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described the silver shiner as "highly sensitive" to pollutants. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of the silver shiner as moderate. We converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of tolerant for the silver shiner. A study assessing the populations of silver shiners in an urbanized Great Lakes tributary found that silver shiners were found in urbanized areas with impaired water quality, but authors suggested that this may have been due to the influence of groundwater seepages (Bunt 2016).

Following a period of urbanization (1958 to 1990) of the Tuckahoe Creek (Virginia) watershed, the closely related *N. rubellus* was not collected from previously occupied sites (Weaver and Garman 1994). Relative abundance of the closely related *N. amplamala* decreased as urbanization of the Little Uchee creek increased from 8-13% (Johnston and Maceina 2009). In contrast, the closely related *N. stilbius* increased in occurrence and relative abundance in the upper Cahaba River (Alabama) following a long period associated with increasing urbanization of the watershed (Onorato et al. 2000).

As a surface-oriented insectivore, the silver shiner feeds at a low trophic level and its dietary exposure to roadway-associated pollutants is likely to be relatively low. However, as a broadcast spawner, the early life stages of this species may be more closely associated with sediment-bound pollutants.

Based on the mixed evidence from previous classifications and the species' traits, the pollutant tolerance of the silver shiner is categorized as somewhat intolerant (3).

Figure 14. Map. Range map for the silver shiner.



SNAIL DARTER

Species

Snail Darter, *Percina tanasi*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999n):

A small but robust fish reaching up to 90 mm (3.5 in) in total length, the snail darter is distinguished by four dark brown saddles that cross and contrast with the lighter brown dorsum. The saddles extend downward and join a lateral band formed by 9-12 indistinct blotches along each side. The eyes are positioned high on the head, with a dark blotch below each orbit. The dorsal and caudal fins are lightly banded, and on males the anal fin is noticeably elongated. Breeding males develop blue-green and gold coloration.

Life History

The habitat of the snail darter consists of small rivers and large creeks with moderate to fast currents (Freeman et al. 1999n). It avoids silty areas and prefers clean substrates of mixed sand/gravel/cobble (Etnier and Starnes 1993, USFWS 2013). Young-of-year individuals are most often found within macrophytes such as water willow (Freeman et al. 1999n). The snail darter diet consists of snails, limpets, and larval insects (Freeman et al. 1999). Individuals have been observed burrowing into sand/gravel substrate like the amber darter, *P. antesella* (Freeman et al. 1999).

Snail darter spawning occurs between February and April in shoals dominated by gravel substrate (Freeman et al. 1999n). While it has not been observed, spawning pairs likely bury eggs in gravel (Freeman et al. 1999n). Newly hatched snail darters swim up to the current and drift downstream, more than 30 miles in some cases (Freeman et al. 1999n, USFWS 2013). After absorption of the yolk sac, juveniles are found in slackwater areas, but by 3-4 months move to shoal habitats (Freeman et al. 1999)n. Snail darters reach sexual maturity at 1-2 years and lifespan is roughly 3-4 years (Freeman et al. 1999n).

Number, Reproduction, Distribution

The snail darter is found only in the upper Tennessee River drainage, across three states: Tennessee, Alabama, and Georgia. According to Ashton and Layzer (2008), the most robust populations of snail darters reside in the French Broad and Hiawassee Rivers in Tennessee. Within Georgia, it has been reported only from South Chickamauga Creek in Catoosa Co. (USFWS 2013). In 2005, a status survey across 18 km reported 5 individuals across a 4.5 km reach (Ashton and Layzer 2008). In 2017, another survey reported 45 individuals at the Swanson Mill Dam (Graysville, GA) (Freeman et al. 1999n).

Conservation

The global conservation ranking status of the snail darter is G2/G3 and the Georgia state conservation ranking status is S1. The snail darter was listed as endangered under the ESA in 1975, then reclassified as threatened in 1984. This species is protected as Endangered in the state of Georgia.

Across its range, the snail darter is threatened by a number of anthropogenic impacts. These include: erosion of soil and stream banks caused by commercial and agricultural activities; altered temperature and flow regimes related to hydroelectric operations; lack of or inconsistent riparian buffer; occasional chemical spills from industrial and commercial activities; fragmentation of populations; and increasing urbanization of surrounding watersheds and associated runoff from impervious areas (USFWS 2013). Within Georgia, it is especially vulnerable due to its occurrence in a single stream reach draining an area that is rapidly developing (i.e. Graysville and Ringgold, Georgia, on the outskirts of Chattanooga, Tennessee; Freeman et al. 1999n).

Actions designed for conservation of the snail darter should aim to improve physical habitat and water quality for all life stages. Specific examples include: implementation of best management practices to limit sediment inputs from agricultural and construction activities, protection/restoration of riparian buffers, improved management of stormwater runoff from urbanizing areas, and maintenance of natural flow regimes by limiting water withdrawals (Freeman et al. 1999n).

Effects of Construction Activities

Sediment

The latest 5-year review of the snail darter by the U.S. Fish and Wildlife Service (USFWS 2013) cites sedimentation as a primary threat to snail darters and their habitat. Ashton and Layzer (2008; FWS 2013) reported that snail darters did not occur in areas where substrate was covered by silt. Scott (2006; USFWS 2013) reported snail darter abundance to be greater in riffle/run areas containing gravel/cobble substrate free of silt. Shollenberger (2019) found that substrate at sites lacking detections of snail darter eDNA had significantly higher proportions of fine sediments. Meador and Carlisle (2007; Meador unpublished data 2020) classified the suspended sediment tolerance of the snail darter as moderate; they also classified the closely related *P. shumardi* as tolerant.

As a benthic invertivore, the snail darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that likely spawns in gravel, snail darter reproduction may be sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration, common among darters.

Because reductions in occupancy and abundance have been consistently reported from silty/embedded areas across its historic range, the overall sediment sensitivity of the snail darter is categorized as intolerant (1).

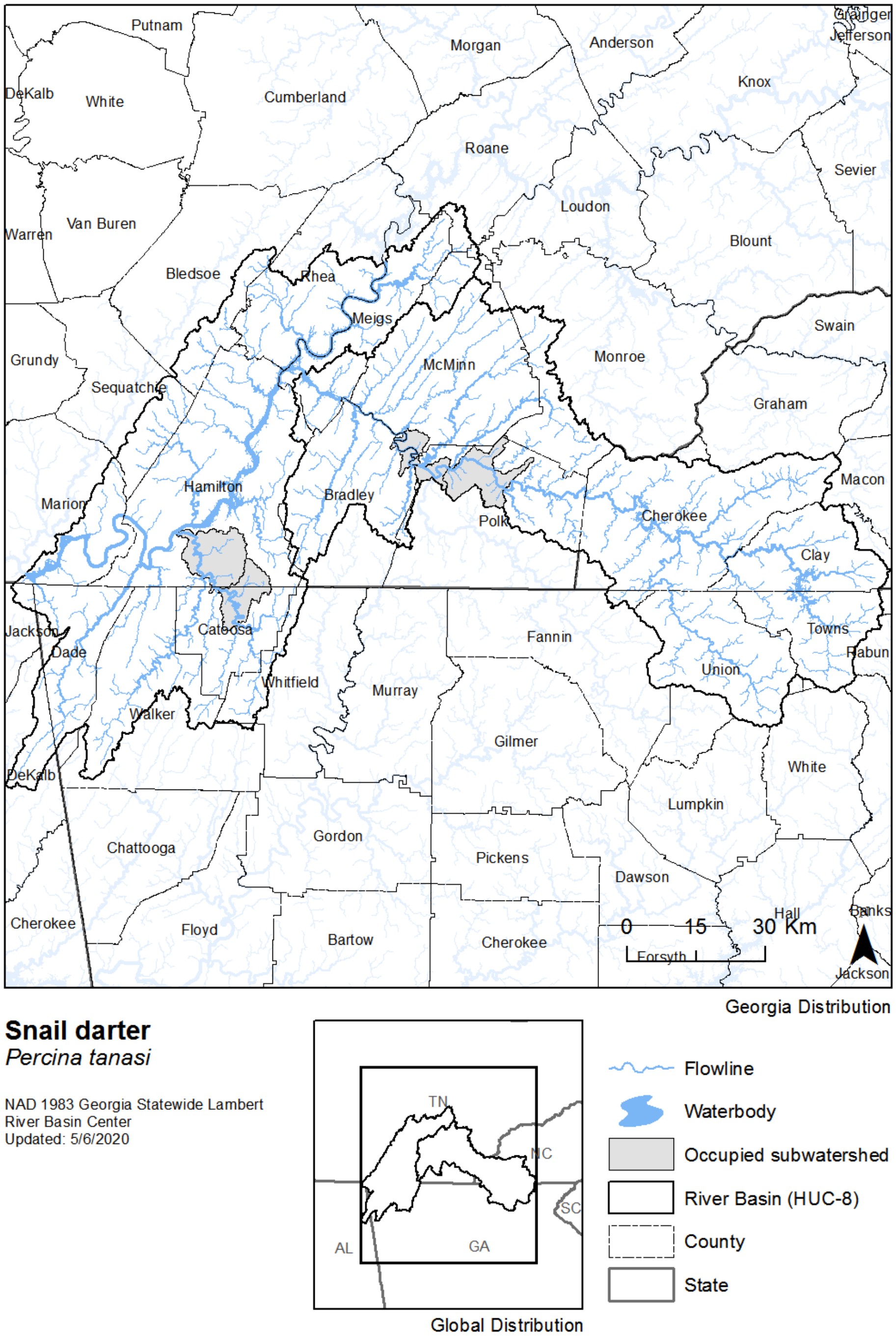
Pollutants

The latest 5-year review of the snail darter by the U.S. Fish and Wildlife Service (USFWS 2013) cites pollutants from urban areas as a primary threat to snail darters and their habitat. Meador and Carlisle (2007; Meador unpublished data 2020) classified the specific conductivity tolerance of the snail darter as moderate; they also classified the closely related *P. shumardi* as moderate.

Because the snail darter feeds on benthic invertebrates, it is likely indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. As a species that likely spawns in gravel, snail darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments; however, this effect may be moderated by the lower binding surface area on larger substrate particles.

Because the traits-based evidence suggests a degree of sensitivity, the pollutant sensitivity of the snail darter is categorized as somewhat intolerant (3).

Figure 15. Map. Range map for the snail darter.



SPOTTED BULLHEAD

Species

Spotted Bullhead, *Ameiurus serracanthus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The spotted bullhead is a small strikingly marked catfish that attains a maximum total length of 23 cm (9 in). It is a member of a group of bullhead species having a black blotch in the base of the dorsal fin and a relatively large eye. The spotted bullhead is distinguished by profuse, round light-colored spots of pupil-sized diameter on the dark body. The body and fins are suffused with yellow, and the spots thus appear to be yellow. Barbels are dusky to dark. The name *serracanthus* refers to the strongly serrated pectoral spine which has 6-20 large serrae, or tooth-like projections, on the posterior margin. All the fins are edged in black, and the caudal fin is moderately emarginate.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): No detailed studies of diet and life history have been made. Residents of northern Florida often refer to the spotted bullhead as "snailcat," due to the large quantities of mollusks it consumes. The original description reported four different species of mollusks identified from stomach contents.

Little is known concerning the life history of the spotted bullhead. Gonad development data suggest that spawning may begin in late winter and extend through spring and early summer. Small individuals less than 30 mm (1.2 in) long have been collected from late June through November, suggesting a protracted spawning season.

The spotted bullhead is known from mainstem and large tributaries. It prefers rocky substrates with moderate currents, and has been collected occasionally over mud near vegetation or other structures such as old stumps in impounded portions of rivers.

Like other fishes in the family Ictaluridae, the spotted bullhead likely constructs shallow nests in fine sediments prior to spawning. Although little is known about the feeding habits of spotted bullhead, it is likely to be an omnivore since bullheads typically consume filamentous algae, larval caddisflies, small fish and snails (Boschung and Mayden 2004).

Numbers, Reproduction, Distribution

The spotted bullhead is found in association with limestone regions in the Coastal Plains of Georgia, Florida, and Alabama. Within Georgia, it has been reported from the Apalachicola, Withlacoochee, and Alapaha Rivers, as well as the Ochlockonee and Suwannee River drainages in the lower Flint. There are no known estimates of population size for the spotted bullhead.

Conservation

The spotted bullhead currently has a global conservation status ranking of G3, a national status of N3, and a Georgia state ranking of S3. It is currently under no federal protections. Approximately half of the spotted bullhead range falls within the state of Georgia and compared to other bullhead species, spotted bullheads have the smallest range in the world (Freeman et al. 1999).

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999): Bullhead catfishes are extremely vulnerable to predation by introduced species of large catfishes, such as flathead and blue catfish. Both of these species have been introduced into the Flint and Chattahoochee River systems. Population fragmentation is also a threat, particularly in heavily impounded Chattahoochee River. The removal of dead-head logs would negatively impact the habitats utilized by this species. Spotted bullhead populations should be carefully monitored to assess the impact of flathead and blue catfish introductions. Efforts should be made to prevent additional spread of these two non-native species.

Effects of Construction Activities on the Spotted Bullhead

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of the spotted bullhead as moderate. The closely related *A. brunneus* and other 'cosmopolitan' species in the Etowah River were found to be more resilient to sedimentation and elevated turbidity following changing land use, compared to endemic species (Walters et al. 2003).

Because spotted bullheads likely construct nests in fine sediment, they are not likely to be sensitive to the initial presence of sediments, but they are still sensitive to sedimentation events following fertilization. The spotted bullhead may have a prolonged spawning period, making their reproduction more resilient to adverse effects from a single sedimentation event. As a likely omnivore, the spotted bullhead is likely not sensitive to the effects of sediment on their prey base because of their ability to adjust foraging habits in response to sedimentation presence or events.

Therefore following Meador and Carlisle, the sediment sensitivity of the spotted bullhead is categorized as tolerant (3).

Pollution

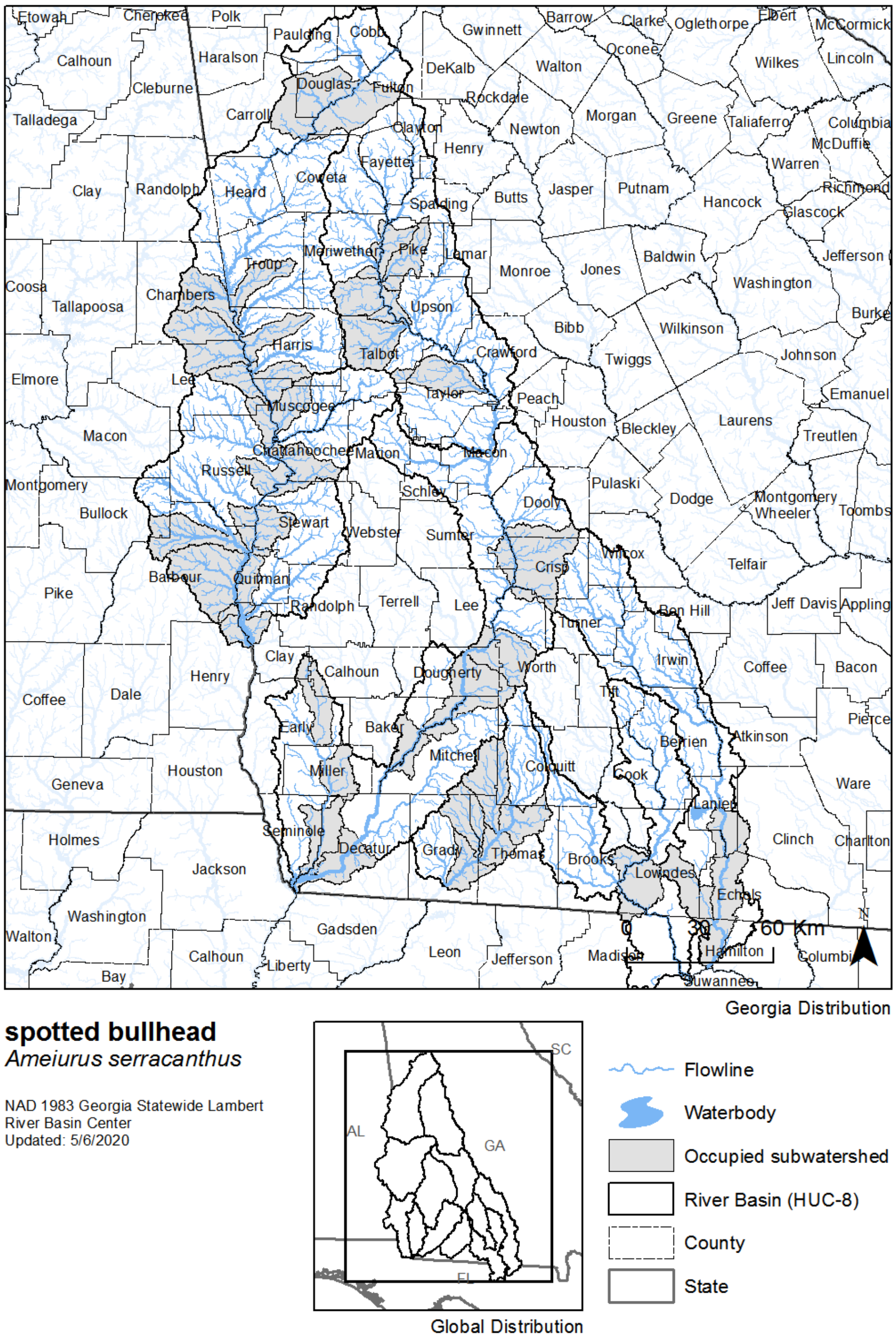
The research team knows of no lab or field studies investigating the effects of construction- or roadway-derived pollutants on spotted bullhead, but some research has been done on closely related species.

The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of moderate for *A. nebulosus*. Following a period of urbanization (1958 to 1990) of the Tuckahoe Creek (Virginia) watershed, several fishes were not collected from previously occupied sites, including *A. natalis* (Weaver and Garman 1994).

Pollutants tend to biomagnify through trophic levels, resulting in higher body burdens and greater exposure in predatory species. Since spotted bullhead feeds on snails and small fish, it may be exposed to pollutants through biomagnification. Because Ictalurids use nests built in fine sediments, the early life stages of spotted bullheads may experience high levels of exposure to pollutants attached to sediments.

Because the balance of information on closely related species and traits-based evidence suggests a degree of sensitivity, the pollutant sensitivity of the spotted bullhead is categorized as somewhat intolerant (3).

Figure 16. Map. Range map for the spotted bullhead.



SICKLEFIN REDHORSE

Species

Sicklefin Redhorse, *Moxostoma sp. 2*

(a.k.a. *Moxostoma* sp. cf. *macrolepidotum*)

Description

Reproduced from Georgia Department of Natural Resources species profile (Albanese and Abouhamdan 2008): The sicklefin redhorse is a large, distinctive sucker with a sickle-shaped (falcate) dorsal fin that is prominent in both juveniles and adults. Adults may exceed 500 mm (20 inches) total length and females grow larger than males. Both lips are divided into longitudinal sections (plicae); these sections are more deeply divided and branching on the lower lip compared to other redhorse species. The posterior edge of the lower lip is slightly angled to straight. Pharyngeal arch includes both comb-like and molariform teeth. The head and sides are olive-brown or brassy and the lower sides and belly are silvery to white. The ventral fins are dusky and are often tinted yellow or orange. Both juveniles and adults have a red caudal fin that varies in intensity from faintly brown-red to bright red. Breeding males develop prominent tubercles on their anal and caudal fins and the relative length of their anal and inner pelvic fin rays are longer than in females.

Life History

Adult sicklefin redhorse are generally found in large creeks or small/medium rivers in riffles, runs, and pools, often in association with woody debris, beds of riverweed (*Podostemum ceratophyllum), and* coarse substrate (gravel, cobble, boulder, and bedrock), free of silt (Albanese and Abouhamdan 2008, USFWS 2016). Adults use deeper mainstem habitat during the overwintering period. Sexual maturity is reached between 5 and 8 years old and maximum age is at least 22 years. The diet of sicklefin redhorse is composed of benthic invertebrates such as snails, crustaceans, insect larvae, and may also include freshwater bivalves (Albanese and Abouhamdan 2008, USFWS 2016).

Sicklefin redhorse in Georgia make spawning runs in late April or May when water temperature is 10-18 º C (Albanese and Abouhamdan 2008) and some evidence shows site-fidelity for spawning activities (USFWS 2016). The spawning act involves groups of males surrounding a female (Albanese and Abouhamdan 2008) in moderate to swift currents in shoals over clean cobble, followed by vigorous shaking and partial burial of fertilized eggs into the substrate (USFWS 2016). Following spawning, adults migrate downstream to larger riverine habitat and larvae/juveniles drift downstream, where juveniles have been associated with moderate/deep pools and boulder/crevice substrate (Stowe 2014, USFWS 2016).

Numbers, Reproduction, Distribution

The range of the sicklefin redhorse is limited to the Blue Ridge region of the Hiwassee and Little Tennessee Rivers of North Carolina and Georgia. Within Georgia, adult Sicklefin Redhorse have been documented migrating into Brasstown Creek during the spring for spawning (Favrot and Kwak 2018). While the historic range is unknown, it has likely been reduced following habitat fragmentation by impoundments and habitat degradation from poor agricultural practices. Some research has been done to evaluate the size and genetic health of the Brasstown Creek population (USFWS 2016, Favrot and Kwak 2018, Moyer et al. 2019). While sample size was small and results are not conclusive, it indicates that the population size is above the minimum threshold recommended to avoid inbreeding depression. Observations of breeding activities in Brasstown Creek (and Valley River, both within the Hiwassee River basin) suggest that the population size is comparable to the estimate developed for the Little Tennessee and Tuckaseegee Rivers (~500 effective population) (Albanese and Abouhamdan 2008, USFWS 2016, Favrot and Kwak 2018).

Conservation

The robust redhorse currently has a global conservation ranking status of G1G2 and a Georgia state conservation ranking of S1, but it is under no federal protections. This species is protected as Endangered in the state of Georgia.

Risks to the longterm persistence of sicklefin redhorse populations include limited population size, introduced predatory species, habitat fragmentation by impoundments, altered flow and temperature regimes, and most importantly, degradation of habitat by changes to land use of the surrounding watersheds. The U.S. Fish and Wildlife Service and the Georgia Department of Natural Resources have partnered with other organizations to address these risks by a number of avenues. Reintroduction of individuals to reaches within the historic range have taken place outside Georgia. Within Georgia, management actions include continued population monitoring and the funding of studies into habitat use, movement of adults and juveniles, reproduction, diet, and other life history characteristics. In 2016, Georgia DNR and USFWS signed a candidate conservation agreement with stakeholders aimed at maintaining existing populations, continuing stocking efforts, and improving the biological knowledge of the species (USFWS 2016).

Effects of construction activities

Sediment

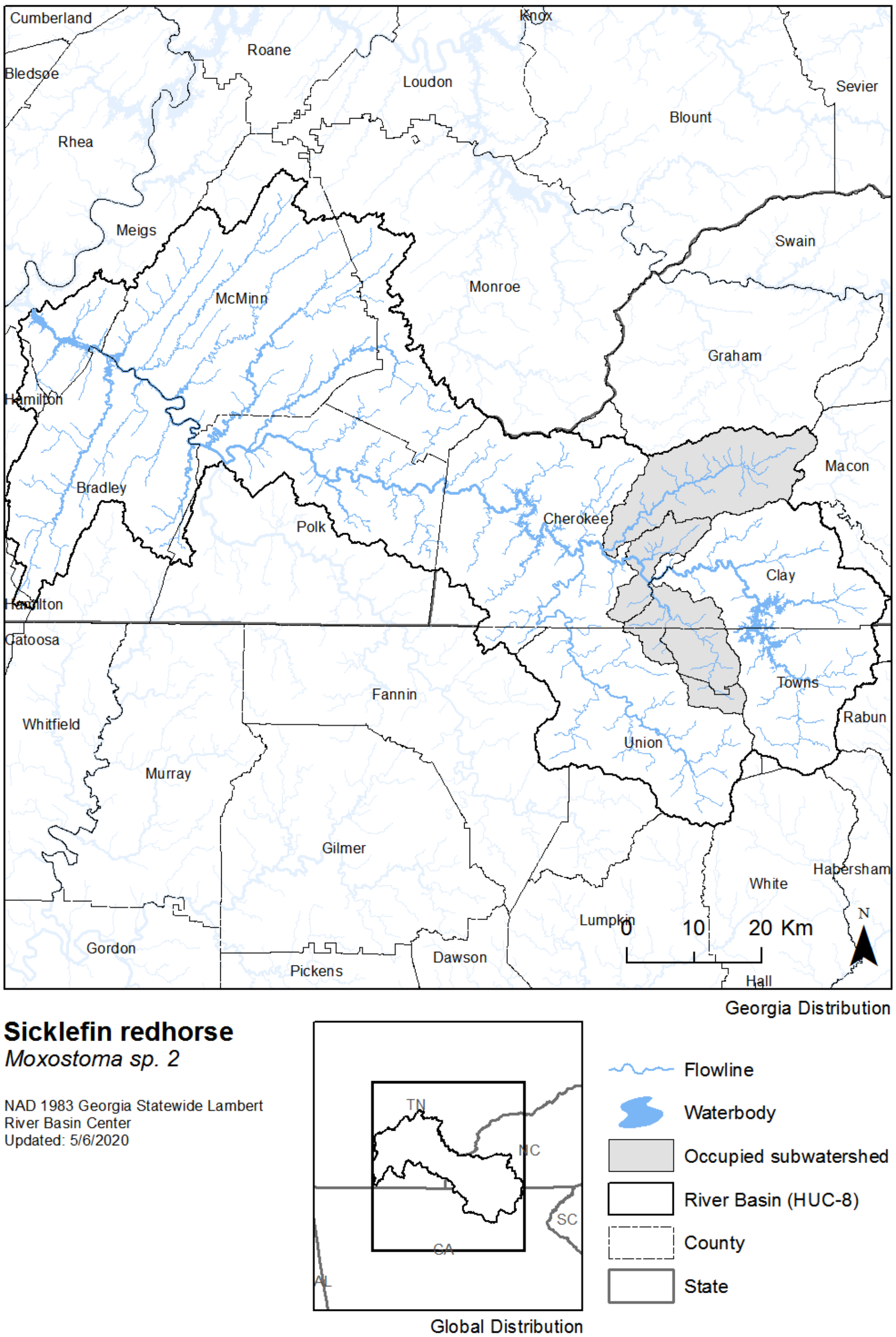
Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described the closely related *M. carinatum* as “highly sensitive” to sedimentation, whereas Meador and Carlisle (2007; Meador unpublished data 2020) categorized *M. carinatum* tolerance to suspended sediment as moderate. The most recent species status assessment (USFWS 2016) cites current and past agricultural land use as a major source of sedimentation and likely factor contributing to past declines of the sicklefin redhorse. However, it also notes that sicklefin populations have persisted in areas with major historical sediment inputs from agriculture and suggests this as evidence that sicklefin redhorse are moderately tolerant of land disturbance and associated sedimentation (USFWS 2016). Jenkins (1999) observed that reaches occupied by sicklefin are generally clear or slightly turbid. Building on this, he suggests that because sicklefin are (assumedly) taste-feeders, they may be less sensitive to potential adverse effects of sediment/turbidity on foraging success/efficiency. Therefore, the sicklefin redhorse sediment sensitivity is categorized as moderate (2).

Pollutants

The most recent species status assessment of the sicklefin redhorse (USFWS 2016) identifies pollutants from urbanized areas as a primary stressor. Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described the closely related *M. carinatum* as "highly sensitive" to industrial pollution. In contrast, Meador and Carlisle (2007; Meador unpublished data 2020) categorized *M. carinatum* tolerance to specific conductivity as moderate. The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of moderate for *M. carinatum*.

As a benthic invertivore, the sicklefin redhorse is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. Based on the mixed classifications of related species and because the traits-based evidence suggests a degree of sensitivity, the sicklefin redhorse pollutant sensitivity is categorized as somewhat intolerant (3).

Figure 17. Map. Range map for the sicklefin redhorse.



STARGAZING MINNOW

Species

Stargazing Minnow, *Phenacobius uranops*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999p):

The stargazing minnow is a very long, slender, silvery fish with small scales and a prominent snout overhanging a sucker-like mouth. It attains a maximum total length of about 120 mm (4.7 in). There are five species in this distinctive genus, which also includes the fatlips minnow (*Phenacobius crassilabrum*) and the riffle minnow (*P. catostomus*) in Georgia. The stargazing minnow is olive dorsally with a brassy mid-dorsal stripe. The prominent mid-lateral stripe is variously flecked with silver to metallic blue and is narrower than that of the fatlips minnow. The lower portion of the body is white, and the pelvic and anal fins are yellowish-olive to white. The dorsal, caudal, and pectoral fins are light olive. The stargazing minnow exhibits no sexually dimorphic coloration. The name "stargazing" refers to the upward tilt of the eyes.

Life History

Stargazing minnows in Virginia spawn from April through June, and life history is compressed: age-1 and age-2 fish are sexually mature and fish rarely exceed lifespans of three years. (Jenkins and Burkhead 1994). Individuals in spawning condition have been found in gravel-cobble riffles and runs, suggesting that this habitat may be used for spawning. Stargazing minnows are insectivores and are known to feed in small groups and consume larval aquatic insects (Etnier and Starnes 1993), finding food with their sensitive lips (Boschung and Mayden 2004). Stargazing minnows most frequently inhabit riffles in clear, small to medium rivers, generally in association with clean gravel and cobble substrate, although young fish often occur in more lentic habitats with vegetation (Etnier and Starnes 1993, Boschung and Mayden 2004).

Number, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999p):

The stargazing minnow occurs in the Tennessee, Cumberland, and Green river drainages of Alabama, Georgia, Kentucky, Tennessee, and Virginia. It occurs within the Ridge and Valley and Highland Rim physiographic provinces, but does not occur within the Blue Ridge. The stargazing minnow has been collected in Georgia in the West and South Chickamauga creek systems in Catoosa County.

The stargazing minnow is only known from a handful of sites in the West and South Chickamauga Creek systems. The species is known from relatively recent collections (i.e., post 2000) in both systems, although collections typically comprise only a few individuals.

An estimate of the total adult population size of the stargazing minnow is unavailable. The population trend over the past ten years is uncertain but distribution and abundance are thought to be relatively stable or slightly declining (NatureServe 2020).

Conservation

The global conservation ranking status of the stargazing minnow is G4 and the Georgia state conservation ranking status is S1. It is currently under no federal protections (Freeman et al. 1999p). This species is protected as Threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999p):

All fishes that are dependent upon clean gravel substrates are vulnerable to changes in habitat from excessive sedimentation. Several species of fishes have apparently been extirpated from the West and South Chickamauga creek systems. Although stargazing minnows are found in streams and habitats that may currently have some slight amount of silt, the clear preference for non-silty gravel-dominated substrates suggests that they may be vulnerable to habitat modification. Main potential threats to the stargazing minnow in Georgia are degradation of tributary streams and the mainstems of South Chickamauga and West Chickamauga creeks. Stream degradation resulting from failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas further threatens the stargazing minnow.

Conserving populations of the stargazing minnow depends on maintaining and restoring habitat and water quality in streams in the South and West Chickamauga creek systems. It is essential to eliminate sediment runoff from land-disturbing activities (such as roadway and housing construction), maintain forested buffers along stream banks, eliminate inputs of contaminants (such as fertilizers and pesticides), eliminate chronic discharges of industrial effluent and sewage, and maintain natural patterns of stream flow. Watershed clearing and urban development can lead to unnaturally flashy storm water runoff, which scours stream channels and results in lower baseflows. For these reasons, practices that promote infiltration of runoff will help protect the stargazing minnow.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the stargazing minnow's tolerance to suspended sediment as moderate. They also categorized three closely related species as moderate (*P. crassilabrum, P. catostomas, P. mirabilis*) and one as intolerant (*P. teretulus*). In Kentucky's Comprehensive Wildlife Conservation Strategy, stargazing minnows are considered to be sensitive to siltation and increased turbidity associated with human activities such as urban development and construction (Kentucky DFWR 2013). The closely related *P. catostomus* was among a group of highland endemic species whose relative richness and relative abundance decreased with increasing turbidity and bedded sediments (Walters et al. 2003).

As a tactile feeder, turbidity may not limit their feeding ability compared to visual feeders, but sedimentation that reduces populations of invertebrate prey within gravel may cause sublethal effects. While spawning of stargazing minnow has not been observed, *P. mirabilis* has been observed in aquaria broadcast spawning approximately 5 cm above gravel, with eggs subsequently adhering to rocks (Bestgen et al. 2003); this same fish did not spawn over sand. As a likely gravel spawner, stargazing minnow reproduction is therefore likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae.
Because of the limited direct evidence and the mix of previous sensitivity classifications, the sediment sensitivity of the stargazing minnow is categorized as moderate (2).

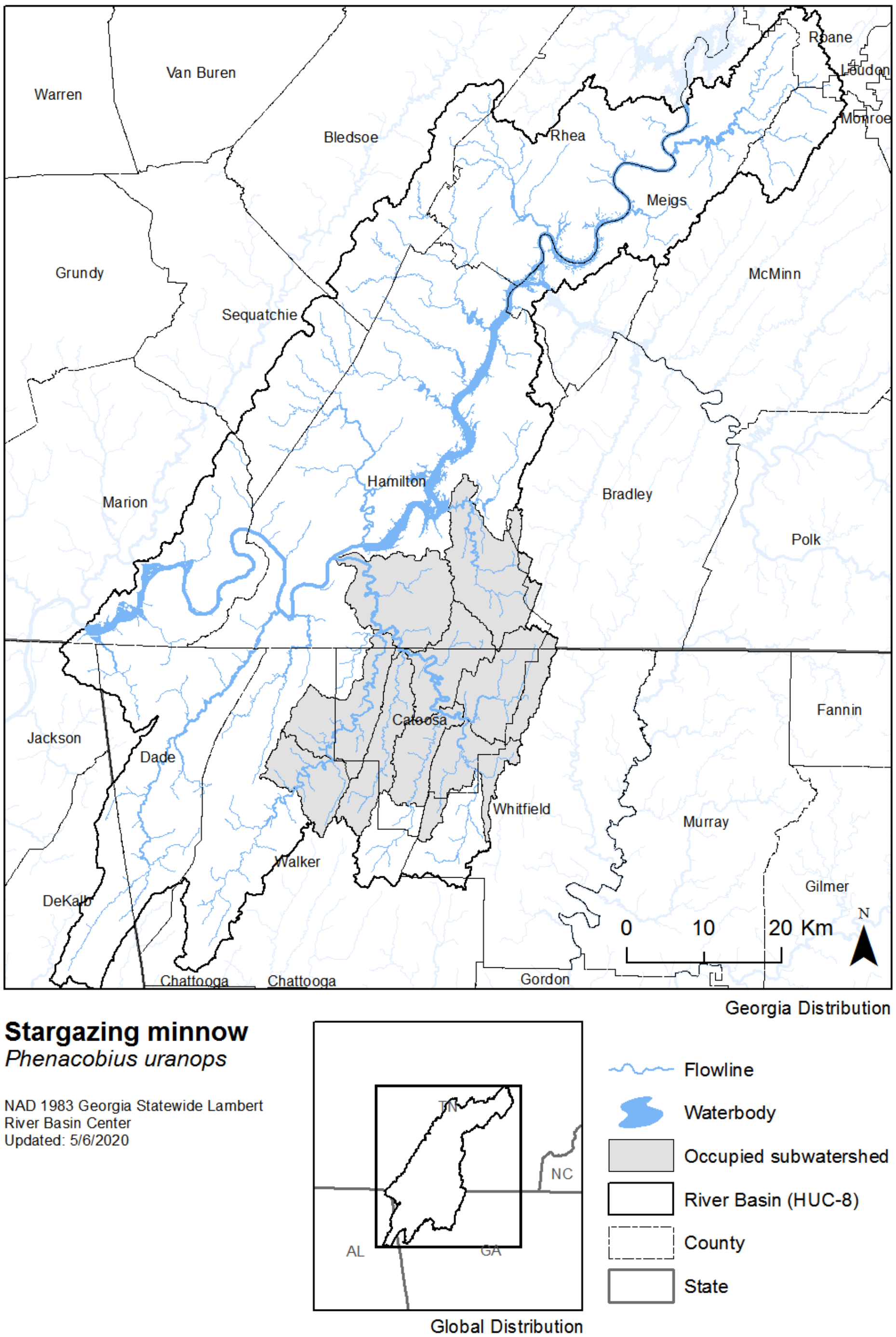
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the stargazing minnow's tolerance to specific conductivity as moderate. They also categorized two closely related species as moderate (*P. catostomas, P. crassilabrum*), one as tolerant (*P. mirabilis*), and one as intolerant (*P. teretulus*). The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of moderate for *P. mirabilis*. Findings by Onorato et al. (2000) suggest that *Phenacobis catostomus* was among species tolerant to sediment/pollutants associated with urbanization.

Because the stargazing minnow likely feeds at a low trophic level (aquatic invertebrates), its dietary exposure to pollutants is relatively low. As a species that lays its eggs directly on gravel substrate, incubating embryos are unlikely to come into direct contact with pollutants associated with fine sediments.

Given the limited information, per Meador and Carlisle, the pollutant sensitivity of the stargazing minnow is categorized as moderate (4).

Figure 18. Map. Range map for the stargazing minnow.



STIPPLED STUDFISH

Species

Stippled Studfish, *Fundulus bifax*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a): The stippled studfish is a light-gold topminnow with silver-blue sides marked by short interrupted rows of dark red to reddish-orange spots. The paired fins are blue-gray, and the caudal and dorsal fins lack marginal black bands. During the breeding season the flanks of this species turn sky blue, fading to dark blue-brown dorsally and to white below. Adults can reach 120 mm (4.7 in) total length.

Life History

The stippled studfish spawns in pairs over clean gravel substrate (Scanlan 2008).

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a): Major life history characteristics should be similar to those for the northern and southern studfish. This suggests the use of margin habitat in flowing streams, use of clean gravel for spawning, and an adaptation to utilizing freshwater snails for a significant portion of the diet. Spawning probably occurs in late spring and summer.

The stippled studfish typically inhabits clear, medium-sized streams. Preferred habitats are pools, stream margins and backwaters over sand or rocky substrate. Although it uses low-velocity habitats, the stippled studfish is restricted to free-flowing streams. Their diet is presumably food items similar to those of the southern studfish and the northern studfish, ranging from aquatic and terrestrial insects to small snails, clams and crayfish.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a): The stippled studfish is endemic to the Coosa and Tallapoosa river systems. It occurs in the Tallapoosa River system above or near the Fall Line in Georgia and Alabama, as well as in Sofkahatchee Creek, a single tributary to the lower Coosa River. In Georgia, the stippled studfish is known from only 2 locations in the Little Tallapoosa River system: one mainstem site and one nearby tributary site. The species is rare throughout its range.

The stippled studfish has not been collected in Georgia since 1990 and may be extirpated from the state. Comprehensive fish surveys were carried out at over 100 sites in the Tallapoosa River system of Georgia and Alabama in the early 2000s. In addition, a targeted survey was carried out at one of the historic sites in Georgia in 2005. Field notes during this survey indicated extensive habitat modification. This species still persists at several locations within Alabama.

Despite uncertainty over general trends in the past 10 years, it is likely that stippled studfish populations are relatively stable or under slow decline (NatureServe 2019).

Conservation

The stippled studfish has a global conservation ranking status of G2/G3, a Georgia state conservation ranking status of S1, and is currently under no US federal protection. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

Stippled studfish have a restricted distribution and are extremely rare. The native range of the stippled studfish is fragmented by four large reservoirs on the Tallapoosa and Little Tallapoosa rivers. Construction of additional impoundments on the Tallapoosa River upstream from Harris Dam would further fragment populations in the main channel of the upper Tallapoosa River and would isolate populations in newly cut off tributaries. Degradation of stream margin habitat because of poor riparian management and excessive sedimentation are additional threats. Conserving species unique to the Tallapoosa River system, such as the stippled studfish, depends on maintaining and improving flowing-water habitats and water quality in the river and its tributaries. It is essential to eliminate sediment runoff from land-disturbing activities (such as roadway and housing construction) and inputs of contaminants (such as fertilizers and pesticides). Forested buffers should be maintained and restored along the banks of the river and the smaller tributary streams that feed the river. Maintaining natural streamflow patterns by preventing excessive water withdrawal or unnaturally flashy runoff (such as from urban stormwater runoff) is also an essential element of protecting riverine habitat quality in the free-flowing and unregulated portions of the Tallapoosa River system.

Effects of Construction Activities

Sediment

Stallsmith (2013) identifies sedimentation as a source of degradation of spawning habitat for the stippled studfish in the Little Tallapoosa River. Of six streams surveyed in the Tallapoosa River, the stippled studfish was detected in only one of the two streams with forested watersheds and was not detected in any streams with watersheds dominated by agricultural activities (Saalfeld et al. 2012).

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of two closely related species, *F. catenatus* and *F. stellifer,* as moderate and intolerant, respectively. In the Osage River Basin, Missouri, the closely related *F. catenatus* was detected in only 4% of the sampled range and only in streams whose beds contained 1-4% fine sediments (Turner and Rabeni 2009).

As a species that spawns over gravel, stippled studfish reproduction is likely sensitive to the degradation of spawning habitat by the initial presence of fine sediments as well as the direct smothering of eggs/larvae by subsequent sedimentation events. As a probable invertivore, the stippled studfish is likely indirectly affected by suspended and bedded sediments via a reduction of macroinvertebrate abundance.

Based on the findings of Saalfeld et al. and the sensitivity of its spawning habitat, the sediment sensitivity of the stippled studfish is categorized as intolerant (1).

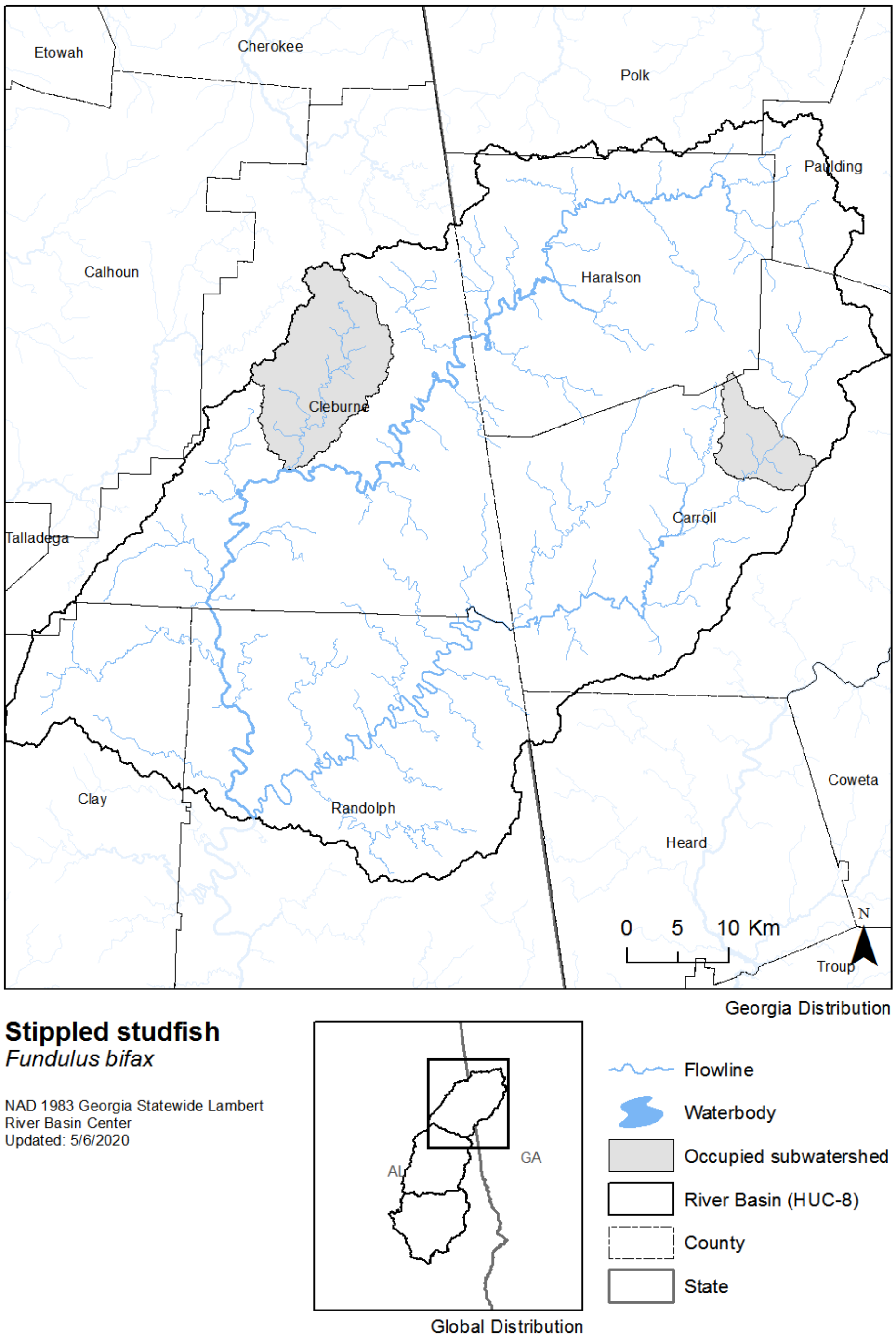
Pollutants

The research team knows of no lab or field studies that directly investigate the effects of roadway- or construction-related pollutants on the stippled studfish, but some work has been done on closely related species. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of two species, *F. catenatus* and *F. stellifer,* as moderate.

The stippled studfish is likely an invertivore and as a member of this feeding guild it is likely to be indirectly affected by pollutants that biomagnify from its prey base. Incubating embryos may come into contact with sediment-associated pollutants; however, because of the low surface area of their preferred spawning gravels to which pollutants may bind, the exposure to those pollutants is likely low.

Considering the limited information and the mix of traits-based evidence, the pollutant sensitivity of the stippled studfish as moderate (4).

Figure 19. Map. Range map for the stippled studfish.



SUWANNEE BASS

Species

Suwannee bass, *Micropterus notius*

Description

Reproduced from Georgia Department of Natural Resources species profile (Bonvechio et al. 1999): The Suwannee bass is a deep-bodied, relatively small black bass that attains a maximum length of about 420 mm (16.5 in). It has a relatively large mouth with the upper jaw extending under the eye, but not past the eye. There are scales on the bases of the soft dorsal and anal fins and a circular patch of teeth on the tongue. The body color is brown overall, with about 12 olive lateral blotches on the sides. Anteriorly, these blotches are wider than the interspaces between them; they fuse together on the caudal peduncle to form a lateral band. There is a large caudal spot that is obviously bordered by a light area, especially in smaller specimens. Young also have boldly mottled soft dorsal, caudal, and anal fins. During the breeding season, adults develop bright turquoise blue on the cheek, breast, and belly.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Bonvechio et al. 1999):

Spawning for Suwannee bass occurs from February through May, with peak spawning occurring in April and May, when water temperatures range from 18-19°C (64-66°F). Nest preparation, spawning and parental care is similar to that of other sunfishes. Eggs are deposited and fertilized in circular depressions swept out near stream margins. Males guard the incubating eggs until they hatch. Suwannee bass are a relatively small bass in comparison to the largemouth bass. They do show evidence of gender specific growth rates with females growing more rapidly and obtaining a larger size than males. Males rarely exceed 13 inches, but females have been known to exceed 16inches. Females can live up to 12 years, but males have not been known to exceed age 9.

Suwannee bass occupy a wide range of habitats, including rocky shoals, runs, pools, large springs, and spring runs. They are often associated with woody debris. This species is apparently absent from the more acidic portions of the river drainages they occur in, for example in the upper Suwannee River in Georgia. Habitat selection for adult Suwannee bass does appear to differ from adult *M. salmoides* in at least one of the rivers examined in Florida, the Withlacoochee River. The Suwannee bass preys heavily on crayfishes, but also eats fishes and aquatic insects. Blue crabs are included in the diet in estuarine areas.

To make nests, males either select areas along the stream margin with high sediment deposition or areas where current is diverted away from the nest by instream structure (Strong et al. 2010). The substrate of the nest can be made up of organic sediments, sand, leaf litter, fine woody debris, pebbles, limestone, and shell (Nagid et al. 2015). Suwannee Bass are known to construct nests near strap-leaf sagittaria and eelgrass which suggests that macrophytes provide important refugia for spawning by reducing sediment influx disturbance to eggs (Strong et al. 2010).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Bonvechio et al. 1999):

The Suwannee bass is endemic to the Suwannee and Ochlockonee river drainages in Georgia and Florida. They occur in the Ichetucknee, Santa Fe, St. Marks, Suwannee, Wacissa and Wakulla rivers of Florida, and in the Alapaha, Ochlockonee and Withlacoochee rivers of Florida and Georgia. Populations are believed to be introduced in the St. Marks and Wacissa river systems of Florida. All three populations of Suwannee bass in Georgia can be characterized as having relatively low abundances in comparison to Florida's populations. The largest population in Georgia occurs in the Ochlockonee drainage. It is believed by researchers that the relative scarcity of this fish is due to a lack of crayfish abundance where water quality parameters are not suitable for crayfish.

Georgia portions of the Suwannee and Ochlockonee drainages have received limited sampling compared to other drainages due to poor accessibility during low water conditions. Recently, Suwannee bass populations were confirmed below the Statenville bridge in the Alapaha River, but none were recovered North of the bridge.

The Suwannee bass is a relatively common species. It is most abundant in the lower 40-50 kilometers of the Santa Fe River in Florida. Although the total adult population is unknown, the short-term trend indicates that Suwanee bass numbers are relatively stable (Nature Serve 2020). Studies from the Suwanee and Santa Fe Rivers in Florida have speculated that the relative scarcity of this species is likely due to inadequate crayfish abundance (Bass and Hitt 1973; Schramm and Maceina 1986).

Conservation

The global conservation ranking status of the Suwanee bass is G3, a Georgia state conservation ranking status of S2, and it is currently under no federal protections. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Bonvechio et al. 1999):

The global conservation ranking status of the Suwannee bass is G3. The state conservation ranking status is S2. It is currently under no federal protections.

The Suwannee bass has the most restricted range of all the black basses. A good sports fishery exists in the Ochlockonee River drainage in Georgia, and to some extent in the Withlacoochee and Alapaha river systems. A long history of fish kills exists for the Ochlockonee River in Georgia, and more recently the Alapahoochee river, a tributary of the Alapaha river, due to poor water quality as influenced by industrial discharges and improper use of pesticides. The primary threat to the Suwannee bass is poor water quality. More recently, the introduced flathead catfish *Pylodictis olivaris* were found to occur in the Ochlockonee River of Florida. This invasive predator has been known to negatively affect native fish populations. At this time, the flathead catfish has not been confirmed in the Georgia waters of the Ochlockonee but may indeed exist. Also, hybridization with largemouth bass has not been thoroughly examined with this species but has been speculated by fisheries biologist to exist in at least one of the Florida populations.

Conserving populations of the Suwannee bass while managing this unique sports fishery will require periodic monitoring of populations and harvest rates, as well as adopting land management practices that ensure good stream habitat. Habitat loss through pollution, drainage and hydrologic alteration of Coastal Plain swamps and rivers must be avoided. Poor land use practices causing erosion and siltation of the limestone outcroppings existing on the Alapaha and Withlacoochee rivers could threaten this species. Maintaining natural stream flow patterns by preventing excessive water withdrawal or unnaturally flashy runoff (such as from urban storm water runoff) also is an essential element of protecting riverine habitat quality. Research has confirmed that genetic differences do exist between Suwannee bass populations in Florida. If supplemental stocking is ever used to manage populations in Georgia, these genetic differences must be taken into account and more thoroughly evaluated for Georgia populations.

Studies from the Suwanee and Santa Fe Rivers in Florida have speculated that the relative scarcity of this species is likely due to inadequate crayfish abundance (Bass and Hitt 1973; Schramm and Maceina 1986).

Effects of construction activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the Suwanee bass tolerance to suspended sediment as intolerant. They also evaluated the suspended sediment tolerance of some closely related species (Near et al. 2005), categorizing two as moderate (*M. salmoides, M. treculi*) and one as intolerant (*M. coosae*).

Multiple studies have examined the effects of turbidity on the foraging of the related *M. salmoides*, identifying multiple mechanisms contributing to adverse effects: delayed perception of prey, greatly reduced capture/foraging rate, and altered prey selection (Shoup and Wahl 2009, Huenemann et al. 2012). One experiment found that hatching success of *M. dolomieu* eggs was not affected by suspended sediment. However, the same study reported that larval survival was 80% higher in the control, with survival decreasing significantly above 100 mg/L TSS (Suedel, Wilkens, and Kennedy 2017). Like other centrarchids, Suwanee bass build shallow nests in fine sediments and maintain them free of fine sediments during incubation. For this reason, their reproduction is likely to be minimally affected by existing or subsequent sedimentation.

The sediment sensitivity of the Suwanee bass is categorized as moderate (2), reflecting a balance of the relatively high sensitivity to suspended sediment but relatively low sensitivity to bedded sediment during reproduction.

Pollutants

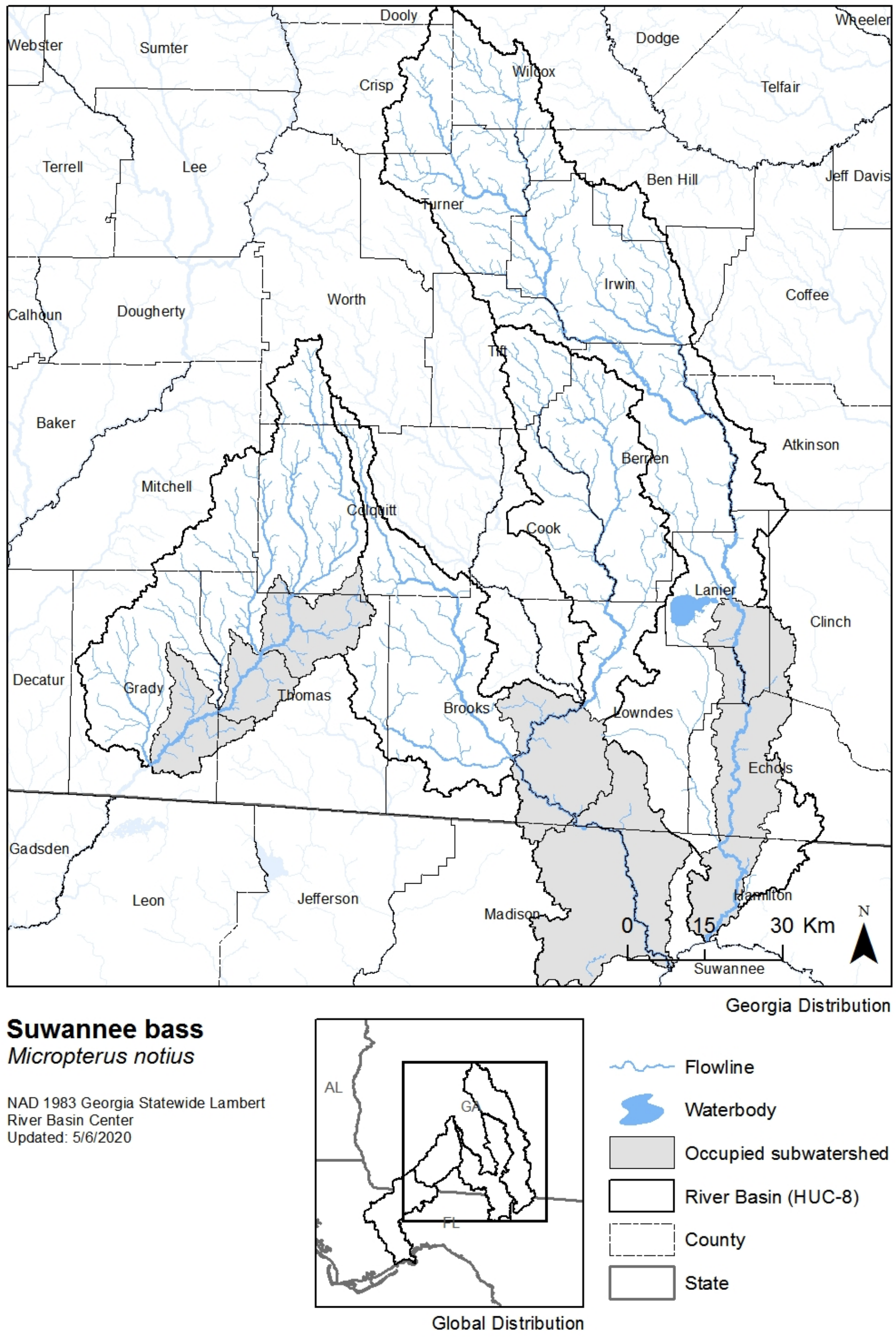
Meador and Carlisle (2007; Meador unpublished data 2020) categorized the Suwanee bass tolerance to specific conductivity as moderate; they also evaluated the specific conductivity tolerance of some closely related species, categorizing two as moderate (*M. coosae, M. salmoides*) and one as tolerant (*M. treculi*). The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of moderate for *M. salmoides*.

Like its congeners and other piscivorous species at the upper levels of the freshwater food webs, the Suwanee bass likely accumulates a greater body burden of many pollutants. Levels of mercury in the closely related *M. salmoides* were found to exceed levels considered safe for human consumption (Lange et al. 1994). Mercury concentrations were correlated with size and weight of *M. salmoides* in reservoirs of the Southeastern US (Abernathy and Cumbie 1977). Elevated mercury levels were found to potentially alter androgen profiles but did not considerably affect general and reproductive health of *M. salmoides* in the lakes of New Jersey, US (Friedmann et al. 2002).

While the substrate used by Suwanee bass for nest construction is more variable than that of many congeners, its incubating eggs remain in direct contact with fine substrate, serving as an exposure route to sediment associated pollutants. As a species that feeds at a high trophic level, it is likely to carry a higher body burden of pollutants that biomagnify.

Based on their high trophic level and their direct contact with fine sediments as embryos, the pollutant sensitivity of the Suwanee bass is categorized as somewhat intolerant (3).

Figure 20. Map. Range map for the Suwannee bass.



TALLAPOOSA DARTER

Species

Tallapoosa Darter, *Etheostoma tallapoosae*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a): The Tallapoosa darter is a moderately-sized species of "snubnose" darter with the characteristic blunt snout. Reaching about 70 mm (2.8 in) total length, the Tallapoosa darter usually has 8-9 chocolate-brown lateral blotches and eight dorsal saddles. Breeding males develop red-orange coloration ventrally and between the lateral blotches and a blue-green anal fin and breast; the dorsal fins have broad red-brown basal bands and are edged by a blue band. Recent studies have detected genetic differences between populations in the Tallapoosa and Little Tallapoosa River systems, but these populations are not known to differ morphologically.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

This species is found primarily in relatively silt-free riffles around gravel, cobble and boulder substrata in stream sizes ranging from creeks to small rivers.

Like other snubnose darters, the Tallapoosa darter is an egg-attacher. One or two eggs at a time are attached to the surfaces of rocks, logs, or vegetation. Males are aggressive but are not territorial. Spawning probably occurs during March and April, although males will obtain spawning coloration earlier in the year.

Their diet consists of benthic aquatic insects.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999aa):

The Tallapoosa darter is endemic to the Tallapoosa River system in Alabama and Georgia and occurs only above the Fall Line. Georgia populations are known from the Tallapoosa River, Little Tallapoosa River, and their tributaries. The Tallapoosa darter appears more widespread in the Tallapoosa system than the Little Tallapoosa system. Tallapoosa darters occur both in small tributary streams and in the main channels of the Tallapoosa and Little Tallapoosa rivers.

A recent status survey found no evidence for decline between 1990 and 2002 and indicated that the Tallapoosa darter remains widespread throughout the upper Tallapoosa River system. However, the same study found that this species is less likely to occur in streams that are upstream from impoundments and in watersheds with relatively high impervious cover.

Conservation

The Tallapoosa darter has a global conservation ranking status of G4, a Georgia state conservation ranking status of S3, and it is not under any federal protections. This species is protected as Rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999a):

The Tallapoosa darter is particularly vulnerable to habitat loss because its distribution is restricted to a single river system. Populations in the Little Tallapoosa River system are isolated from downstream populations by Harris Reservoir in Alabama and are not as widespread as those in the main Tallapoosa River. Populations in both systems are threatened by accelerated stream degradation by excessive inputs of silt and sediment. Stream degradation is the result of failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas.

Conserving species unique to the Tallapoosa River system, such as the Tallapoosa darter, depends on maintaining and improving flowing-water habitats and water quality in the river and its tributaries. Because of genetic structuring, it is important to protect populations in both the Tallapoosa and Little Tallapoosa River systems. It is essential to eliminate sediment runoff from land-disturbing activities (such as roadway and housing construction) and inputs of contaminants (such as fertilizers and pesticides). Forested buffers should be maintained along the banks of the river and the smaller tributary streams that feed the river. Maintaining natural patterns of streamflow by preventing excessive water withdrawal or unnaturally flashy runoff (such as from urban storm water runoff) is also an essential element of protecting riverine habitat quality in the free-flowing and unregulated portions of the Tallapoosa River system. Impounding streams should be a last resort for developing water supplies.

Effects of Construction Activities

Sediment

In a study of the spawning characteristics of the Tallapoosa darter, Hubbell and Banford (2019) describe sedimentation of its habitat as a "leading threat." Similarly, sedimentation is considered a primary stressor to the closely related *E. brevirostrum and E. chermocki* (Hartup 2005, FWS 2019), also in the *Ulocentra/Adonia* subgenus. Wenger and Freeman (2007) identified sedimentation as a primary stressor to two closely related species (*E. scotti, E. brevirostrum*) and other imperiled species of the Etowah River. Walters et al. (2003) found that relative richness and relative abundance of "highland endemic" species, including the Cherokee darter, *E. scotti*, decreased with increasing turbidity and bedded sediments. Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of several closely related species, categorizing three as moderate (*E. duryi, E. flavum, E. ramseyi*) and one as intolerant (*E. coosae*).

As a benthic invertivore, the Tallapoosa darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. Because the Tallapoosa darter attaches its eggs to rocks, logs, or vegetation, the eggs are likely less vulnerable to the potential adverse effects of a sedimentation event. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration, common among darters (Seehausen et al. 1997; Burkhead and Jelks 2001).

While spawning habitat of the Tallapoosa darter may not be highly sensitive to sediment, the remaining traits-based evidence and the evidence on closely related species suggest a high level of sensitivity to sediment. Therefore, the overall sediment sensitivity of the Tallapoosa darter is categorized as intolerant (1).

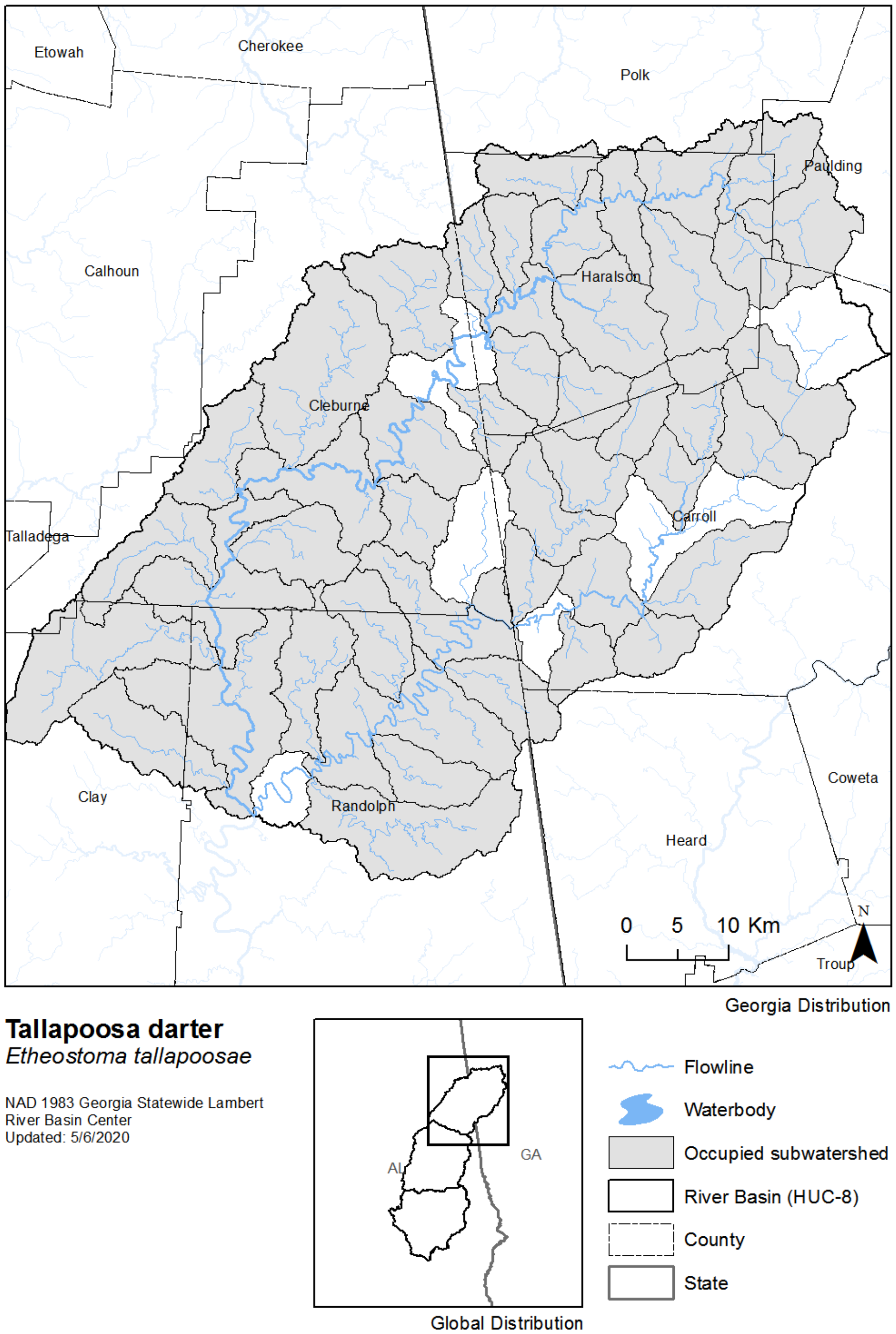
Pollutants

There are no studies investigating the effects of construction- or roadway-derived pollutants on the Tallapoosa darter, but some data exist on its closely related species in the subgenus *Ulocentra/Adonia*. Stormwater pollutants are considered a primary stressor to several species (*E. brevirostrum, E. chermocki, E. scotti)* closely related to the Tallapoosa darter (Hartup 2005; Wenger and Freeman 2007; FWS 2019). Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the specific conductivity tolerance of several closely related species, categorizing all four as moderate (*E. coosae, E. duryi, E. flavum, E. ramseyi*). Wenger and Freeman (2008) found that abundance of *E. scotti* decreased with increasing imperviousness; however, Wenger et al. (2008) found no relationship between imperviousness and occurrence.

The Tallapoosa darter is a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. Because it attaches its eggs to rocks, logs, or vegetation, those eggs are less likely to come into direct contact with sediment-bound pollutants during development.

With limited direct species information and mixed traits-based evidence, the overall pollutant sensitivity of the Tallapoosa darter is categorized as somewhat intolerant (3).

Figure 21. Map. Range map for the Tallapoosa darter.



TANGERINE DARTER

Species

Tangerine Darter, *Percina aurantiaca*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

One of the largest darters with a maximum total length exceeding 17 cm (6.7 in), the tangerine darter takes its common name from the brilliant orange coloration that adorns the belly and underside of the head of adult males. Females and juveniles are less intensely colored with yellow on the undersides. Both sexes have dark blotches that blend together to form a dark stripe along the fish's sides, and a single row of small dark spots above. The dorsum is tinted yellow; the dorsal fins are bright orange in males and yellow in females. Males may retain the orange coloration on their bellies past the spawning season and throughout much of the year.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The tangerine darter inhabits high gradient rivers and large streams, where adults occupy swiftly flowing, moderately deep riffles and runs, and deeper pools in winter. Juveniles occupy shallower, slower habitats adjacent to faster water areas. Unlike most darter species, the tangerine darter is often observed hovering over, instead of resting on the stream bottom.

Like many stream fishes, tangerine darters feed primarily on aquatic invertebrates. Juveniles are known to include mayfly and dipteran larvae in their diet, while adults feed heavily on larval caddisflies. The aquatic plant riverweed (*Podostemum ceratophyllum*) is an important feeding habitat.

This large darter may live 4 years or longer. Spawning occurs primarily in May and June. As is typical of the genus *Percina*, the tangerine darter is an egg-burying species. The male straddles the female during spawning and the pair quivers as gametes are buried in the gravel. Large colorful males participate in the most spawning events, but territories are not defended.

Number, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):

The tangerine darter occurs in the upper Tennessee River drainage in Georgia, North Carolina, Tennessee and Virginia. In Georgia, this large darter is known only from the Toccoa River system. Most records are from the mainstem river upstream of Lake Blue Ridge.

Twenty-nine randomly selected sites, located upstream and downstream of Lake Blue Ridge on the mainstem Toccoa River, were surveyed by snorkeling during summer 2008. The tangerine darter was observed at 17 of these sites (59%), all of which were located upstream of Lake Blue

Ridge. Although there is no historic data for comparison, this relatively high rate of occupied sites suggests that the tangerine darter population in Georgia is currently stable. However, given the relatively short section of river occupied (about 33 river kilometers or 20 miles), this species remains vulnerable.

An estimate of the tangerine darter's adult population size is unavailable. The species' shortterm population trend is described by NatureServe (2020) as relatively stable.

Conservation

The tangerine darter has a global conservation status ranking of G4 and a Georgia state conservation ranking status of S2. It is currently under no federal protections. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999):
Impoundments throughout the upper Tennessee River system limit available habitat for the tangerine darter. The portions of the system that remain free-flowing are vulnerable to degradation by excessive inputs of silt and sediment, which fill-in the gravel and cobble substrata that support the fish's prey and developing eggs. Stream degradation results from failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas. Increasing development of second homes utilizing poor

construction and riparian management practices poses a threat to this species. Finally, hemlock wooly adelgid is a significant threat to riparian zone habitats along the Toccoa River.

Conserving populations of the tangerine darter will require maintaining and improving habitat quality in the upper Toccoa River by eliminating sediment runoff (from land-disturbing activities such as roadway and housing construction) and maintaining forested buffers along stream banks. There are many opportunities to enhance and widen riparian zone habitats by planting native trees and shrubs along creeks and streams. The Georgia Forestry Commission provides information on treatment options for hemlock wooly adelgid. Finally, ongoing monitoring efforts should be continued for this species.

Effects of Construction Activities

Sediment

Sutherland et al. (2002) found that relative abundance of gravel-spawners declined, including the closely related *P. evides*, as turbidity and bedded sediments increased. Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described the closely related *P. evides* as 'highly sensitive' to sedimentation. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the tangerine darter tolerance to suspended sediment as intolerant; they also evaluated the suspended sediment tolerance of the closely related *P. evides*, categorizing it as moderate.

As a benthic invertivore, the tangerine darter is likely indirectly affected by sediment via a reduction of macroinvertebrate abundance. As a species that spawns in gravel, tangerine darter reproduction is likely sensitive to sedimentation by both degradation of habitat and direct smothering of eggs/larvae.

Based on the sensitivity of its spawning habitat, the sediment sensitivity of the tangerine darter is categorized as intolerant (1).

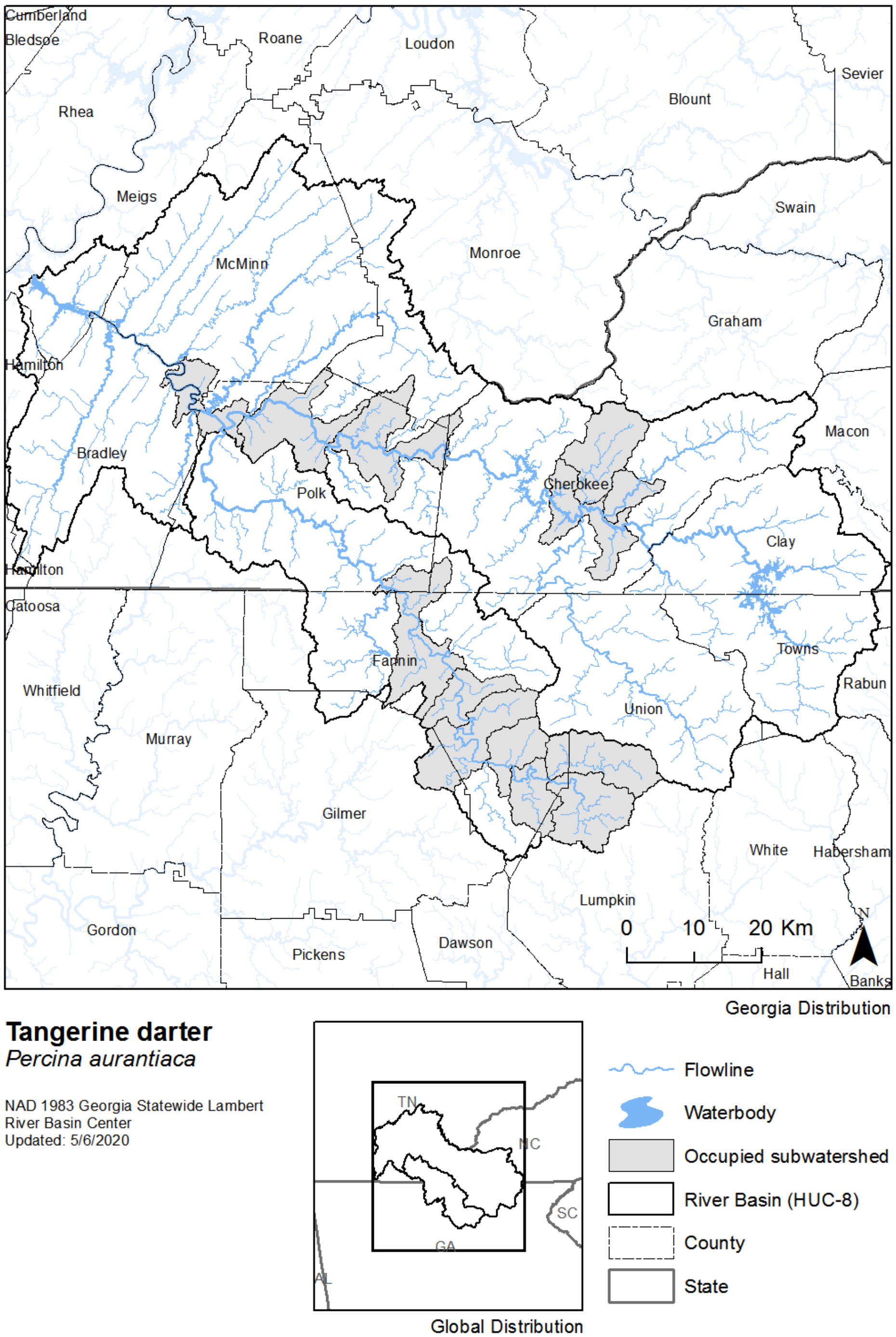
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the tangerine darter tolerance to conductivity as intolerant; they also evaluated the conductivity tolerance of the closely related *P. evides* as moderate.

Because the tangerine darter feeds on benthic invertebrates, it is indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. As a species that buries its eggs in gravel, tangerine darter eggs/larvae are likely exposed to roadway pollutants that are bound to bedded sediments, though this effect may be reduced by the lower surface area available for binding with pollutants.

Based on the work by Meador and Carlisle, the pollutant sensitivity of the tangerine darter is categorized as somewhat intolerant (3).

Figure 22. Map. Range map for the tangerine darter.



TENNESSEE DACE

Species

Tennessee Dace, *Chrosomus tennesseensis*

(formerly *Phoxinus tennesseensis*)

Description

Reproduced from Georgia Department of Natural Resources species profile (Skelton and Mitchell 2008): The Tennessee dace is a slender minnow with a somewhat pointed snout. This species has distinct breeding and non-breeding color phases. During most of the year (non-breeding) the back is an olive color with small scattered black specks. A black stripe of varying intensity runs from the upper connection of the gill cover with the body, to the base of the caudal fin. A second stripe runs below this stripe from the snout to the base of the caudal fin. The lower stripe may appear slightly kinked upwards over the pelvic fins. In some cases individuals of this species can be completely pale. The belly is whitish and the fins are clear to yellowish. During the April-May breeding season, the stripes are more intense and the lower stripe appears to be broken into two parts above the pelvic fins. The area between the upper and lower stripes is yellowish, and in very bright individuals, the snout may be yellowish. There are silvery spots at the bases of the pectoral, pelvic, dorsal, and caudal fins. The belly is scarlet, and in exceptionally bright individuals, the gill cover is also bright red. The underside of the head is black and the paired fins are bright yellow. Males average brighter than females. Non-breeding adults may have some red on the belly and yellow in the fins at any time of the year. This fish reaches a maximum total length of about 75 mm (3 inches).

Life History

Reproduced from Georgia Department of Natural Resources species profile (Skelton and Mitchell 2008): Like other members of this genus, spawning for the Tennessee dace occurs in late spring, from early April to about mid-June. Spawning takes place over small, clean, gravel substrates at the head of small riffles. Tennessee dace sometimes spawn over the nests of other minnows like the creek chub (*Semotilus atromaculatus*) and the stoneroller (*Campostoma*). Often, up to 20 males will follow a single female in a straight line before around two males stop and hold their positions, ready to spawn. No parental care is provided. Most individuals are mature by the end of their first year and probably live to four years. Tennessee dace are multiple clutch spawners. Total numbers of mature ova range from 398-721 and range in size from 0.9-1.5 mm in diameter.

This species is typically found in pool areas of clear headwater creeks less than 2 m (6½ feet) in width. Most of the streams in which this species occurs have a rocky substrate and overhanging banks that provide hiding places.

Tennessee dace primarily feed on organic detritus, algae, and diatoms. They will also eat aquatic insect larvae and have been observed picking at material on the surface of the water.

Tennessee dace is a broadcast spawner (Jenkins and Burkhead, 1994). The fecundity of Tennessee dace is lowest among its congeners (Hamed et al., 2008). In a study from Northeast Tennessee, highest densities of Tennessee dace were recorded from spring-fed, first order streams characterized by silt-bottomed pools and small riffles flowing through mixed-deciduous forest (Hamed et al., 2008). The spawning behavior, age structure, and growth of Tennessee dace resembles other congeners with lifespans generally less than three years, and age class structure dominated by one and two year old fish (Hamed et al., 2008).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Skelton and Mitchell 2008): The Tennessee dace is endemic to the upper Tennessee River drainage and most populations are found in the Ridge and Valley physiographic province in northeastern Tennessee. Three or four populations are known from extreme southeastern Virginia and a single population is known from the Lookout Creek system in northwestern Georgia.

Only a single population of this species is known in Georgia and it occurs on private land. This population represents the southernmost natural population of the Tennessee dace. Populations on the edge of a species range are a high priority for conservation because they often represent distinct evolutionary lineages with different adaptive potential than populations in the center of the species range. A nearby population reported from Whiteside, Marion County, TN was documented in 1889 and is considered extirpated.

The total adult abundance of the Tennessee dace is not well known but is estimated to be at least a few thousand. The short-term trend in population has experienced <30% decline to relatively stable levels. Population size, number of subpopulations and range are likely under decline, but exact estimates of current rate of decline are not available (NatureServe 2020).

Conservation

The Tennessee dace has a current global conservation ranking status of G3. It has a Georgia state conservation ranking status of S1. It is not currently under any federal protections. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Skelton and Mitchell 2008): Because of its small known range in Georgia, the Tennessee dace could easily be extirpated from the state. Small headwater streams are vulnerable to impacts associated with residential and commercial development. Small streams are often “piped,” which results in the complete loss of habitat for a headwater specialist such as the Tennessee dace. Other impacts to headwater streams include destruction of streamside forest, impoundment, alteration of natural stream flow patterns due to increases in paved or other impervious surfaces in the watershed, and water quality impairment associated with nutrients, toxic chemical, and sediment runoff. Heavy sedimentation resulting from poor development and land management practices may cover gravel spawning substrates needed by this species for reproduction.

Additional surveys are needed to identify more populations of this species in Georgia, if they exist. Current land use in the local watershed is dominated by agricultural and forestry uses. Local residents can protect this population by following best-management practices for agriculture and forestry, minimizing the use of fertilizers and pesticides, and protecting forests along the banks of the stream. Wider forested buffers are needed in areas with steep slopes or in areas that are adjacent to intensive agricultural use. Establishing conservation easements along this stream may help protect this population from future development pressures without conflicting with current land uses.

Effects of Construction Activities

Sediment

Burkhead and Jenkins (1991) suggest that increased siltation is a major factor in declining abundances of Tennessee dace. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of two congeners, *C. oreas* and *C. erythrogaster,* as intolerant and moderate, respectively.

Because the Tennessee dace spawns over clean gravel, its reproduction is likely sensitive to the adverse effects of sedimentation; however it sometimes rely on nests built by other benthic nest-building species for spawning (Hamed et al., 2008). Benthic nest builders and nest-associates are relatively insensitive to the initial presence of sediment because they spawn over a sediment-free nest (Sutherland et al., 2002), but they are still sensitive to sedimentation events following fertilization. Omnivorous fish like the Tennessee dace are likely less sensitive to sediments because of their ability to adjust foraging habits in response to sedimentation presence or events.

Based on the adaptability of its spawning behavior, the sediment sensitivity of the Tennessee dace is categorized as moderate (2).

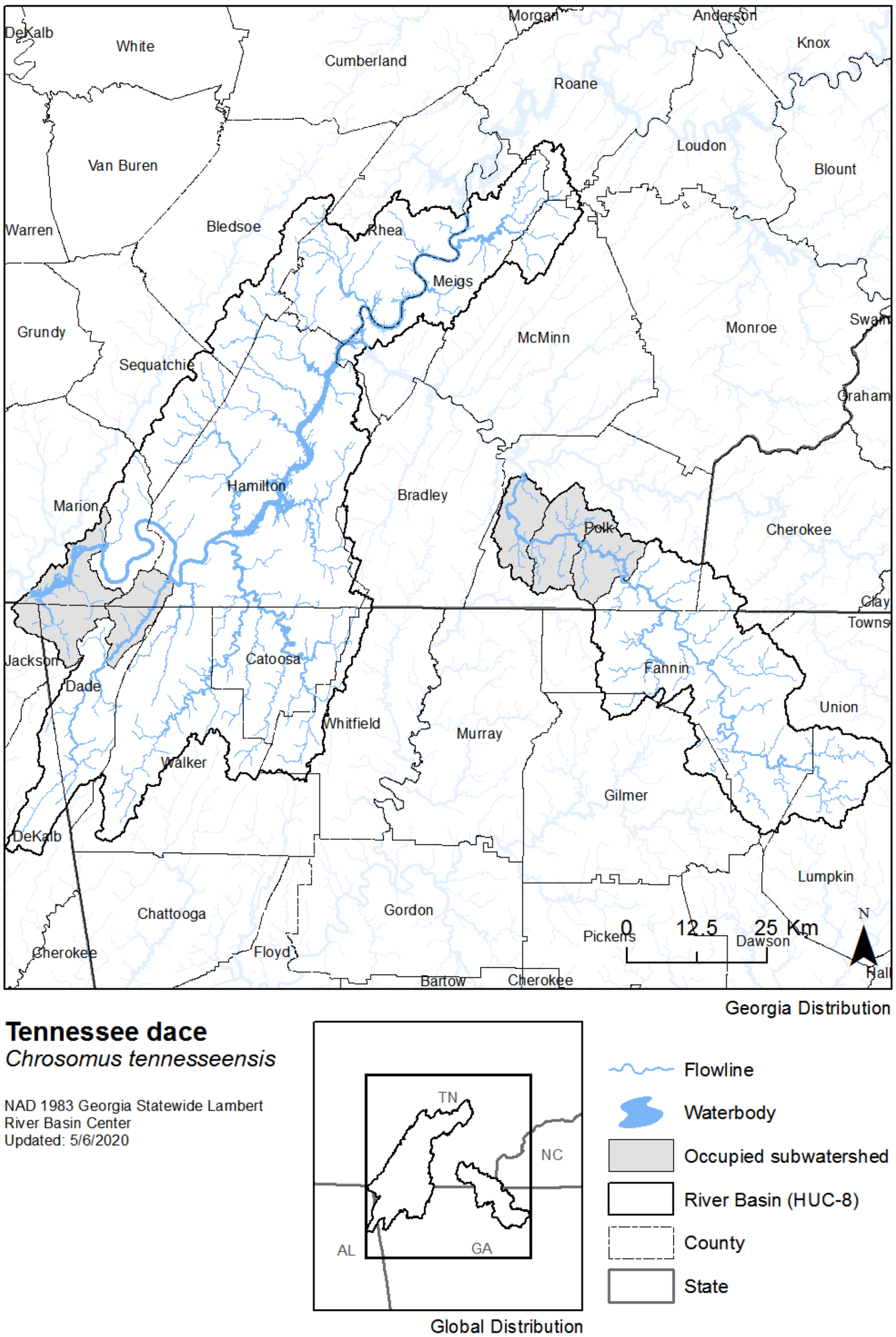
Pollutants

While the research team know of no laboratory or field investigations that directly investigated the sensitivity of the Tennessee dace to construction- or roadway-associated pollutants, some research has examined its congeners. Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of *C. oreas* and *C. erythrogaster* as intolerant and tolerant, respectively. The research team converted the quantitative ionic tolerance data from Griffith et al. (2018) into tolerance categories (intolerant, moderate, tolerant), which yielded a classification of intolerant and tolerant for *C. oreas* and *C. erythrogaster*, respectively. Hitt et al. (2016) found abundance of the related *C. cumberlandensis* to be negatively related to stream conductivity.

Because Tennessee dace spawn in clean gravels or gravel nests, their eggs/larvae are less likely to come into direct contact with sediment-bound pollutants. As algae/insect drift feeders, they feed at a lower trophic level and are likely to have a lower exposure to dietary pollutants.

Based on the mix of classifications of its closely related species, the pollutant sensitivity of the Tennessee dace is categorized as moderate (4).

Figure 23. Map. Range map for the Tennessee dace.



TRISPOT DARTER

Species

Trispot Darter, *Etheostoma trisella*

Description

Reproduced from the U.S. Fish and Wildlife Service most recent species status assessment for the trispot darter (USFWS 2017c): The trispot darter is a small bodied, benthic fish distinguished from the other four Ozarka species by its complete lateral line, single anal spine, and scaled cheeks (Williams and Robinson 1980, p. 150). Adult males and females range in size from 1.3 - 1.6 inches (33 - 40 mm) standard length (Mettee et al. 1996, p. 675), and the body is slender to moderately stout. The darter has three prominent black dorsal saddles, pale undersurface, and a dark bar below the eye (Bailey and Richards 1963, p. 15 - 16). Scattered dark blotches exist on the fin rays. During breeding season males are a reddish-orange color and have green marks along their sides and a red band through their spiny dorsal fin.

Life History

Adult trispot darters make relatively short, seasonal migrations between distinct breeding (late November to late April) and non-breeding habitats (late April to late October), spending a bit more time in non-breeding habitat (USFWS 2017c). Adult non-breeding habitat is found at the margins, and other areas of low-velocity waters, of small/medium rivers or lower reaches of tributaries in association with woody debris, detritus, and vegetation. Substrate is primarily composed of gravel and cobble, often with a layer of fine sediments. Migration upstream to breeding habitats begins in the late fall. Breeding habitat is described as "intermittent to partially intermittent seepage areas and ditches with little to no flow; shallow depths (<30cm); moderate leaf litter covering mixed cobble, gravel, sand, and clay; a deep layer of soft silt over clay; and emergent vegetation" (USFWS 2017c). These habitats develop in the winter months as the water table rises with rainfall. Females, in coordination with males, broadcast adhesive eggs which stick to macrophytes or rocks (USFWS 2017c).

The diet of trispot darters is dominated by aquatic insects (Ephemeroptera, Chironomidae) in both breeding and non-breeding habitats. Trispot darters may live to three years, but average lifespan is more likely two years (USFWS 2017c).

Numbers, Reproduction, Distribution

The trispot darter historically occurred throughout the Upper Coosa River system in Georgia, Alabama, and Tennessee, above the fall line and within the ridge and valley ecoregion (USFWS 2017c). The trispot darter now occurs only in "Little Canoe Creek, Ballplay Creek tributaries, Conasauga River and tributaries, and Coosawattee River and tributary" (USFWS 2017c). The current range of the trispot darter has been reduced by 80% relative to historical collections (USFWS 2017c). In locations where trispot darters are known to occur, they are collected in relatively low abundance (USFWS 2017c). The total population size is unknown and the short-term population trend is uncertain but is described as stable by the GA Dept. of Natural Resources (Freeman et al. 1999).

Conservation

The trispot darter currently has a global conservation ranking of G1, a Georgia state conservation ranking of S1, and it is federally listed as threatened under the ESA (USFWS 2017c). This species is protected as Endangered in the state of Georgia. The greatest threat to the trispot darter is reduced connectivity between breeding and non-breeding habitats by impoundments, degraded intermediate habitat, road crossing structures, and natural barriers to passage (e.g. beaver dams). In addition to the low levels of connectivity between habitats within populations, there is no connectivity among populations across the species' range, making the species vulnerable to local extirpation by unanticipated catastrophic events. Degradation of habitat is a primary threat and stems from a number of sources: altered flow regimes downstream of hydroelectric facilities, increased sedimentation from agricultural activities, reduced flows by water withdrawals, reduced size and vegetation within the riparian zone, and a mix of pollutants from various sources. Pollutants include nutrients, pharmaceuticals, and pesticides/herbicides from agriculture; as well as metals and hydrocarbons from roadways and urbanized areas (USFWS 2017c).

Recommended actions aimed at conservation of the trispot darter include: continued efforts to monitor populations, identify and protect habitat, remove existing barriers to movement, avoid creation of additional barriers, enhance riparian zones along streams, reduce pollutant inputs from agriculture and roadways (Freeman et al. 1999).

Effects of Construction Activities

Sediment

No studies have investigated the effects of sediment on the trispot darter, although sedimentation was identified as a risk to viability of trispot darter populations in the most recent species status assessment by the U.S. Fish and Wildlife Service (USFWS 2017c). Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the suspended sediment tolerance of some species closely related to the trispot darter, categorizing five as moderate (*E. serrifer, E. fusiforme, E. edwini, E. zonifer, E. fricksium*) and one as intolerant (*E. hopkinsi*).

As a benthic invertivore, the trispot darter may be indirectly affected by sediment via a reduction of macroinvertebrate abundance. The above described 'breeding habitat' includes silt and fine sediments as characteristics, suggesting that trispot darter reproduction may not be sensitive to additional inputs of sediment; however, a distinction between breeding habitat and spawning sites may be important. Broadcast eggs adhere to vegetation and rocks, the latter of which may be degraded by added sediments, adversely affecting survival of embryos. Because trispot darter habitat (both breeding and non-breeding) is generally low-velocity, any adverse effects resulting from an elevation of fine sediment may be prolonged by a lack of sediment flushing by the current.

With limited information on either the trispot darter or closely related species, based on the mix of traits-based information, the trispot darter sediment sensitivity is categorized as moderate (2).

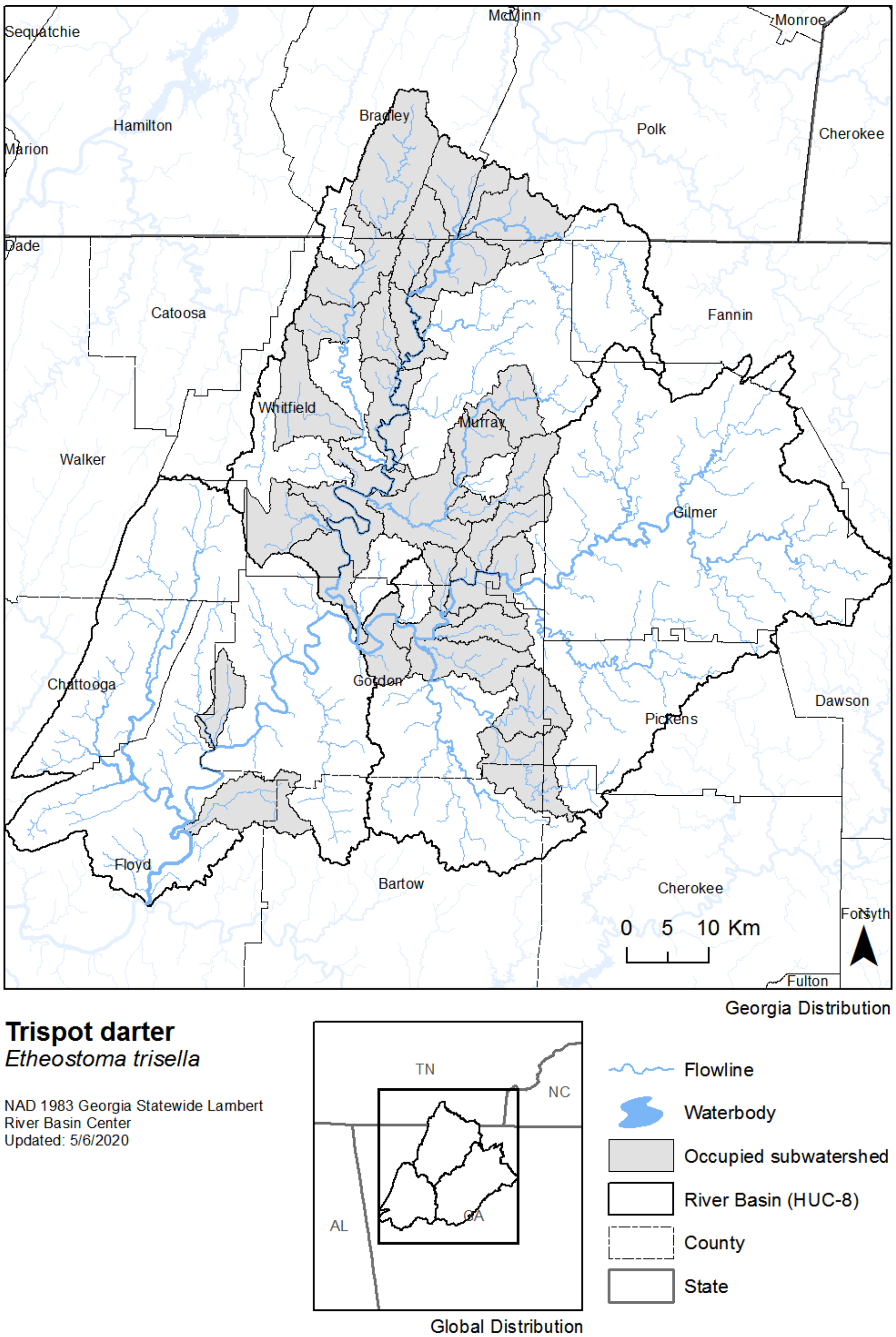
Pollutants

No studies have investigated the effects of construction- or roadway-associated pollutants on the trispot darter. Pollutants associated with roadways and urbanization (such as metals and hydrocarbons) were identified as risks to viability of trispot darter populations in the most recent species status assessment by the U.S. Fish and Wildlife Service (USFWS 2017c). Meador and Carlisle (2007; Meador unpublished data 2020) evaluated the conductivity tolerance of some species closely related to the trispot darter, categorizing five as moderate (*E. serrifer, E. fusiforme, E. edwini, E. gracile, E. hopkinsi*) and two as intolerant (*E. zonifer, E. fricksium*).

The trispot darter is a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. Because it attaches its eggs to vegetation and rocks, trispot darter eggs are less likely to come into direct contact with sediment-bound pollutants during development.

With limited information on either the trispot darter or closely related species, based on the mix of traits-based information, the trispot darter pollutant sensitivity is categorized as somewhat intolerant (3).

Figure 24. Map. Range map for the trispot darter.



WOUNDED DARTER

Species

Wounded Darter, *Etheostoma vulneratum*

Description

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999b): The wounded darter attains a total length of about 87 mm (3.4 in). This species has a frenum, six branchiostegal fin rays, and narrowly joined gill membranes. Males and females have a prominent suborbital bar (teardrop) and faint horizontal rows of pigment along the light-brown to olive body. There is a vertical row of four dark spots on the base of the caudal fin: two prominent spots clustered near the middle of the fin and 2 less prominent spots on the fin margins. There are eight dorsal saddles and about 10 vertical bars that are more evident in juvenile fish than more darkly colored adults. Although pigmentation intensifies during spawning, adult males are brightly colored throughout the year with a green breast and red spots along the sides. Bright red spots mark the front and rear margins of the first dorsal fin. The second dorsal fin is reddish, and the caudal fin is predominantly red with black streaks of pigment between the middle fin rays. Females from the Toccoa River have a red ocellus in the first dorsal fin, but otherwise lack bright breeding coloration. Descriptions from other drainages have noted that females may have some red-spots on their sides.

Life History

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999b): The wounded darter lives in moderate to large rivers, inhabiting deep runs with gentle to moderate current over boulders and large cobble substrates. They are usually found in the crevices underneath boulders and large cobbles, particularly in reaches where these substrates are stacked on top of each other and not embedded by fine sediment.

Like many other darters, the wounded darter feeds primarily on aquatic invertebrates. A large proportion of their diet consists of larval midges, but they have also been reported to feed on larval mayflies, caddisflies, craneflies, and aquatic mites.

Spawning has been documented between late May and late July, when water temperatures ranged 16-20 ° C. The wounded darter is an egg-clumping species. Females deposit clutches of eggs on the undersides of rock ledges, where territorial males defend the eggs until they hatch. Clutch sizes of 17-166 eggs have been reported, with higher numbers probably reflecting deposition over multiple spawning events and possibly by multiple females. Wounded darters reach sexual maturity at 2 years of age. Their lifespan is unknown, but the closely related spotted darter (*E. maculatum*) is known to live 4-5 years

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999b):

The wounded darter occurs only in the upper Tennessee River system in east Tennessee, North Carolina, Virginia and Georgia. In Georgia, it inhabits the mainstem Toccoa River and downstream portions of larger tributary streams. Most records are from the mainstem Toccoa River upstream from Blue Ridge Reservoir; the only record downstream of the reservoir is from the Fightingtown Creek system.

Twenty-nine randomly selected sites, located upstream and downstream of Lake Blue Ridge on the mainstem Toccoa River, were surveyed by snorkeling during summer 2008. The wounded darter was observed at 9 of these sites (31%), all of which were located upstream of Lake Blue Ridge. There is no historic data for comparison, but this percentage of occupied sites provides a benchmark for future population assessments.

According to NatureServe, the short-term trend shows a decline of 10-30%. The population trend over the past 10 years or three generations is uncertain, but distribution and abundance may be slowly declining (NatureServe 2019).

Conservation

The wounded darter has a global conservation status ranking of G3, a Georgia state ranking of S1, and it is not currently under any federal protection. This species is protected as Endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Freeman et al. 1999b): Impoundments throughout the upper Tennessee River system limit available habitat for the wounded darter. The portions of the system that remain free-flowing are vulnerable to degradation by excessive inputs of silt and sediment. Stream degradation results from failure to employ Best Management Practices (BMPs) for forestry and agriculture, failure to control soil erosion from construction sites and bridge crossings, and increased stormwater runoff from developing urban and industrial areas. Increasing development of second homes utilizing poor construction and riparian management practices poses a significant threat to this species. Finally, hemlock wooly adelgid is an additional threat to aquatic habitats in this region.

Conserving populations of the wounded darter will require maintaining and improving habitat quality in the upper Toccoa River by eliminating sediment runoff (from land-disturbing activities such as roadway and housing construction) and maintaining forested buffers along stream banks. There are many opportunities to enhance and widen riparian zone habitats by planting native trees and shrubs along creeks and streams. Ongoing monitoring efforts should be continued for this species.

Given the species limited range within Georgia, it remains vulnerable to extirpation.

Effects of Construction Activities

Sediment

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the suspended sediment tolerance of the wounded darter as moderate. Meador and Carlisle also categorized the closely related *E. maculatum* as intolerant. Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) similarly described the *E. maculatum* as “highly sensitive” to sedimentation.

As a benthic invertivore, the wounded darter is likely indirectly and adversely affected by sediment via a reduction of macroinvertebrate abundance. As a species that lays clumps of eggs on the undersides of rock ledges, possibly over multiple spawning events, and provides some level of parental care, the eggs of the wounded darter may be less vulnerable to the potential adverse effects of a sedimentation event. However, by filling in cavities, elevated sedimentation would reduce the initial amount and quality of both adult habitat and spawning habitat. Elevated turbidity may disrupt spawning cues or curtail spawning activity by reducing perception of males' striking nuptial coloration that is common among darters (Seehausen et al. 1997; Burkhead and Jelks 2001).

Based on the sensitivity of adult and spawning habitat, the overall sediment sensitivity of the wounded darter is categorized as intolerant (1).

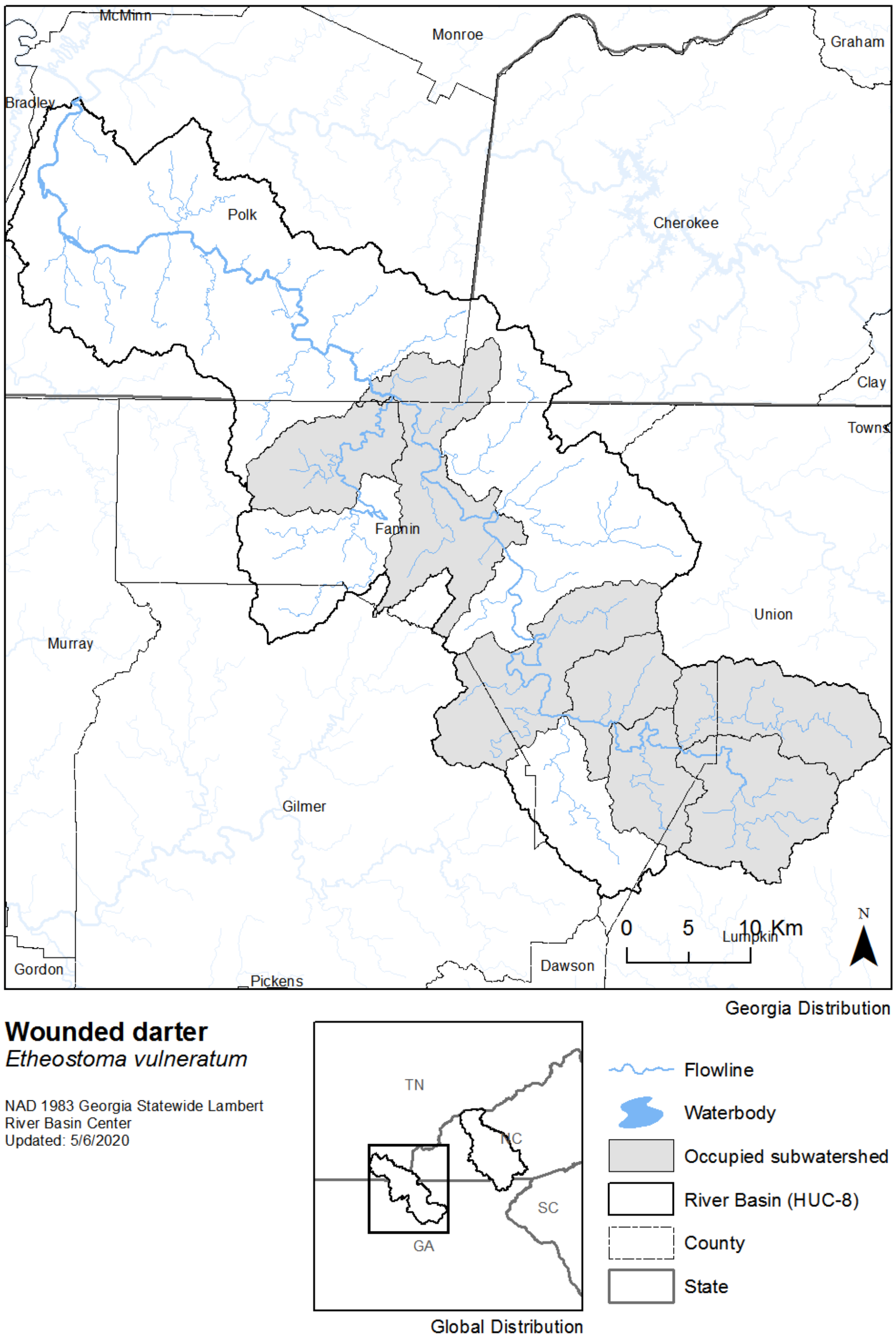
Pollutants

Meador and Carlisle (2007; Meador unpublished data 2020) categorized the specific conductivity tolerance of the wounded darter as moderate; they also categorized the closely related *E. maculatum* as moderate. Based on previous work (Trautman 1981, Ohio EPA 1987), Miltner et al. (2004) described *E. maculatum* as "highly sensitive"' to pollutants. Dye and Benton (2001) found that *E. maculatum* was only collected at upstream sites free from mercury contamination along the North Fork Holston River, suggesting it is intolerant of mercury.

The wounded darter is a benthic invertebrate feeder, and as a member of this feeding guild it is likely to be indirectly affected by the effects of pollutants on its prey base. It is likely to carry a higher body burden of pollutants since its prey base comes into direct contact with sediment-bound pollutants. Because it attaches its eggs to the undersides of rock ledges, those eggs are less likely to come into direct contact with sediment-bound pollutants during development.

Based on the work by Meador and Carlisle and the life history traits, the overall pollutant sensitivity of the wounded darter is categorized as somewhat intolerant (3).

Figure 25. Map. Range map for the wounded darter.



MUSSELS

ALABAMA CREEKMUSSEL

Species

Alabama Creekmussel, *Pseudodontoideus connasaugaenis*
(formerly *Strophitus connasaugaensis*)

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Shell thin, compressed to slightly inflated with an elliptical or elongate shape. Anterior margin broadly rounded. Posterior margin typically rounded to truncate. Ventral margin straight to slightly arcuate. Umbos elevate slightly above hingeline. Posterior ridge low and rounded. Periostracum typically yellowish green in juveniles to dark brown in adults. Left and right valve each with single, compressed pseudocardinal teeth. Lateral teeth greatly reduced to absent. Umbo cavity shallow and wide. Nacre typically bluish gray to white. The Alabama creekmussel strongly resembles the Southern Creekmussel (*P. subvexus*) and may be the same species in the eastern Mobile River basin.

Life History

The Alabama creekmussel is a relatively short-term brooder and is a member of the Pleurobemini tribe (Graf and Cummings 2020). It is found in areas with moderate water velocity and sand/gravel substrate in medium-sized streams to large-sized rivers (Wisniewski 2018).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Endemic to the Alabama River basin of Alabama, Georgia, and Tennessee. Historically widespread throughout range but becoming restricted to a few waters in Alabama and Georgia. In the Mobile River basin of Georgia, the Alabama creekmussel appears to occur only in the Conasauga River. Extensive surveys have not found the species elsewhere in the upper Coosa River basin in Georgia.

The Alabama creekmussel was observed gravid between October and January and glochidia appear to transform on 19 fish species, making it a host generalist. The Alabama creekmussel is thought to release a mucous net of glochidia during reproduction.

Conservation

The Alabama creekmussel currently has a global conservation ranking status of G3, a Georgia state conservation ranking of S1, and is under no US federal protection. This species is listed as endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Excess sedimentation due to inadequate riparian buffer zones, development, and agriculture covers suitable habitat and could potentially bury mussels. Poor agricultural practices may also cause eutrophication and degrade water quality. Industrial effluent as well as sewage treatment plant discharges may also be degrading water quality. Minimizing sedimentation in the Upper Coosa River basin and its tributaries is a key component to conserving the Alabama creekmussel. Restoration of riparian buffers will stabilize banks providing clean gravel and sand substrates for the species.

Effects of Construction Activities

Sediment

The research team is aware of no direct studies on the effects of sediment on the Alabama creekmussel. Because the Alabama creekmussel is found in gravel or sand substrate, additional sediment inputs may adversely affect its preferred habitat. As a short-term brooder (tribe Pleurobemini), it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

It is also important to consider the effects of increased sedimentation on the host fish used by the Alabama creekmussel for reproduction. As a reproductive generalist, potential impacts of sedimentation on host fishes are likely smaller, relative to reproductive specialists.

On balance of habit preferences and brooding sensitivity, the sediment sensitivity of Alabama creekmussel is categorized as intolerant (1).

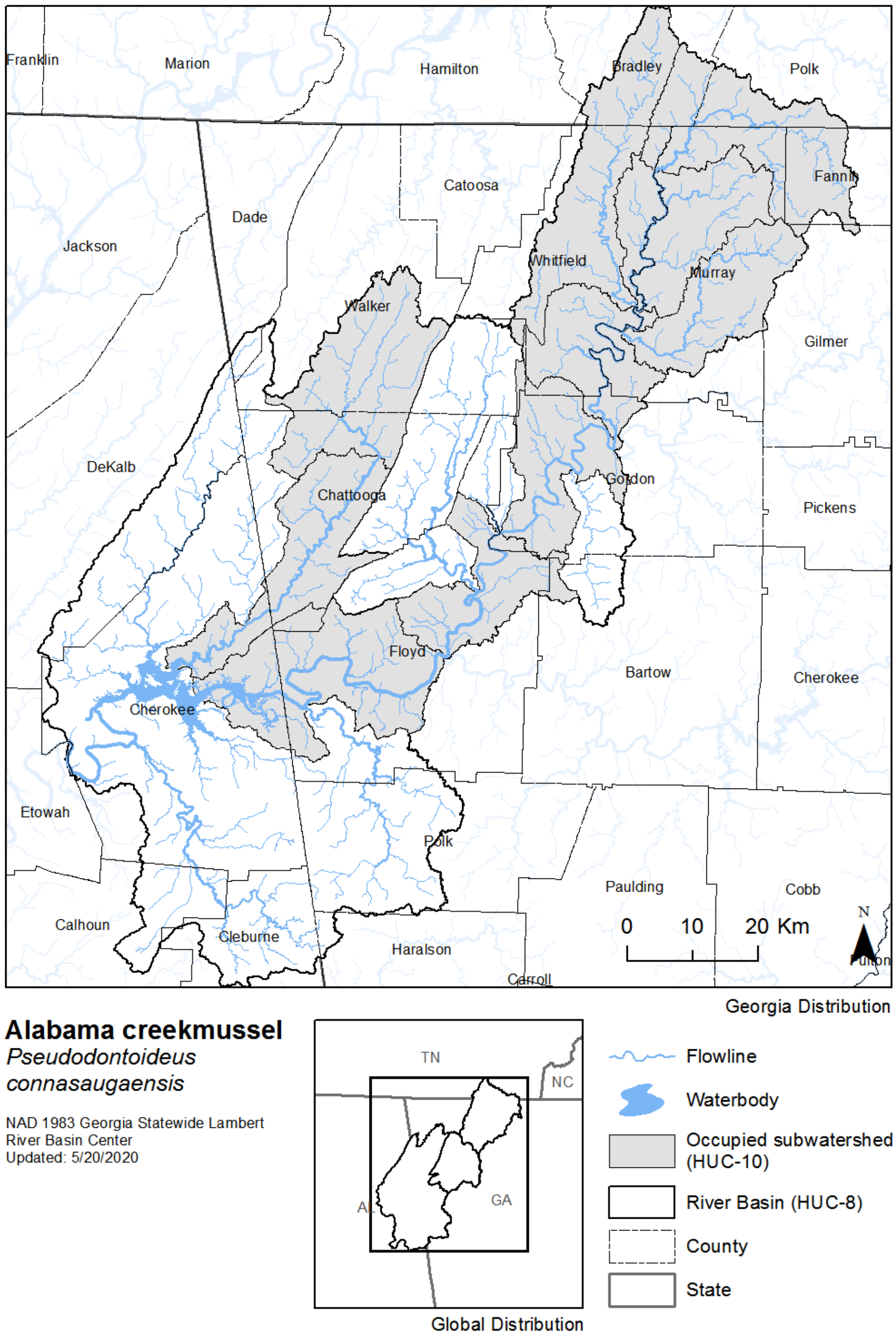
Pollutants

The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the Alabama creekmussel. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. The research team can make inferences based on data from other members of the tribe Pleurobemini – the Eastern elliptio (*Elliptio complanata*). *E. complanata* has been used in studies that examine the potential impacts of heavy metals (Cheney and Criddle 1996) and polyaromatic hydrocarbons (PAHs; Cheney et al. 2001). Both studies found that mussels exposed to road-associated metals or PAHs exhibited diverse patterns of effects that included both stimulation and inhibition of metabolic activity in this species. They also found that exposure to PAHs led to irreversible gill damage. Municipal wastewater contains contaminants that can be similar in composition to those found associated with construction or roadways (Chambers et al. 1997). Recent research in *E. complanata* suggests that exposure to these contaminant mixtures may lead to immunomodulatory responses, increased susceptibility to pathogens, and genotoxicity (Lacaze et al. 2013; Gagné et al. 2015). Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that persistence of multiple *Elliptio* spp. varied widely (Gillies et al. 2003). *E. complanata* and *E. crassidens* were resilient, with no indication that imperviousness may be correlated with their abundance. However, *E. icterina* presence did decline with increasing imperviousness (individuals were not found at 1/3 locations sampled after 1992). Of all *Elliptio* data available for this study, *E. arctata* had the most significant decline in relation to increased urbanization and imperviousness. By 1992, *E. arctata* had disappeared from all three locations where they were historically found. This study displays the large variability in response to urbanization within the same genus of freshwater mussels.

It is also important to examine the potential effects of pollutants on the host fish used by Alabama creekmussel. The Alabama creekmussel is a reproductive generalist which may allow use of a variety of hosts, including some that may be more tolerant of pollutants.

Based on direct studies with congener species, the pollutant sensitivity of the Alabama creekmussel is categorized as somewhat intolerant (3).

Figure 26. Map. Range map for the Alabama creekmussel.



ALABAMA MOCCASINSHELL

Species

Alabama Moccasinshell, *Medionidus acutissimus*

Description

Reproduced from U.S. Fish and Wildlife Service (2019h): The Alabama moccasinshell is a small, delicate species, measuring up to 55 mm in length (Williams et al. 2008). The shell is narrowly elliptical, and thin, with a well-developed acute posterior ridge that terminates in an acute point on the posterior ventral margin. The posterior slope is finely corrugated. The periostracum is yellow to brownish yellow, with broken green rays across the entire surface of the shell. The thin nacre is translucent along the margins and salmon-colored in the umbos.

Life History

The Alabama moccasinshell inhabits medium streams to large rivers in gravel substrates with moderate to strong currents (USFWS 2000; Wisniewski 2018).

The Alabama moccasinshell is a member of tribe Lampsilini and a long-term brooder that is typically gravid from October through the following June (USFWS 2019h). Topminnows (*Fundulus* spp.) and darters (*Etheostoma* and *Percina* spp.) are known to be suitable fish hosts for this species (USFWS 2019h). Recent fish host trials also have identified the banded sculpin (*Cottus carolinae*) as a suitable host for the Alabama moccasinshell (Johnson 2018).

Numbers, Reproduction, Distribution

The Alabama moccasinshell is endemic to the Mobile Basin of Alabama, Georgia, Mississippi, and Tennessee. This species is also endemic to the Escambia, Choctawhatchee, and Yellow Rivers of Alabama (Wisniewski 2018). Overall, the Alabama moccasinshell has disappeared from much of its historic range (*e.g.*, southern Alabama) and it is believed to be extirpated from the Florida panhandle (Blalock-Herod et al. 2005). In Georgia, the Alabama moccasinshell seems to be restricted to the Conasauga River and several of its tributaries (Wisniewski 2018; USFWS 2019h). The range of this species is highly fragmented, even in Alabama where the stronghold populations occur (USFWS 2019b). In locations where populations can be found, they are generally small and localized (USFWS 2019h).

Conservation

The Alabama moccasinshell has a global conservation ranking of G2, a Georgia state conservation ranking of S1, and is federally listed as threatened under the ESA (USFWS 2019h). This species is listed as endangered in the state of Georgia.

The primary threats to the Alabama moccasinshell include changes in hydrological regime (*e.g.,* water withdrawals, drought), excess sedimentation, pollution and water quality issues, extreme reduction and fragmentation of habitat and range, low population sizes, and vulnerability of small, localized populations to stochastic events (Wisniewski 2018; USFWS 2019h). In the Conasauga, pollutants associated with agricultural and runoff (*e.g.*, herbicides, surfactants, hormones) are considered a concern for this species (USFWS 2019h).

Recommended actions aimed at conservation of the Alabama moccasinshell in Georgia include: minimizing sedimentation in critical habitats, restoration of riparian habitats, evaluation of population sizes, and reintroduction of stocks in viable habitat (Wisniewski 2018). Currently, the species is considered stable and is not believed to have lost any populations since being listed (USFWS 2019h).

Effects of Construction Activities:

Sediment

The research team is aware of no direct studies on the effects of sediment on the Alabama moccasinshell or other associated *Medionidus* spp. Because the Alabama moccasinshell is found in gravel substrates, additional sediment inputs may adversely affect its preferred habitat. As a long-term brooder, Alabama moccasinshells may be less sensitive to episodic elevated suspended sediment; however, long-term brooders may demonstrate significant declines in reproductive success due to excessive levels of sediment exposure during or after fertilization. Elevated suspended sediment during reproduction may also reduce visibility of lures to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Based on their life history, the sediment sensitivity of the primary hosts, darters (*Etheostoma* and *Percina* spp.), is categorized as intolerant.

On the balance of high sensitivity of preferred habitat and host fish, but lower sensitivity due to brooding strategy, he sediment sensitivity of Alabama moccasinshell is categorized as intolerant.

Pollutants

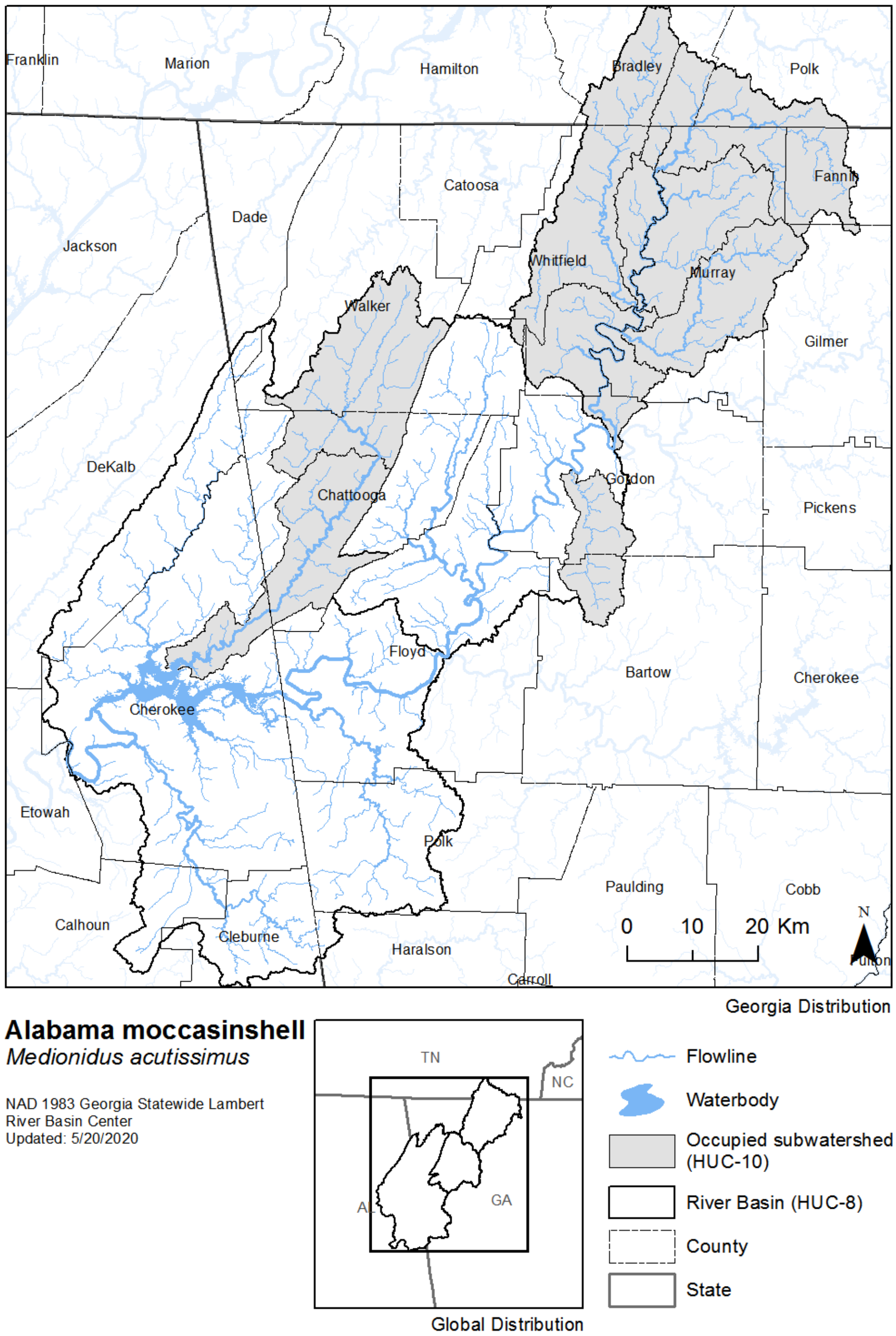
The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the Alabama moccasinshell. Cherry et al. (2002) found that glochidia of the closely related Cumberland moccasinshell (*Medionidus conradicus*) were among the most sensitive species when exposed to copper. A more recent report states that this trend does not hold true for all metals, as *M. conradicus* seems to be relatively tolerant to zinc (cited in Markich et al. 2017 as personal communication from M. McCann). Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the congener *Medionidus penicillatus* was extirpated by 1992 from one of two sites where the species was found (Gillies et al. 2003).

Indirect effects of pollution on host fish used by Alabama moccasinshell must also be considered. Based on their life history, the pollutant sensitivity of the primary host fishes, darters, is categorized as somewhat intolerant.

Based on general mussel sensitivity as well as direct evidence with closely related species and sensitivity of host fish, the pollutant sensitivity of Alabama moccasinshell is categorized as somewhat intolerant.

Figure 27. Map. Range map for the Alabama moccasinshell.



ALABAMA SPIKE MUSSEL

Species

Alabama Spike Mussel, *Elliptio arca*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Typically compressed to moderately inflated shell, elliptical or elongate in shape. Maximum length is approximately 90 mm. Anterior margin is broadly rounded while posterior margin is typically rounded to biangulate. Ventral margin relatively straight to slightly arcuate. Posterior ridge sharply angular to round in larger individuals. Umbos slightly projecting above hingeline. Periostracum typically dark brown to black in adults. Juveniles may be yellow to green with fine rays near the umbo. Left valve with two, triangular, stumpy pseudocardinal teeth and two low, and straight lateral teeth. Right valve with one low, serrated pseudocardinal tooth and one, typically high, straight, and long lateral tooth. Umbo cavity typically shallow and wide. Nacre variable but typically bluish white to salmon.

Life History

The Alabama spike is a short-term brooder and is a member of the Pleurobemini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Found in gravel or sand shoals in medium sized creeks to large rivers. Occasionally found in sand-bottomed runs with slow, steady current. Rarely found in slack water or silt.

Females were found releasing glochidia from June through July. Primary glochidial hosts are the Redspot Darter (*Etheostoma artesiae*) and Blackbanded Darter (*Percina nigrofasciata*) (Haag and Warren 2003).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Endemic to the Gulf Slope drainages in Alabama, Georgia, Mississippi, and Tennessee. Historically widespread throughout its range but becoming restricted to a few river systems in Alabama, Mississippi, and Georgia. In Georgia, the Alabama Spike appears to be restricted to the Oostanaula River. Although two collections of single specimens of the Alabama Spike were made from the mainstem Coosawattee and Conasauga rivers in 1997 and 1998, respectively, few recent collections of live individuals have been made, suggesting that this species may be extremely rare or extirpated from these rivers.

Conservation

The Alabama spike currently has a global conservation ranking status of G2G3Q, a Georgia state conservation ranking of S1, and is under no US federal protection. This species is listed as endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Excess sedimentation due to inadequate riparian buffer zones, development, and agriculture covers suitable habitat and could potentially bury mussels. Poor agricultural practices may also cause eutrophication and degraded water quality. Incompatible dam operations on the Coosawattee River are thought to be a reason for the possible extirpation of this species from the river.

Irregular flow regimes coupled with cold hypolimnetic discharges are believed to have caused the decline of the species in the Coosawattee and Oostanaula rivers. Minimizing the impacts of sedimentation within the Conasauga River may improve existing habitat within the river and provide suitable areas for reintroduction/ augmentation of the species.

Effects of Construction Activities:

Sediment

The research team is aware of no direct studies on the effects of sediment on the Alabama spike. However, one study with a congener (*E. crassidens*) postulated that sedimentation may be a contributing factor to declines of the elephantear in Missouri (Hinck et al. 2012). Because the Alabama spike is found in gravel or sand shoals, additional sediment inputs are likely to adversely impact its preferred habitat. In addition, as a short-term brooder (tribe Pleurobemini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Based on their life history traits, the sediment sensitivity of darters in general is categorized as intolerant.

Based on the sensitivity of both their brooding behavior and their host fish, the sediment sensitivity of the Alabama spike mussel is categorized as intolerant (1).

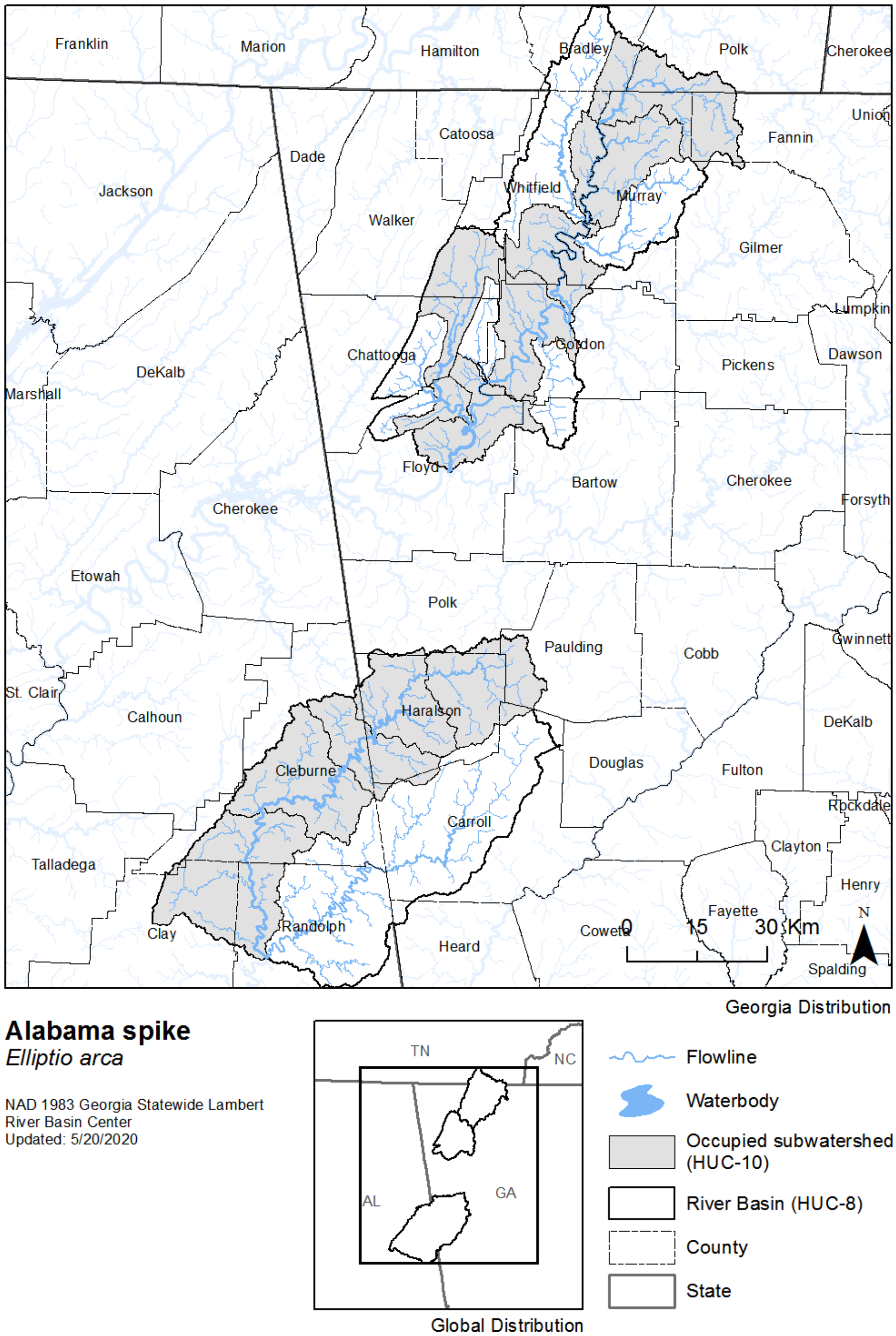
Pollutants

The research team is aware of no field or lab studies investigating the effects of construction- or road-associated pollutants on the Alabama spike, but inferences can be made based on data from a congener species – the Eastern elliptio (*Elliptio complanata*). *E. complanata* has been used in studies that examine the potential impacts of heavy metals (Cheney and Criddle 1996) and polyaromatic hydrocarbons (PAHs; Cheney et al. 2001). Both studies found that mussels exposed to road-associated metals or PAHs exhibited diverse patterns of effects that included both stimulation and inhibition of metabolic activity in this species. They also found that exposure to PAHs led to irreversible gill damage. Municipal wastewater contains contaminants that can be similar in composition to those found associated with construction or roadways (Chambers et al. 1997). Recent research in *E. complanata* suggests that exposure to these contaminant mixtures may lead to immunomodulatory responses, increased susceptibility to pathogens, and genotoxicity (Lacaze et al. 2013; Gagné et al. 2015). Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that persistence of multiple *Elliptio* spp. varied widely (Gillies et al. 2003). *E. complanata* and *E. crassidens* were resilient, with no indication that imperviousness may be correlated with their abundance. However, *E. icterina* presence did decline with increasing imperviousness (individuals were not found at one out of three locations sampled after 1992). Of all *Elliptio* data available for this study, *E. arctata* had the most significant decline in relation to increased urbanization and imperviousness. By 1992, *E. arctata* had disappeared from all three locations where they were historically found. This study displays the large variability in response to urbanization within the same genus of freshwater mussels.

It is also important to examine the potential effects of pollution on the host fish used by Alabama spike. Based on their life history traits, the pollutant sensitivity of darters is categorized as somewhat intolerant.

Based on the direct studies with congener species and the sensitivity of host fish, the pollutant sensitivity of the Alabama spike is categorized as somewhat intolerant (3).

Figure 28. Map. Range map for the Alabama spike mussel.



ALTAMAHA ARCMUSSEL

Species

Altamaha Arcmussel, *Alasmidonta arcula*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Shell is delicate, inflated, often with distinct concentric sculpturing near the umbo. Rarely exceeds 80 mm in length. Umbos are elevated above the hingeline and positioned centrally to slightly anterior of the triangulate shell. Adults typically have brown to yellow periostracum with dark rays. Posterior ridge is sharp and straight. Right valve has one delicate pseudocardinal tooth and a short, delicate lateral tooth. Left valve has one to two delicate, serrated pseudocardinal teeth with lateral teeth absent or reduced. Beak cavity is shallow and nacre is typically white or iridescent.

Life History

The Altamaha arcmussel can be found in sandy mud below sand bars in slow-moving waters (Johnson 1970). This species has historically been collected in the Ocmulgee River in mid-channel areas on sand bars (shallow water < 1 meter deep; Clarke 1981). The Altamaha arcmussel was also found in the Altamaha River mainstem in silty sands and detritus in backwater areas (J. Brim Box, personal observation).

The Altamaha arcmussel is thought to be a short-term brooder and is a member of the Anodontini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Little is known about the life history of the Altamaha arcmussel. Several animals with partially filled gills have been observed in late May and October. The host fish for the Altamaha arcmussel is unknown although glochidia have successfully transformed on the Eastern Mosquitofish, Robust Redhorse, and Striped Jumprock. However, the Eastern Mosquitofish is not considered to be a primary host as it is unlikely that these species would interact under natural conditions and metamorphosis success of the Robust Redhorse and Striped Jumprock were low (Johnson et al. 2012).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Historically believed to be endemic to the Lower Altamaha River basin including the Ohoopee, Oconee, Ocmulgee, and Little Ocmulgee rivers. One relict shell was collected in 1993 from Turkey Creek (Oconee River), Laurens County. Recent collections of the species indicated that the species occurs upstream into Lake Jackson (Jasper County) and the Alcovy River in the Ocmulgee River watershed and upstream to Mt. Vernon in the Oconee River. In addition, recent genetic and conchological analyses of specimens collected from the Ogeechee and Savannah river basins suggest that the Altamaha arcmussel also occurs in these basins. Live individuals have been found at multiple sites in the Savannah River upstream into Clarks Hill Lake.

Conservation

The Altamaha arcmussel currently has a global conservation ranking status of G2, a Georgia state conservation ranking of S3, and is under no US federal protection.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): The Altamaha arcmussel was recommended for removal from Georgia's state protected species list as threats to this species do not appear as imminent as previously thought due to expansions in it known distribution. Examination of the basic life history and development of culture and propagation techniques were identified as top research priorities needed for the conservation of this species in the Georgia State Wildlife Action Plan. Riparian buffers should be protected to avoid unnecessary bank erosion as this species often is found in shallow areas near the water's edge.

Effects of Construction Activities

Sediment

The research team is unaware of any direct studies on the effects of sediment on the Altamaha arcmussel or other *Alasmidonta* spp. Because the Altamaha arcmussel is often found in sandy mud and slow-moving waters, therefore additional sediment inputs may not substantially alter its preferred habitat. However, as a short-term brooder (tribe Anodontini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

Additionally, indirect effects of sediment on host fish used by the mussel for reproduction must be considered. The primary host(s) of the Altamaha arcmussel is unknown, but robust redhorse and striped jumprock have been identified as marginal hosts. Based on their life history traits, the sediment sensitivity of these two fishes is categorized as intolerant.

On balance of their more sensitive brooding behavior and less sensitive habitat, the sediment sensitivity of the Altamaha arcmussel is categorized as moderate (2).

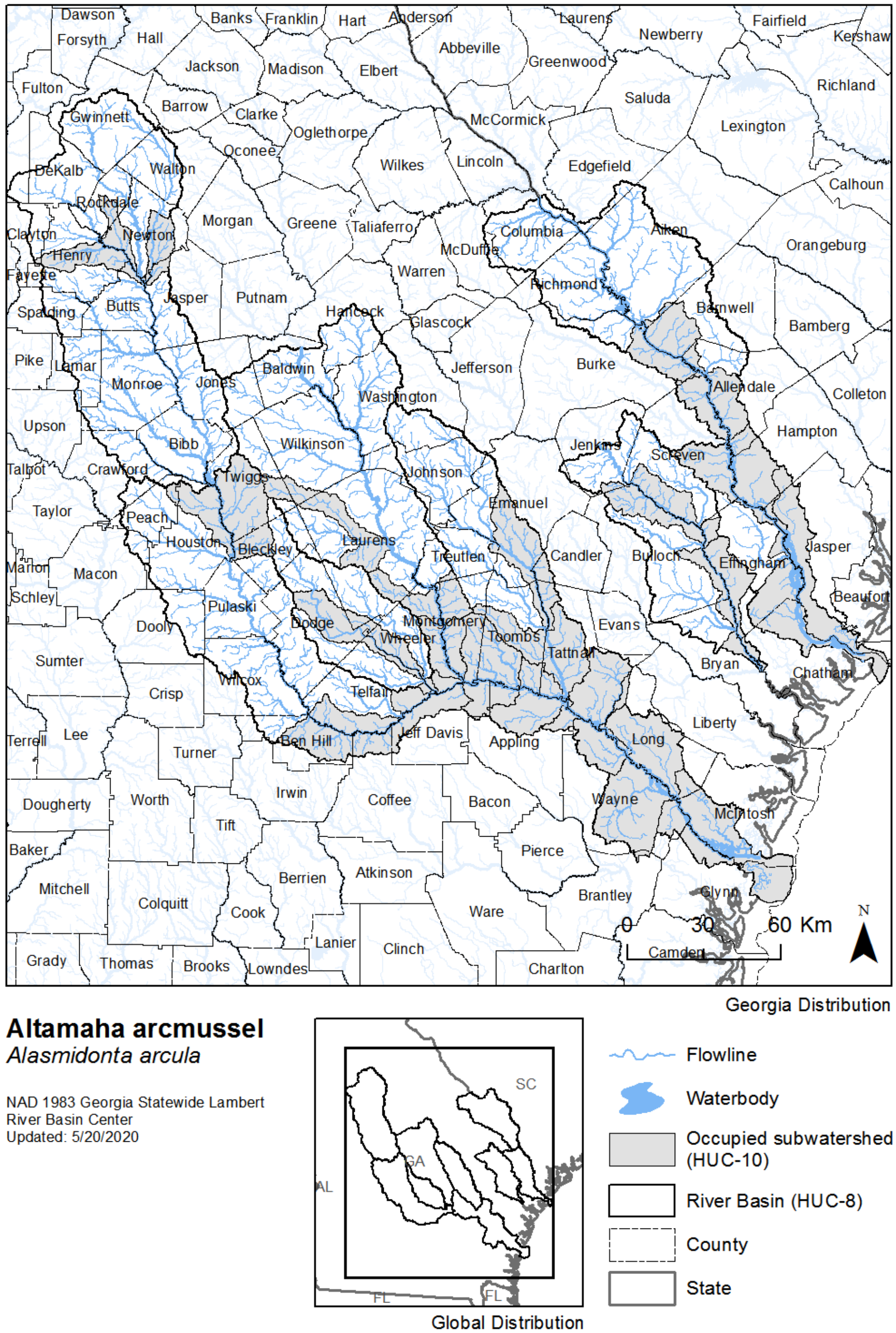
Pollutants

The research team is aware of no data available describing the effects of construction- or roadway-derived pollutants on the Altamaha arcmussel. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the closely-related Southern elktoe (*Alasmidonta triangulata*) was likely extirpated by 1992 from the only site where data was available (Gillies et al. 2003). In that study, impervious surface area was associated with mussel declines, though not directly implicated.

Indirect effects of sediment on host fish used by Altamaha arcmussel must also be considered. The primary host(s) is unknown, but Robust Redhorse and Striped Jumprock have both been identified as marginal hosts. Based on their life history traits, the pollutant sensitivity of both robust redhorse and striped jumprock is categorized as moderate.

Based on direct evidence for the closely related *A. triangulata* that suggests a strong negative relationship with urbanization, pollutant sensitivity of the Altamaha arcmussel is categorized as very intolerant (2).

Figure 29. Map. Range map for the Altamaha arcmussel.



ALTAMAHA SPINYMUSSEL

Species

Altamaha Spinymussel, *Elliptio spinosa*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2011):

The Altamaha spinymussel (*Elliptio spinosa*) is a freshwater mussel in the family Unionidae, endemic to (found only in) the Altamaha River drainage of southeastern Georgia. The Altamaha River is formed by the confluence of the Ocmulgee and Oconee rivers and lies entirely within the State of Georgia. The species was described by I. Lea in 1836 from a site near the mouth of the Altamaha River in Darien, Georgia (Johnson 1970, p. 303). This species reaches a shell length of approximately 11.0 centimeters (cm). The shell is subrhomboidal or subtriangular in outline and moderately inflated. As the name implies, the shells of these animals are adorned with one to five prominent spines. These spines may be straight or crooked, reach lengths from 1.0 to 2.5 cm, and are arranged in a single row that is somewhat parallel to the posterior ridge. In young specimens, the outside layer or covering of the shell (periostracum) is greenish-yellow with faint greenish rays, but as the animals get older, they typically become a deep brown, although some raying may still be evident in older individuals. The interior layer of the shell (nacre) is pink or purplish (Johnson 1970, p. 303).

Life History

Very little is known regarding the life history of the Altamaha spinymussel. The Altamaha spinymussel is a member of the Pleurobemini tribe and likely reproduces in the spring and summer (USFWS 2019a). The species is assumed to be a short-term brooder based on general life history traits of other species in the genus *Elliptio*. (USFWS 2019a). The host fishes used by this species for reproduction are unknown. (USFWS 2019a). One brooding *E. spinosa* was collected in May but contained only eggs. The specimen was returned to the lab upon which the eggs developed to mature glochidia in mid-June. No transformation was observed on any fish but the viability of the glochidia may have been marginal (Johnson et al. 2011)

The Altahama spinymussel is associated with coarse-to-fine sandy sediments of sandbars, sloughs, and mid-channel islands. These mussels also seem to be restricted to swiftly flowing waters (USFWS 2011).

Numbers, Reproduction, Distribution

The Altamaha spinymussel is endemic to the Coastal Plain portion of the Altamaha River and the lower portion of its three major tributaries, the Ohoopee, Ocmulgee, and Oconee Rivers (USFWS 2011). Recent research has revealed significant declines in recruitment throughout this species' historical range (USFWS 2011). The highest number of Altamaha spinymussels found in the Altamaha River in the 1990s and 2000s was nine (cited as Albanese 2005 personal communication in USFWS 2011).

Surveys in the Ocmulgee River yielded 19 live Altamaha spinymussels in the 2000s (Dinkins et al. 2004). More recently, surveys in the Ocmulgee in 2015 and 2018 did not yield any live Altamaha spinymussels (USFWS 2019a). Currently, the Altamaha spinymussel is considered in extremely low numbers or extirpated in the Ohoopee and Oconee Rivers (USFWS 2011). Population estimates for the Altamaha spinymussel are not feasible with the current data; however, available trends suggest that the species is experiencing declines throughout its range (USFWS 2011; 2019a).

Conservation

The Altamaha spinymussel has a global conservation ranking of G1/G2, a Georgia state conservation ranking of S1, and is federally listed as an endangered species under the ESA (Wisniewski 2018). This species is listed as endangered in the state of Georgia.

The main stem of the Altamaha River and lower Ocmulgee and Ohoopee Rivers are designated as critical habitat for this species (USFWS 2011; Wisniewski 2018). Threats to the Altamaha spinymussel include habitat degradation, recreational activities, and an overall lack of knowledge regarding their life history traits (*e.g.*, reproduction and host fishes). Habitat degradation may include excess sedimentation, pollution, and altered flow regimes due to agriculture or thermoelectric power generation (USFWS 2011; 2019a). The Altamaha spinymussel tends to prefer habitat with firm sand substrate, thus, sedimentation was identified as a primary threat to this species when listed in 2011 (USFWS 2011; USFWS 2019a). In addition to legacy sediment, present-day agriculture, silviculture, and mining all may be contributing excess sediment to critical habitats within the Altamaha River system (USFWS 2019a). Contaminants were also identified as a potential threat for the persistence of the Altamaha spinymussel, as much of the area designated as critical habitat has historically been contaminated with pollutants like mercury (USFWS 2011; 2019a).

Recommended actions to conserve the Altamaha spinymussel include: comprehensive surveys across critical habitats to identify populations and understand demographics (*i.e.*, number of juveniles and adults), host fish identification, evaluation of habitat quality (*e.g.*, substrate, temperature, flow), and additional genetic analyses (USFWS 2019a).

Effects of Construction Activities

Sediment

The research team is aware of no direct studies on the effects of sediment on the Altamaha spinymussel. However, one study postulated that sedimentation may be a contributing factor to declines of the congener *Elliptio crassidens* in Missouri (Hinck et al. 2012). Because the Altamaha spinymussel is found in firm sand substrate, additional sediment inputs may substantially alter its preferred habitat. As a short-term brooder it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. The primary host(s) of the Altamaha spinymussel is unknown, thus, the research team cannot make inferences regarding potential impacts of sedimentation on host fishes.

Based on preferred habitat and more sensitive brooding behavior, the sediment sensitivity of the Altamaha spinymussel is categorized as intolerant (1).

Pollutants

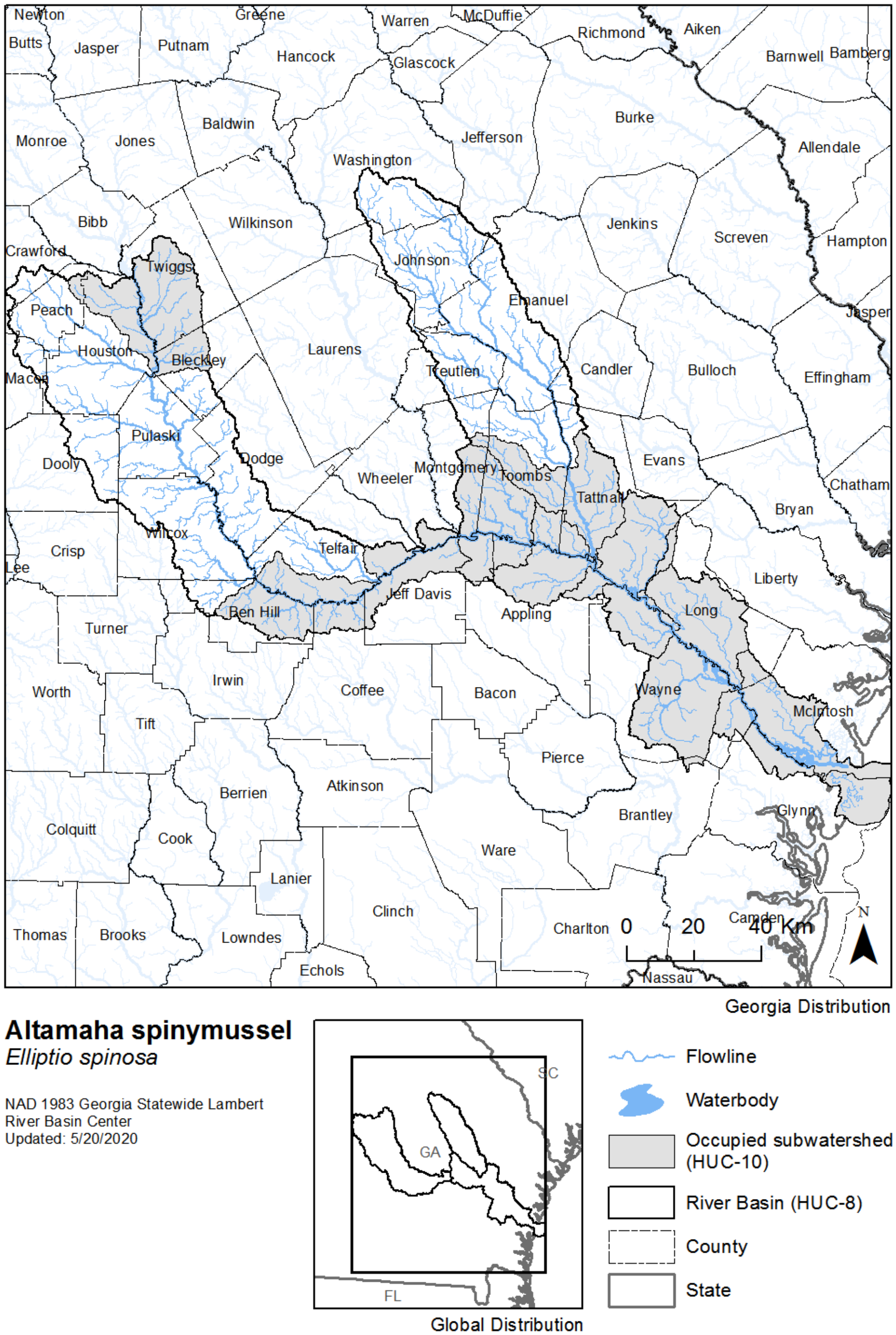
The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the Altamaha spinymussel, but inferences can be made based on data from a congener species – the Eastern elliptio (*E. complanata*). *E. complanata* has been used in two studies that examine the potential impacts of heavy metals (Cheney and Criddle 1996) and polyaromatic hydrocarbons (PAHs; Cheney et al. 2001) on metabolic maintenance. Both studies found that mussels exposed to road-associated metals or PAHs exhibited diverse patterns of effects that included both stimulation and inhibition of metabolic activity in this species. They also found that exposure to PAHs lead to irreversible gill damage. Municipal wastewater contains contaminants that can be similar in composition to those found associated with construction or roadways (Chambers et al. 1997). Recent research in *E. complanata* suggests that exposure to these contaminant mixtures may lead to immunomodulatory responses, increased susceptibility to pathogens, and genotoxicity (Lacaze et al. 2013; Gagne et al. 2015). Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that persistence of multiple *Elliptio* spp. monitored varied widely (Gillies et al. 2003). *E. complanata* and *E. crassidens* were resilient, with no indication that imperviousness may be correlated with their abundance. *E. icterina* presence did decline with increasing imperviousness (individuals were not found at 1/3 locations sampled after 1992). Of all *Elliptio* data available for this study, *E. arctata* presented with the most significant decline in relation to increased urbanization and imperviousness. By 1992, *E. arctata* had disappeared from all three locations where they were historically found. This study displays the large variability in response to urbanization within the same genus of freshwater mussels.

Indirect effects of pollution on host fish used by Altamaha spinymussel must also be considered. The host fishes used for reproduction by this species are not known. Thus, inferences cannot be made regarding potential impacts of pollution on host fishes for the Altamaha spinymussel.

Based on direct evidence for closely related elliptio species, the pollutant sensitivity of the Altamaha spinymussel is categorized as somewhat intolerant (3).

Figure 30. Map. Range map for the Altamaha spinymussel.



APALACHICOLA FLOATER

Species

Apalachicola Floater, *Utterbackiana heardi*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Shell is thin and extremely inflated and rarely exceeds 110 mm in length. Umbos are slightly elevated above the hingeline and positioned near anterior third of shell. Anterior margin of shell is broadly rounded and posterior margin is bluntly pointed and terminates at or above the midline of the shell. Ventral margin broadly rounded. Hingeline is straight. Umbo is low and elevated slightly above hingeline. Posterior ridge broadly rounded. Typically with glossy, light green to light brown periostracum sometimes having fine green rays. Pseudocardinal and lateral teeth absent. Umbo cavity is wide and shallow. Nacre white.

Life History

The Apalachicola floater is a short-term brooder and is a member of the Anodontini tribe (Graf and Cummings 2020). It is most often found in lentic waters (lakes, oxbows, sloughs, and backwaters) with substrates composed of mud, sand, or detritus (Wisniewski 2018).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Appears to be endemic to the lower Apalachicola, Chattahoochee, Flint River basin and Ochlockonee River Basin of Florida and Georgia. The Apalachicola Floater is currently known from sporadic locations in the Chattahoochee River upstream to Columbus and the Flint River upstream to Montezuma.

Little is known about the life history of the Apalachicola floater. The brooding period for this species is presumed to parallel that of the Barrel floater (*Anodonta couperiana*), which exchanges gametes during late summer and broods until mid-November. The host fishes for the Apalachicola floater are unknown. It is presumed that like other closely related anodontine mussels, this species produces a mucus net as a glochidia dispersal strategy and is likely a host generalist. A single hermaphroditic individual has been reported for this species (Williams et al. 2014).

Conservation

The Apalachicola floater currently has a global conservation ranking status of G2, a Georgia state conservation ranking of S4, and is under no US federal protection. This species is listed as rare in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Habitat fragmentation may isolate populations and prevent fish movement, limiting the distribution of host fishes carrying glochidia. Excess sedimentation due to inadequate riparian buffer zones and incompatible agricultural practices may also cover suitable habitat and could potentially bury individuals.

Effects of Construction Activities

Sediment

The research team is unaware of any direct studies on the effects of sediment on the Apalachicola floater or other closely related species. Because the Apalachicola floater is often found in soft sediments, additional sediment inputs may not substantially alter its preferred habitat. However, as a short-term brooder (tribe Anodontini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

Additionally, indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Host(s) for the Apalachicola floater are unknown, thus, inferences cannot be made regarding potential impacts of sedimentation on host fishes for the Apalachicola floater.

Because of their more sensitive brooding behavior and less sensitive habitat, the sediment sensitivity of the Apalachicola floater is categorized as moderate (2).

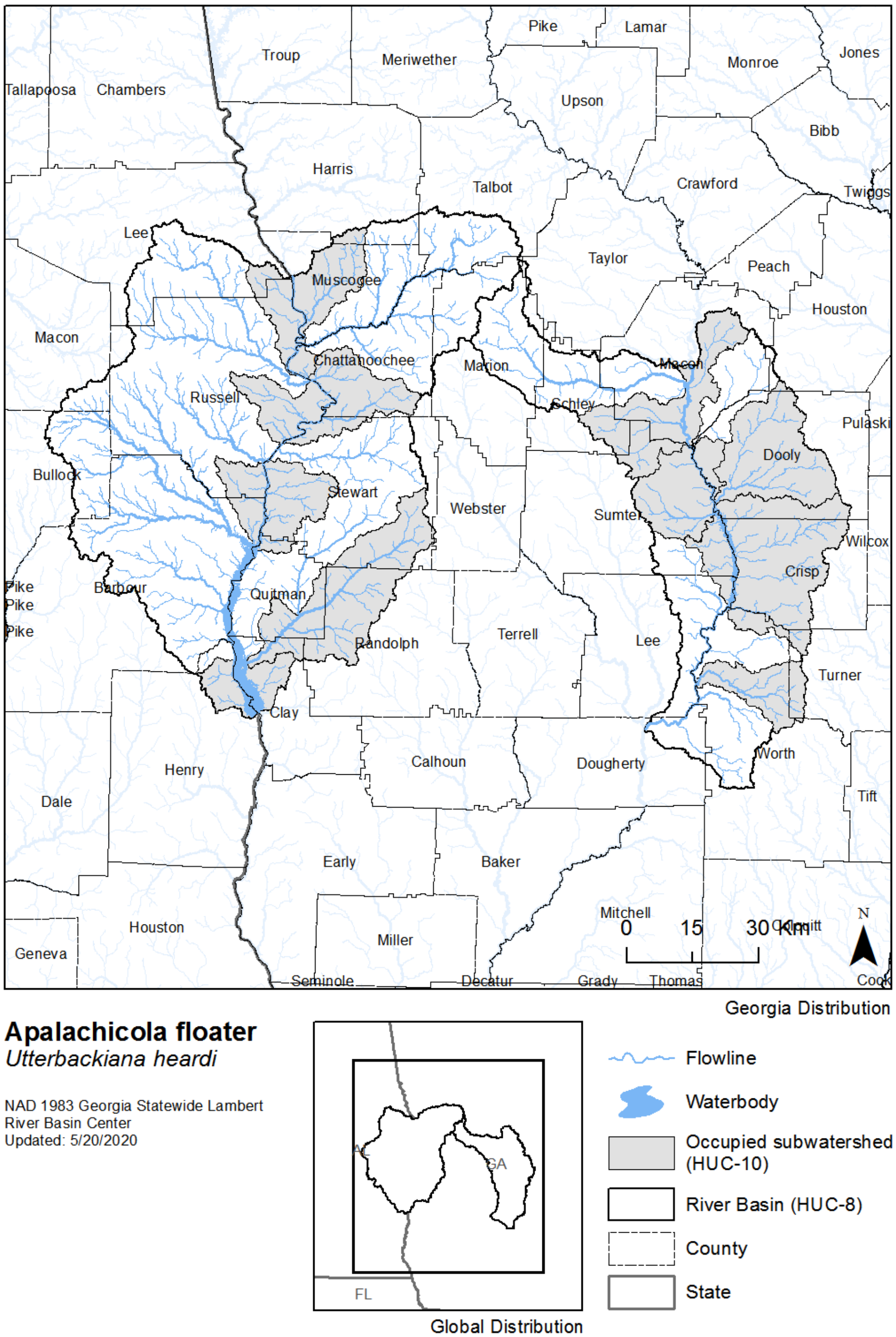
Pollutants

The research team is aware of no data available describing the effects of construction- or roadway-derived pollutants on the Apalachicola floater. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

It is also important to examine the potential effects of pollution on the host fish used by the Apalachicola floater. However, the host fishes used for reproduction by this species are unknown. Thus, inferences cannot be made regarding potential impacts of pollution on host fishes for the Apalachicola floater.

Based on general mussel sensitivity to pollutants, the pollutant sensitivity of the Apalachicola floater is categorized as somewhat intolerant (3).

Figure 31. Map. Range map for the Apalachicola floater.



ATLANTIC PIGTOE

Species

Atlantic Pigtoe, *Fusconaia masoni*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Shell profile is sub-rhomboidal and rarely exceeds 50 mm in length. The umbo is positioned slightly anterior of middle of valves and is elevated well above the hingeline. Anterior margin round while posterior margin typically truncate. Posterior ridge is prominent. Periostracum is yellow to dark brown and clothlike. Nacre color typically white. Individuals occurring in headwater streams tend to be more elongate.

Life History

The Atlantic pigtoe is a short-term brooder and is a member of the Pleurobemini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): The preferred habitat for this species is coarse sand and gravel at the downstream end of riffles. This species is rarely found in substrates of fine sand and silt or mud.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): This species historically occurred from the James River basin in Virginia south to the Altamaha River basin of Georgia. In Georgia, this species was historically collected from the type locality and from Mill Race in the Brier Creek sub-basin (Savannah River Basin) in Burke County. Within the Ogeechee River basin, this species was historically collected from the Ogeechee River in Warren and Screven counties, as well as the outfall of Magnolia Springs in Jenkins County, and the Ogeechee River in Screven County. The Atlantic pigtoe was last collected in Georgia during a 1991 survey of the Ogeechee River Basin. Only four live individuals were collected from Williamson Swamp Creek near Bartow in Jefferson County despite extensive searches throughout the entire basin. In 2004 and 2007, surveys of historical locations yielded no live individuals. Although surveyed extensively in the past, only two historic records of the Atlantic Pigtoe are known from the Altamaha River and the species is presumably extirpated from the basin.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Gravid individuals have been found during late June. Bluegill (*Lepomis macrochirus*) and shield darter (*Percina peltata*) successfully transformed glochidia of this species.

Conservation

The Atlantic pigtoe currently has a global conservation ranking status of G2, a Georgia state conservation ranking of S1, and is under no US federal protection. This species is listed as endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Although no live individuals have been collected in Georgia, it is possible that the species may still persist. The Ogeechee River harbors relatively large populations of native unionids, which may hinder the detection of this species. Continued survey efforts in this basin will help to determine if this species persists in the basin. Survey data for the Brier Creek sub-watershed is lacking, therefore the Atlantic Pigtoe may persist in Brier Creek. Currently, the Ogeechee River basin of Georgia is experiencing substantial development and timber removal along the banks. Excess sedimentation due to inadequate riparian buffer zones, development, and agriculture covers suitable habitat and could potentially bury mussels. Poor agricultural practices may also cause eutrophication and degrade water quality. Increasing water temperatures may also be contributing to the disappearance of Atlantic pigtoe in its historic range (J. Wisniewski, personal communication).

Effects of Construction Activities:

Sediment

The research team is aware of no direct studies on the effects of sediment on the Atlantic pigtoe. However, the effects of sediment have been studied in other members of *Fusconaia* and can serve as a basis for estimating impacts. Previous research in the Wabash pigtoe (*Fusconaia flava*) found that *F. flava* experienced a lower survival rate than the giant floater (*Pyganadon grandis*) when buried in detritus, sand, mucky sand, or silt (Imlay 1972). Furthermore, another study found that 55% of exposed *F. flava* died when buried in 10 cm of silt and sand (Marking and Bills 1980). The second study postulated that the lower survival rates of *F. flava* compared to *Lampsilis* spp. may be due to the sessile nature of *F. flava*. The Atlantic pigtoe is also a sessile species; therefore, it is possible that the adverse impacts seen in *F. flava* are similar in the Atlantic pigtoe. A more recent evaluation in Missouri found that declines of another member of tribe Pleurobemini, the elephantear (*Elliptio crassidens*), were likely linked to erosion and sedimentation (Hinck et al. 2012). Because the Altlantic pigtoe is found in coarse sand or gravel associate with riffles, additional sediment inputs are likely to adversely impact its preferred habitat. In addition, as a short-term brooder (tribe Pleurobemini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

It is also important to consider the effects of increased sedimentation on the host fish used by the mussel for reproduction. The Atlantic pigtoe is likely a reproductive generalist which may allow use of a variety of hosts, including some that may be more tolerant of sediment, though based on their preferred habitat, most likely hosts include darters and other riffle species that are generally sensitive to sediment.

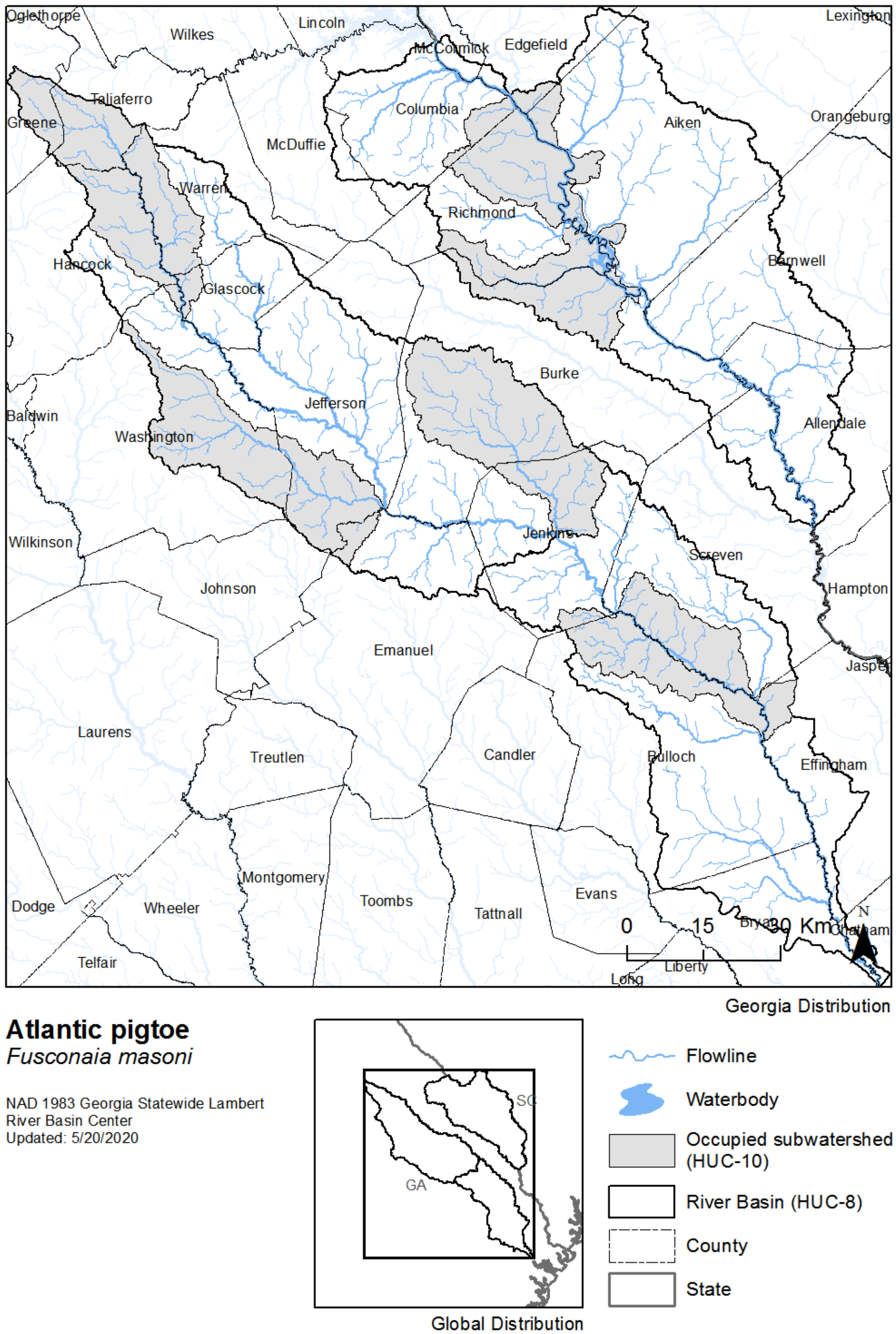
Based on sensitivity of preferred habitat and direct evidence from other species in the genus *Fusconia*, the sediment sensitivity of the Atlantic pigtoe is categorized as intolerant (1).

Pollutants

The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the Atlantic pigtoe. Inferences can be made based on data from another member of the tribe Pleurobmini – the Eastern elliptio (*Elliptio complanata*). *E. complanata* has been used in studies that examine the potential impacts of heavy metals (Cheney and Criddle 1996) and polyaromatic hydrocarbons (PAHs; Cheney et al. 2001). Both studies found that mussels exposed to road-associated metals or PAHs exhibited diverse patterns of effects that included both stimulation and inhibition of metabolic activity in this species. They also found that exposure to PAHs led to irreversible gill damage. Municipal wastewater contains contaminants that can be similar in composition to those found associated with construction or roadways (Chambers et al. 1997). Recent research in *E. complanata* suggests that exposure to these contaminant mixtures may lead to immunomodulatory responses, increased susceptibility to pathogens, and genotoxicity (Lacaze et al. 2013; Gagné et al. 2015). Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that persistence of multiple *Elliptio* spp. varied widely (Gillies et al. 2003). *E. complanata* and *E. crassidens* were resilient, with no indication that imperviousness may be correlated with their abundance. However, *E. icterina* presence did decline with increasing imperviousness (individuals were not found at 1/3 locations sampled after 1992). Of all *Elliptio* data available for this study, *E. arctata* had the most significant decline in relation to increased urbanization and imperviousness. By 1992, *E. arctata* had disappeared from all three locations where they were historically found. This study displays the large variability in response to urbanization within the same genus of freshwater mussels. It is also important to examine the potential effects of pollution on the host fish used by the Atlantic pigtoe. The Atlantic pigtoe is likely a reproductive generalist which may allow use of a variety of hosts including some that may be more tolerant of pollutants, though based on their preferred habitat, most likely hosts include darters and other riffle species. Based on their life history traits, the pollutant sensitivity of darters is categorized as somewhat tolerant.

Based on direct studies with related species and the sensitivity of likely host fish, the pollutant sensitivity of the Atlantic pigtoe is categorized as somewhat intolerant (3).

Figure 32. Map. Range map for the Atlantic pigtoe.



COOSA MOCCASINSHELL

Species

Coosa Moccasinshell, *Medionidus parvulus*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2019g): The Coosa moccasinshell is a small species measuring up to 58 mm in length (Williams et al. 2008). The shell is thin and fragile, elongate and elliptical to rhomboidal in outline. The posterior ridge is inflated and smoothly rounded, terminating in a broadly rounded point; the posterior slope is finely corrugated. The periostracum is light to dark brown and raying is usually not visible. The nacre is greenish-gray and may occasionally lighten around the ventral shell margin.

Life History

The Coosa moccasinshell inhabits small streams to large rivers in gravel substrates with moderate to strong currents (USFWS 2003; Wisniewski 2018).

The Coosa moccasinshell is a member of tribe Lampsilini, and much like the Alabama moccasinshell, is believed to be a long-term brooder that reproduces starting in the fall and continues until the release of glochidia in the summer of the following year (USFWS 2019g).

Researchers also postulate that this species, like other *Medionidus* spp., use mantle lures to attract fish hosts. While this species remains embedded in the stream bottom for most of the year, it is thought that females move to the surface of the stream bottom during glochidial release periods (USFWS 2019a). Host trials performed for this species indicate that bronze darters (*Percina palmaris*) and Mobile logperch (*Percina kathae*) are good hosts (USFWS 2019g). Greenbreast (*Etheostoma jordani*) and blackbanded darters (*Percina nigrofasciata*) are considered marginal hosts (Johnson 2018).

Numbers, Reproduction, Distribution

The Coosa moccasinshell is endemic to the Cahaba, Black Warrior, and Coosa Rivers and their tributaries in Alabama, Georgia, and Tennessee (USFWS 2019g). Since the listing of this species in 1993, its presence has only been confirmed in the Conasauga River and one of its tributaries (Holly Creek, Murray County, GA; USFWS 2019g). Currently, the Coosa moccasinshell is known from a 3-km stretch of Holly Creek and a 4-km stretch of the Conasauga River in Tennessee. There is an additional reintroduced population in the Little Cahaba River in Alabama (Johnson 2012). However, only 4 of the original 59 reintroduced individuals were detected as of 2018 (cited as P. Johnson pers. comm. in USFWS 2019g). Overall, the remaining populations of this species are very small and are highly localized (USFWS 2019g).

Conservation

The Coosa moccasinshell has a global conservation ranking of G1Q, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (USFWS 2019g). This species is listed as endangered in the state of Georgia.

Similar to the Alabama moccasinshell, the primary threats to the Coosa moccasinshell include changes in hydrological regime (*e.g.,* water withdrawals, drought), excess sedimentation, pollution and water quality issues, extreme reduction and fragmentation of habitat and range, low population sizes, and vulnerability of small, localized populations to stochastic events (Wisniewski 2018; USFWS 2019a). In the Conasauga River, pollutants associated with agricultural runoff (*e.g.*, herbicides, surfactants, hormones) are considered a concern for this species (USFWS 2019g).

Recommended actions aimed at conservation of the Coosa moccasinshell in Georgia include: minimizing sedimentation in critical habitats, restoration of riparian habitats, evaluation of minimum population sizes, and reintroduction of stocks in viable habitat (Wisniewski 2018). Although no populations have been entirely lost since listing (2003), the Coosa moccasinshell is declining and remains in low abundance where it occurs (USFWS 2019g).

Effects of Construction Activities:

Sediment

The research team is aware of no direct studies on the effects of sediment on the Coosa moccasinshell or other associated *Medionidus* spp. Because the Coosa moccasinshell is found in gravel substrates, additional sediment inputs may adversely affect its preferred habitat. As a long-term brooder, the Coosa moccasinshell may be less sensitive to episodic elevated suspended sediment; however, long-term brooders may experience significant declines in reproductive success due to excessive levels of sediment exposure during or after fertilization. Elevated suspended sediment during reproduction may also reduce visibility of lures to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Based on their life history, the sediment sensitivity of the primary hosts, darters and logperch (*Etheostoma* and *Percina* spp.), is categorized as intolerant.

On the balance of high sensitivity of preferred habitat and host fish, but lower sensitivity due to brooding strategy, the sediment sensitivity of the Coosa moccasinshell is categorized as intolerant (1).

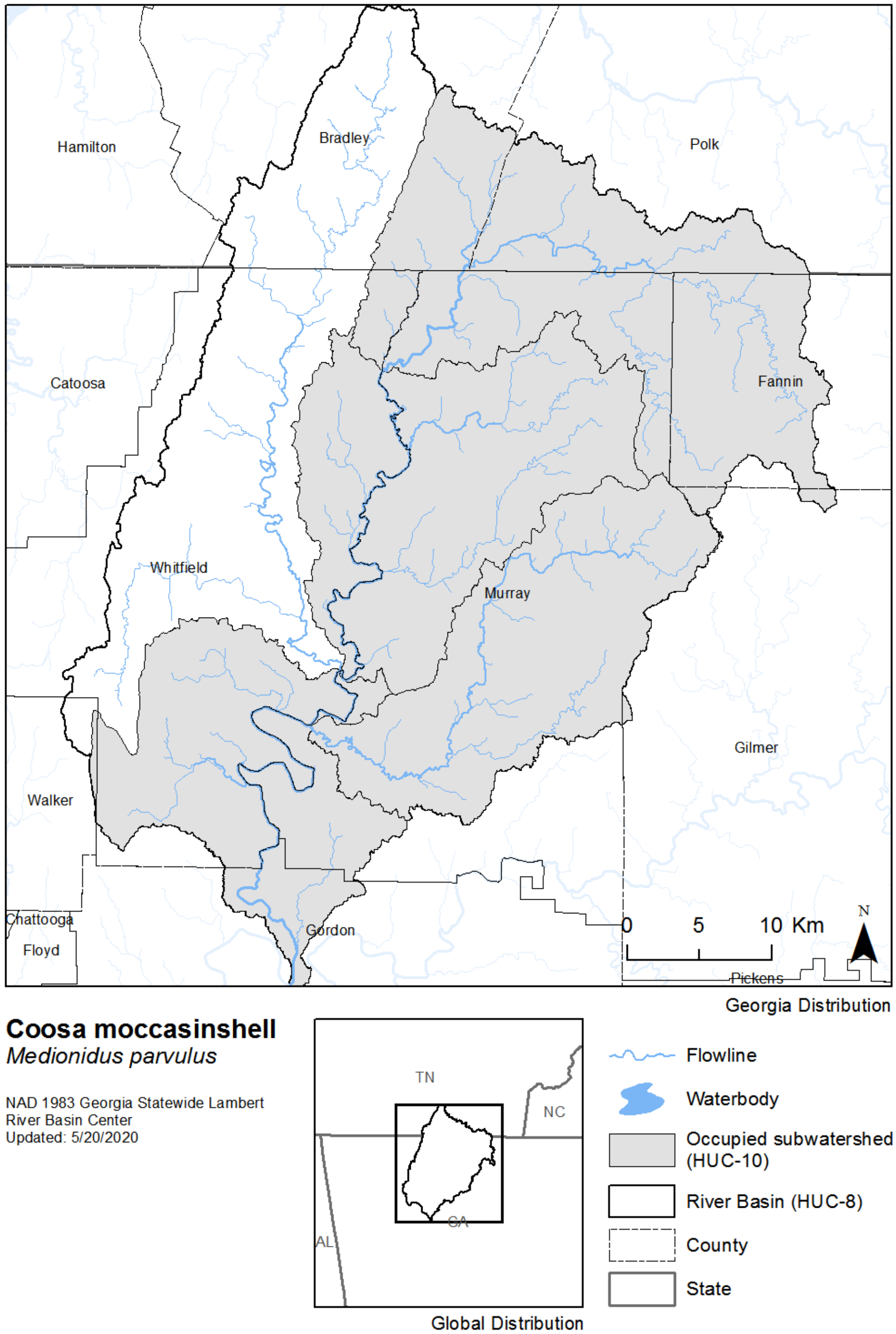
Pollutants

The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the Coosa moccasinshell. Cherry et al. (2002) found that glochidia of the closely related Cumberland moccasinshell (*Medionidus conradicus*) were among the most sensitive species when exposed to copper. A more recent report states that this trend does not hold true for all metals, as *M. conradicus* seems to be relatively tolerant to zinc (cited in Markich et al. 2017 as personal communication from M. McCann). Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that a congener, the Gulf moccasinshell (*Medionidus penicillatus*), was extirpated from one of two sites where the species was previously found (Gillies et al. 2003).

Indirect effects of pollution on host fish must also be considered. Based on their life history, the pollutant sensitivity of the primary host fishes, darters, is categorized as somewhat intolerant.

Based on general mussel sensitivity as well as direct evidence with closely related species and sensitivity of host fish, the pollutant sensitivity of Coosa moccasinshell is categorized as somewhat intolerant (3).

Figure 33. Map. Range map for the Coosa moccasinshell.



DELICATE SPIKE MUSSEL

Species

Delicate Spike Mussel, *Elliptio arctata*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Typically compressed to moderately inflated shell, elliptical or elongate in shape. Maximum length is approximately 90 mm. Anterior margin is broadly rounded while posterior margin is typically rounded to biangulate. Ventral margin relatively straight to slightly arcuate. Posterior ridge sharply angular to round in larger individuals. Umbos slightly projecting above hingeline. Periostracum typically dark brown to black in adults. Juveniles may be yellow to green with fine rays near the umbo. Left valve with two triangular stumpy pseudocardinal teeth and two low and straight lateral teeth. Right valve with one low, serrated pseudocardinal tooth and one typically high, straight, and long lateral tooth. Umbo cavity typically shallow and wide. Nacre variable but typically bluish white to salmon.

Life History

The delicate spike is thought to be a short-term brooder and is a member of the Pleurobemini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): This species is found in gravel or sand shoals in medium to large rivers. Occasionally found in sand-bottomed runs with slow, steady current. Usually found adjacent to or underneath large boulders or limestone bedrock in center channel; rarely found in slack water or silt.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Historically widespread from the Apalachicola River Basin west to the Pearl River in Mississippi, but becoming more restricted throughout its range. Within Georgia, the delicate spike historically occurred in the Mobile and Apalachicola River basins, above and below the Fall Line. It currently appears to be extremely rare or extirpated in the Mobile River basin of Georgia. Only three recent collections of live individuals have been made and few shells have been collected despite extensive sampling in the Conasauga, Coosawattee, and Oostanaula rivers. In the Apalachicola River basin, this species appears to be restricted to the Flint River and its tributaries. The delicate spike has also been reported from the Atlantic Slope of Georgia, but this report may be of a different or unrecognized species.

The life history of this species is poorly understood, but females are believed to brood glochidia in the spring or summer. Glochidial hosts are unknown.

Conservation

The delicate spike currently has a global conservation ranking status of G2G3Q, a Georgia state conservation ranking of S2, and is under no US federal protection. This species is listed as endangered in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Excess sedimentation due to inadequate riparian buffer zones, development, and agriculture covers suitable habitat and could potentially bury mussels. Poor agricultural practices may also cause eutrophication and degrade water quality. Incompatible dam operations on the Coosawattee River may be affecting downstream unionids. Excessive agriculture water pumping in the Lower Flint River basin may be affecting individuals occupying smaller streams prone to drying during periods of extreme drought.

Effects of Construction Activities

Sediment

The research team is aware of no direct studies on the effects of sediment on the delicate spike mussel. However, one study with a congener (*Elliptio crassidens*) postulated that sedimentation may be a contributing factor to declines of the *E. crassidens* in Missouri (Hinck et al. 2012). Because the delicate spike is found in gravel or sand shoals, additional sediment inputs are likely to adversely affect its preferred habitat. In addition, as a short-term brooder (tribe Pleurobemini) it is more likely to experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Unfortunately host fish for the delicate spike are currently not known, so inferences cannot be made regarding potential impacts of sedimentation on its host fishes.

Based on the sensitivity of their brooding behavior and preferred habitat, the sediment sensitivity of the delicate spike mussel is categorized as intolerant (1).

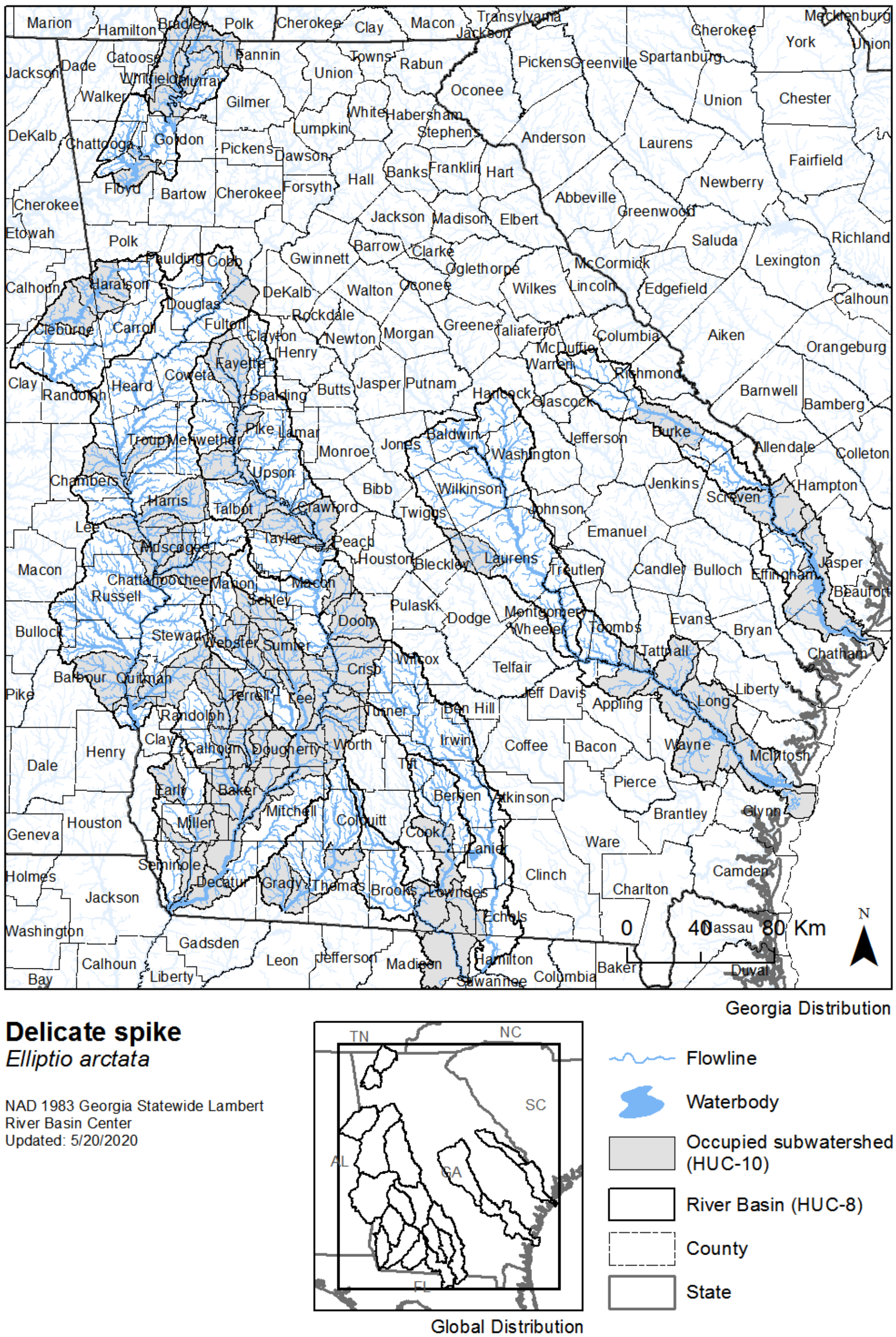
Pollutants

The research team is aware of no studies investigating the effects of construction- or road-associated pollutants on the delicate spike, but inferences can be made based on data from a congener species – the Eastern elliptio (*Elliptio complanata*). *E. complanata* has been used in studies that examine the potential impacts of heavy metals (Cheney and Criddle 1996) and polyaromatic hydrocarbons (PAHs; Cheney et al. 2001). Both studies found that mussels exposed to road-associated metals or PAHs exhibited diverse patterns of effects that included both stimulation and inhibition of metabolic activity in this species. They also found that exposure to PAHs led to irreversible gill damage. Municipal wastewater contains contaminants that can be similar in composition to those found associated with construction or roadways (Chambers et al. 1997). Recent research in *E. complanata* suggests that exposure to these contaminant mixtures may lead to immunomodulatory responses, increased susceptibility to pathogens, and genotoxicity (Lacaze et al. 2013; François et al. 2015). Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that persistence of multiple *Elliptio* spp. varied widely (Gillies et al. 2003). *E. complanata* and *E. crassidens* were resilient, with no indication that imperviousness may be correlated with their abundance. However, *E. icterina* presence did decline with increasing imperviousness (individuals were not found at 1/3 locations sampled after 1992). Of all *Elliptio* data available for this study, the delicate spike had the most significant decline in relation to increased urbanization and imperviousness. By 1992, the delicate spike had disappeared from all three locations where they were historically found. This study displays the large variability in response to urbanization within the same genus of freshwater mussels.

It is also important to examine the potential effects of pollution on the host fish used by delicate spike. However, the host fishes used for reproduction by this species are not known. Thus, inferences cannot be made regarding potential impacts of pollution on host fishes for the delicate spike mussel.

Based on direct studies with congener species, the pollutant sensitivity of the delicate spike is categorized as very intolerant (2).

Figure 34. Map. Range map for the delicate spike.



FAT THREERIDGE MUSSEL

Species

Fat Threeridge, *Amblema neiseri*

Description

Reproduced from the U.S. Fish and Wildlife Service recovery plan for the Fat threeridge (USFWS 2003):

The fat threeridge is a medium-sized to large, subquadrate, inflated, solid, and heavy-shelled mussel that reaches a length of 10.2 centimeters. Large specimens are so inflated that their width approximates their height. The umbos (bulge or beak that protrudes near the hinge of a mussel) are in the anterior quarter of the shell. The dark brown to black shell is strongly sculptured with seven to eight prominent horizontal parallel plications (ridges). As is typical of the genus, no sexual dimorphism is displayed in shell characters. Internally, there are two subequal pseudocardinal teeth in the left valve and typically one large and one small tooth in the right valve (shell half). The lateral teeth are heavy, long, and slightly arcuate (curved like a bow), with two in the left valve and one in the right valve. The inside surface of the shell (nacre) is bluish white to light purplish and very iridescent.

Life History

The fat threeridge inhabits small to large rivers in slow to moderate currents and is found in the main river channel (USFWS 2003). This species prefers habitat comprised of cobble, sand, and sandy mud substrates (USFWS 2003).

The fat threeridge is a member of the Amblemini tribe and is considered a short-term summer brooder, as gravid females were observed in Florida when water temperatures reached approximately 24°C (75°F) in May – June (USFWS 2019d). Glochidia of this species are expelled in a mass that wraps around host fish and are thought to be viable for two days following release (USFWS 2019d). The fat threeridge is known to metamorphose on 23 species of fish, with the highest metamorphosis rates on darters and minnows (Fritts and Bringolf 2014). The fat threeridge may live to 27 years, and the estimated age to sexual maturity is three years (USFWS 2007; 2019d).

Numbers, Reproduction, Distribution

The fat threeridge is an endemic of the Apalachicola-Chattahoochee-Flint (ACF) River System and historically occupied the mainstem habitats of the ACF River Basin (USFWS 2003; 2019). Within the Flint River system in Georgia, the fat threeridge was once found in Baker, Decatur, Dougherty, Macon, and Mitchell Counties (Wisniewski 2018). As of 2003, the fat threeridge was known to only occupy approximately 42% of its former range (USFWS 2003). Thought to be extirpated from the Flint River, this species was rediscovered in the Flint River near the

Baker/Mitchell county line (Newton, GA) in 2006 – 2007 (USFWS 2019d). Live fat threeridge were still extant at this location in low numbers in 2019 (GADNR 2020). This is the only known extant and reproducing population in Georgia and its true abundance is not known (Wisniewski et al. 2013; 2014; USFWS 2019d).

Conservation

The fat threeridge currently has a global conservation ranking of G1, a Georgia state conservation ranking of S1, and it is federally listed as endangered under the ESA (Wisniewski 2018). Threats to this species are linked to anthropogenic disturbances, including destabilization of stream channels due to maintenance (*e.g.,* dredging activities), degraded water quality, and absence of host fishes (USFWS 2003; 2019d). Another concern for the fat threeridge is insufficient water flow due to agriculture, as the lower Flint River and upper Chipola basins are highly sensitive to water withdrawal and many associated streams go dry during drought (Albertson and Torak 2002). Previous droughts in these basins led occupied streams to go dry (2000 and 2006 – 2007, USFWS 2019d).

The major listing criteria used for the fat threeridge were habitat alterations and common pollutants, though specific pollutants were not identified (USFWS 2019d). Habitat alterations must be managed in such a way that it not only serves to reduce habitat threats to the fat threeridge but also benefits their host fishes (USFWS 2003). The reduction of pollution in critical habitats is also a priority for conservation of this species, as water quality in associated habitats is considered impaired (USFWS 2007; 2019d).

Effects of Construction Activities

Sediment

The research team is aware of no direct studies on the effects of sediment on the fat threeridge. Because the fat threeridge is found in coarse substrates, additional sediment input may degrade its preferred habitat. As a short-term brooder, (tribe Amblemini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress. Suspended sediment may also interfere with larval threads used for reproduction (Brim Box and Mossa 1999).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. The fat threeridge is considered a reproductive generalist, but the highest rates (~ 43% or greater) of successful metamorphosis are reported for the green sunfish (*Lepomis cyanellus*), turquoise darter (*Etheostoma inscriptum*), tessellated darter (*Etheostoma olmstedi*), Apalachee shiner (*Pteronotropis grandipinnis*), and swamp darter (*Etheostoma fusiforme*; Fritts and Bringolf 2014). Based on their life history traits, the general sediment sensitivity of sunfishes, shiners, and darters is categorized as moderate, intolerant, and intolerant, respectively. Based on their preferred habitat, more sensitive brooding behavior and host fish sensitivity, the sediment sensitivity of the fat threeridge is categorized as intolerant (1).

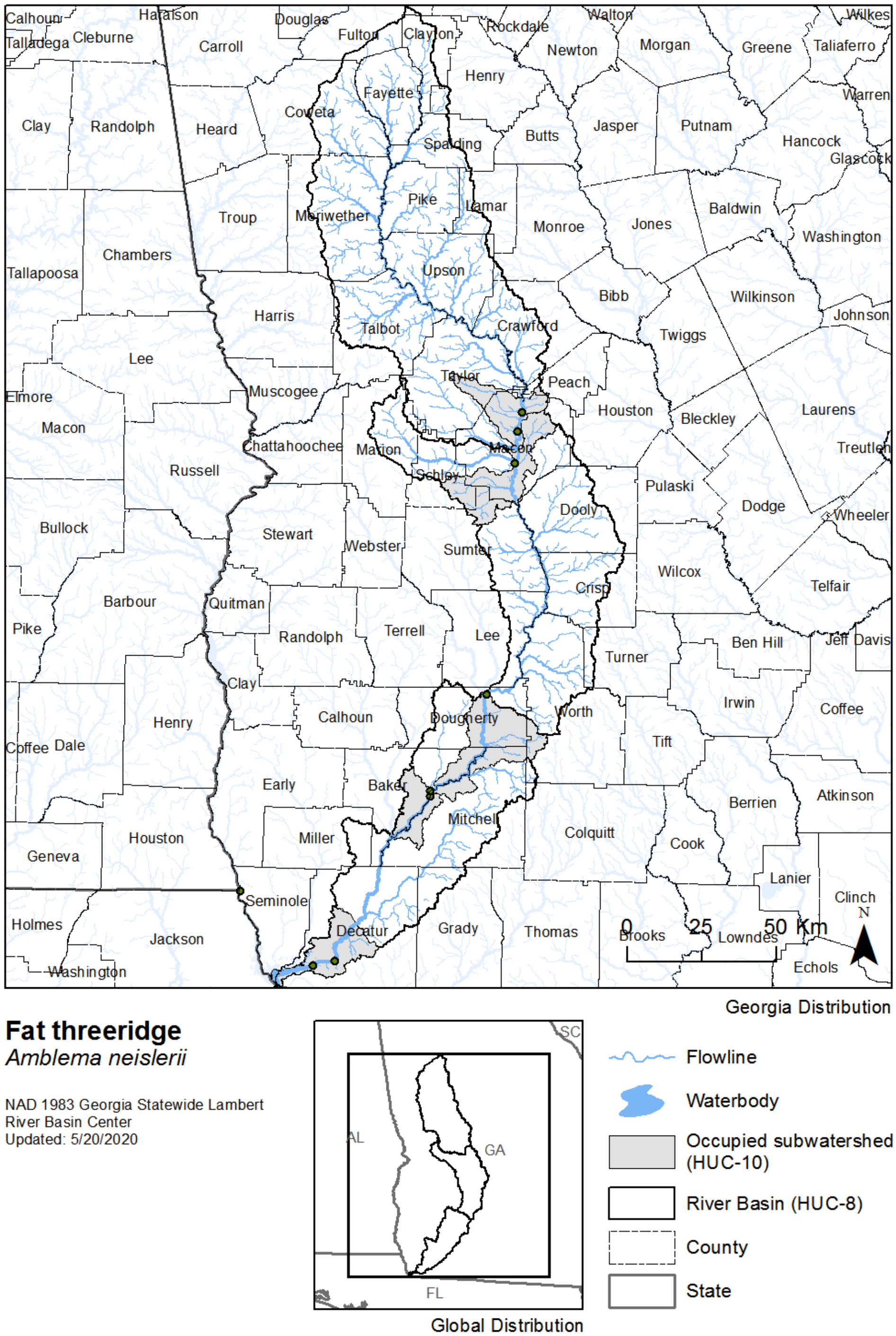
Pollutants

The research team is aware of no data available describing the effects of construction- or roadway-derived pollutants on the fat threeridge. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

Indirect effects of pollution on host fish used by fat threeridge must also be considered. Based on their life history traits, the pollutant sensitivity of sunfishes (including bass) is categorized as intolerant; of darters is categorized as moderate, and of other hosts such as minnows is categorized as tolerant.

Based on general mussel sensitivity and host fish sensitivity, the pollutant sensitivity of fat threeridge is categorized as somewhat intolerant (3).

Figure 35. Map. Range map for the fat threeridge.



FINELINED POCKETBOOK

Species

Finelined Pocketbook, *Hamiota altilis*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2019c): The Finelined pocketbook is yellow-brown in color, suboval in shape, and can grow to 117 mm in length (Williams et al. 2008). The ventral margin of the shell is angled posteriorly in females, resulting in a pointed posterior margin. The periostracum is yellow-brown to blackish and has fine rays on the posterior half. The nacre is white, becoming iridescent posteriorly. The Finelined pocketbook can be distinguished from a similar species, the orangenacre mucket, by its more elongate shape, thinner shell, white nacre, pointed posterior, and ray ornamentation.

Life History

The finelined pocketbook is known to inhabit small creeks to large rivers with slight to moderate currents. It has been found in multiple substrate types including sand, gravel, and gravel-cobble substrates without heavy silt deposits (Wisniewski 2018; USFWS 2019c).

The finelined pocketbook is a member of tribe Lampsilini. It is a long-term brooder, with females releasing glochidia as superconglutinates or conglutinates from March through at least May (USFWS 2019c). This species also uses a demibranch display to lure host fishes. Known suitable host fishes include redeye bass (*Micropterus coosae*), Alabama bass (*M. henshalli*), spotted bass (*M. puctulatus*), largemouth bass (*M. salmoides*), and green sunfish (*Lepomis cyanellus*).

Numbers, Reproduction, Distribution

The finelined pocketbook is endemic to the eastern Mobile Basin of Alabama, Georgia, and Tennessee. Extant populations in Georgia can be found in the Conasauga, Elijay, and Tallapoosa Rivers as well as several of their tributaries and tributaries to the Etowah River (USFWS 2019c). In locations where this species can be found, they typically occur in low abundances and are heavily fragmented (USFWS 2019c). More recent surveys found a population in Boardtown Creek (Elijay River population) that appears to be substantial and actively reproducing (cited as Wisniewski pers. comm. in USFWS 2019c). In addition, another population was found upstream of Lake Allatoona in the Shoal Creek watershed of the Etowah River, Georgia (cited as Wisniewski pers. comm. in USFWS 2019c). There is also an additional extant population in Euharlee Creek in the Etowah River of Georgia (J. Wisniewski, pers. Comm.).

Conservation

The finelined pocketbook currently has a global conservation ranking of G2/G3, a Georgia state conservation ranking of S2, and is federally listed as threatened under the ESA (USFWS 2019c). This species is listed as threatened in the state of Georgia.

The primary threats to the finelined pocketbook include habitat degradation (*e.g.*, fragmentation due to dams and impoundments, sedimentation, urbanization), water quality issues and pollution, and climate change (USFWS 2019c). More populations of the finelined pocketbook have been discovered in recent years, but these populations are small and their distribution is fragmented due to the presence of dams and impoundments (USFWS 2019c). Climate change and associated changes to ambient temperatures and hydrological regime are also of concern for the persistence of the finelined pocketbook, as these species have limited refugia from climatic events (*e.g.*, drought, flooding; USFWS 2019c).

Recommended actions aimed at conservation of the finelined pocketbook include: minimizing sedimentation in the Conasauga River and its associated tributaries, restoration of riparian buffers, minimization of habitat degradation, and evaluation of population sizes where they occur in Georgia (Wisniewski 2018; USFWS 2019c).

Effects of Construction Activities

Sediment

The research team is aware of no direct studies on the effects of sediment on the finelined pocketbook. However, the effects of sediment have been studied in a closely related genus, *Lampsilis*, and can serve as a basis for estimating impacts. Tuttle-Raycraft et al. (2017) found that fatmucket (*L. siliquoidea*) and the wavy-rayed lampmussel (*L. fasciola*) exposed to suspended solids (≥ 8 mg/L) exhibited significant reductions in clearance rates (suspension feeding rates) compared to controls. They also report that juveniles experienced a five-fold decrease in feeding rate relative to adults, which suggests that the effects of sediment exposure vary based on age class. A more recent study examined the effects of suspended sediments on juvenile *L. siliquoidea* and found that exposure elicited responses associated with physiological stress (reduced proteins, reduced ATP production, and oxidized proteins; Buczek et al. 2018). Because the finelined pocketbook is found in coarse substrate without heavy silt, additional sediment inputs may adversely affect its preferred habitat. As a long-term brooder that is reproductively active in spring, summer, and fall, the finelined pocketbook may experience significant declines in reproductive success due to excessive levels of sediment exposure. Elevated suspended sediment during reproduction may also reduce visibility of lures to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Black basses (*Micropterus* spp.) are considered primary fish hosts, while sunfish (*Lepomis* spp.) are considered secondary fish hosts for this species (Williams et al. 2008). Based on life history traits, the general sediment sensitivity of black basses and sunfish is categorized as moderate.

Based on the balance of habitat preference, direct evidence with closely related species, brooding and host attraction strategies, and host sensitivity, the sediment sensitivity of the finelined pocketbook is categorized as intolerant (1).

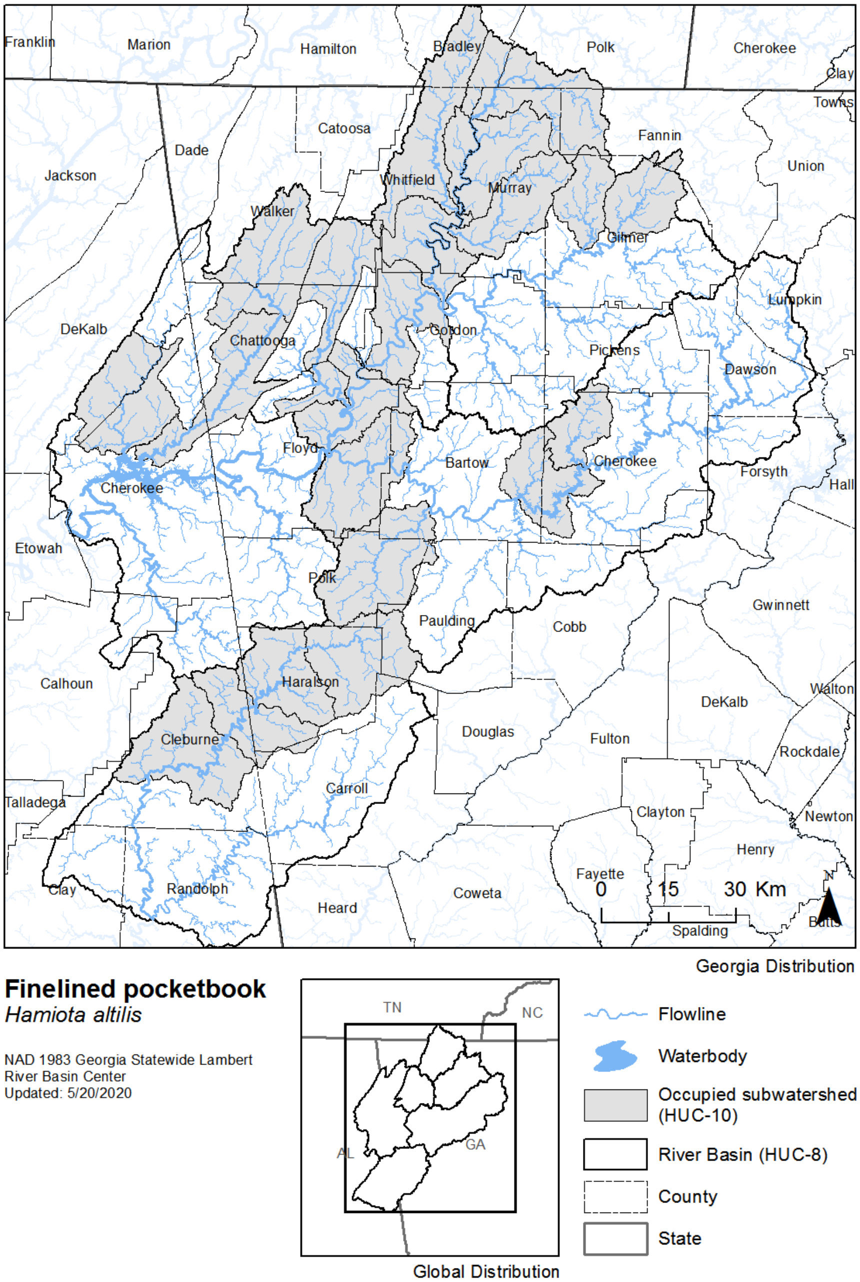
Pollutants

The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the finelined pocketbook. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the closely-related shinyrayed pocketbook (*Hamiota subangulata*) was likely extirpated from 25% of sites by 1992 where data was available (Gillies et al. 2003). Furthermore, another study evaluated the effects of urbanization in a similar species, the fatmucket (*Lampsilis siliquoidea*), found that increased imperviousness and overall urbanization was significantly associated with decreases in mussel populations (including *L. siliquoidea*; Myers-Kinzie et al. 2002).

Indirect effects of pollution on host fish used by finelined pocketbook must also be considered. The primary host fish used by the finelined pocketbook are sunfish and, potentially, black basses. Based on their life history traits, the pollution sensitivity of these species is categorized as somewhat intolerant.

Based on general mussel sensitivity to pollutants as well as studies with closely related species, the pollutant sensitivity of the finelined pocketbook is categorized as somewhat intolerant (3).

Figure 36. Map. Range map for the finelined pocketbook.



GEORGIA PIGTOE

Species

Georgia Pigtoe, *Pleurobema hanleyianum*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2014): The shell of the adult Georgia pigtoe reaches about 50 to 65 millimeters (mm) in length. It is oval to elliptical and somewhat inflated. The posterior ridge is low and evenly rounded when evident. The anterior end is rounded, while the posterior margin is bluntly pointed below. Dorsal and ventral margins are curved, and the beaks rise slightly above the hinge line. The periostracum (membrane on the surface of the shell) is yellowish-tan to reddish-brown and may have concentric green rings. The beak cavity is shallow, and the shell interior is white to dull bluish-white (Parmalee and Bogan 1998, Williams et al. 2008).

Life History

Little is known about the life history of the Georgia pigtoe. It has been found in shallow runs and riffles with moderate to strong current. The species also appears to prefer coarse sand-gravel-cobble substrates (USFWS 2014).

The Georgia pigtoe is a member of tribe Pleurobemini and is believed, like other *Pleurobema* spp., to be a short-term brooder with viable glochidia in the late spring or early summer. It is assumed that this species uses cyprinids as host fish (Wisniewski 2018).

Numbers, Reproduction, Distribution

The Georgia pigtoe is endemic to the Coosa River Basin in Alabama, Georgia, and Tennessee (USFWS 2014). Historically, the range for this species included more than 480 km of river channels, but all recent collections come from a 43 km stretch of the Consasauga River – constituting a more than 90% reduction of its historical range (USFWS 2014; 2019). Presently, the Georgia pigtoe is only known from a few isolated shoals in the Upper Conasauga River (Murray and Whitfield counties, Georgia) and in Polk County, Tennessee. This species is extremely rare where found and no population estimates are available (USFWS 2014; 2019).

Conservation

The Georgia pigtoe has a global conservation ranking of G1, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (USFWS 2014). This species is listed as endangered in the state of Georgia.

Threats to the conservation of the Georgia pigtoe include habitat loss, alterations to hydrological regimes (*e.g.*, impoundments and dams, redirection of flow), degraded water quality, excess sedimentation, and climate change (USFWS 2014). More than 60% of the Coosa River Basin is impacted by flow regulation due to dams and impoundments (USFWS 2014). Historic and contemporary activities such as mining, industry, construction, and agriculture all have adversely impacted water quality in the Coosa River basin (USFWS 2014). The remaining small populations of this species are also vulnerable to stochastic events associated with climate change (*e.g.*, drought and flooding).

Recommended actions aimed at conservation of the Georgia pigtoe include minimization of sedimentation in the Coosa River Basin, continuation of flow improvements in habitats, restoration of riparian buffers, monitoring extant populations, and reintroduction of this species in suitable habitats (USFWS 2014; Wisniewski 2018). Furthermore, a thorough examination of the life history of the Georgia pigtoe is necessary for its conservation (Wisniewski 2018).

Effects of Construction Activities

Sediment

The research team is aware of no direct studies on the effects of sediment on the Georgia pigtoe. However, the effects of sediment have been studied in other members of genus *Pleurobema* and can serve as a basis for estimating impacts. Exposure to sediment caused reduced feeding and overall metabolism in the Mississippi pigtoe (*Pleurobema beadleanum*; Aldridge et al. 1987). A more recent study found that increased riverine sediment loading was negatively associated with the presence of the clubshell mussel (*Pleurobema clava*; Roley and Tank 2016).

Because the Georgia pigtoe is found in riffles with coarse substrate, additional sediment inputs may adversely affect its preferred habitat. As a short-term brooder it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress. Sediment may also reduce the visibility of conglutinates to host fish, thereby reducing reproductive fitness (Brim Box and Mossa 1999).

Indirect effects of sediment on host fish used by Georgia pigtoe must also be considered. Based on their life history traits, the sediment sensitivity of cyprinids (e.g. shiners and other minnows) is categorized as intolerant.

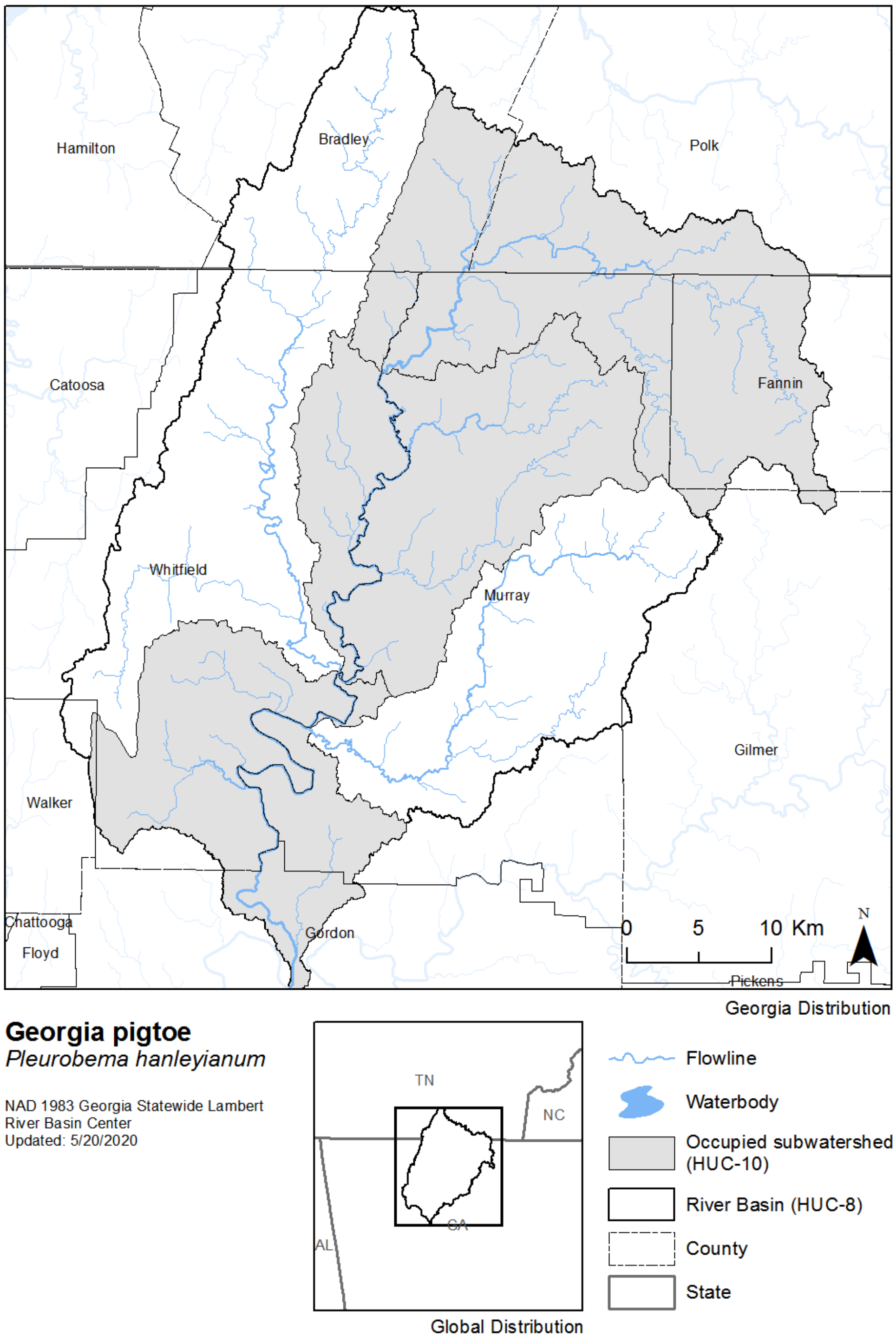
Based on preferred habitat, brooding strategy, and sensitivity of host fish, the sediment sensitivity of Georgia pigtoe is categorized as intolerant (1).

Pollutants

The research team is aware of no data available describing the effects of construction- or road-associated pollutants on the Georgia pigtoe. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. Indirect effects of pollutants on host fish for the Georgia pigtoe must also be considered. Based on their life history traits, the pollution sensitivity of cyprinid fishes is categorized as somewhat intolerant.

Based on general mussel sensitivity to pollutants and sensitivity of host fish, we categorize the pollution sensitivity of Georgia pigtoe as somewhat intolerant (3).

Figure 37. Map. Range map for the Georgia pigtoe.



GULF MOCCASINSHELL

Species

Gulf Moccasinshell, *Medionidus penicillatus*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2003): The Gulf moccasinshell is a small mussel that reaches a length of about 5.6 cm, is elongate-elliptical or rhomboidal in outline, fairly inflated, and has relatively thin valves. The ventral margin is nearly straight or slightly rounded. The posterior ridge is rounded to slightly angled and intersects the end of the shell at the base line. Females tend to have the posterior point above the ventral margin and are somewhat more inflated. Sculpturing (ridges/bumps on a shell caused by natural processes) consists of a series of thin, radially-oriented plications along the length of the posterior slope. The remainder of the surface is smooth and yellowish to greenish brown with fine, typically interrupted green rays. The left valve has two stubby pseudocardinal and two arcuate lateral teeth. The right valve has one pseudocardinal tooth and one lateral tooth. Nacre color is smoky purple or greenish and slightly iridescent at the posterior end.

Life History

The Gulf moccasinshell inhabits small to medium creeks to large rivers with slow to moderate currents. This species prefers a substrate made of sand, gravel, or silty sand (USFWS 2003).

The Gulf moccasinshell is a member of tribe Lampsilini, and is a long-term brooder that reproduces starting in the fall and continues until the release of glochidia in the spring of the following year (USFWS 2003). Like other *Medionidus* spp., the Gulf moccasinshell uses a mantle lure to attract fish hosts. While this species remains embedded in the stream bottom for most of the year, females move to the surface of the stream bottom during glochidial release periods and flap their mantle margins (USFWS 2003). Primary host fishes used by the Gulf moccasinshell include the brown darter (*Etheostoma edwini*) and blackbanded darter (*Percina nigrofasciata*; O'Brien and Williams 2002; Fritts and Bringolf 2014).

Numbers, Reproduction, Distribution

The Gulf moccasinshell is endemic to Apalachicola River basin of Alabama, Georgia, and Florida (Wisniewski 2018). Historically, this species could be found in the main steams and tributaries throughout the Apalachicola-Chattahoochee-Flint River basin (USFWS 2003). The Gulf moccasinshell is thought to be extirpated from the Upper and Middle Chattahoochee sub-basins, as well as the Spring Creek sub-basin (USFWS 2019f). The population found in the Sawhatchee Creek system (Lower Chattahoochee sub-basin) is the largest known assemblage of the Gulf moccasinshell in Georgia and shows evidence of recruitment (USFWS 2019f). The species appears to be rare or extirpated outside of the Chattahoochee and Flint River drainages in Georgia. Overall, the Gulf moccasinshell is reported to have lost almost 80% of its historical range (USFWS 2003).

Conservation

The Gulf moccasinshell has a global conservation ranking of G2, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (USFWS 2003). This species is listed as endangered in the state of Georgia.

Major threats to the Gulf moccasinshell include altered hydrological regimes (*e.g.,* water withdrawal or dams), drought, dredging, mining, pollution, and habitat degradation (USFWS 2019f). The rivers inhabited by this species (*e.g.,* ACF basin) are heavily impacted by drought and changes to the hydrological regime, as they are downstream of major main-stem dams or in areas of high industrial/agricultural water use (USFWS 2019f). Non-native species, including bivalves (*e.g.,* Asian clams) and fish also may pose a threat to this species (USFWS 2003; Wisniewski 2018).

The Gulf moccasinshell is considered highly unlikely to recover without significant human intervention (USFWS 2006). Recommended actions aimed at the conservation of the Gulf moccasinshell include: minimizing soil erosion throughout its range with better management practices, improvement of water quality, additional studies to understand the effects of drought and water withdrawals, and reintroduction of the species into currently unoccupied areas within the ACF basin (USFWS 2003; Wisniewski 2018).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the Gulf moccasinshell or other associated *Medionidus* spp. Because the Gulf moccasinshell is found in coarse substrates, additional sediment inputs may adversely affect its preferred habitat. As a long-term brooder, the Gulf moccasinshell may be less sensitive to episodic elevated suspended sediment; however, long-term brooders may experience significant declines in reproductive success due to excessive levels of sediment exposure during or after fertilization. Elevated suspended sediment during reproduction may also reduce visibility of lures to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Based on their life history, we categorize the sediment sensitivity of the primary hosts, darters (*Etheostoma* and *Percina* spp.), as intolerant.

On the balance of high sensitivity of preferred habitat and host fish, but lower sensitivity due to brooding strategy, we categorize the sediment sensitivity of Gulf moccasinshell as intolerant (1).

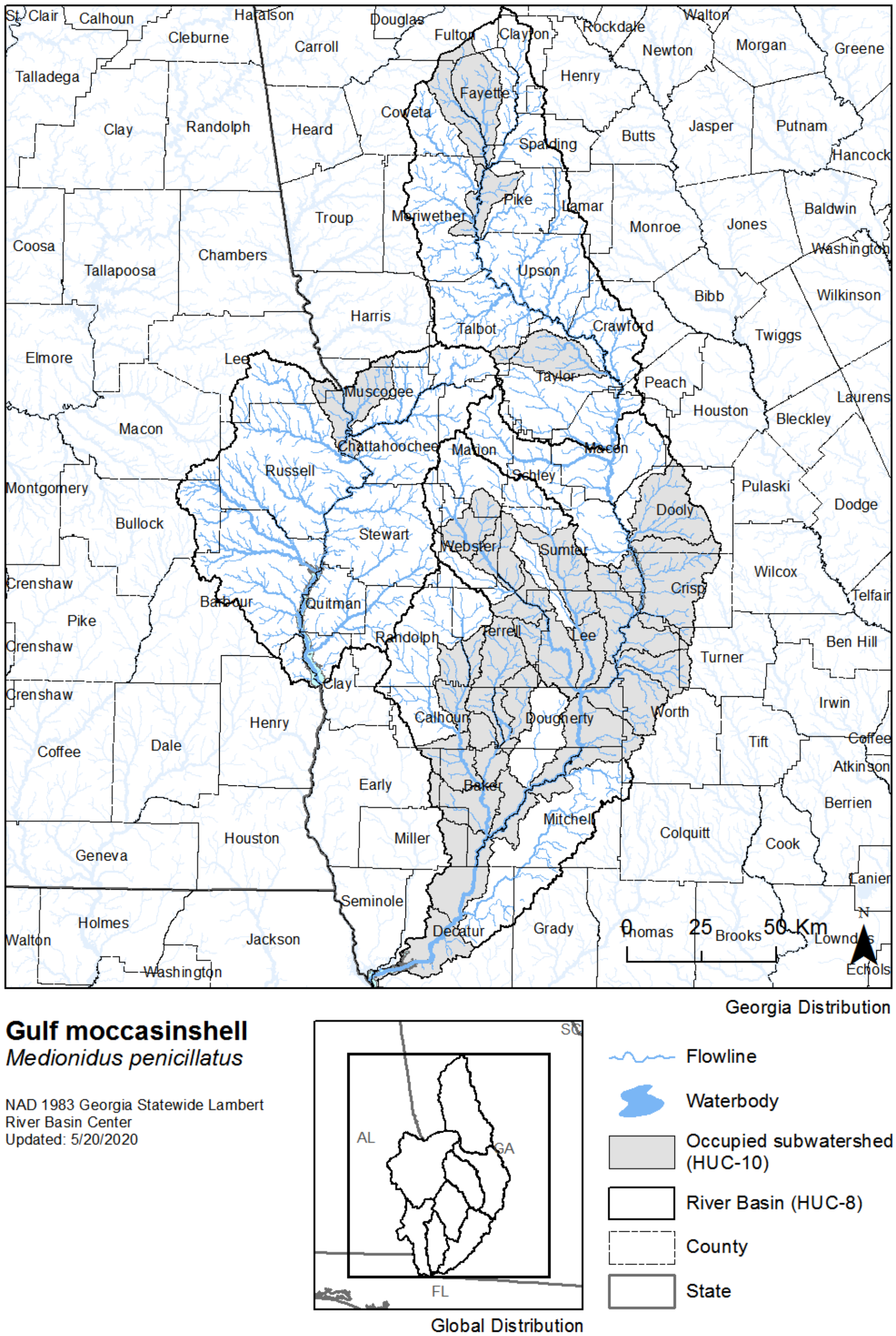
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the Gulf moccasinshell. Cherry et al. (2002) found that glochidia of the closely related Cumberland moccasinshell (*Medionidus conradicus*) were among the most sensitive species when exposed to copper. A more recent report states that this trend does not hold true for all metals, as *M. conradicus* seems to be relatively tolerant to zinc (cited in Markich et al. 2017 as personal communication from M. McCann). Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the Gulf moccasinshell was extirpated from one of two sites where the species was previously found (Gillies et al. 2003).

Indirect effects of pollution on host fish used by Coosa moccasinshell must also be considered. Based on their life history, we categorize the pollutant sensitivity of the primary host fishes, darters, as somewhat intolerant.

Based on general mussel sensitivity, direct evidence with closely related species, direct evidence of negative association with impervious surfaces, and sensitivity of host fish, we categorize the pollutant sensitivity of Coosa moccasinshell as somewhat intolerant (3).

Figure 38. Map. Range map for the Gulf moccasinshell.



INFLATED SPIKE MUSSEL

Species

Inflated Spike Mussel, *Elliptio purpurella*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Shell is small, inflated, and elliptical or elongate in shape. Maximum length is approximately 65 mm. Anterior margin is broadly rounded while posterior margin is typically rounded or truncated. Ventral margin is relatively straight to slightly arcuate. Umbos project slightly above hingeline. Posterior ridge rounded and flattens posterioventrally. Periostracum typically green to dark brown or black in adults. Often with broad green rays present. Left valve with two triangular pseudocardinal teeth and short, straight lateral teeth. Umbo cavity typically shallow and wide. Nacre typically purple or white.

Life History

The inflated spike is likely a short-term brooder and is a member of the Pleurobemini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Generally is found in sand and limestone shoals in medium sized creeks to large rivers. Occasionally found in sand-bottomed runs with slow, steady current; often found in clay-bottomed streams (Brim Box and Williams 2000).

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Historically presumed as endemic to the Apalachicola River Basin in Alabama, Florida, and Georgia. However recent collections from the Ochlockonee River Basin have expanded the range of this species. The inflated spike appears to be limited in its distribution throughout the lower Flint River basin, but often occurs in relatively high abundance when present.

The life history of this species has been poorly studied. Surveys conducted during the early 1990's checked 369 individuals between the months of May and September but failed to find any gravid females. However, several brooding individuals were found during sampling of Spring Creek (Miller County) during May of 2012 and 2013. This suggests that the species likely broods from early to mid-spring until May.

Conservation

The inflated spike currently has a global conservation ranking status of G2, a Georgia state conservation ranking of S2, and is under no US federal protection. This species is listed as threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Excess sedimentation due to inadequate riparian buffer zones, development, and agriculture covers suitable habitat and could potentially bury mussels. Poor agricultural practices may also cause eutrophication and degrade water quality. Excessive agriculture water pumping in the lower Flint River basin appears to stress the aquatic resources of the Flint and Ochlockonee river basins in periods of extreme drought.

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the inflated spike mussel. However, one study with a congener (*Elliptio crassidens*) postulated that sedimentation may be a contributing factor to declines of the *E. crassidens* in Missouri (Hinck et al. 2012). Because the inflated spike is found in gravel or sand shoals, additional sediment inputs are likely to adversely affect its preferred habitat. In addition, as a short-term brooder (tribe Pleurobemini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

It is also important to consider the effects of increased sedimentation on the host fish used by the mussel for reproduction. However, the host fishes used for reproduction by this species are not known. Thus, we cannot make inferences regarding potential impacts of sedimentation on host fishes for the inflated spike mussel.

Based on their preferred habitat and sensitivity of their brooding behavior, we categorize the sediment sensitivity of the inflated spike mussel as intolerant (1).

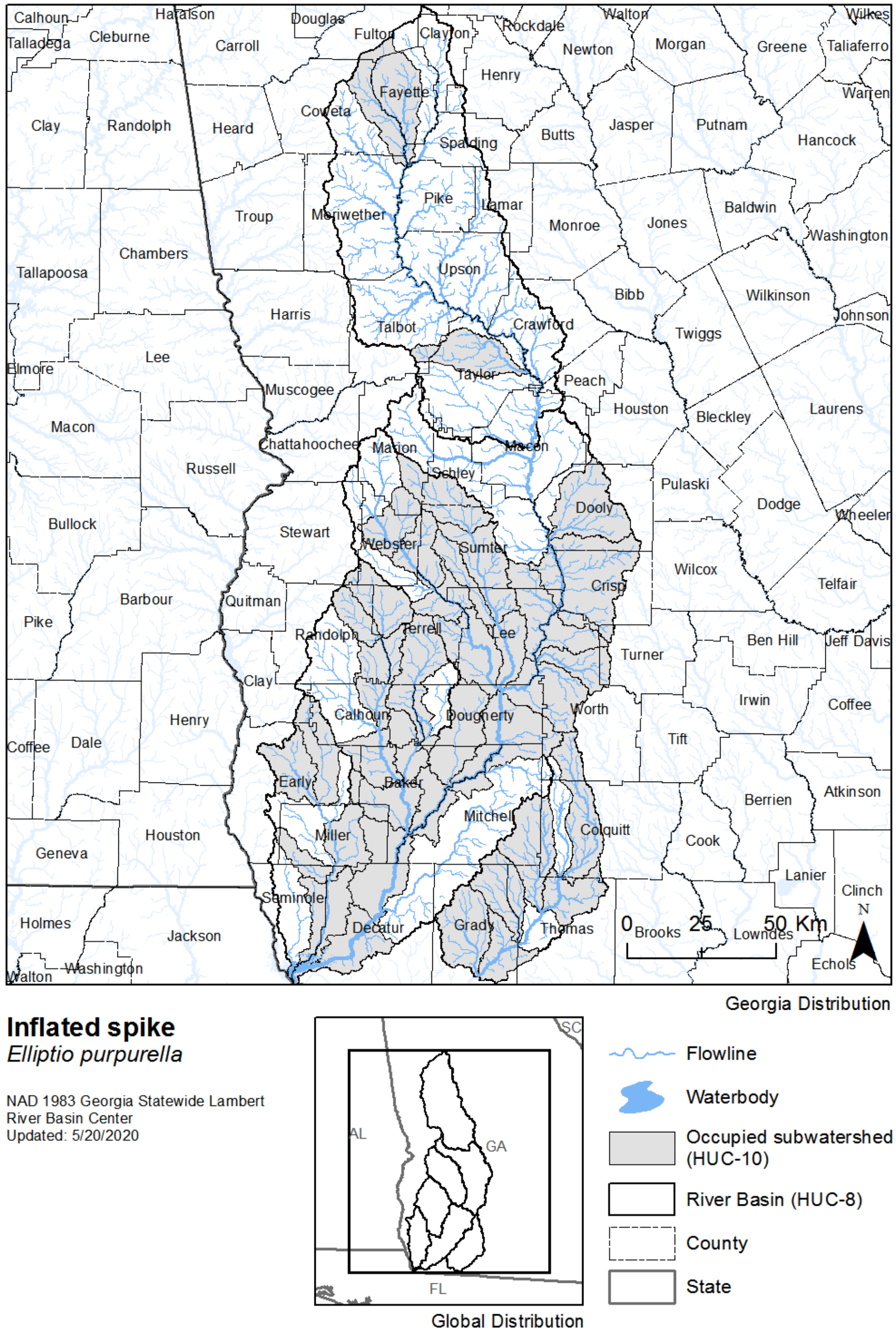
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the inflated spike, but we can make inferences based on data from a congener species – the Eastern elliptio (*Elliptio complanata*). *E. complanata* has been used in studies that examine the potential impacts of heavy metals (Cheney and Criddle 1996) and polyaromatic hydrocarbons (PAHs; Cheney et al. 2001). Both studies found that mussels exposed to road-associated metals or PAHs exhibited diverse patterns of effects that included both stimulation and inhibition of metabolic activity in this species. They also found that exposure to PAHs led to irreversible gill damage. Municipal wastewater contains contaminants that can be similar in composition to those found associated with construction or roadways (Chambers et al. 1997). Recent research in *E. complanata* suggests that exposure to these contaminant mixtures may lead to immunomodulatory responses, increased susceptibility to pathogens, and genotoxicity (Lacaze et al. 2013; François et al. 2015). Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that persistence of multiple *Elliptio* spp. varied widely (Gillies et al. 2003). *E. complanata* and *E. crassidens* were resilient, with no indication that imperviousness may be correlated with their abundance. However, *E. icterina* presence did decline with increasing imperviousness (individuals were not found at 1/3 locations sampled after 1992). Of all *Elliptio* data available for this study, *Elliptio arctata* had the most significant decline in relation to increased urbanization and imperviousness. By 1992, *E. arctata* had disappeared from all three locations where they were historically found. This study displays the large variability in response to urbanization within the same genus of freshwater mussels.

It is also important to examine the potential effects of pollution on the host fish used by the inflated spike. The host fishes used for reproduction by this species are not known. Thus, we cannot make inferences regarding potential impacts of sedimentation on host fishes for the inflated spike.

Based on direct studies with congener species, we categorize the pollutant sensitivity of the inflated spike as somewhat intolerant (3).

Figure 39. Map. Range map for the inflated spike.



OVAL PIGTOE

Species

Oval Pigtoe, *Pleurobema pyriforme*

Description

Reproduced from U.S. Fish and Wildlife (USFWS 2003): The Oval pigtoe is a small to medium-sized mussel that attains a length of about 6.1 cm. The shell is suboviform and compressed. The periostracum is shiny smooth; yellowish, chestnut or dark brown; rayless; and with distinct growth lines. The posterior slope is biangulate and forms a blunt point on the posterior margin. The umbos are slightly elevated above the hingeline. No sexual dimorphism is displayed in Pleurobema shell characters. Internally, the pseudocardinal teeth are fairly large, crenulate (bumpy/notched), and double in each valve. The lateral teeth are somewhat shortened, arcuate, and also double in each valve. Nacre color varies from salmon to bluish white and is iridescent posteriorly

Life History

The oval pigtoe inhabits small creeks to small rivers in slow to moderate current. It is often found in silty sand to sand and gravel substrates (USFWS 2003).

The oval pigtoe is a member of tribe Pleurobemini and is a short-term brooder with viable glochidia observed from May into early July (USFWS 2003; Wisniewski 2018). This species releases well-formed, white-pinkish glochidia as conglutinates to infect host fishes (USFWS 2003). Metamorphosis of oval pigtoe glochidia has been reported on sailfin shiner, mosquitofish, and six cyprinid species found in the Apalachicola River basin (O'Brien and Williams 2002; Fritts and Bringolf 2014).

Numbers, Reproduction, Distribution

The oval pigtoe was historically found in four major stream systems from Alabama, Georgia and Florida. These stream/river systems include the Econfina, the Apalachicola-Chattahoochee-Flint system, the Ochlockonee, and the Suwannee (USFWS 2003). As of 2003, the oval pigtoe had been eliminated from 50 – 70% of its former range (USFWS 2003; 2007). Spring Creek (Flint River system) and Sawhatchee Creek (Lower Chattahoochee system) represent some of the only extant populations in Georgia. The population found in the Lower Chattahoochee sub-basin is the largest population in the state of Georgia. (USFWS 2019f).

Conservation

The oval pigtoe has a global conservation ranking of G2, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (USFWS 2003). This species is listed as endangered in the state of Georgia.

Threats to the oval pigtoe include alterations to the hydrological regime (dams, impoundments, water withdrawal), dredging, mining, disruption of stream channels, pollution, excess sedimentation, and habitat loss and degradation (USFWS 2019f). Drought and alteration to flows contribute to further loss of habitat and fragmentation of persisting populations. This is of particular concern in the Apalachicola, Flint, and Ochlockonee Rivers, which are all downstream of major mainstem dams or are in areas with high levels of water use (municipal, industrial, agricultural; USFWS 2019f). Because many populations are isolated and fragmented, the oval pigtoe is vulnerable to stochastic events such as droughts and floods (USFWS 2019f).

Recommended actions aimed at conservation of the oval pigtoe include minimizing soil erosion with better management practices, improvement of water quality throughout critical habitats, additional studies to understand the effects of drought and water withdrawals, surveys for additional populations, and a better understanding of physiological tolerance of temperature and oxygen content (USFWS 2003; Wisniewski 2018).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the oval pigtoe. However, the effects of sediment have been studied in other members of genus *Pleurobema* and can serve as a basis for estimating impacts. Exposure to sediment caused reduced feeding and overall metabolism in the Mississippi pigtoe (*Pleurobema beadleanum*; Aldridge et al. 1987). A more recent study found that increased riverine sediment loading was negatively associated with the presence of the clubshell mussel (*Pleurobema clava*; Roley and Tank 2016).

Because the oval pigtoe is found in riffles with coarse substrate, additional sediment inputs may adversely affect its preferred habitat. As a short-term brooder it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress. Sediment may also reduce the visibility of conglutinates to host fish, thereby reducing reproductive fitness (Brim Box and Mossa 1999).

Indirect effects of sediment on host fish used by the oval pigtoe must also be considered. Based on their life history traits, we categorize the sediment sensitivity of cyprinids (e.g. shiners and other minnows) as intolerant.

Based on preferred habitat, brooding strategy, and sensitivity of host fish, we categorize the sediment sensitivity of the oval pigtoe as intolerant (1).

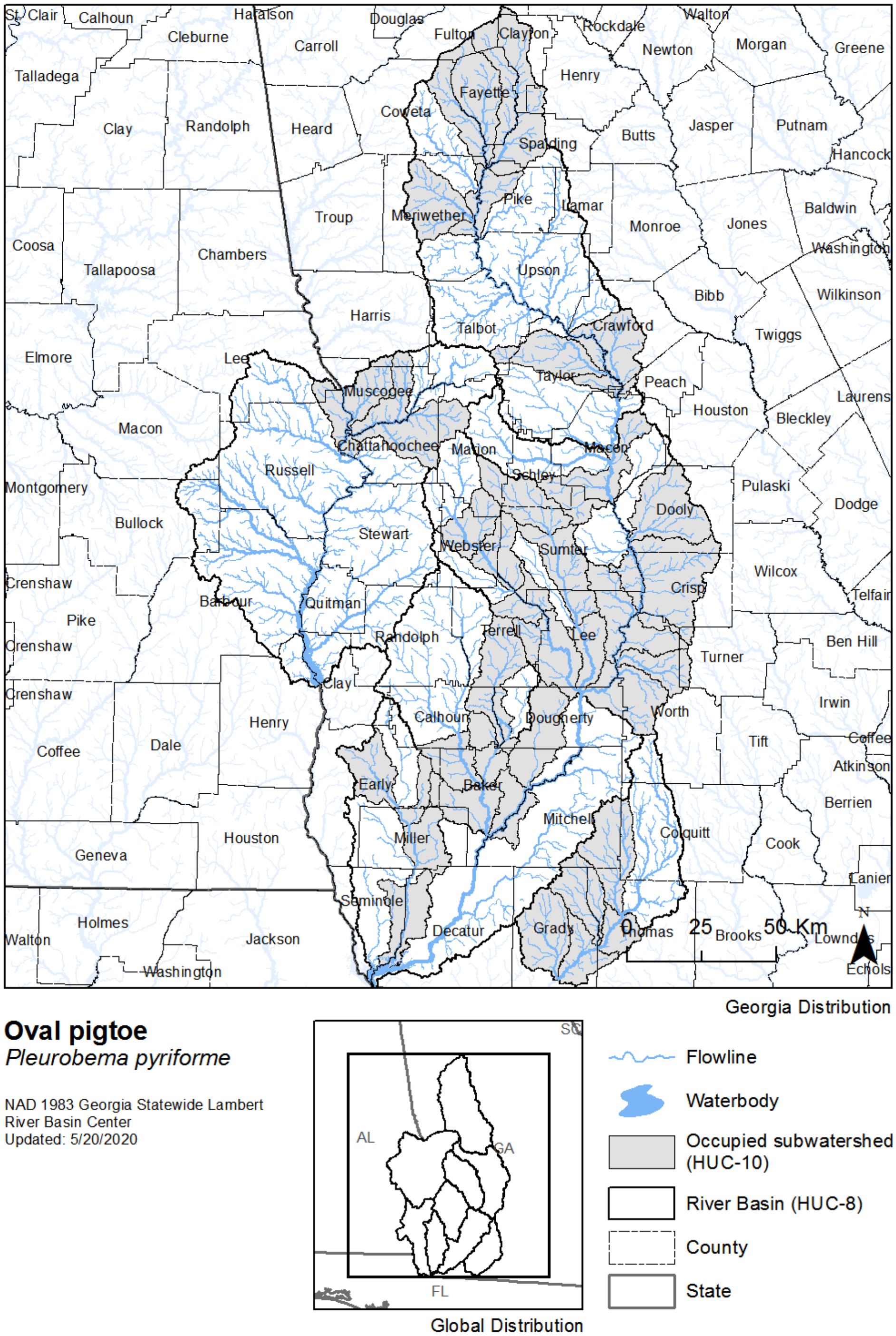
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the oval pigtoe. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

Indirect effects of pollutants on host fish used by the oval pigtoe must also be considered. Based on their life history traits, we categorize the pollutant sensitivity of cyprinid fishes as somewhat intolerant.

Based on general mussel sensitivity to pollutants and sensitivity of host fish, we categorize the pollutant sensitivity of the oval pigtoe as somewhat intolerant (3).

Figure 40. Map. Range map for the oval pigtoe.



PURPLE BANKCLIMBER

Species

Purple Bankclimber, *Elliptoideus sloatianus*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2003):

The Purple bankclimber is a very large, heavy-shelled, strongly sculptured mussel reaching lengths of 20.5 cm. A well-developed posterior ridge extends from the umbo to the posterior ventral margin of the shell. The posterior slope and the disk just anterior to the posterior ridge are sculptured by several irregular plications that vary greatly in development. The umbos are low, extending just above the dorsal margin of the shell. No sexual dimorphism is displayed in Purple bankclimber shell characters. Internally, there is one pseudocardinal tooth in the right valve and two in the left valve. The lateral teeth are very thick and slightly curved, with one in the right valve and two in the left valve. Nacre color is whitish near the center of the shell becoming deep purple towards the margin, and very iridescent posteriorly.

Life History

The purple bankclimber prefers small to large river channels in slow to moderate currents. The substrates used by this species include sand or sand mixed with mud or cobble substrate

(USFWS 2003; Wisniewski et al. 2013; Wisniewski et al. 2014). Surveys in the Apalachicola-Chattahoochee-Flint River (ACF) basin found that over 80% of purple bankclimbers sampled were found at sites with sand/limestone substrate (Brim Box and Williams 2000).

The purple bankclimber is a member of tribe Pleuroblemini and known to be a short-term brooder that releases glochidia in the late winter – early spring (USFWS 2003). The purple bankclimber is thought to release larval threads or conglutinates during reproduction. The primary host fishes used by this species for reproduction are sturgeon (Acipenseridae family; Fritts et al. 2012). Potential marginal host fishes include darters (*Percina* spp.) and minnows (*Gambusia* spp.), although metamorphosis on darters was found to be extremely low relative to sturgeon (USFWS 2003; Fritts et al. 2012).

Numbers, Reproduction, Distribution

The purple bankclimber is historically known from the ACF basin and Ochlockonee River of Alabama, Florida, and Georgia (USFWS 2019f). It is thought to be extirpated from the Chattahoochee River, as extensive surveys of habitats where they were known to occur yielded no live individuals (USFWS 2019f). A 2011 survey by GADNR found the purple bankclimber at approximately 49% of sites (19/39 sites; 105 individuals) sampled in the Lower Flint sub-basin (USFWS 2019f). A larger number of individuals (1154 live mussels) were observed in surveys in the Middle Flint sub-basin in 2010. In 2014, the purple bankclimber was found at seven locations (62 individuals) in the upper Flint River sub-basin (USFWS 2019f). The population of purple bankclimbers in the upper section of the Apalachicola River is thought to be large but evidence suggests that it is experiencing poor recruitment (USFWS 2019f).

Conservation

The purple bankclimber has a global conservation ranking of G2, a Georgia state conservation ranking of S2, and is federally listed as a threatened species under the ESA (Wisniewski 2018). This species is listed as threatened in the state of Georgia.

Major threats to the purple bankclimber include altered hydrological regimes (*e.g.,* water withdrawal or dams), dredging, mining, pollution, fish host exclusion due to migration barriers, and habitat degradation (USFWS 2019f). The rivers inhabited by the purple bankclimber (*e.g.,* Flint and Apalachicola) are heavily impacted by drought and changes to the hydrological regime, as they are downstream of major main-stem dams or in areas of high industrial/agricultural water use (USFWS 2019f). Nonnative species, including bivalves (*e.g.,* Asian clams) and fish (Flathead catfish) also may pose a threat to this species (USFWS 2003; Wisniewski 2018).

Recommended actions aimed at the conservation of the purple bankclimber include: minimizing soil erosion throughout habitat with better management practices, improvement of water quality throughout important habitats, additional studies to understand the effects of drought and water withdrawals, and reintroduction or passage of host fishes (Gulf sturgeon) into the Flint and Chattahoochee Rivers upstream of the Woodruff Dam (USFWS 2003; Wisniewski 2018).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the purple bankclimber. Because the purple bankclimber is generally found in coarse substrate, additional sediment inputs may alter its preferred habitat. As a short-term brooder it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress. Suspended sediment may also interfere with larval threads used for reproduction (Brim Box and Mossa 1999).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. The purple bankclimber uses sturgeon (*Acipenser* spp.) and darters (*Percina* spp.) as host species. Based on their life history, sediment sensitivity of sturgeon is classified as intolerant and darters sediment sensitivity is classified as moderate.

Based on preferred habitat, brooding behavior, and host fish sensitivity, we categorize the sediment sensitivity of purple bankclimber as intolerant (1).

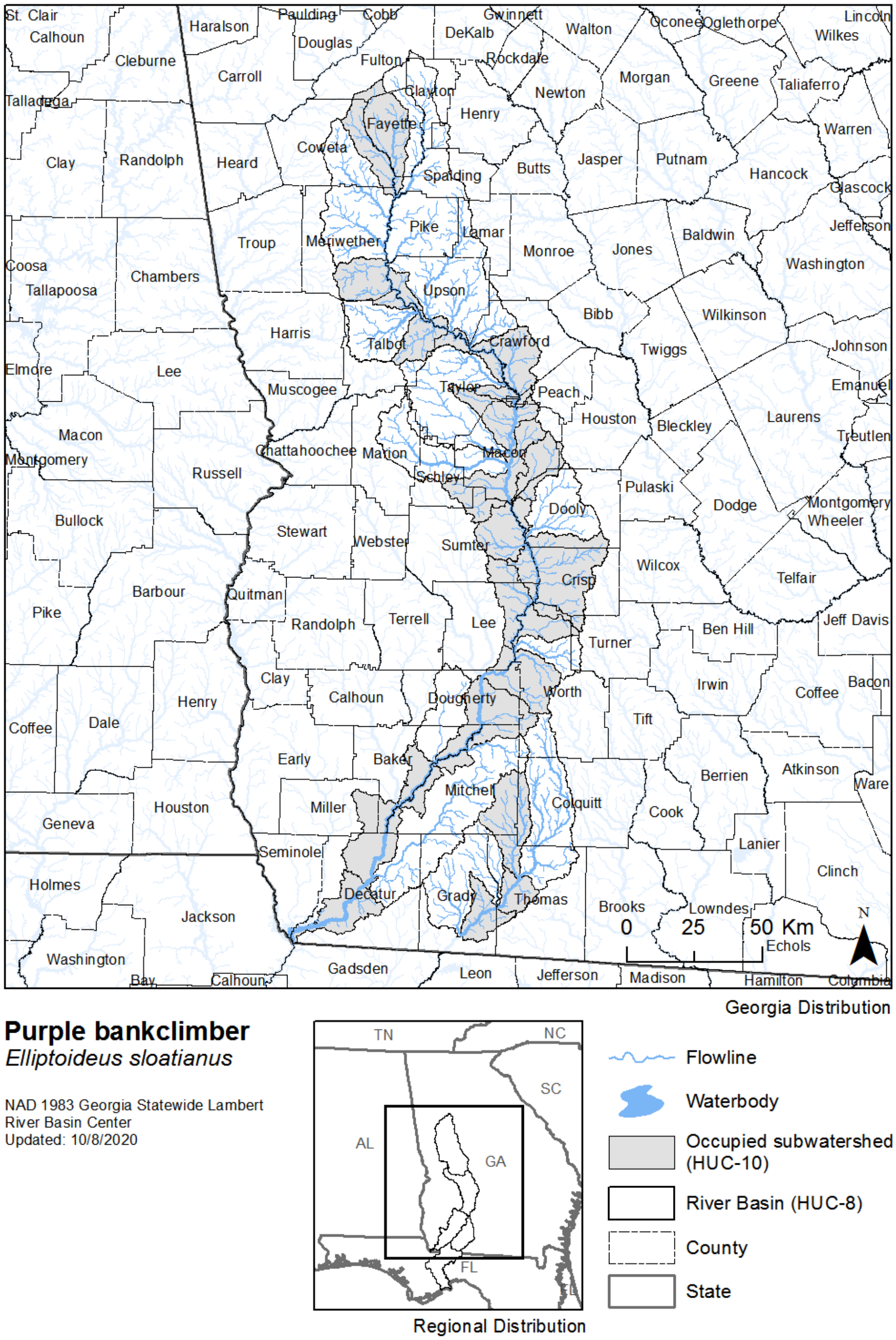
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the purple bankclimber. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the purple bankclimber was likely extirpated by 1992 from the only site where data was available (Gillies et al. 2003).

Indirect effects of pollution on host fish used by purple bankclimber must also be considered. Primary host fish used by the purple bankclimber are sturgeon, and darters are considered secondary hosts. Based on their life history traits, we categorize the pollutant sensitivity of sturgeon and darters as moderate and somewhat intolerant, respectively.

Based on general mussel sensitivity to pollutants as well as limited direct evidence with purple bankclimber, we categorize the pollutant sensitivity of purple bankclimber as somewhat intolerant (3).

Figure 41. Map. Range map for the purple bankclimber.



RAYED CREEKSHELL

Species

Rayed Creekshell, *Strophitus radiatus*

(formerly *Anodontoides radiatus*)

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Shell is thin, moderately inflated, elongate, and rarely exceeds 75 mm (3 inches) in length. Umbos slightly elevated above the hingeline and positioned anteriorly. Anterior margin of shell is rounded while posterior margin is bluntly pointed to rounded. Ventral margin broadly rounded. Posterior ridge rounded near umbo, but flattens ventrally. Adults typically with dark green or amber periostracum often with dark green rays. One rudimentary, pseudocardinal tooth and with lateral teeth absent. Beak cavity shallow and wide. Nacre white. The Rayed creekshell can be distinguished from the Southern rainbow (*Villosa vibex*) by the latter having well developed teeth. The umbos in the Rayed creekshell typically are narrower and elevate above the hingeline more than that of the southern rainbow. Recent publications suggest that individuals identified as the Southern creekmussel (*Strophitus subvexus*) from the Apalachicola River Basin were incorrectly identified and were actually the Rayed creekshell.

Life History

The rayed creekshell belongs to the Anodontini tribe (Graf and Cummings 2020) and is likely a short-term brooder. The rayed creekshell is most often found in small creeks to larger rivers with sand, mud, or gravel substrate.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Endemic to the Apalachicola River Basin from Alabama, Florida, and Georgia. The rayed creekshell was known from the Chattahoochee and Flint Rivers and their tributaries. Current distribution in Georgia appears to be restricted to the lower Flint River tributaries as well as the mainstem river up to the Fall Line.

The brooding period and host fish are unknown for this species. Gravid rayed creekshells have been collected out of the Mobile River basin from August through December. Furthermore, In the ACF basin, gravid females were collected in late September and early December.

Rayed creekshells may broadcast glochidia in mucus strands similar to the closely related *Anodontoides ferussacianus* (Watters et al. 2009). Glochidia occupy the entire outer gill and the glochidial host is not known (Watters et al. 2009).

Conservation

The rayed creekshell currently has a global conservation ranking status of G2G3, a Georgia state conservation ranking of S2, and is under no US federal protection. This species is listed as threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Habitat fragmentation may isolate populations and prevent fish movement, limiting the distribution of host fishes carrying glochidia. Additionally, construction of impoundments could further fragment populations and inundate suitable habitat. Excessive water withdrawals in the Lower Flint River Basin coupled with severe drought could cause this species to become extirpated from Georgia. Excess sedimentation due to inadequate riparian buffer zones and incompatible agricultural practices may also cover suitable habitat and could potentially bury individuals. Rapid development of the northern extent of the Flint River Basin could severely impact the remaining populations of this species.

Effects of Construction Activities

Sediment

We are unaware of any direct studies on the effects of sediment on the rayed creekshell or other *Alasmidonta* spp. Because the rayed creekshell is found in mud, sand or gravel, additional sediment inputs may not substantially alter its preferred habitat. However, as a likely short-term brooder (tribe Anodontini) it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

The host fishes used for reproduction by this species are not known. Thus, we cannot make inferences regarding potential impacts of sedimentation on host fishes for the rayed creekshell.

Due to their more sensitive brooding behavior and less sensitive habitat, we categorize the sediment sensitivity of the rayed creekshell as moderate (2).

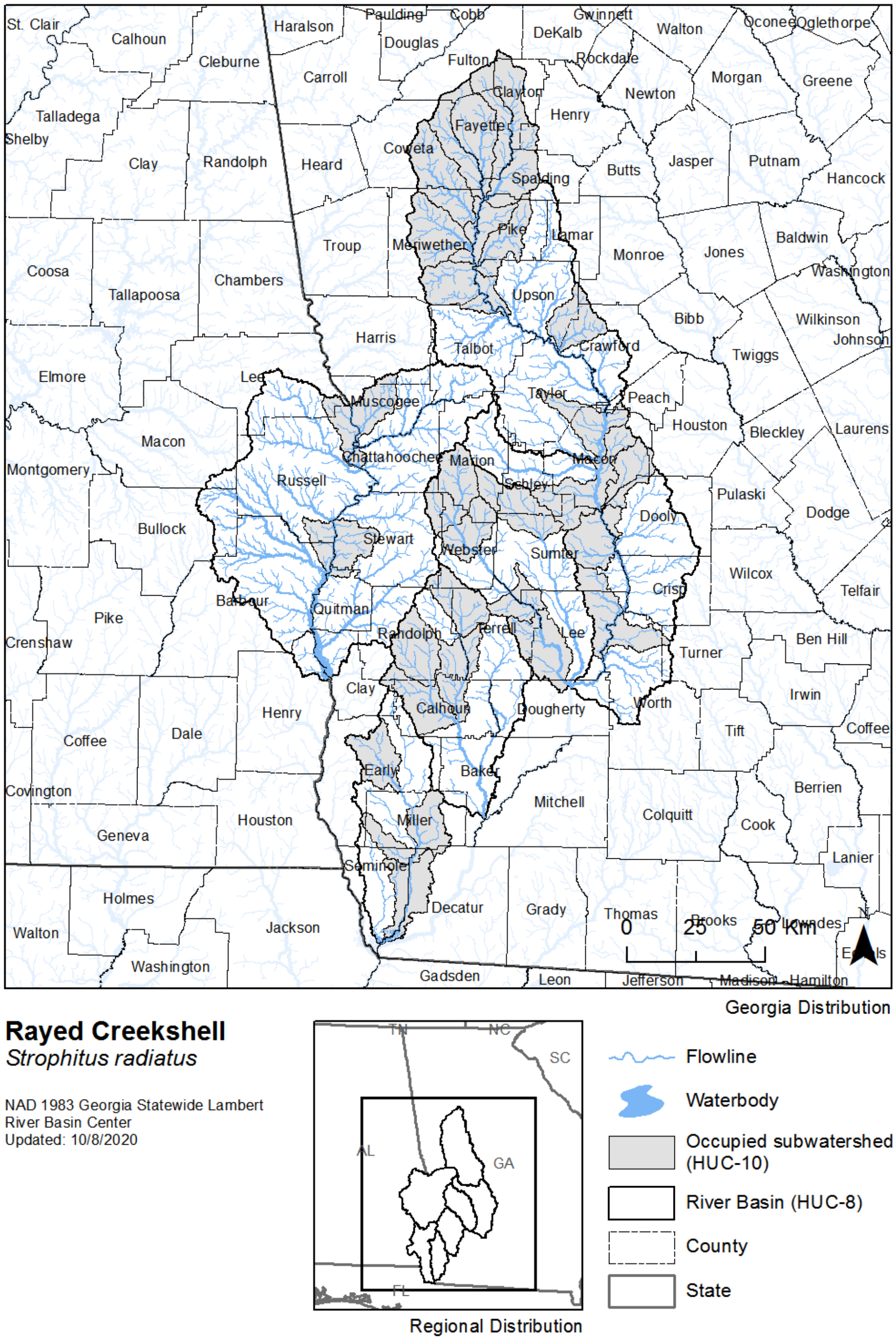
Pollutants

We are not aware of any direct studies describing the effects of construction- or roadway-derived pollutants on the rayed creekshell. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. Furthermore, a study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the rayed creekshell was extirpated (by 1992) from the only site where historic data was available (Gillies et al. 2003). Additionally, a study on the effects of urbanization on freshwater mussels found that increased imperviousness and overall urbanization was significantly associated with population decreases of the congener, *Strophitus undulatus* (Myers-Kinzie et al. 2002).

Indirect effects of pollutants on host fish used by rayed creekshell must also be considered. However, host fish species used for reproduction by this mussel species are unknown. Thus, we cannot make inferences regarding potential impacts of pollutants on host fishes for the rayed creekshell.

Based on direct evidence of its extirpation from areas with increased imperviousness, as well as that of the closely related *S. undulatus*, we categorize pollutant sensitivity of the rayed creekshell as very intolerant (2).

Figure 42. Map. Range map for the rayed creekshell.



RAYED KIDNEYSHELL

Species

Rayed Kidneyshell, *Ptychobranchus foremanianus*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2019c): The Rayed kidneyshell is oval to elliptical in outline and can reach between 85 – 100 mm in length (Williams et al. 2008). The shell is moderately compressed and may be flattened ventral to the umbos. The posterior ridge is high, rounded and the posterior slope is moderately steep. The pseudocardinal teeth are heavy, and the laterals are heavy, straight to slightly curved and short. The periostracum is tawny to brown, usually without rays, but when present are thin, sparse, and usually confined to the posterior slope (Williams et al. 2008).

Williams et al. (2008) recommended that *Ptychobranchus greenii* should be split into two distinct species – *P. foremanianus,* the rayed kidneyshell, and *P. greenii,* the triangular kidneyshell. These two species are presumably monophyletic, and the main physical difference in the two species is a lack of well-defined dark green rays on the periostracum of *P. greenii* (Williams et al. 2008). In a phylogenetic analysis using mitochondrial DNA, Roe (2013) found that individuals resolved into separate clades; however further work may be necessary to determine if formal species designations need to be made (Roe 2013; USFWS 2019c).

Typically occupies riffles in medium to large rivers with moderate flow and gravel and sand substrates.

Life History

The life history of the rayed kidneyshell is assumed to be very similar to that of *P. greenii.* The rayed kidneyshell inhabits medium to larger rivers in riffle areas of moderate water velocity with sand/gravel substrate (Wisniewski 2018). The rayed kidneyshell and triangular kidneyshell are members of tribe Lampsilini and are long-term brooders, with glochidia observed brooding from autumn into the following spring or summer (USFWS 2019). The glochidia of these species are packaged into conglutinates that resemble aquatic fly larvae or fish eggs (Hartfield and Hartfield 1996; Haag and Warren 1997). Darters are reported to be suitable fish hosts for the species, with the Warrior darter, Tuskaloosa darter, blackbanded darter, greenbreast darter, and logperch all successfully producing juveniles (Haag and Warren 1997; Johnson 2018; USFWS 2019c).

Numbers, Reproduction, Distribution

The rayed kidneyshell is endemic to the eastern Mobile River basin of Alabama, Georgia, and Tennessee (Wisniewski 2018). Historically, this species could be found in Black Warrior, Alabama, Cahaba, Coosa, and Tallapoosa rivers and their associated tributaries (Wisniewski 2018). Extant populations in Georgia appear to be restricted to the Conasauga River and its tributaries, the mainstem Coosawattee River (downstream of Carters Reservoir), and the Coosa

River (Wisniewski 2018; USFWS 2019). The remaining populations of the two species are small and localized (USFWS 2019).

Conservation

The rayed kidneyshell has a global conservation ranking of G1, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (as *P. greenii*; USFWS 2019c). This species is listed as endangered in the state of Georgia.

Threats to the rayed kidneyshell include alterations to the hydrological regime (*e.g.*, dams, impoundments, water withdrawal, droughts), excess sedimentation, pollution and water quality issues, extreme reduction and fragmentation of habitat and range, and low population sizes (USFWS 2019c). Drought and alteration to flow contributes to further loss of habitat and fragmentation of persisting populations. Because many populations are isolated and fragmented, the rayed kidneyshell is vulnerable to stochastic events such as droughts and floods (USFWS 2019c).

Recommended actions aimed at conservation of the rayed kidneyshell include minimizing sedimentation in the Conasauga River and its associated tributaries, improvement of water quality, restoration of riparian habitats, and reintroduction or augmentation to re-establish viable populations (Wisniewski 2018).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the rayed kidneyshell or other associated *Ptychobranchus* spp. Because the rayed kidneyshell is primarily found in coarse substrates, additional sediment inputs may adversely affect its preferred habitat.

As a long-term brooder, the rayed kidneyshell may be less sensitive to episodic elevated suspended sediment; however, long-term brooders may demonstrate significant declines in reproductive success due to excessive levels of sediment exposure during or after fertilization. Elevated suspended sediment during reproduction may also reduce visibility of conglutinates to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Based on their life history, we categorize the sediment sensitivity of the primary hosts, darters (*Etheostoma* and *Percina* spp.), as intolerant.

On the balance of habitat sensitivity and host fish, but lower sensitivity due to brooding strategy, we categorize the sediment sensitivity of the rayed kidneyshell as intolerant (1).

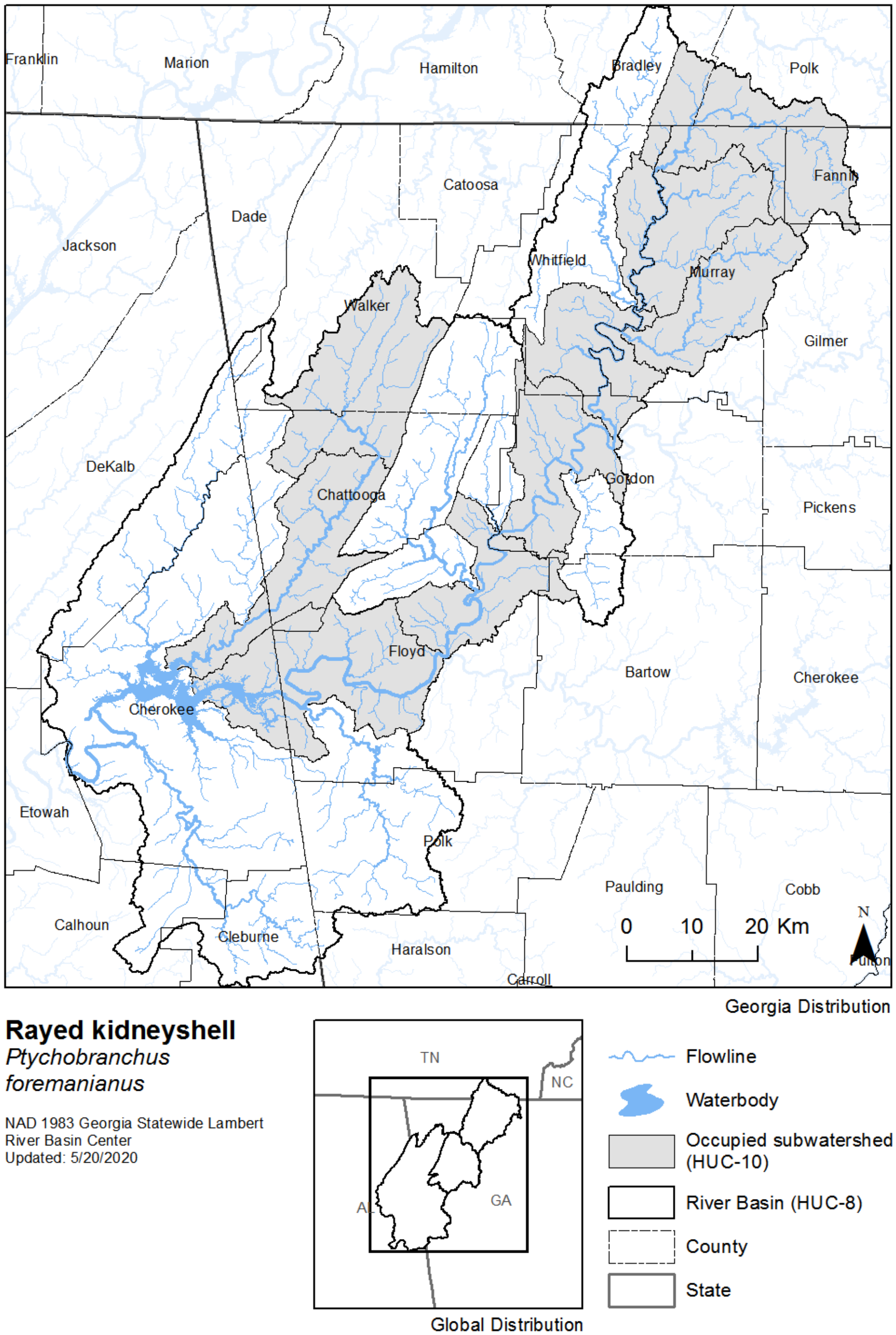
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the rayed kidneyshell. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

Indirect effects of pollutants on host fish used by the rayed kidneyshell must also be considered. Based on their life history, we categorize the pollutant sensitivity of the primary host fishes, darters, as somewhat intolerant.

Based on general mussel sensitivity as well as sensitivity of host fish, we categorize the pollutant sensitivity of the rayed kidneyshell as somewhat intolerant (3).

Figure 43. Map. Range map for the rayed kidneyshell.



SAVANNAH LILLIPUT

Species

Savannah Lilliput, *Toxolasma pullus*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Shell is small, typically less than 35 mm in length. Valves somewhat thick and inflated. Anterior margin rounded, ventral margin straight to convex in females. Posterior margin typically broadly pointed in males while more truncated or broadly rounded in mature females. Umbos typically elevate to the hingeline or slightly above. Periostracum usually satiny and black or brown. Left valve with two triangular pseudocardinal teeth and short straight lateral teeth. Right valve with one triangular pseudocardinal tooth and one lateral tooth. Umbo pocket shallow. Nacre variable, ranging from bluish-white to pink, purple, or iridescent.

Life History

The Savannah lilliput is thought to be a long-term brooder and is a member of the Lampsilini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

Typically found in shallow water near the banks of streams, rivers, ponds, and lakes with little flow. This species is usually found in soft substrates such as mud, silty sand, and sand.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Known from the Neuse River Drainage, North Carolina, south to the Altamaha River in Georgia. In Georgia, the Savannah Lilliput is known from the Savannah, Ogeechee, and Altamaha River systems. From 1975 through 1980 the Savannah Lilliput was found at eleven different sites in the Ohoopee River.

Gravid females have been observed between late April through early August, but not during mid-September. Glochidia successfully transformed on hybrid sunfish (*Lepomis* sp.) (Hanlon and Levine 2004). Successful transformation likely occurs on other *Lepomis* species.

Conservation

The Savannah lilliput currently has a global conservation ranking status of G2, a Georgia state conservation ranking of S2, and is under no US federal protection. This species is listed as threatened in the state of Georgia.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Habitat fragmentation may isolate populations and prevent fish movement, limiting the distribution of host fishes carrying glochidia. Additionally, construction of impoundments could further fragment populations and inundate suitable habitat. Excessive water withdrawals in the Lower Flint River Basin coupled with severe drought could cause this species to become extirpated from Georgia. Excess sedimentation due to inadequate riparian buffer zones and incompatible agricultural practices may also cover suitable habitat and could potentially bury individuals. Rapid development of the northern extent of the Flint River Basin could severely impact the remaining populations of this species.

Effects of Construction Activities

Sediment

There are no direct studies on the effects of sediment on the Savannah lilliput. However, during reproduction this species uses a lure to attract suitable hosts for their glochidia and elevated suspended sediment may reduce visibility of the lure to host fishes (McNichols et al. 2011). Because the Savannah lilliput is usually found in soft substrates and is a long-term brooder that is reproductively active spring, summer, and fall, it may be somewhat more tolerant of episodic sediment events.

It is also important to consider indirect effects of increased sedimentation on the host fish used by the Savannah lilliput for reproduction. A previous study reported that very high concentrations of suspended clay (1250 – 5000 mg/L) led to reduced attachment and metamorphosis of *L. siliquoidea* (a member of Tribe Lampsilini) glochidia on host fishes (*Micropterus salmoides*; Beussink 2007). This study suggested that acute exposure of host fishes to high amounts of suspended clay may affect their suitability as hosts. Based on their life history traits, we categorize the sediment sensitivity of the Savannah lilliput fish hosts (*Lepomis* spp. and other sunfishes, in general) as moderate.

Based on duration of brooding, reliance on a lure to attract hosts, and less sensitive habitat, we categorize the sediment sensitivity of the Savannah lilliput as moderate (2).

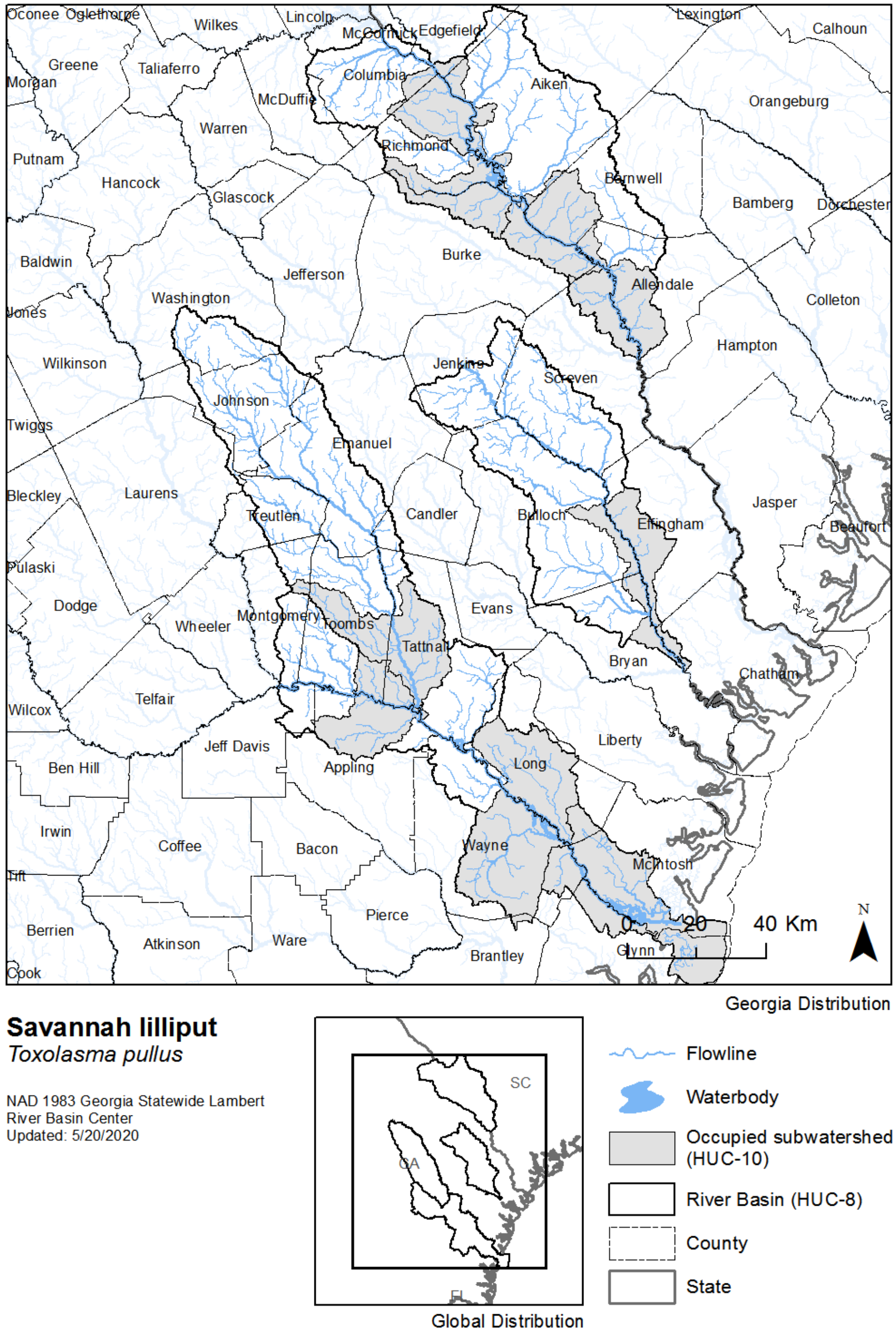
Pollutants

We are aware of no data that describes the effects of construction- or roadway-derived pollutants on the Savannah lilliput. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the congener, *T. paulus*, was likely extirpated from 30% of sites by 1995 where data was available (Gillies et al. 2003). Furthermore, another study evaluated the effects of urbanization in freshwater mussels found that increased imperviousness and overall urbanization was significantly associated with decreases in *T. paulus* (Myers-Kinzie et al. 2002).

Indirect effects of pollutants on host fish used by the Savannah lilliput must also be considered. Primary host fish for the Savannah Lilliput are Bluegill. Based on their life history traits, we categorize the pollutant sensitivity of Bluegill as moderate.

Based on direct evidence for the closely related *T. paulus* that suggests a negative relationship with urbanization, we categorize pollutant sensitivity of the Savannah lilliput as somewhat intolerant (3).

Figure 44. Map. Range map for the Savannah lilliput.



SHINYRAYED POCKETBOOK

Species

Shinyrayed Pocketbook, *Hamiota subangulata*

Description

Reproduced from U.S. Fish and Wildlife Service (2003): The Shinyrayed pocketbook is a medium-sized mussel that reaches approximately 8.4 cm in length. The shell is subelliptical, with broad, somewhat inflated umbos and a rounded posterior ridge. The shell is fairly thin but solid. The surface is smooth and shiny, light yellowish brown in color with fairly wide, bright emerald green rays over the entire length of the shell. Older specimens may appear much darker brown with obscure rays. Female specimens are more inflated postbasally, whereas males appear to be more pointed posteriorly. Internally, the pseudocardinal teeth are double and fairly large and erect in the left valve, with one large tooth and one spatulate tooth in the right valve. The lateral teeth are relatively short and straight, with two in the left valve and one in the right valve. The nacre is white, with some specimens exhibiting a salmon tint in the vicinity of the umbonal cavity.

Life History

The shinyrayed pocketbook can be found in medium-sized streams to larger rivers, with clean to sandy substrates with variable current. Individuals are often found in the interface of the stream channel and sloping bank habitats, where sediment size and current speed fluctuate (USFWS 2003; Wisniewski 2018).

The shinyrayed pocketbook, a member of tribe Lampsilini, is a long-term brooder that is reproductively active year-round. This species produces superconglutinates (found April – September) that resemble small fish and attach to potential host fishes (USFWS 2003; Wisniewski 2018). This strategy may be used alone or in conjunction with a mantle lure display to attract host fishes. Known suitable host fishes for this species include largemouth bass (*Micropterus salmoides*), spotted bass (*M. punctatus*), redeye bass (*M. coosae*), and shoal bass (*M. cataractae*; all transformation rates > 78%; USFWS 2003; Fritts and Bringolf 2014).

Numbers, Reproduction, Distribution

The shinyrayed pocketbook is an endemic of the Apalachicola-Chattahoochee-Flint (ACF) and Ochlockonee River systems (USFWS 2003). This species is thought to be extirpated from the Apalachicola River and the upper Chattahoochee River (USFWS 2007; 2019f). As of 2007, the shinyrayed pocketbook was known to only occupy approximately 39% of its former range (USFWS 2007). In locations where subpopulations occur, they are generally low in abundance (USFWS 2007; 2019f). The Spring Creek sub-basin contains the largest number of shinyrayed pocketbooks known in Georgia; researchers have tagged 262 individuals in this location and have observed evidence of successful recruitment (USFWS 2019f).

Conservation

The shinyrayed pocketbook has a global conservation ranking of G2, a Georgia state conservation ranking of S2, and is federally listed as endangered under the ESA (USFWS 2019f). This species is listed as endangered in the state of Georgia.

The primary threats to the shinyrayed pocketbook include habitat degradation (*e.g.*, fragmentation due to dams and impoundments, sedimentation, urbanization), pollution, and climate change (USFWS 2019f). Drought associated with climate change, coupled with water withdrawals, is a major threat to the persistence of the shinyrayed pocketbook in the state of Georgia (Wisniewski 2018; USFWS 2019f). Intense droughts may not only cause stress to the mussel itself, but may also limit the distribution of host fishes for this species (Wisniewksi 2018).

Recommended actions aimed at conservation of the shinyrayed pocketbook include: evaluation and implementation of environmental flow criteria, investigating tolerances for the species (*e.g.*, dissolved oxygen, thermal), minimization of habitat degradation, and evaluation of population sizes where they occur in Georgia (Wisniewski 2018; USFWS 2019f).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the shinyrayed pocketbook. However, the effects of sediment have been studied in another similar genus, *Lampsilis*, and can serve as a basis for estimating impacts. Tuttle-Raycraft et al. (2017) found that fatmuckets (*L. siliquoidea*) and wavy-rayed lampmussels (*L. fasciola*) exposed to suspended solids (≥ 8 mg/L) exhibited significant reductions in clearance rates (suspension feeding rates) compared to controls. They also report that juveniles experienced a five-fold decrease in feeding rate relative to adults, which suggests that the effects of sediment exposure vary based on age class. A more recent study examined the effects of suspended sediments on juvenile *L. siliquoidea* and found that exposure elicited responses associated with physiological stress (reduced proteins, reduced ATP production, and oxidized proteins; Buczek et al. 2018). Because the shinyrayed pocketbook is found in clean to sandy substrates, additional sediment inputs may adversely affect its preferred habitat. As a long-term brooder active year-round, the shinyrayed pocketbook may be less sensitive to episodic elevated suspended sediment; however, long-term brooders may experience significant declines in reproductive success due to excessive levels of sediment exposure during or after fertilization. Elevated suspended sediment during reproduction may also reduce visibility of lures to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Black basses (*Micropterus* spp.) are considered primary fish hosts and based on their life history we categorize the general sediment sensitivity of black basses as moderate.

On the balance of increased sediment sensitivity of preferred habitat and host attraction method with lower sensitivity for brooding strategy, we categorize the sediment sensitivity of the shinyrayed pocketbook as intolerant (1).

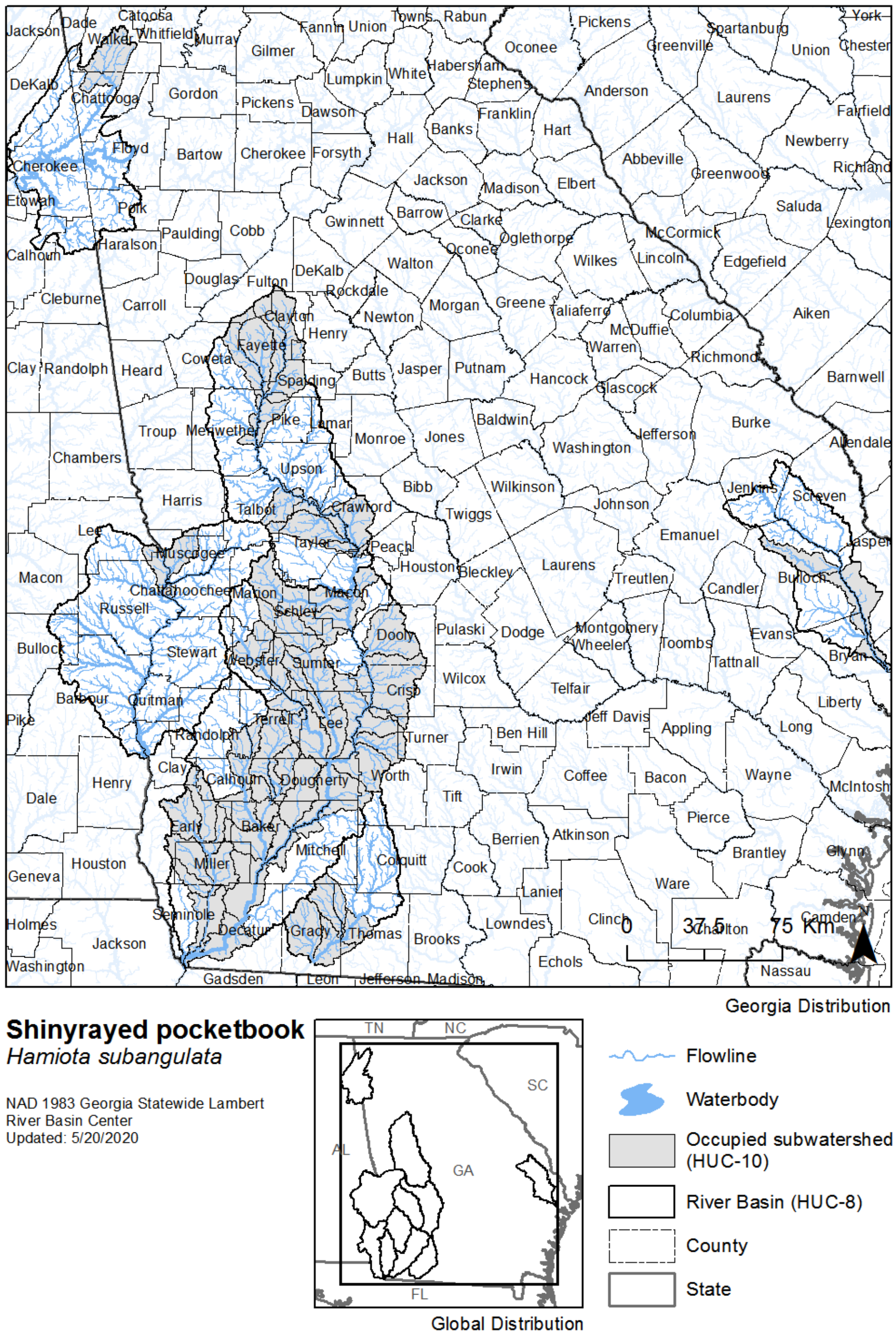
Pollutants

We are aware of no data available describing the effects of construction- or roadway-derived pollutants on the shinyrayed pocketbook. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the shinyrayed pocketbook was likely extirpated from 25% of sites by 1992 where data was available (Gillies et al. 2003). Furthermore, another study evaluated the effects of urbanization in a similar species, the fatmucket (*Lampsilis siliquoidea*), found that increased imperviousness and overall urbanization was significantly associated in mussel populations (including *L. siliquoidea*; Myers-Kinzie et al. 2002).

Indirect effects of pollution on host fish used by shinyrayed pocketbook must also be considered. The primary hosts used by the shinyrayed pocketbook are black basses. Based on their life history traits, we categorize the pollution sensitivity of black basses as somewhat intolerant.

Based on general mussel sensitivity as well as direct field observations and sensitivity of host fish, we categorize the pollutant sensitivity of the shinyrayed pocketbook as somewhat intolerant (3).

Figure 45. Map. Range map for the shinyrayed pocketbook.



SOUTHERN CLUBSHELL

Species

Southern Clubshell, *Pleurobema decisum*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2019c): The Southern clubshell is a medium sized mussel with lengths up to 93 mm long (Williams et al. 2008), with a thick shell, and heavy hinge plate and teeth. The shell outline is roughly rectangular, produced posteriorly with umbos usually terminal to the anterior margin. The posterior ridge is moderately inflated and ends abruptly with little development of the posterior slope at the dorsum of the shell. The periostracum is yellow to yellow-brown with occasional green rays or spots on the umbo in young specimens.

Life History

The Southern clubshell inhabits large streams to large rivers with sand or gravel/cobble substrates with low to moderate flow (USFWS 2000; Wisniewksi 2018).

The Southern clubshell is a member of tribe Pleurobemini and a short-term brooder that reproduces in the summer. Females reach sexual maturity at approximately 26 mm in length (Haag and Warren 2003). Gravid females have been found in June and July (USFWS 2019c).

The species releases well-formed, orange-white glochidia as conglutinates. Shiners (*Cyprinella* and *Luxilus* spp.) have been identified as fish hosts for the Southern clubshell (USFWS 2019c).

Numbers, Reproduction, Distribution

The Southern clubshell is endemic to the Mobile River Basin in Alabama, Georgia, Mississippi, and Tennessee. Historically this species was known from every major stream system in the Mobile River Basin (USFWS 2000). In Georgia, the Southern clubshell was formerly known throughout much of the upper Coosa River basin (USFWS 2000). While this species is considered to be improving in Alabama where stronghold populations occur, this species appears to be only found in the Conasauga River drainage and the Coosawattee River system (Salacoa Creek) in Georgia (Wisniewski 2018; USFWS 2019c).

Conservation

The Southern clubshell has a global conservation ranking of G2, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (USFWS 2000). This species is listed as endangered in the state of Georgia.

Threats to the conservation of the Southern clubshell include habitat degradation and modification, excess sedimentation, degradation of water quality, alterations to hydrological flow (*i.e.*, impoundments, dams, redirection of flow), lack of enforcement to prohibit take, and fragmentation of populations that leads to a loss of genetic diversity (USFWS 2019c). Because many populations are isolated and fragmented, this species is vulnerable to abrupt changes in land-use practices (*e.g.*, runoff, pollution) and stochastic events such as droughts and floods (USFWS 2019c).

Recommended actions aimed at conservation of the Southern clubshell include: minimization of sedimentation in the upper Coosa River Basin and its tributaries, continuation of flow improvements in habitats, restoration of riparian buffers, determination of the viable population sizes, and reintroduction of this species in suitable habitats where it has been extirpated (USFWS 2000; Wisniewski 2018; USFWS 2019c).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the Southern clubshell. However, the effects of sediment have been studied in other members of genus *Pleurobema* and can serve as a basis for estimating impacts. Exposure to sediment caused reduced feeding and overall metabolism in the Mississippi pigtoe (*Pleurobema beadleanum*; Aldridge et al. 1987). A more recent study found that increased riverine sediment loading was negatively associated with the presence of the Clubshell mussel (*Pleurobema clava*; Roley and Tank 2016).

Because the Southern clubshell is found in coarse substrate, additional sediment inputs may adversely affect its preferred habitat. As a short-term brooder, it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress.

Sediment may also reduce the visibility of conglutinates to host fish, thereby reducing reproductive fitness (Brim Box and Mossa 1999).

Indirect effects of sediment on host fish used by the Southern clubshell must also be considered. Based on their life history traits, we categorize the sediment sensitivity of shiners as intolerant.

Based on preferred habitat, brooding strategy, and sensitivity of host fish, we categorize the sediment sensitivity of the Southern clubshell as intolerant (1).

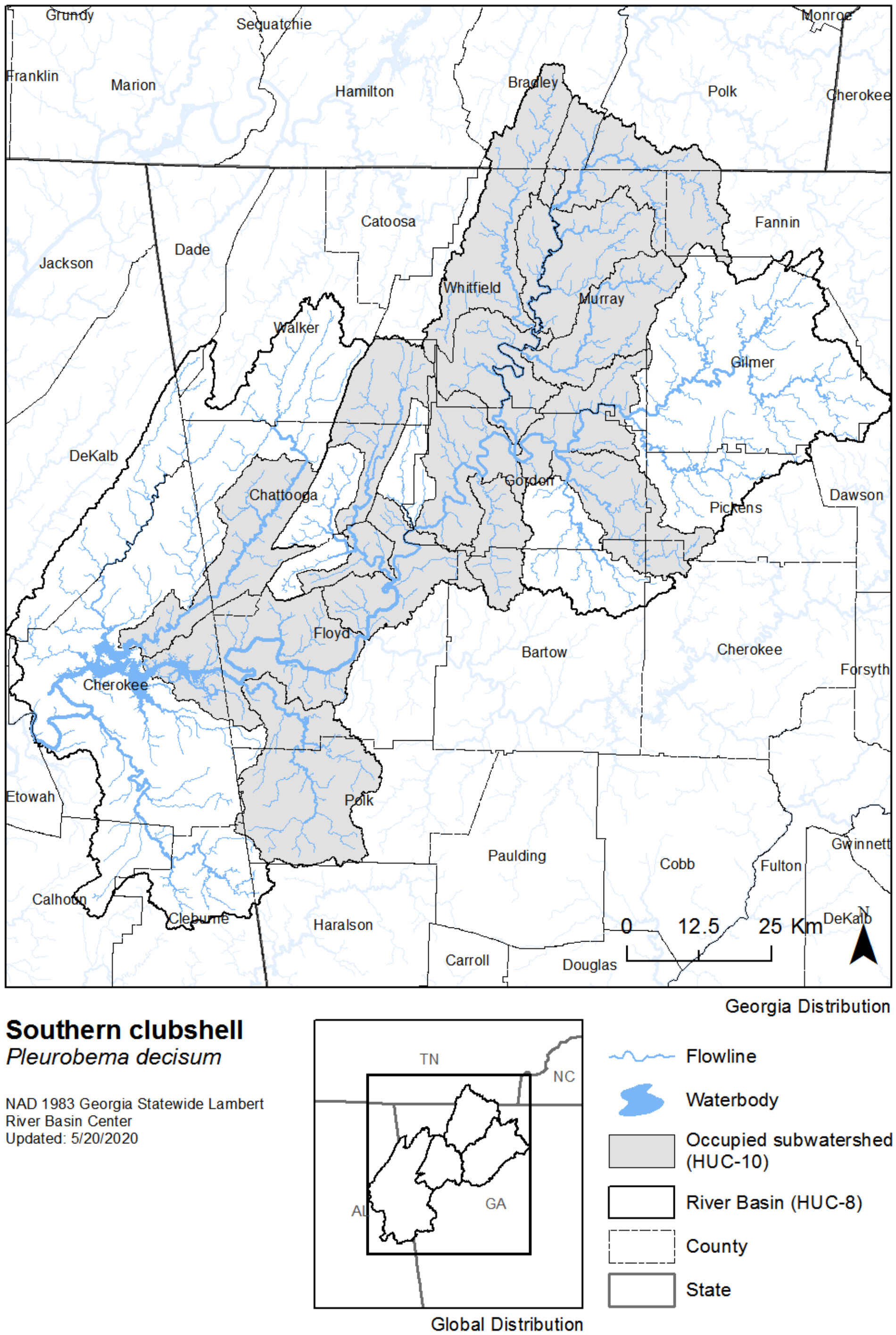
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the Southern clubshell. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.

Indirect effects of pollution on host fish used by the Southern clubshell must also be considered. Based on their life history traits, we categorize the pollutant sensitivity of shiners as somewhat intolerant.

Based on general mussel sensitivity to pollutants, limited direct evidence, and sensitivity of host fish, we categorize the pollutant sensitivity of the Southern clubshell as somewhat intolerant (3).

Figure 46. Map. Range map for the Southern clubshell.



SOUTHERN ELKTOE MUSSEL

Species

Southern Elktoe Mussel, *Alasmidonta triangulata*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): The Southern elktoe has a moderately thin, inflated shell, often with distinct concentric sculpturing originating at the umbo and rarely exceeding 70 mm in length. Umbos are elevated above the hingeline and positioned to the anterior portion of the sub-triangular shell. Anterior margin of shell is rounded while posterior margin is bluntly pointed. Posterior ridge sharp angular. Adults typically with dark brown to black periostracum with faint rays while young individuals have yellow to green with green rays present. Left valve often with two compressed, poorly developed pseudocardinal teeth and reduced or absent lateral tooth. Right valve with one compressed, high pseudocardinal tooth and lateral teeth reduced or absent. Umbo cavity is deep and nacre white.

Life History

The Southern elktoe is thought to be a short-term brooder and is a member of the Anodontini tribe (Graf and Cummings 2020).

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Found on gently sloping banks with soft substrate. Often in slackwater areas and possibly in reservoirs. Mixtures of mud, sand, and gravel substrate.

Numbers, Reproduction, Distribution

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): This species was historically reported from the Savannah, Ogeechee, Flint, and Chattahoochee Rivers in Georgia. However recent genetic analyses suggest that individuals found in the Ogeechee and Savannah Rivers are the Altamaha arcmussel; therefore, the Southern elktoe is likely restricted to the Flint and Chattahoochee rivers. The Southern elktoe is currently known only from Chickasawhatchee Creek near Elmodel Wildlife Management Area in Baker County (Golladay and Muenz 2005), Patsiliga Creek in Taylor County, and Flint River near Bainbridge in Decatur County (Wisniewski et al. 2014). An additional weathered shell was also collected from Potato Creek, Upson County (Crow 2000). One population also remains in Uchee Creek (Chattahoochee River), Russell County, Alabama. The largest population of the species appears to occur in the lower Flint River near Bainbridge.

Brooding individuals were collected in October 2014 but glochidia had poor viability (J. Wisniewski and J. Nelson, unpublished data). Additional life history work initiated in 2017 found females brooding viable glochidia in November. Primary host fishes for the Southern Elktoe appear to be catostomids (P.D. Johnson, personal communication).

Conservation

The Southern elktoe currently has a global conservation ranking status of G1, a Georgia state conservation ranking of S1, and is under no federal protections.

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018): Habitat fragmentation may isolate populations and prevent fish movement, limiting the distribution of host fishes carrying glochidia. Additionally, construction of impoundments may further fragment populations and inundate suitable habitat. Excessive water withdrawals in the lower Flint River basin coupled with severe drought could cause this species to become extirpated from Georgia. Excess sedimentation due to inadequate riparian buffer zones also covers suitable habitat and potentially bury individuals.

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the Southern elktoe or other associated *Alasmidonta* spp. Because the Southern elktoe is often found in soft substrate with a mix of mud, sand, and gravel, additional sediment inputs may not substantially alter its preferred habitat. However, as a short-term brooder (tribe Anodontini) the Southern elktoe may be highly susceptible to reproductive failure from sediment exposure and an increased likelihood of aborted broods due to stress.

Additionally, indirect effects of sediment on host fish used by the mussel for reproduction must be considered. Based on life history traits, we categorize the sediment sensitivity of the likely primary host(s) of the Southern elktoe, Catostomids, as moderate.

On balance of their more sensitive brooding behavior and less sensitive habitat, we categorize the sediment sensitivity of Southern elktoe as moderate (2).

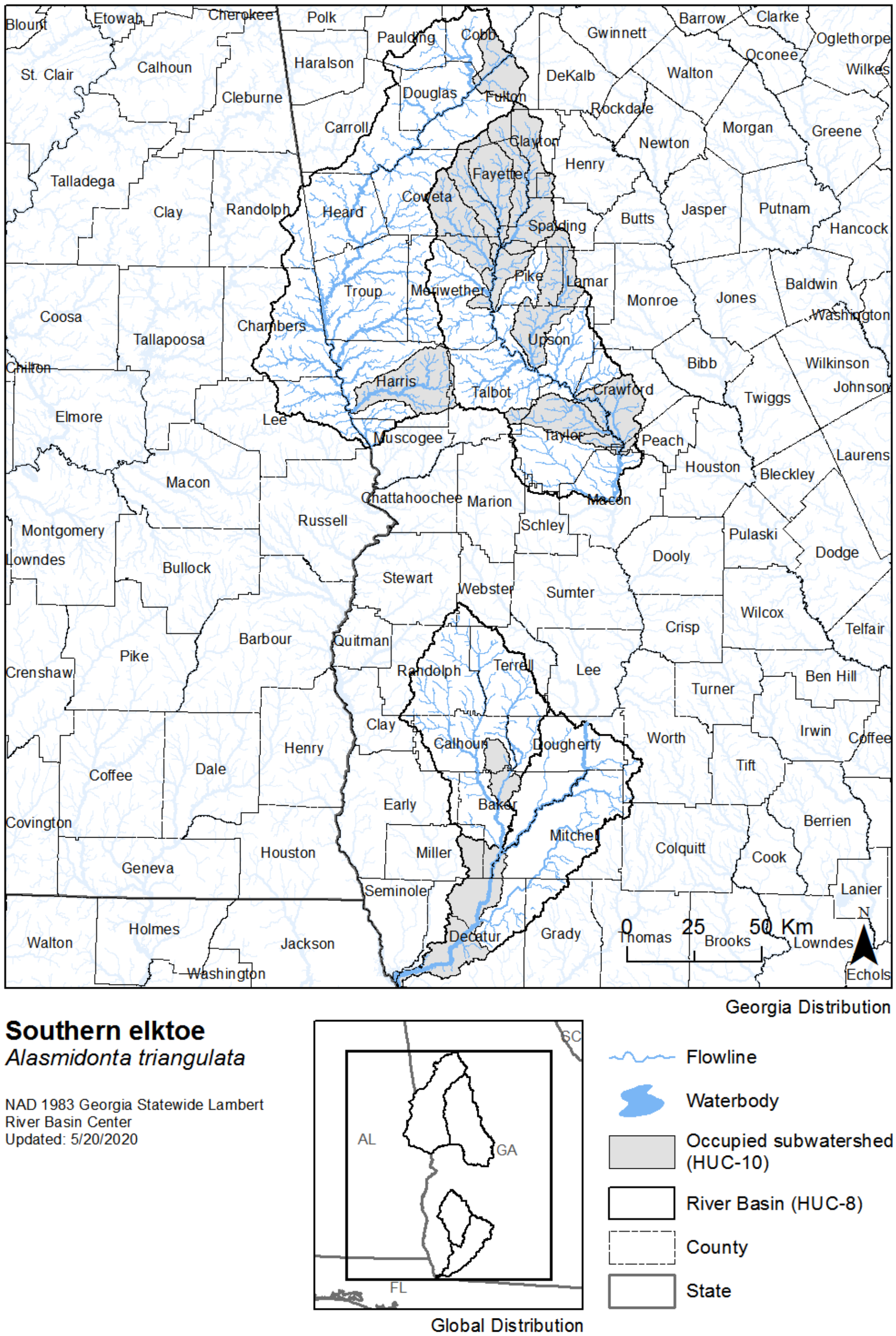
Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the Southern elktoe. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed area (1979 – 1997; Atlanta, GA) found that the Southern elktoe was likely extirpated by 1992 from the only site where data was available (Gillies et al. 2003).

Indirect effects of sediment on host fish used by Southern elktoe must also be considered. Based on their life history traits, we categorize the pollutant sensitivity of the likely primary hosts, Catostomids, as moderate.

Based on direct evidence that suggests a strong negative relationship with urbanization, we categorize pollutant sensitivity of the Southern elktoe as very intolerant (2).

Figure 46. Map. Range map for the Southern elktoe.



SOUTHERN PIGTOE

Species

Southern Pigtoe, *Pleurobema georgianum*

Description

Reproduced from U.S. Fish and Wildlife Service (USFWS 2019e): A small to medium-sized mussel occasionally exceeding 60 mm in length. Shell elliptical to oval in outline and somewhat compressed. Posterior slope is smoothly rounded. Pseudocardinal teeth (specialized hinge teeth unique to freshwater mussel) are small but well-developed, and the nacre is white. Periostracum is yellow to yellow-brown. Growth lines are numerous and may be dark brown. Small specimens may have green spots at the growth lines along the posterior ridge and near the umbo.

Life History

The Southern pigtoe inhabits riffles, runs, and shoals of medium creeks to large rivers in sand and cobble/gravel substrates with moderate flow (Wisniewski 2018; USFWS 2019e).

The Southern pigtoe is a member of tribe Pleurobemini and is a short-term brooder that is gravid in spring and early summer (Williams et al. 2008; USFWS 2019e). It is assumed that the Southern pigtoe, like other *Pleurobema* spp., releases conglutinates during reproduction to infect their preferred fish hosts. Shiners (*Cyprinella* spp.) have been reported as likely host fishes for the Southern pigtoe (Johnson 2018; USFWS 2019e).

Numbers, Reproduction, Distribution

The Southern pigtoe is endemic to Coosa River and its tributaries in Alabama, Georgia, and Tennessee (USFWS 2019e). Presently, the species is known to occur in the following Coosa River tributaries in Georgia: Conasauga River (Murray and Whitfield counties), Holly Creek (Murray county), and Armuchee Creek (Floyd county; USFWS 2019e). Where this species still occurs, it is found in small and localized populations (USFWS 2019e). Overall, the range of the Southern pigtoe remains highly fragmented and all populations are rare and restricted (USFWS 2019e).

Conservation

The Southern pigtoe has a global conservation ranking of G1, a Georgia state conservation ranking of S1, and is federally listed as endangered under the ESA (USFWS 2019e). This species is listed as endangered in the state of Georgia.

Threats to the conservation of the Southern pigtoe are similar to those reported for other threatened mussels in the Coosa River Basin. These threats include changes in hydrological regime (*e.g.,* water withdrawals, drought), excess sedimentation, pollution and water quality issues, extreme reduction and fragmentation of habitat and range, low population sizes, and vulnerability of small, localized populations to stochastic events (Wisniewski 2018; USFWS

2019a; USFWS 2019g). In the Conasauga River, pollutants associated with agricultural runoff (*e.g.*, herbicides, surfactants, hormones) are considered of concern for threatened freshwater mussels (USFWS 2019e).

Recommended actions aimed at the conservation of the Southern pigtoe include minimizing sedimentation in critical habitats, restoration of riparian buffers, evaluation of population sizes, and reintroduction of stocks in viable habitat (Wisniewski 2018). Furthermore, a better understanding of the basic life history characteristics of this species is necessary for future conservation efforts (Wisniewski 2018). Overall, the populations of the Southern pigtoe, including the most robust ones in Alabama, are in decline (USFWS 2019e).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the Southern pigtoe. However, the effects of sediment have been studied in other members of genus *Pleurobema* and can serve as a basis for estimating impacts. Exposure to sediment caused reduced feeding and overall metabolism in the Mississippi pigtoe (*Pleurobema beadleanum*; Aldridge et al. 1987). A more recent study found that increased riverine sediment loading was negatively associated with the presence of the clubshell mussel (*Pleurobema clava*; Roley and Tank 2016).

Because the Southern pigtoe is found in coarse substrate, additional sediment inputs may adversely affect its preferred habitat. As a short-term brooder it may experience reproductive failure due to lack of fertilization and an increased likelihood of aborted broods due to stress. Sediment may also reduce the visibility of conglutinates to host fish, thereby reducing reproductive fitness (Brim Box and Mossa 1999).

Indirect effects of sediment on host fish used by Southern pigtoe must also be considered. Based on their life history traits, we categorize the sediment sensitivity of shiners as intolerant.

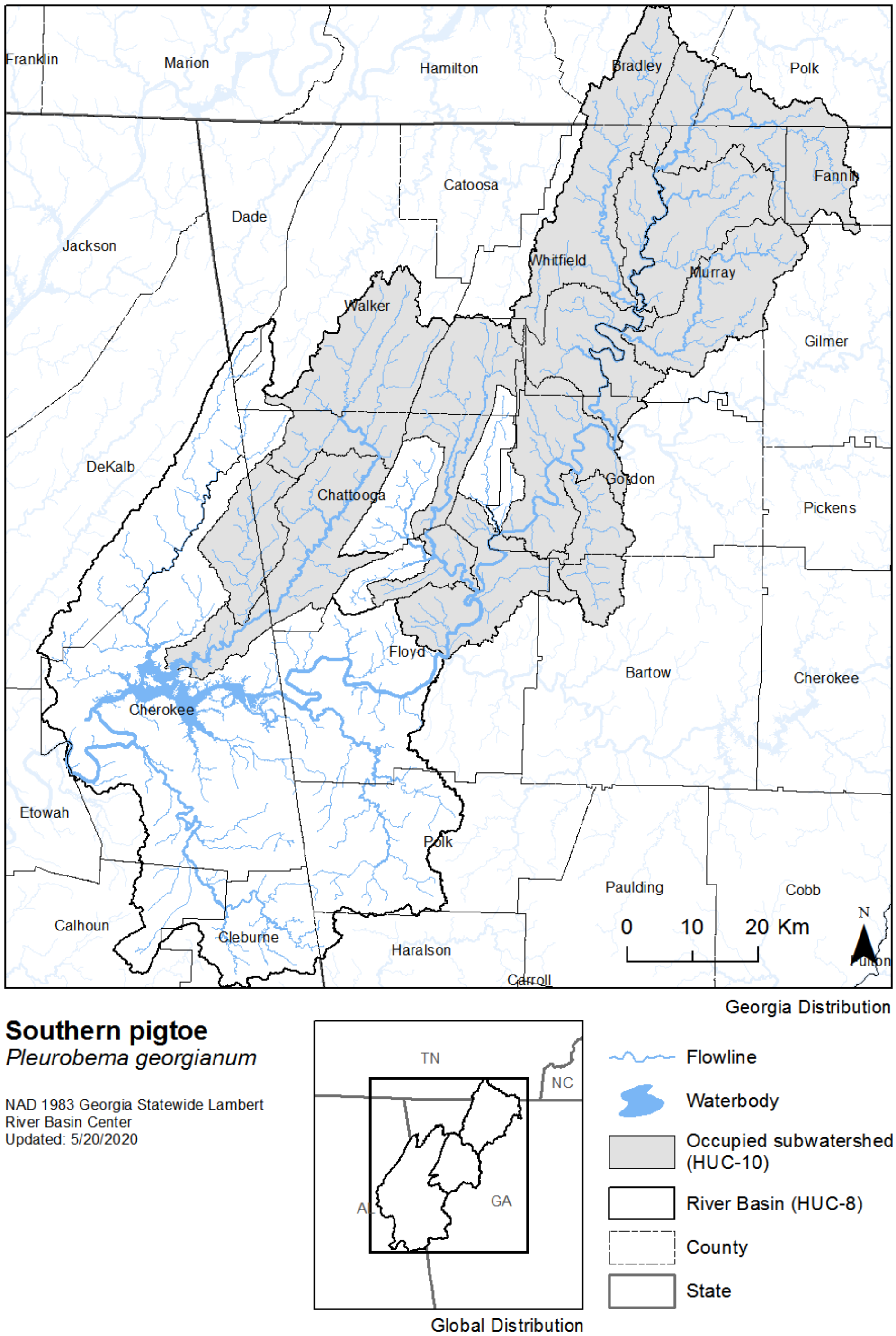
Based on preferred habitat, brooding strategy, and sensitivity of host fish, we categorize the sediment sensitivity of Southern pigtoe as intolerant (1).

Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the Southern pigtoe. Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds.
Indirect effects of pollution on host fish used by Southern pigtoe must also be considered. Based on their life history traits, we categorize the pollutant sensitivity of shiners as somewhat intolerant.

Based on general mussel sensitivity to pollutants, limited direct evidence with Southern pigtoe, and sensitivity of host fish, we categorize the pollutant sensitivity of Southern pigtoe as somewhat intolerant (3).

Figure 47. Map. Range map for the Southern pigtoe.



SUWANNEE MOCCASINSHELL

Species

Suwannee Moccasinshell, *Medionidus walkeri*

Description

Reproduced from the U.S. Fish and Wildlife Service (USFWS 2015): The Suwannee moccasinshell is a small mussel that rarely exceeds 50 millimeters in length. Its shell is oval in shape and sculptured with corrugations extending along the posterior ridge, although the corrugations are sometimes faint. The shell exterior (periostracum) is greenish yellow to brown with green rays of varying width and intensity in young individuals, and olive brown to brownish black with rays often obscured in mature individuals (Williams et al. 2014, p. 278). The sexes can be distinguished, with female shells being smaller and longer than the males (Johnson 1977, p. 177). The Suwannee moccasinshell is easily distinguished from all other mussels in the Suwannee River Basin by having an oval outline and sculpture on the posterior slope (Williams et al. 2014, p. 279).

Life History

The Suwannee moccasinshell inhabits larger streams with slow to moderate currents, with substrates composed of muddy sand or sand with some gravel (USFWS 2015). Individuals have been found at depths ranging from 0.5 – 2.5 m along bank margins with moderate slope (USFWS 2015). This species is also associated with large woody debris, as individuals have often been found near embedded logs (USFWS 2015).

The Suwanee moccasinshell is a member of tribe Lampsilini and a long-term brooder that reproduces starting in the fall and continues until the release of glochidia in the summer of the following year (USFWS 2016). Suwanee moccasinshell and other *Medionidus* spp. use mantle lures to attract fish hosts. Host trials for this species found that the Suwanee moccasinshell is a specialist that uses darters as hosts (Johnson et al. 2016).

Numbers, Reproduction, Distribution

The Suwannee moccassinshell is endemic to the Suwannee River Basin in Florida and Georgia. Its historical range includes the lower and middle Suwannee River mainstems, as well as two large tributary rivers (the Santa Fe River subbasin and the lower Withlacoochee River mainstem; Williams 2015; USFWS 2016). This species has experienced a drastic reduction in its range (USFWS 2016). Where it is found, densities are exceedingly low relative to other mussel species (USFWS 2016). The most recent record for the Suwannee moccassinshell in Georgia was found in the upper Withlacoochee River (Brooks and Lowndes counties) in 1969 (USFWS 2016; Wisniewski 2018).

Conservation

The Suwannee moccasinshell has a global conservation ranking of G1, a Georgia state conservation ranking of SH, and is federally listed as threatened under the ESA (USFWS 2016). This species is listed as endangered in the state of Georgia.

The greatest threats to the Suwannee moccasinshell include changes in hydrological regime (*e.g.*, flow reduction, drought), habitat degradation, pollution, excess sedimentation, climate change, and removal of associated microhabitat (e.g. embedded logs; USFWS 2016). Flow declines up to 30% have been observed in the lower Santa Fe and Suwannee Rivers due to water withdrawals. The upper Suwannee (a formerly perennial system) has dried multiple times since 2000 (USFWS 2016). Discharges of pollutants from industry, mines, water treatment plants, and runoff from agricultural lands all threaten the Suwannee moccasinshell. Ammonia and pesticides are a concern, as these contaminants are highly toxic to juvenile mussels and are widely used on agricultural lands throughout the basin (USFWS 2016). Phosphorus and nitrogen are also of note, as the levels of these nutrients have increased markedly in these systems. Finally, the small population size and restricted range of this species make them vulnerable to catastrophic events (USFWS 2016).

Recommended actions aimed at conservation of the Suwannee moccasinshell include: minimizing degradation of critical habitat in the Suwannee River Basin, proper management of water resources, improved treatment of discharged wastewater, and reductions of pesticide and fertilizer use in the watershed (USFWS 2016). Further, additional understanding of the life history of the Suwannee moccasinshell will aid greatly in conservation (Wisniewski 2018).

Additional work is needed to confirm if the Suwannee moccasinshell is still extant in the state of Georgia (Wisniewski 2018).

Effects of Construction Activities

Sediment

We are aware of no direct studies on the effects of sediment on the Suwanee moccasinshell or other associated *Medionidus* spp. Because the Suwanee moccasinshell is primarily found in coarse substrates, additional sediment inputs may adversely affect its preferred habitat. As a long-term brooder, the Suwanee moccasinshell may be less sensitive to episodic elevated suspended sediment; however, long-term brooders may experience significant declines in reproductive success due to excessive levels of sediment exposure during or after fertilization. Elevated suspended sediment during reproduction may also reduce visibility of lures to host fishes (McNichols et al. 2011) and reduce attachment and metamorphosis of glochidia on host fishes (Beussink 2007).

Indirect effects of sediment on host fish used by the mussel for reproduction must also be considered. Based on their life history, we categorize the sediment sensitivity of the primary hosts, darters (*Etheostoma* and *Percina* spp.), as intolerant.

On balance of high sensitivity of preferred habitat and host fish, but lower sensitivity due to brooding strategy, we categorize the sediment sensitivity of Suwanee moccasinshell as intolerant (1).

Pollutants

We are aware of no data available describing the effects of construction- or road-associated pollutants on the Suwanee moccasinshell. Cherry et al. (2002) found that glochidia of the closely related Cumberland moccasinshell (*Medionidus conradicus*) were among the most sensitive species when exposed to copper. A more recent report states that this trend does not hold true for all metals, as *M. conradicus* seems to be relatively tolerant to zinc (cited in Markich et al. 2017 as personal communication from M. McCann). Mussels are generally among the most sensitive of organisms to a number of pollutants including metals, major ions, and some organic compounds. A study on the effects of increased imperviousness on native freshwater mussels from the Line Creek Watershed (1979 – 1997; Atlanta, GA) found that a congener, the Gulf moccasinshell (*Medionidus penicillatus*), was extirpated (by 1992) from one of two sites where the species was previously found (Gillies et al. 2003).

Indirect effects of pollution on host fish used by Suwanee moccasinshell must also be considered. Based on their life history, we categorize the pollutant sensitivity of the primary host fishes, darters, as somewhat intolerant.

Based on general mussel sensitivity as well as direct evidence with closely related species and sensitivity of host fish, we categorize the pollutant sensitivity of Suwanee moccasinshell as somewhat intolerant (3).

Survey data from Georgia were insufficient to create a range map for this species.

SNAILS

INTERRUPTED ROCKSNAIL

Species

Interrupted Rocksnail, *Leptoxis foremani*

Description

Reproduced from Georgia Department of Natural Resources species profile (Wisniewski 2018):

The shell of *Leptoxis formani* is oval to globose, with a maximum length of approximately 20 mm (⅞ inch), typically with three or less whorls and small striations covering the whorls. The periostracum is light brown to orange, with younger individuals often orange. The sutures are pronounced, shoulders are weak, and columnella is purple to white, and darker towards the base. Juveniles may be distinguished from those of other juveniles of the genus by tightly coiled whorls and strong placations.

Life History

Like other pleurocerid snails, the interrupted rocksnail inhabits shoals and bedrock outcrops and is considered to be a generalist scraper, feeding on benthic algae (Powell and Hartfield 2014). Females become reproductive at about age two and deposit 2-20 eggs between March and May (Powell and Hartfield 2014, Wisniewski 2018). They may live up to five years (Powell and Hartfield 2014).

Numbers, Reproduction, Distribution

Although once distributed widely in the Upper Coosa basin, the current known distribution of the interrupted rocksnail is limited to a 12km reach of the Oostanaula River in Georgia (Wisniewski 2018).

Conservation

The interrupted rocksnail has a global conservation status ranking of G1 and a Georgia conservation ranking status of S1. It is considered endangered under the US Endangered Species Act and state endangered in Georgia.

Although the primary cause of the species' decline has been loss of lotic habitat due to construction of impoundments on the Coosa River (Powell and Hartfield 2014), the remaining populations are considered to be threatened by sedimentation and impaired water quality in the Ooostanaula River (Wisniewski 2018).

Effects of Construction Activities

Sediment

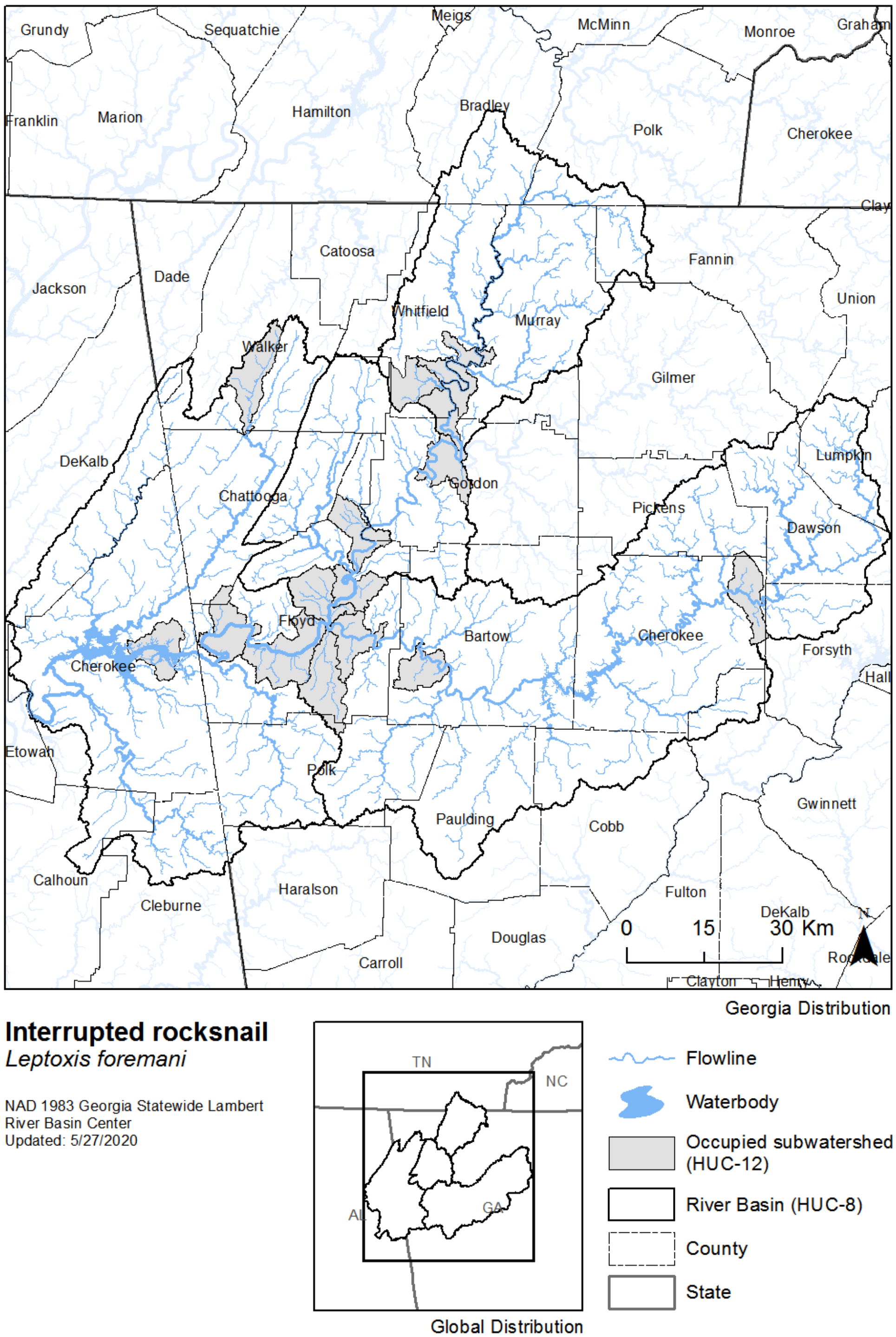
Species in the genus *Leptoxis* attach their eggs to rocks with minimal siltation or vegetation (Whelan et al. 2015), which may make them sensitive to sedimentation. Excess sedimentation is considered to be a major threat to the interrupted rocksnail (Wisniewski 2018). Based on the limited available information, we categorize the sediment sensitivity of the interrupted rocksnail as intolerant (1).

Pollutants

Many groups of aquatic snails are considered sensitive to water quality impairment and have been used as bioindicators. While we know of no lab or field studies investigating the effects of pollutants on the interrupted rocksnail, Gibson et al. (2016) found that the congener *L. ampla* was highly sensitive to the widely used surfactant sodium dodecyl sulfate, with an EC50 several orders of magnitude lower than that of either other gastropods or of unionid mussels. Fong and Hoy (2012) found that low concentrations of antidepressants can reduce the ability of the congener *L. carinata* to remain attached to substrates.

Based on the limited available information, we categorize the pollutant sensitivity of the interrupted rocksnail as very intolerant (2).

Figure 48. Map. Range map for the interrupted rocksnail.



TURTLES

ALABAMA MAP TURTLE

Species

Alabama Map Turtle, *Graptemys pulchra*

Description

The Alabama map turtle reaches a maximum carapace length of 27 cm in females and 12 cm in males (Jensen 2007c). The carapace is mostly olive-colored with faint yellow reticulated patterns. Younger adults and males have a series of laterally compressed spines, which are especially pronounced posteriorly. A narrow dark stripe extends along the length of the keel, though it may be interrupted. The marginal scutes have conspicuous concentric yellow markings on the dorsal surface and concentric dark rings on the ventral surface. The pale yellow plastron has dark lines along the seams. The skin is dark brown or olive with many light-green or yellow stripes. The head has a large yellow or light-green patch or "mask" between and behind the eyes, distinguishing this species from Northern map turtles. Like other map turtles, adult female Alabama map turtles also have heads wider than males (Jensen 2007c).

Life History

Male Alabama map turtles reach sexual maturity at 4 years old (Jensen 2007). Females, which reach sexual maturity at about 14 years of age, nest from late April through August, with a nesting peak in June. They may lay 6-7 clutches per season with an average of 4-6 eggs. Nests are laid in the sandy soils of stream beaches and sandbars (Jensen 2007c, Jensen et al. 2008).

Alabama map turtles inhabit medium-sized rivers to large creeks with sand bars and sandy banks, logs and other basking sites, deep pools, and abundant mollusks (Jensen 2007). Males and juveniles eat insects, snails, and mussels; mollusks are important in females' diet of female, insects more important for males and juveniles. Like all map turtles, Alabama map turtles also spend a lot of time basking in full sunlight (Jensen 2007c).

Numbers, Reproduction, Distribution

The Alabama map turtle's range is confined to the Mobile Bay drainage, including rivers in Alabama, Mississippi, and Georgia. It is found in the Oostanaula River, Conasauga River, and, more recently, in the Coosa River of northwestern Georgia. A 2014-2015 survey of the Coosa River found 252 individuals at densities ranging from 0.5 turtles/km to 5.1 turtle/km among the stream reaches (Jensen 2016). Males, females, and juveniles were found in this survey, which indicates a healthy reproducing population with significant recruitment.

Conservation

The Alabama map turtle has a global conservation rank of G4 and conservation rank of S3 in the state of Georgia. It is protected as rare in Georgia and is considered a SWAP high priority species. It currently has no federal protection.

Within Georgia, Alabama map turtles occur in limited localities and are therefore vulnerable to habitat alterations (Jensen 2007c). Disturbances to the natural hydrology and water quality from impoundment, siltation, and pollution threaten their native mollusk food source. The removal of snags and fallen logs along waterways limits the availability of basking and shelter sites important for this species. While not strictly documented, illegal take for both human consumption and the pet trade may be a significant problem (Jensen 2007c).

Effects of Construction Activities

Sediment

In a study investigating the effects of riparian buffers in agricultural areas on the closely related *G. barbouri*, Sterrett et al. (2011) found that their abundance was negatively associated with the percentage of undisturbed land cover, citing increased sedimentation as a possible mechanism.

Sedimentation and elevated turbidity may reduce foraging efficiency and likely reduces abundance and diversity of the invertebrate prey base of the Alabama map turtle. Because nesting occurs on sandbars and river banks, there is no exposure route for sedimentation to directly affect its spawning.

Relying on the traits-based evidence and the Sterrett et al. (2011) study, we categorize the sediment sensitivity of the Alabama map turtle as moderate (2).

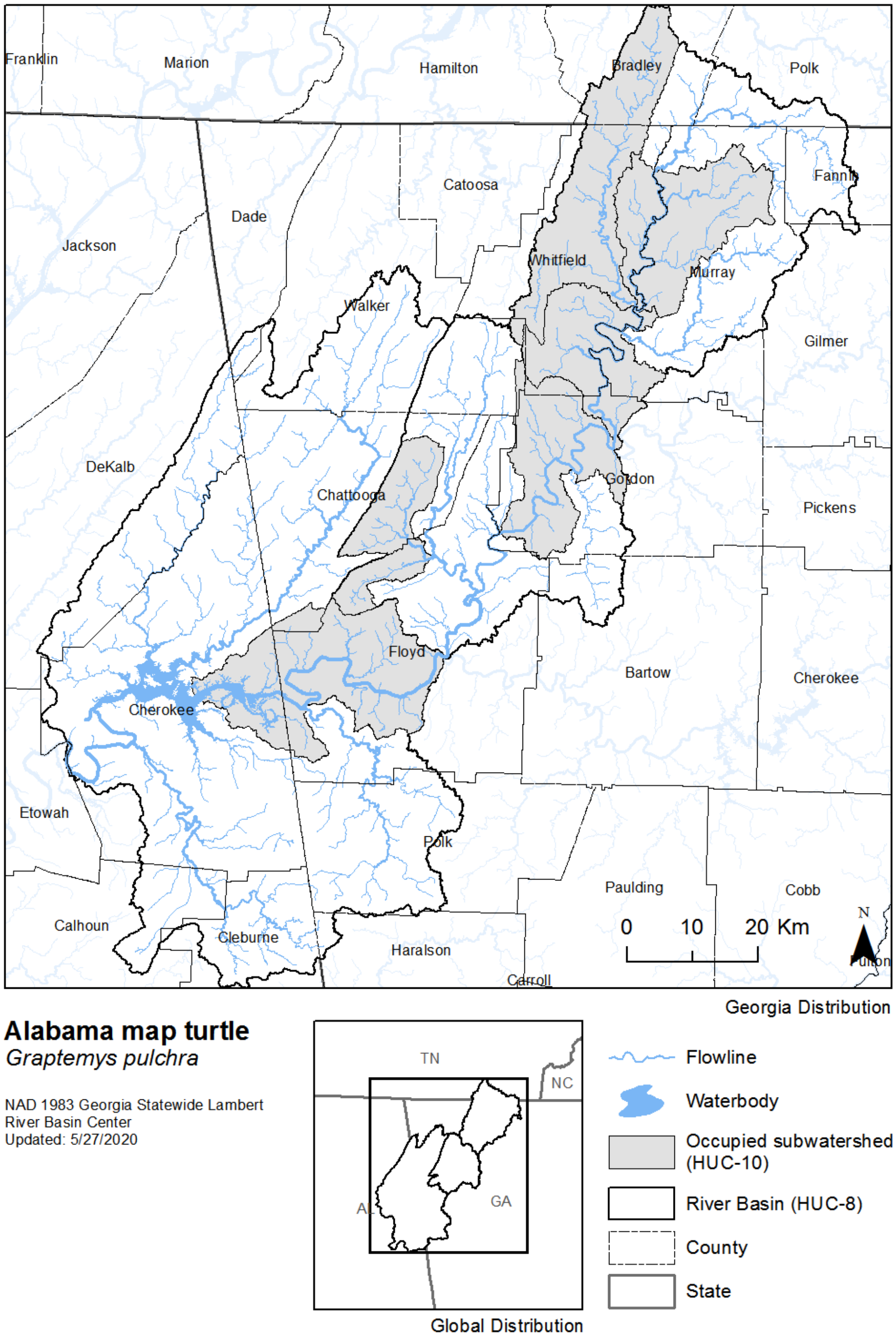
Pollutants

We know of no lab or field studies investigating the effects of roadway-associated pollutants on the Alabama map turtle.

As a relatively long-lived species, the Alabama map turtle is likely to bioaccumulate organic pollutants through its diet. Because it primarily breathes air for respiration, it has a reduced direct exposure route to dissolved metals. Its incubating eggs are not exposed to either pollutants in solution or those bound to sediments.

Based on limited information, we categorize the pollutant sensitivity of the Alabama map turtle as moderate (4).

Figure 49. Map. Range map for the Alabama map turtle.



ALLIGATOR SNAPPING TURTLE

Species

Alligator Snapping Turtle, *Macrochelys temminckii*

Description

The alligator snapping turtle is the largest freshwater turtle species in North America (Jensen 2007d). Its carapace is pattern-less dark to reddish brown with three jagged ridges along the broad flat base of its length, while the plastron is reduced and cross-shaped. The turtle's massive head is triangular with an elongated snout and powerful, strongly hooked jaws. Most individuals have dark brown skin with small dermal projections on their throat and chin (Jensen 2007d).

Until recently, all populations of alligator snapping turtles were regarded as a single, wide-ranging species, *Macrochelys temminckii*. This was until recent research used morphological and mitochondrial genetic variation to describe two new species, *Macrochelys apalachicolae* (Choctawhatchee-Ochlockonee drainages) and *Macrochelys suwanniensis* (Suwannee drainage), and restricted *M. temminckii* to western populations (Alabama-San Antonio drainages; Thomas et al. 2014). However, other research has suggested the retention of *M. apalachicolae* within *M. temminckii* until further morphological or molecular diagnosis is conducted (Folt & Guyer 2015). We follow the U.S. Fish and Wildlife Service and the Georgia Dept. of Natural Resources in retaining *M. apalachicolae* within *M. temminckii.*

Life History

The alligator snapping turtle primarily inhabits freshwater river systems and associated fluvial habitats, such as lakes, canals, oxbows, swamps, ponds, and bayous (Pritchard 2006). Alligator snapping turtles, like most reptiles have indeterminate growth, have been measured to grow up to 80 cm in carapace length and weigh over 100 kg (Jensen 2007d).

The alligator snapping turtle is characterized by low survivorship in early life stages, and delayed maturation, but surviving individuals may live many decades once they reach maturity. It does not reach sexual maturity until 11-13 years of age in the wild, with mating taking place in late winter or early spring and is subsequently followed by an April through June nesting season (Jensen 2007d). Adult females leave the water only to nest, while the hatchlings return to the water from their nest (Pritchard 2006). Typically, a mature female only produces one clutch of eggs per year, with a single clutch typically being comprised of approximately 25 eggs (Pritchard 2006). Nests are most often found excavated in riverbanks, but have also been found in agricultural fields near rivers (Jensen et al. 2008).

Alligator snapping turtles, especially younger individuals, are known for the unusual feeding behavior of lying otherwise motionless on the stream bottom with their jaws agape, wiggling their specialized, worm-like tongue appendage (Jensen 2007d). *Macrochelys* species are dietary generalists, feeding on fish, crayfish, mollusks, birds, carrion, turtles, and plant material. While thought to be relatively sedentary by some, this species has also been documented moving substantial distances upstream of their original capture (Jensen 2007d).

Numbers, Reproduction, Distribution

The range of the alligator snapping turtle includes river drainages along the Gulf of Mexico from Georgia to Texas, but also extends along the Mississippi River system northward into Iowa. The current distribution of the species within Georgia includes the Chattahoochee, Flint, Ochlockonee, Withlacoochee, and Alapaha Rivers (Jensen & Birkhead 2003). In the Flint River, capture rates were among the lowest anywhere in the state, suggesting that historic commercial collection heavily depleted the population (Jensen and Birkhead 2003). The total population of the Apalachicola River system is estimated to be 45,000 individuals, occurring at a density of 281.3 per 1,000 hectares of open water (USFWS 2019i).

Conservation

The alligator snapping turtle has a global conservation rank of G3G4 and a state conservation rank of S3 in the state of Georgia. It is not federally protected, but it is listed as threatened in the state of Georgia and it is considered a SWAP high priority species.

Prior to receiving protection in the state, these turtles were trapped heavily for commercial purposes, particularly to supply meat for the turtle soup industry. Removing adults of a late maturing species like the alligator snapping turtle has a disproportionate effect on populations. Water pollution and stream dredging have also been identified as threats to this species.

Sediment

We know of no lab or field studies that investigate the effects of sediment on the alligator snapping turtle or closely related species.

Sedimentation and elevated turbidity may reduce foraging efficiency and likely reduces abundance and diversity of the invertebrate prey base of the alligator snapping turtle. However, this effect is likely mitigated by the wide variety of its diet. Because nesting occurs on riverbanks, there is no exposure route for sedimentation to directly affect its spawning.

Relying on the traits-based evidence, we categorize the sediment sensitivity of the alligator snapping turtle as tolerant (3).

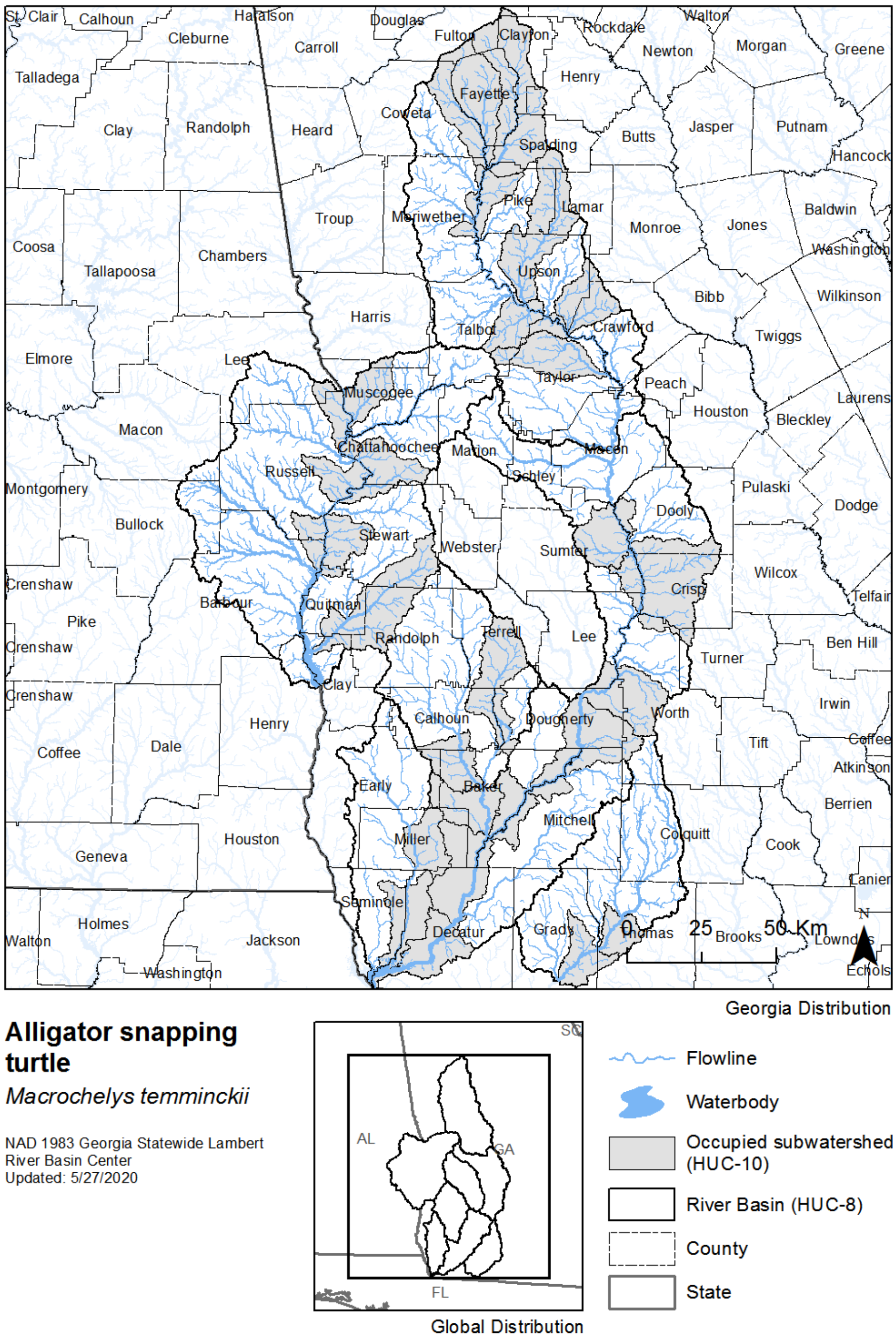
Pollutants/Contaminants

We know of no lab or field studies investigating the effects of roadway-associated pollutants on the alligator snapping turtle or closely related species.

As a long-lived predatory species, the alligator snapping turtle is likely to bioaccumulate organic pollutants through its diet. Because it breathes air for respiration, it has a reduced direct exposure route to dissolved metals. Its incubating eggs are not exposed to either pollutants in solution or those bound to sediments.

Based on limited information, we categorize the pollutant sensitivity of the alligator snapping turtle as moderate (4).

Figure 50. Map. Range map for the alligator snapping turtle.



BARBOUR'S MAP TURTLE

Species

Barbour's Map Turtle, *Graptemys barbouri*

Description

Barbour's map turtle displays extreme sexual dimorphism (Jensen 2007a). While adult males reach a maximum carapace length of only 13 cm (5 inches), females may grow to 33 cm (13 inches) and an 80% greater body mass than males. Females also have enormous heads relative to males, with powerful jaws used for crushing snails and bivalves. The carapace has a mid-dorsal keel with black-tipped spines posteriorly. The carapace is olive to olive brown with yellow, C-shaped markings. The plastron is pale yellow with narrow, dark markings on the seams. Skin color is generally dark-green to black with light green or yellow markings and stripes (Jensen 2007a).

Life History

Female Barbour's map turtles mature at a specific size based on individual fitness rather than a specific age, which may take 10-20 years, whereas males may mature in 2-4 years (Sanderson 1974). Females typically deposit 4-11 eggs a few centimeters beneath the surface on sandbars or riverbanks. Several clutches may be produced in a season (Jensen 2007a). Nesting occurs from

June through August on sandbars or river banks with eggs incubating approximately 60 days (Jensen 2007, Jensen et al. 2008). Hatchlings, juveniles, and adult males feed largely on aquatic invertebrates, while females eat mostly clams and other mollusks (USFWS 2017b).

Numbers, Reproduction, Distribution

The presumed natural range of this species is confined to the ACF drainage of the Florida panhandle, southeast Alabama, and southwest Georgia. This includes the Appalachicola, Chattahoochee, and Flint Rivers within the Coastal Plain region. A Barbour's map turtle population of unknown origin was discovered within the Ochlockonee River in Florida, which suggests they may inhabit the Georgia portions of this drainage (Jensen 2007a; USFWS 2017b).

Conservation

Barbour’s map turtle has a conservation rank of G2 globally and S3 in the state of Georgia. It is not federally protected, but it is considered a SWAP high priority species and is listed as threatened in the state of Georgia.

Streams and rivers inhabited by Barbour's map turtles have been degraded by impoundment, dredging, and pollution (Jensen 2007a). These impacts have slowed the natural water flow, reducing the availability of basking sites, and nearly eliminated the native mollusk prey base. Other threats include illegal collection, entrapment in fishing gear, and illegal shooting. They are especially vulnerable due to their restricted range (Jensen 2007a).

Effects of Construction Activities

Sediment

In a study investigating the effects of riparian buffers in agricultural areas on Barbour's map turtles, Sterrett et al. (2011) found that their abundance was negatively associated with the percentage of disturbed land cover. The authors cited sedimentation of habitat and its effects on prey as a possible mechanism responsible for the observed negative association.

Sedimentation and elevated turbidity may reduce foraging efficiency and likely reduces abundance and diversity of the invertebrate prey base of the Barbour's map turtle. Because nesting occurs on sandbars and river banks, there is no exposure route for sedimentation to directly affect its spawning.

Relying on the traits-based evidence and the results of Sterrett et al. (2011), we categorize the sediment sensitivity of the Barbour's map turtle as moderate (2).

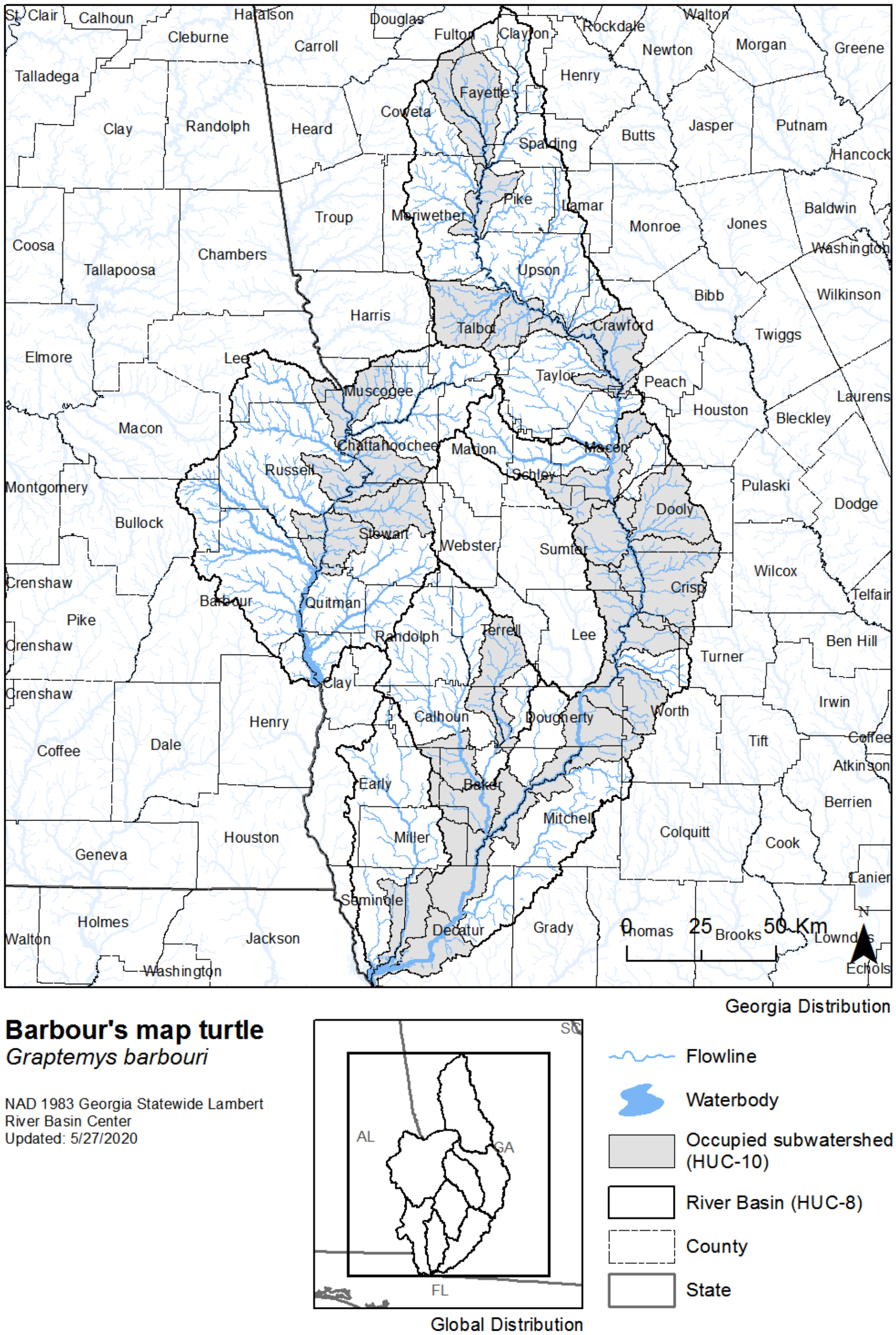
Pollutants

We know of no lab or field studies investigating the effects of roadway-associated pollutants on Barbour's map turtle.

As a relatively long-lived species, Barbour's map turtle is likely to bioaccumulate organic pollutants through its diet. Because it primarily breathes air for respiration, it has a reduced direct exposure route to dissolved metals. Its incubating eggs are not exposed to either pollutants in solution or those bound to sediments.

Based on limited information, we categorize the pollutant sensitivity of Barbour's map turtle as moderate (4).

Figure 51. Map. Range map for the Barbour's map turtle.



BOG TURTLE

Species

Bog Turtle, *Glyptemys muhlenbergii*

(formerly *Clemmys muhlenbergii)*

Description

The bog turtle is the smallest turtle species, reaching only 11.5 cm (4½ inches) in maximum carapace length (Floyd and Jensen 2007). The low-keeled, black, brown, or mahogany-colored carapace is usually rough, and the plastron is typically black with yellow or cream-colored blotches along the midline. A conspicuous orange, yellow, or red blotch is present on each side of the head behind the eye. Skin color is brown to pink and may have some reddish mottling. Juveniles are similar to adults except that they have a yellow plastron with a large black blotch in the center (Floyd and Jensen 2007).

Life History

Bog turtles are most active during spring, early summer, and early fall. Winter hibernacula sites consist of mammal burrows, tussocks of sedges, or mucky soil (Floyd and Jensen 2007). These turtles forage on land and in the water with a variable diet including spiders, beetles, flies, snails, ants, moths, dragonflies, caddisflies, plant stems and fragments, root hairs, and moss (Klemens

1993). Male turtles roam widely in search of females shortly after they become active in late March. Courtship and breeding occur from late April to early June, and eggs are laid from May to July, either buried in soft soil or rotted wood, placed in thick beds of sphagnum moss, or deposited in the top of sedge tussocks. In Georgia, incubation ranges from 52 to 60 days with hatchlings emerging in late August or September and immediately burrowing into the surrounding substrate. Bog turtles reach sexual maturity at 7-9 years of age. Predators of eggs, juveniles, and adults include raccoons, skunks, opossums, foxes, wading birds, crows, birds of prey, snapping turtles, bullfrogs, water snakes, mink, and muskrat (USFWS 2001; Floyd and Jensen 2007).

Numbers, Reproduction, Distribution

Bog turtles have a patchy range extending from western Massachusetts southward to extreme northeastern Georgia (Floyd and Jensen 2007). A large gap in it range in West Virginia and northern Virginia splits the northern and southern populations. Bog turtles were discovered in Georgia in 1979 when an individual was captured in a trap set for ruffed grouse. Bog turtles' southernmost limit reaches northern Georgia where their abundance was likely never high. All Georgia populations lie within the Blue Ridge physiographic province within wetlands above 150 m (1800 feet) in elevation. Of eleven known localities of bog turtles in Georgia, half of them are from the observations of a single individual. In three of these sites, the populations are apparently extirpated due to habitat succession and site drainage. The Chattahoochee National Forest holds at least two natural populations, but the viability of one population is uncertain. Populations at two sites on private land are the source of hatchling turtles for the ongoing headstarting and population augmentation projects within restored habitat on federal lands (Floyd and Jensen 2007).

In other southern populations, adult survival is at or below that of what is considered acceptable for stable populations (93%), juvenile survival (50-68%) is lower than adult survival (Tutterow, Graeter, and Pittman 2017).

Conservation

Reproduced from Georgia Department of Natural Resources species profile (Floyd and Jensen 2007):

Restoration of mountain bog hydrology has seldom been attempted, and never in conjunction with bog turtle site repatriation. Ironically, the presence of cattle within the margins of mountain bog habitat in many cases has been shown to maintain at least marginally suitable bog turtle habitat presumably by mimicking grazing disturbance of now extirpated elk. Where wetland hydrology is intact, restoration of mountain bog habitats ideally could be achieved through the restoration of natural disturbance regimes. In reality, however, within the current fragmented landscape, there no longer exists the network of hydrologically intact mountain bog habitats of differing successional stages necessary to naturally perpetuate bog flora and fauna over time and over the landscape. Furthermore, the progression of the effects of natural disturbance, such as impoundment by beaver, take many decades to produce suitable, yet ephemeral early successional bog habitat, during which time such habitats are unsuitable for the majority of rare bog species of conservation concern. Because the characteristics of early successional bog habitat can be achieved relatively quickly through mechanical woody vegetation removal, this method of artificial disturbance is the one most often employed within restoration efforts despite the method's limited long-term effectiveness. Since mechanical woody vegetation removal at best only mimics wind throw, its effectiveness is merely temporary when used alone, as compared to a more natural and gradual process of bog creation (e.g., beaver impoundment). Consequently, in order to assure continued existence of rare bog flora and fauna across the Southern Appalachian landscape, conservationists must continually maintain an early successional state within a number of restored mountain bog habitats through mechanical woody vegetation removal, judicious use of herbicides, and prescribed fire. Management of known bog turtle sites is difficult since most occur on private land. The possibility of establishing conservation easements to maintain the early successional bog communities on private land sites should be investigated and utilized whenever feasible. Efforts to locate additional bog turtle sites and mountain bog habitat within the vast federally owned lands and surrounding private landholdings in the northeast mountains is considered a high priority.

Effects of Construction Activities

Sediment

We know of no lab or field studies investigating the effects of sediment on the bog turtle. In Georgia, bog turtles prefer low-strength wetland soils that are approximately 40-60% silt, as they spend most of their time in the topmost part of the soil (Feaga et al. 2013). Percent silt above this threshold may not affect abundance, but areas with soil profiles below 40% silt had lower turtle abundance (<5 indivudals; Stratmann et al. 2020). This suggests that elevated inputs of fine sediments are unlikely to significantly alter the preferred habitat of the bog turtle. Because nesting occurs outside of aquatic systems, there is no exposure route for sedimentation to directly affect its reproduction. As a dietary generalist that feeds on prey in both aquatic and terrestrial environments, the bog turtle is not likely to be adversely affected by the effects of sediment on its prey base.

For these reasons, we categorize the sediment sensitivity of the bog turtle as tolerant (3).

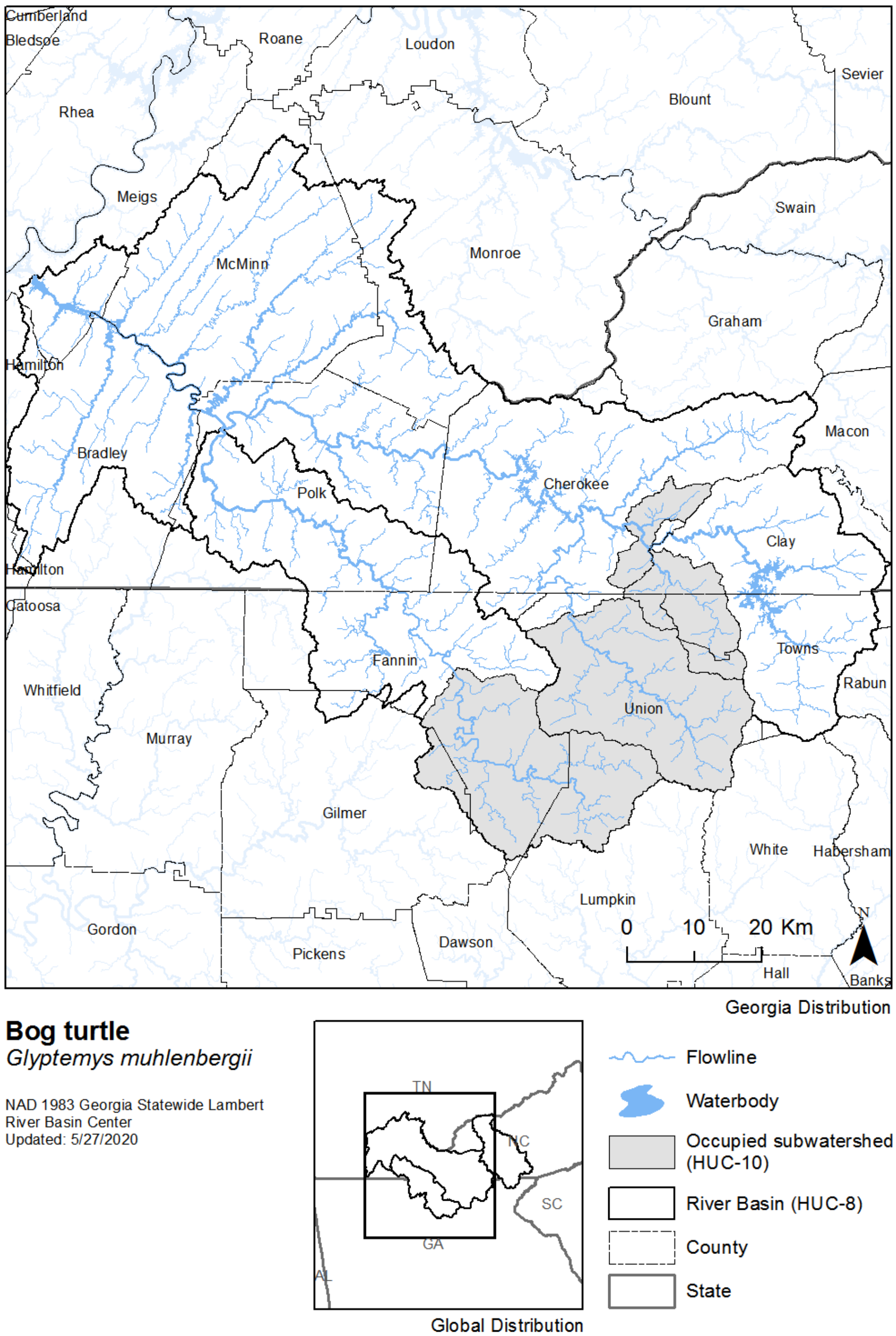
Pollutants

We know of no lab or field studies investigating the effects of roadway-associated pollutants on the bog turtle. The U.S. Fish and Wildlife Service identifies stormwater runoff from roadways as a threat to the persistence of bog turtles in the 2001 recovery plan (USFWS 2001).

As a relatively long-lived species, the bog turtle is likely to bioaccumulate organic pollutants through its diet. Because it breathes air, it has a reduced direct exposure route to dissolved metals. Its incubating eggs are not exposed to either pollutants in solution or those bound to sediments.

Because of the limited exposure routes, we categorize the pollutant sensitivity of the bog turtle as moderate (4).

Figure 52. Map. Range map for the bog turtle.



NORTHERN MAP TURTLE

Species

Northern Map Turtle, *Graptemys geographica*

Description

The Northern map turtle has an olive-green carapace with fine, lighter green or yellow lines that form a reticulated pattern resembling a topographic map (Jensen 2007b). They have a low, vertebral keel, though not as prominent as the keel found on other map turtle species. Juveniles and adult males may have low vertebral spines on the posterior portion of the carapace. The cream to yellow plastron is unmarked in adults, though the bridge and lower marginal scutes have longitudinal dark lines and circular dark markings, respectively. The skin is olive to dark-brown or black with many narrow yellow to light green stripes. Behind each eye is a small yet distinctive yellow spot. Juveniles have dark markings along the seams of the plastron and a more intricate carapace pattern. This species has strong sexual dimorphism in both body size and head size. While males may grow up to 15 cm (6 inches) in carapace length, females may grow up to 27 cm (10½ inches), and females have wider heads than males, which contributes to their different diets (Jensen 2007b).

Life History

Northern map turtle breeding occurs in both spring and fall, and nesting lasts from late May to mid-July (Jensen 2007b). Females dig nests in soft soil or sand on river banks or even seasonally-inundated sandbars, typically laying 9-17 eggs. Up to three clutches may be produced by a single female each year. Although hatchlings begin to emerge in August or September, some may over-winter in the nest cavity and emerge the following spring. Northern map turtles primarily inhabit large streams and rivers with an abundance of basking sites such as exposed rocks or woody debris. In other parts of its range, they may inhabit large reservoirs and even small brooks (Jensen 2007b).

They feed primarily on mollusks but may also eat insects and plant material (Jensen 2007). In the Susquehanna River in Maryland, males generally eat smaller gastropod species, and females with their larger heads can feed on larger pleurocerid snails (Richards-Dimitrie et al. 2013).

Numbers, Reproduction, Distribution

The Northern map turtle range includes eastern and central North America, from southern Canada to central Alabama and west to Oklahoma. In Georgia, this species is found in the extreme northwestern corner of the state in the upper tributaries of the Coosa River drainage, primarily the Conasauga River, as well as Little Chickamauga Creek of the Tennessee River drainage (Jensen 2007).

Conservation

The Northern map turtle has a global conservation rank of G5 and a rank of S1 in Georgia. They are protected as rare in Georgia and they have no federal protection. A significant threat to Northern map turtles is stream degradation, which contributes to the decline or loss of their mollusk prey base. Siltation, loss of stream-side shading, and water pollution result in eutrophic conditions unfavorable to aquatic invertebrates (Jensen 2007b).

Effects of Construction Activities

Sediment

In a study investigating the effects of riparian buffers in agricultural areas on the closely related *G. barbouri*, Sterrett et al. (2011) found that their abundance was negatively associated with the percentage of disturbed land cover, citing increased sedimentation as a possible mechanism.

Sedimentation and elevated turbidity may reduce foraging efficiency and likely reduces abundance and diversity of the invertebrate prey base of the Northern map turtle. Because nesting occurs on sandbars and river banks, there is no exposure route for sedimentation to directly affect its spawning.

Relying on the traits-based evidence and the Sterrett et al. (2011) study, we categorize the sediment sensitivity of the Northern map turtle as moderate (2).

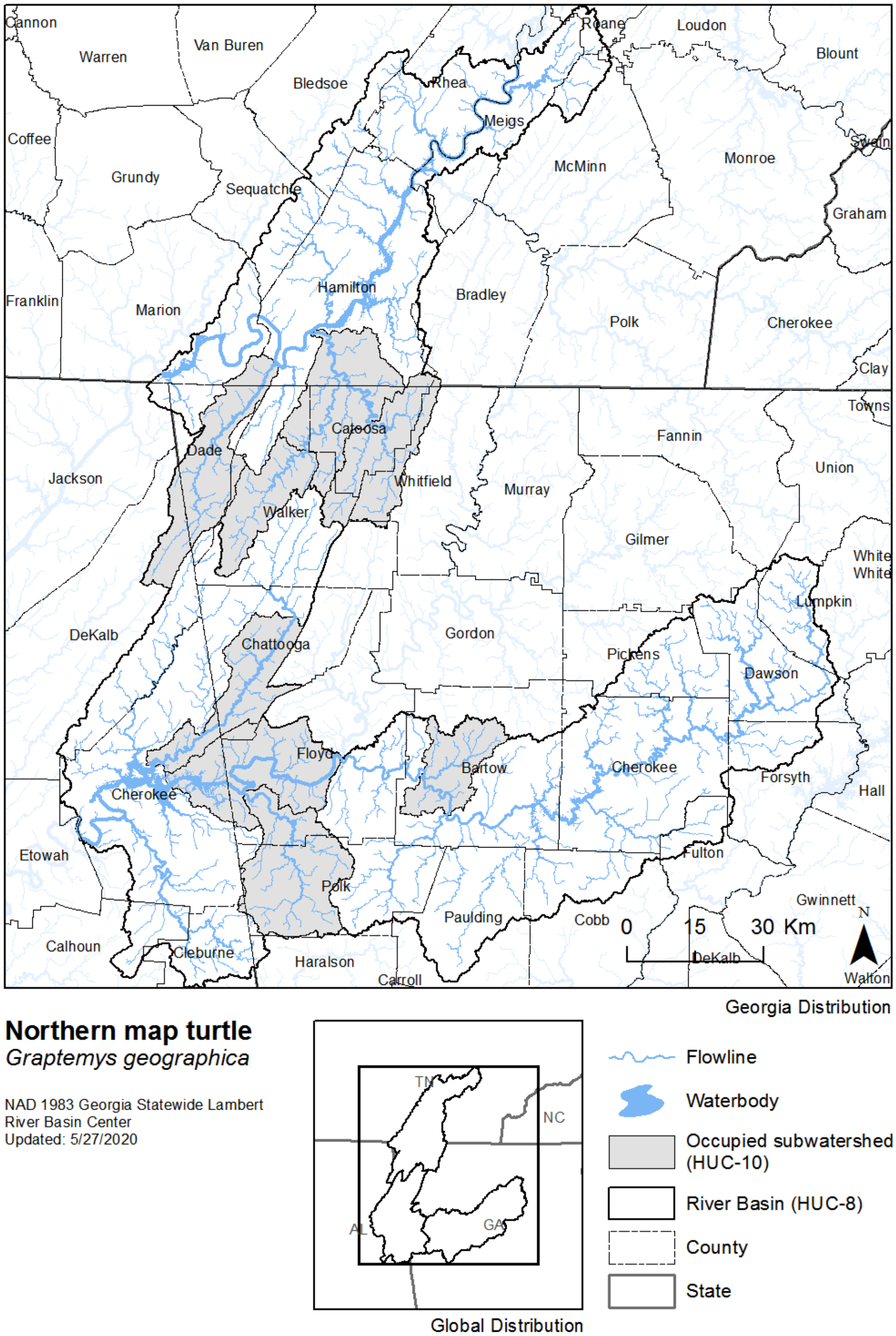
Pollutants

We know of no lab or field studies investigating the effects of roadway-associated pollutants on the Northern map turtle.

As a relatively long-lived species, the Northern map turtle is likely to bioaccumulate organic pollutants through its diet. Because it primarily breathes air for respiration, it has a reduced direct exposure route to dissolved metals. Its incubating eggs are not exposed to either pollutants in solution or those bound to sediments.

Based on limited information, we categorize the pollutant sensitivity of the Northern map turtle as moderate (4).

Figure 53. Map. Range map for the Northern map turtle.



SUWANNEE ALLIGATOR SNAPPING TURTLE

Species

Suwannee Alligator Snapping Turtle, *Macrochelys suwanniensis*

Description

The Suwannee alligator snapping turtle is one of the largest freshwater turtle species in North America (Jensen 2007). Its carapace is pattern-less dark to reddish brown with three jagged ridges along the broad flat base of its length, while the plastron is reduced and cross-shaped. The turtle's massive head is triangular with an elongated snout and powerful, strongly hooked jaws. Most individuals have dark brown skin with small dermal projections on their throat and chin (Jensen 2007).

Until recently, all populations of alligator snapping turtles were regarded as a single, wide-ranging species, *Macrochelys temminckii*. This was until recent research used morphological and mitochondrial genetic variation to describe two new species, *Macrochelys apalachicolae* (Choctawhatchee-Ochlockonee drainages) and *Macrochelys suwanniensis* (Suwannee drainage), and restricted *M. temminckii* to western populations (Alabama-San Antonio drainages; Thomas et al. 2014). However, other research has suggested the retention of *M. apalachicolae* within *M. temminckii* until further morphological or molecular diagnosis is conducted (Folt & Guyer 2015).

Life History

The Suwannee alligator snapping turtle primarily inhabits freshwater river systems and associated fluvial habitats, such as lakes, canals, oxbows, swamps, ponds, and bayous (Pritchard 2006). Suwannee alligator snapping turtles, like most reptiles have indeterminate growth, have been measured to grow up to 80 cm in carapace length and weigh over 100 kg (Jensen 2007).

The Suwannee alligator snapping turtle is characterized by low survivorship in early life stages, and delayed maturation, but surviving individuals may live many decades once they reach maturity. It does not reach sexual maturity until 11-13 years of age in the wild, with mating taking place in late winter or early spring and is subsequently followed by an April through June nesting season (Jensen 2007). Adult females leave the water only to nest, while the hatchlings return to the water from their nest (Pritchard 2006). Typically, a mature female only produces one clutch of eggs per year, with a single clutch typically being comprised of approximately 25 eggs (Pritchard 2006). Nests are most often found excavated in riverbanks, but have also been found in agricultural fields near rivers (Jensen et al. 2008).

Suwannee alligator snapping turtles, especially younger individuals, are known for the unusual feeding behavior of lying otherwise motionless on the stream bottom with their jaws agape, wiggling their specialized, worm-like tongue appendage (Jensen 2007). *Macrochelys* species are dietary generalists, feeding on fish, crayfish, mollusks, birds, carrion, turtles, and plant material. While thought to be relatively sedentary by some, this species has also been documented moving substantial distances upstream of their original capture (Jensen 2007).

Numbers, Reproduction, Distribution

The Suwannee alligator snapping turtle is limited to the Suwannee River system of Georgia and Florida. The total population of the Suwannee River system is estimated to be 2,000 individuals, occurring at a density of 76.2 per 1,000 hectares of open water (USFWS 2019i).

Conservation

The Suwannee alligator snapping turtle has a global conservation rank of G2 and a state conservation rank of S2 in the state of Georgia. It is not federally protected, but it is listed as threatened in the state of Georgia and it is considered a SWAP high priority species.

Prior to receiving protection in the state, these turtles were trapped heavily for commercial purposes, particularly to supply meat for the turtle soup industry. Removing adults of a late maturing species like the Suwannee alligator snapping turtle has a disproportionate effect on populations. Water pollution and stream dredging have also been identified as threats to this species.

Sediment

We know of no lab or field studies that investigate the effects of sediment on the Suwannee alligator snapping turtle or closely related species.

Sedimentation and elevated turbidity may reduce foraging efficiency and likely reduces abundance and diversity of the invertebrate prey base of the Suwannee alligator snapping turtle. However, this effect is likely mitigated by the wide variety of its diet. Because nesting occurs on river banks, there is no exposure route for sedimentation to directly affect its spawning.

Relying on the traits-based evidence, we categorize the sediment sensitivity of the Suwannee alligator snapping turtle as tolerant (3).

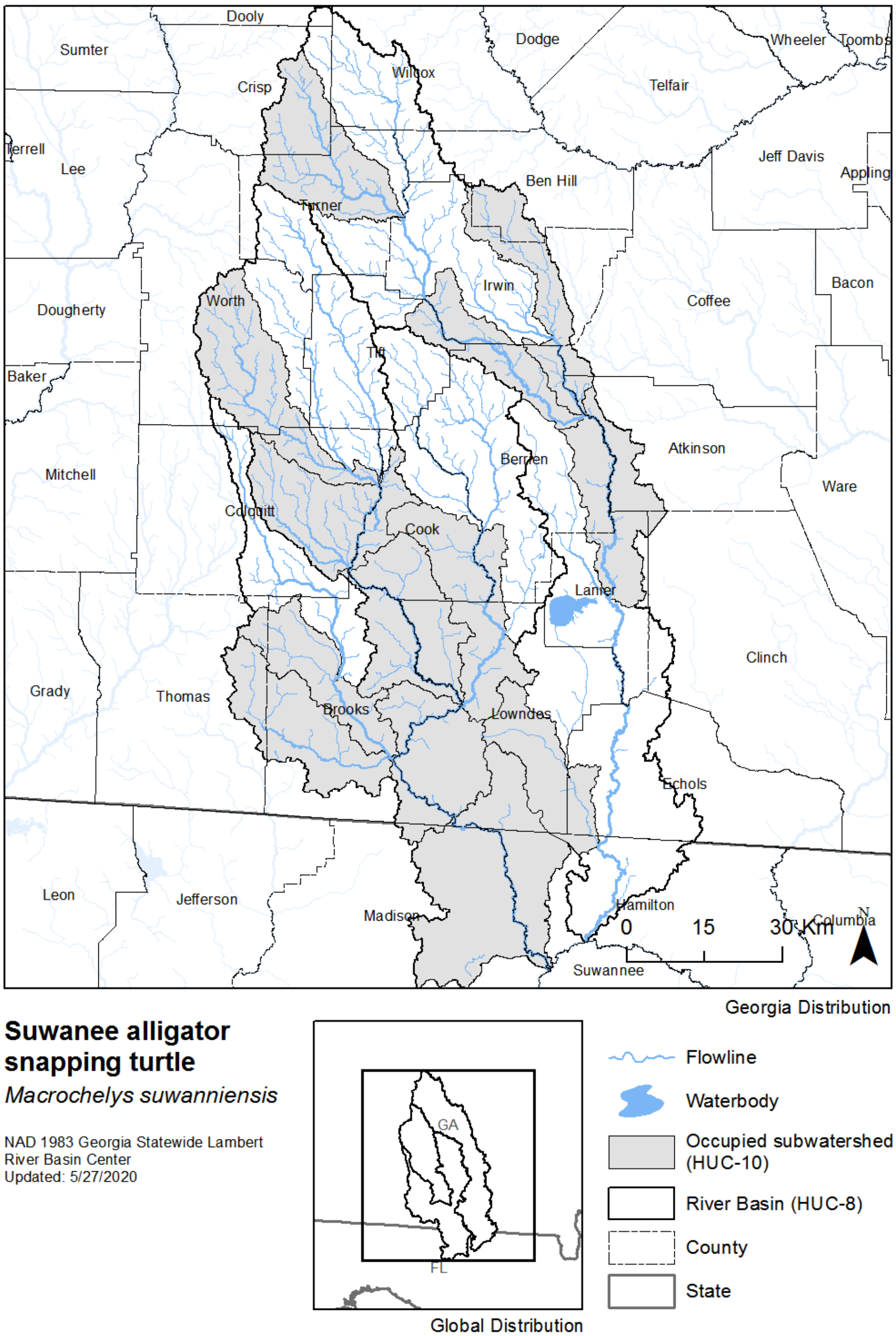
Pollutants

We know of no lab or field studies investigating the effects of roadway-associated pollutants on the Suwannee alligator snapping turtle or closely related species.

As a long-lived predatory species, the Suwannee alligator snapping turtle is likely to bioaccumulate organic pollutants through its diet. Because it breathes air for respiration, it has a reduced direct exposure route to dissolved metals. Its incubating eggs are not exposed to either pollutants in solution or those bound to sediments.

Based on limited information, we categorize the pollutant sensitivity of the Suwannee alligator snapping turtle as moderate (4).

Figure 54. Map. Range map for the Suwanee alligator snapping turtle.



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